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November 28, 1994

JOHN WAIHEE
GOVERNOR

TO: Jeanne K. Schultz, Director
Department of Business, Economic Development and Tourism

SUBJECT: Final Environmental Impact Statement - Commercial Satellite Launching Facility at Palima Point

I am pleased to accept the Final Environmental Impact Statement for the Conceptual Plan for a Commercial Satellite Launching Facility at Palima Point, Kau, Island of Hawaii, upon the Office of Environmental Quality Control's recommendation that it fulfills the requirements of Chapter 343, Hawaii Revised Statutes.

The potential impacts are adequately described in the statement which, together with the comments made by reviewers, provide useful analysis of the proposed action. My acceptance of the statement is an affirmation of the adequacy of that statement under the applicable laws but does not constitute an endorsement of the proposed action.

This Final Environmental Impact Statement is based upon the elements of a conceptual plan. Therefore, the submission of a supplemental environmental impact statement, if and when an actual project is proposed, will be required in accordance with Chapter 343, Hawaii Revised Statutes.

/S/ John Waihee

JOHN WAIHEE

c: Office of Environmental Quality Control

CONCEPTUAL PLAN

COMMERCIAL SATELLITE LAUNCHING FACILITY

Palima Point, Ka'ū, Hawaii

FINAL

ENVIRONMENTAL IMPACT STATEMENT

VOLUME I

October 1994

DBEDT

THE DEPARTMENT OF BUSINESS, ECONOMIC DEVELOPMENT & TOURISM

FINAL ENVIRONMENTAL IMPACT STATEMENT

CONCEPTUAL PLAN FOR A COMMERCIAL SATELLITE LAUNCHING FACILITY

Palima Point, Ka`u, Hawaii

Proposed by:

THE STATE OF HAWAII
DEPARTMENT OF BUSINESS, ECONOMIC DEVELOPMENT & TOURISM

Jeanne K. Schultz, Director

Date: 10-31-94

FINAL ENVIRONMENTAL IMPACT STATEMENT
October 1994

PROJECT: CONCEPTUAL PLAN FOR A COMMERCIAL SATELLITE LAUNCHING FACILITY

LOCATION: PALIMA POINT, DISTRICT OF KA`U, HAWAII

PROPOSING AGENCY:
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GOVERNOR JOHN WAIHEE
STATE OF HAWAII

SUMMARY

INTRODUCTION AND PURPOSE

A stated goal of the State is to diversify Hawaii's economy. The Department of Business, Economic Development & Tourism (DBEDT) has been studying the feasibility of establishing a commercial satellite launching facility in Hawaii as one way to attain this goal. Although the project would be developed by the private sector, the State intends to facilitate the process by obtaining ownership rights to a site and applying for master development approvals and permits. The actions that "triggered" the State's role in the Environmental Impact Statement (EIS) process under Chapter 343 HRS and the EIS Rules (Section 11-200-5) are DBEDT's proposed future involvement in the land acquisition and permitting activities of the project.

Because there is no actual project proposed at the present time, the EIS is based upon the elements of a conceptual plan. Environmental and safety issues are assessed under a maximum capacity build-out scenario for a conceptual project. The accident scenarios for each rocket and propellant were developed to test the environmental and safety limits of the assessed activities. The acceptability or non-acceptability of the impacts disclosed--and the efficacy of the mitigating measures presented--is left to be determined by legislative and regulatory bodies and the community. The EIS is intended to provide factual data to be used as the basis for making informed decisions as to the environmental feasibility of locating a commercial launch facility at Palima Point, Hawaii.

After completion of the EIS, the State of Hawaii does not anticipate further active participation in the launch site initiative at the present time. A supplemental environmental impact statement--which would be the responsibility of the private developer--and various licenses, permits and agreements with state, county and federal agencies would have to be completed before a launch facility could be developed at Palima Point. Development of such a facility by private industry would only occur if driven by sufficient demand for commercial launch services.

THE PROPOSED PROJECT

The proposed launch facility, which would be located at Palima Point, District of Ka'u, County of Hawaii (T.M.K. 9-6-2: portions of parcels 01-06, 09, 10, 20, 28, 47-49; and 9-6-13: portions of parcels 03, 05 & 06), would include three launch pads and associated support facilities and infrastructure. The assessment is based on full build-out of the launch site and it is assumed that all available launch pad space--three 1,500-foot-diameter circular launch areas--is utilized. It is also assumed that all support functions will be located on the Spaceport. The Conceptual Plan assumes full development over a 3-year period following the completion of permitting and land acquisition. Permitting includes completing all necessary agreements. After land rights and major development permits are obtained, an undetermined period of time would be required to negotiate major agreements with the launch companies and the users. Construction of infrastructure, range instrumentation and support facilities would require two years. The first sELV launch could occur as early as 18 months after construction begins, with mELV operations commencing the following year.

Although development will only occur on about 1,000 to 1,200 acres, a total of about 10,400 acres must be controlled to insure safety of the population during launch operations. This

area--which is defined as the population control zone (PCZ)--extends for 2.9 miles behind the launch pads. There are no homes within this zone at the proposed Palima Point site. The PCZ is set back far enough from the pads so that if a failure were to occur early in flight, even considering the effects of wind, the debris would land within the PCZ or in the ocean. During launch operations only authorized persons will be allowed within the area. The offshore shipping hazard area, which must be clear during launch, would be up to 13 miles long and approximately 6 miles wide.

A Conceptual Shoreline Access Management Plan addresses issues regarding public access to the shoreline within the PCZ and proposes management strategies. The primary objective of the Plan is to provide access to and use of the shoreline area, while at the same time insuring public health and safety during launches and other potentially dangerous operations, and protecting shoreline resources and the launch site facilities. The Plan is based on the management approach described in the State Launch Facility Management Plan.

Candidate vehicles for the proposed launch facility include suborbital sounding rockets and orbital launch vehicles (Atlas, Delta, Taurus and Scout). The Atlas IIAS and Delta II are considered to be medium expendable launch vehicles (mELVs); Taurus and Scout are considered to be small expendable launch vehicles (sELVs). The environmental impact analyses focus on the "worst case" vehicle for a particular action or event being evaluated; therefore, the assessment deals primarily with potential environmental impacts of launching mELVs (Atlas and/or the Delta).

There are six major commercial and scientific applications of space: (1) communications satellites, (2) weather satellites, (3) remote sensing, (4) navigation, (5) materials processing, and (6) space science. Early missions would probably be oriented toward either communications or earth observation including government weather satellites. Certain payloads, however, are prohibited by State law. These include those which carry weapons of destruction, nuclear waste materials, or use radioactive materials as a power source. Some payloads related to the military could be launched, however, including weather, communications, and navigation satellites.

Propellants considered in the various analyses include solid propellant rocket motors (SRMs); non-hypergolic liquid propellants and gases including liquid oxygen, liquid hydrogen, RP-1 (kerosene), nitrogen and helium; and, hypergolic propellants such as Aerozine-50, nitrogen tetroxide and hydrazine. Transportation of rocket stages, SRMs and liquid propellants from Hilo to the launch site would be via Highway 11. Most rocket fuels are classified by the U. S. Department of Transportation as hazardous materials because of their flammable and/or toxic properties. Trucks carrying hazardous materials will be escorted; the hazardous materials (HAZMAT) team will ride in a convoy transporting the propellants.

The number of orbital launches each year will depend on many factors, including the number and types of available launch pads, payload market demands, and the time needed to prepare a rocket for launch. It is assumed that an mELV pad could accommodate four to six launches per year and an sELV pad eight to twelve. Sounding rockets are normally launched from an elevated rail and require few support facilities. Short processing times could allow at least twelve sounding rocket launches per year. Most launches will occur during daylight hours, however, some will take place at night (about 20 percent at full development) because of particular mission-specific launch window constraints.

BENEFICIAL EFFECTS

As with any large development project, construction expenditures would provide a significant stimulus to the Big Island economy. The project would support an average of about 370 construction workers over a development period of about 2.5 years. Actual construction

employment would vary considerably over this period, and would reach about 600 workers during peak activity. Many construction workers would come from other parts of the Island or the State.

Once it is fully operational, the proposed Spaceport is expected to create about 270 permanent direct jobs. About two-thirds of the jobs would be filled soon after the main Spaceport facilities are constructed; the remaining employment growth is expected to occur gradually. Approximately 120 of these jobs, primarily semi-skilled and unskilled, are expected to be filled by residents of Ka`u or nearby communities.

In addition to the permanent work force, a number of scientists, engineers and technicians from out-of-state organizations would stay in Ka`u a few weeks at a time to assist in preparing payloads and launching rockets. The number of these transient workers would vary considerably over time, but is expected to average about 150 workers at any one time.

The skills required for Spaceport operations would range over a wide variety of training and experience, such as: laborers, semi-skilled workers, skilled tradesmen, technicians, engineers, managers, and administrative support staff. Salaries would be comparatively high, averaging about $34,000 per year in 1992 dollars.

Indirect employment--generated by launch companies and employees who purchase goods and services in the area--is expected to total about 420 jobs. These jobs would be distributed throughout the economy. They would range over a variety of skills and pay levels, including entry level, semi-skilled, skilled, and management positions. An estimated 250 of these jobs would be located in Ka`u, while most of the remaining 170 jobs would be in Hilo.

Jobs that require specialization would necessarily be filled by candidates who have received the prerequisite education as well as training and experience at launch sites on the mainland and various high technology operations in Hawaii. As the Spaceport matures, it is expected that an increasing number of Hawaii residents would be promoted from within the launch-related organizations to the specialized and senior positions after they gain on-the-job training and experience.

A broad spectrum of employment opportunities would allow some University graduates to stay in Hawaii rather than seek employment on the mainland and some former Hawaii residents to return to Hawaii. Other high-technology projects in Hawaii such as astronomy on Mauna Kea have a positive record of hiring support staff of various ranks from the local populace. Because these new jobs would generally pay higher than average wages, many families would be able to achieve a higher standard of living than would be possible without the proposed project.

At project completion, revenues to the County are expected to exceed expenditures by $3.7 million per year and State revenues are expected to exceed expenditures by about $4 million per year. The resulting combined fiscal impact on the State and County is that revenues are expected to exceed expenditures by an estimated $7.7 million per year.

ADVERSE IMPACTS AND PROPOSED MITIGATING MEASURES

NATURAL HAZARDS

Lava Flows. The launch pad area of the proposed facility is located within Lava Flow Hazard Zone 1, the most hazardous zone. The risk of inundation at the Palima Point site varies from high in the area downslope of the Kilauea southwest rift zone (the launch pad area) to moderate elsewhere. The only mitigating measure is to build lava diversion structures around the launch pads. If the lower Southwest Rift Zone of Kilauea should erupt, however, it is likely

that the launch pads would be inundated and destroyed. Lava diversion techniques would only provide a temporary solution. If the rift propagates through the diverters or through the launch pads, there would be no feasible way to prevent destruction of the facilities.

Earthquakes. Three primary earthquake hazards of concern at the Palima Point site are ground shaking, ground failure, and tsunami. The westernmost pad near Pu`u Pili is the most likely complex to be affected by tsunami run-up. The other launch pads and facilities are located at higher elevations and are therefore less vulnerable to tsunami run-up. Tsunami effects can be mitigated through appropriate siting and structural design.

The rocket propellants stored at the proposed launch facility pose a hazard to the local population and environment in the event that an earthquake causes a failure of containment. Fires may spread through combustible vegetation and toxic or caustic gases may be generated as products of combustion. Explosions can cause overpressures which may break windows and may scatter unburned propellant and debris over wide areas. Toxic or caustic gases can also be released into the atmosphere. On-site emergency response will serve to minimize some of the effects; design of the facilities to Uniform Building Code (UBC) 4 can also reduce the risk.

The worst case scenario would be the occurrence of a major earthquake when a fully-fueled launch vehicle is on the pad prior to lift-off. At this time the launch vehicle has minimal lateral support to withstand earthquake forces and would be exposed to puncture via toppling or slamming against adjacent support towers. If this happens the liquid propellants will most likely ignite and the rocket will be consumed. The effects would include toxic emissions from uncombusted hypergolic propellants, explosive overpressures and fire. The Delta II represents the most serious hazard because it contains the largest amounts of toxic/explosive propellants.

The probability that all the events leading to such a catastrophe would occur simultaneously is extremely small. On-site emergency response will reduce the adverse effects.

PROPELLANT TRANSPORT ACCIDENTS

Solid Propellants. If a solid propellant accidentally ignites and burns, the consequences can include the release of hot toxic gases, the generation of local fires, or the ignition of adjacent rocket motors. The resulting exhaust cloud may also be corrosive. A solid propellant produces large volumes of gas upon burning, which can lead to rupture and/or explosion. The rupture of a container may produce fragments.

The threat of a vehicle collision exists while the SRMs are being trucked to Palima Point. Whether or not a solid propellant will ignite or explode as the result of an impact depends on the plastic properties and shock wave propagation through the propellant. Direct exposure of the propellant to the flame temperature of a gasoline fire (>3000 F) for more than a few seconds would ignite the propellant since the flame temperature is well above the range of possible ignition temperatures. The probability of direct exposure of the propellant to a gasoline fire is considered low.

Although ignition of an SRM as a result of a transportation accident is considered to be unlikely, further analysis of actual hazards will be required when an actual project is defined.

Liquid Propellants. Accidental spills of toxic material could be caused by: a container being dropped from a crane, a drum falling from a truck, a valve being left open, or hose failure. Human error, such as improper packing, loading and unloading, rather than poor container design, causes the majority of releases involving small packages (drums and cylinders). Although the probability of these accidents occurring is very low, there is no

guarantee that an accident will not happen. Adverse impacts that could be generated by an accidental spill include:

* **Risks To Human Health.** The results of the EIS analyses indicate that increased lifetime cancer risk and acute adverse health effects in the surrounding community will occur from just one transportation spill of hydrazine and that acute adverse health effects will occur from just one transportation spill of nitrogen tetroxide. This emphasizes the need for proactive measures which will: (1) reduce the chances that an accident will occur, and (2) reduce the chances that an accident results in a release. It is also clearly demonstrated that an active emergency response capability to accompany transportation vehicles in order to contain, collect, and remove any spilled fuel is needed. Active response will reduce exposure and hence reduce risk significantly.

* **Risks to Sensitive Ecological Species.** A worst case transportation spill scenario would be an accident occurring near Hawaii Volcanoes National Park. In this scenario, the highest concentrations are estimated to be closest to the highway. Within 20 m of the highway, estimated concentrations of hydrazine, UDMH and nitrogen tetroxide are above levels that have been found to produce adverse effects in faunal species. The concentrations of these compounds decrease with distance from the spill site. Only N_2O_4/NO_2 is still unacceptably high at 1 km from the spill site.

  While estimated concentrations of the three substances could potentially produce adverse effects to biota close to the highway, the three most sensitive habitats within the park are located farther away from Highway 11 and would not likely be affected by any spills.

* **Other Adverse Impacts From Transportation Accidents.** If an accident involving a hazardous propellant occurs--even if there is no leak or spill--a safety zone would be established to protect the public from danger. The extent of this zone would vary by type of accident and release. The duration would also vary--certain highway segments could be closed for hours. This is significant because there are no alternate roads to Highway 11. This type of closure is expected to happen very infrequently.

NORMAL LAUNCHES AND LAUNCH FAILURES

Vehicle Scenarios. A normal launch, as the name implies, indicates a successful launch. The rocket ascends along a nominal trajectory functioning within design parameters. A conflagration represents a vehicle failure where the vehicle solid rocket booster(s) explode, resulting in scattered burning solid propellant fragments. A conflagration can occur either on the launch pad or during ascent. Each scenario has different effects. The conflagration scenario does not apply to vehicles that do not utilize solid propellants.

Deflagration represents a vehicle failure where the liquid fuels react in a fireball explosion. The exhaust cloud resulting from the fireball is comprised of vaporized hypergols and combustion by-products. An errant rocket can also be destroyed by the range safety officer (command destruct). This produces a breakup and falling debris, which have the potential to cause injury or damage.

Major Effects. The major effects of concern are:

o Toxic Exhaust and Vapor Clouds. Rocket exhaust products are characterized as a ground cloud plus the plume trailing behind the ascending launch vehicle. Volatile and particulate substances that could be harmful to people, animals and vegetation released during a successful launch and during launch failures when solid fuel explodes and burns

(conflagrations), include HCl and Al_2O_3. Potential emitted substances during launch failures when liquid fuel is involved (deflagration) include: hydrazine, UDMH, nitrogen tetroxide, FDH and DMNA. These propellants are toxic and/or corrosive. If released in an accident, vapors and aerosols may be transported by prevailing winds in the form of clouds. Such clouds may pose a health hazard to people and are potentially harmful to animals and vegetation.

- o Explosions. Uncontrolled combustion of the propellants at a very fast rate may produce a blast wave with the potential for damage by crushing forces and winds.

- o Debris. Vehicle fragments may land upon structures or populated areas. Fragments may include burning propellants which could explode or burn upon landing thus posing additional hazards such as fires and explosions.

- o Launch-Generated Noise and Vibration. With each rocket launch, there will be intense noise for one or two minutes within several miles of the launch site. Because the Atlas II AS and the Delta II booster systems are expected to generate essentially the same noise levels, they are treated as one and the same in the analysis.

- o Sonic Boom. A sonic boom can result from acoustical energy that is generated when a rocket exceeds the speed of sound. The shape and footprint of the sonic boom from any particular launch will be affected by the launch trajectory and meteorological conditions. Meteorological conditions can alter the peak overpressures, shift the focal region up or down range, and distort the shape of the footprint. Sonic boom effects from successful launches are evaluated for both the Atlas IIAS and the Delta II.

Potential Impacts. A summary of potential impacts on people, property and sensitive ecological species follows. It should be noted that most of the results were based on a Hypothetical Worst Case weather scenario that combines the worst aspects of vertical wind velocity profiles and inversion layer conditions. The result is to predict the highest downwind ground level concentrations of pollutants. Assessment results that show that there would be no adverse effects even under the Hypothetical Worst Case conditions generally indicate that they would not be expected under any other condition.

- * **Risks to Human Populations From Toxic Emissions.** Cancer risks and cancer burden were calculated using EPA methodology. These results indicate that if an individual were to be in the general area of the Spaceport (Pahala, Na`alehu, etc.) during successful launches or during several launch failures during their life, the risk of cancer would be negligible and no additional cancer would be expected in the population as a result of these activities. In the unlikely event that a launch failure was immediately followed by rain, the risk of cancer due to possible contamination of individual roof-catchment drinking water systems would also be negligible.

  A hazard index approach was used for the evaluation of acute (short-term) and chronic (long-term) noncancer health effects due to exposure to launch emissions. The analysis results indicate that no adverse chronic or acute health effects would occur in either off-site populations or facility workers due to successful launches.

  Chronic adverse health effects may occur in people living near the Spaceport if launch failures occur during certain unfavorable weather conditions and these failures involve the rupture and explosion of the Delta second-stage containing hydrazine. Acute adverse health effects such as respiratory irritation might also occur during a launch failure. An off-site hazard index could be as high as 2.0 at Pahala if conflagration occurs during

ascent at 10 seconds after lift-off. Because the chronic hazard index only slightly exceeds 1.0, however, there is only a small chance that chronic respiratory irritation would occur even in sensitive individuals in Pahala even after several failures. Both chronic and acute noncancer adverse health effects may also occur in on-site workers as a result of launch failures.

The airborne concentrations of rocket exhaust or unburned rocket fuel will be so low by the time they are transported under certain wind conditions to the Kona Coast that no measurable increase in respiratory irritation, cancer, or other adverse effects is expected in the population on the Kona side of the island due to successful launches or launch failures. This includes cumulative impacts added to the impacts of volcanic emissions.

Standard launch safety procedures--which include analysis of real-time meteorological data--would preclude a launch under conditions that would cause adverse affects to off-site populations. The evaluations of effects on facility workers is also extremely conservative in that it is assumed that indoor workers are exposed to levels of contaminants present in outdoor air and that all workers within the population control zone are exposed to the maximum centerline ground level concentration that would occur within the PCZ. Additionally, the ability of a HAZMAT team to respond to a launch accident and reduce ground level concentrations is not considered.

* **Risks to Sensitive Ecological Species From Toxic Emissions.** The ecological zone of concern (ECZ) is an area within 15 km (about 9 miles) of the launch site. It is highly unlikely that exposure to hydrogen chloride (HCl) from a normal launch would be detrimental to flora and fauna either within the ECZ or at distances farther downwind from the launch site. It is also reasonable to assume--at least for short-term exposures of approximately 1-hour duration--that exposures to concentrations of Al_2O_3 are unlikely to result in measurable adverse effects to biota. A conflagration on the launch pad is also unlikely to produce an adverse effects in biota.

  HCl produced during conflagration events occurring 5 and 10 seconds after lift-off could potentially produce adverse effects in sensitive receptors within the PCZ. Aluminum oxide particles released during a conflagration event 10 seconds after lift-off could also adversely affect biota.

  A liquid fuel deflagration could release carcinogenic substances such as hydrazine, UDMH, FDH and DMNA as well as N_2O_4/NO_2 which is noncarcinogenic. Exposure to expected concentrations of DMNA and hydrazine are unlikely to produce adverse effects. Exposures to the estimated concentrations for N_2O_4/NO_2 and UDMH/FDH have a probability of producing adverse effects in sensitive biotic receptors.

  It is unknown how simultaneous exposure to all of these carcinogens (as would be the case in a deflagration event) would effect ecological receptors. Multiple exposure could result in additive, synergistic or antagonistic toxicological effects.

* **Noise Impacts to Off-Site Communities.** Rocket launch noise in Pahala and Punalu`u may be sufficiently loud to mask normal outdoor conversation for a half minute or so, but should not mask normal speech at more distant locations. Also, in the closer locations, the rocket noise may startle some persons or awaken them if they are sleeping. Community response analysis indicates that about 18 percent of the population of Pahala may be highly annoyed if all launches occur between 7 am and 10 pm; and about 39 percent will be annoyed if half the launches occur between 10 pm and 7 am. It is expected that community reaction will be minimal among those not already opposed to the launch facility and possibly substantial among those who are already opposed.

* **Noise Impacts on Sensitive Ecological Species.** The effect of low (but inaudible) frequency noise levels on reproductive behavior and development is uncertain. Generally, faunal species (particularly birds) would be most sensitive early in the breeding season during the nest site selection phase, when noise could cause the birds to abandon the site.

* **Explosive Overpressure Effects on Off-Site Communities.** Based on calculations by ACTA Inc., an explosion on the launch pad would cause overpressures that could break windows at Punalu`u and Pahala. Further analysis is required to determine the extent of this damage.

  Close to the launch pad, the overpressure due to shock would exceed 1 psi. Although there is no conclusive evidence from actual studies, it is believed that this could potentially cause damage to nearby archaeological sites.

* **Explosive Overpressure Effects on Sensitive Ecological Species.** Close to the launch pad, the overpressure due to the shock would exceed 1 psi; this could have significant effects on nearby fauna, however, there is no clinical data supporting this.

* **Debris Effects.** Launch holds during Kona weather will prevent debris from falling on land outside of the immediate vicinity of the launch pads. It is anticipated that Spaceport employees will be appropriately protected during launch. During a launch, the PCZ and the offshore area downrange will be closed to unauthorized persons.

  Debris from an abort would result in the loss of flora in the launch area. It is not expected that this would result in a significant impact since vegetation on site consists primarily of introduced species. Fauna near the launch pad would also be affected, however, none of the debris footprints indicate an effect on the Kamehame Hill area, an area frequented by the green and hawksbill turtles. Fauna near the launch pad will be affected. There is a remote possibility that debris resulting from destruction of a rocket launched from the southern pad could impact the turtle nesting area. If calculations of debris patterns show that the Kamehame Hill and beach area could be affected, mitigating measures will have to be developed in cooperation with the USFWS and the NMFS.

ON-SITE TOXIC SPILLS

Spill Scenario. Prior to launch, fuel is transferred into the vehicle. Hypergolic propellants may be loaded up to 3 days prior to launch while cryogenic propellants are loaded within the last 3 hours of the countdown. The Delta II second stage contains 615 gallons of Aerozine-50 and 728 gallons of nitrogen tetroxide in separate tanks. If both tanks rupture or leak, the resulting fuel and oxidizer mix would result in fire. The spill from either substance alone results in a more hazardous condition because the vapors from the unburned liquids are toxic. The rupture of a launch vehicle tank of hypergolic propellant after the rocket is fueled produces the greatest adverse effects.

Worst Case Effects. It is assumed that the entire contents of a launch vehicle tank is released under two worst case meteorological conditions - a summer nighttime condition and a summer daytime condition. The analysis is also based on the assumption that the spilled liquid is allowed to remain and evaporate over time with no effort being made at remediation. This is an improbable situation which would not be allowed to happen. A spill would be actively contained and cleaned-up immediately, most likely within 5 to 20 minutes depending upon the size of the spill. With the source of the contaminant removed, airborne concentrations and hence exposures and risks would be significantly lower than predicted in this analysis.

* **Effects on Human Health.** The individual cancer risk from just one worst-case on-site spill from a Delta second stage tank (615 gallons of Aerozine-50) is significant. The total community excess cancer burden per 70-year lifetime is 4.0 estimated excess cancers based on 1990 population estimates and 4.2 excess cancers based on 2000 population projections. Acute and chronic adverse health effects in the surrounding community will also occur from a spill of either 615 gallons of Aerozine-50 or 728 gallons of nitrogen tetroxide during unfavorable wind conditions from just one worst-case on-site spill.

  The need for both passive containment (dikes, berms, etc.) and more importantly, active containment which consists of active emergency response to contain, collect, and remove the spilled fuel are clearly indicated. Active response will reduce exposure and therefore reduce risk significantly.

* **Effects on Sensitive Ecosystems.** The worst case spill scenario produces high concentration gradients emanating from the source of the spill for many kilometers downwind. The predicted exposure point concentrations depend on the spill pool area and the weather at the time of the spill.

  The highest concentrations of COCs are estimated within the PCZ. Despite the decrease in the concentration gradient, however, ecological receptors outside this zone are still exposed to high concentrations. Within the zone, the probability exists that mobile ecological receptors that utilize Palima Point (such as Hawaiian hoary bats, Hawaiian Hawk and sea turtles) could be exposed to concentrations of UDMH/FDH and N_2O_4/NO_2 that could cause adverse affects. Receptors that are distributed outside of the PCZ but within the 15 km zone of ecological concern could also be adversely affected by exposure to concentrations N_2O_4/NO_2.

  Mitigation measures that include immediate containment can quickly reduce the release of chemicals of concern (COCs) into the atmosphere. Active containment of spills reduces the concentration of COCs (especially as a function of distance), thereby decreasing exposure of sensitive biotic receptors to potentially adverse effects.

* **Effects on Groundwater.** An uncontrolled spill of either Aerozine-50 or RP-1 (kerosene) would result in the fuel percolating into the groundwater, spreading laterally toward the shore and discharging into the ocean. The contaminants would make the groundwater unsuitable for drinking water supplies without treatment until the contaminants had completely discharged into the ocean. Existing drinking water wells are landward of the proposed facility near the town of Pahala and along the highway to the south of the site. Spills at the Spaceport would not affect those areas.

  The quality of water in anchialine ponds near the shore, if any exist downgradient from a spill, could be affected because the ponds are actually exposures of groundwater, and contaminants in the groundwater surrounding the ponds would be present in similar concentrations in pond waters. The contaminants entering the ocean with migrating groundwater will be exposed to turbulent wave action and strong currents and would likely be difficult to detect.

  The extent of impacts on marine biota are difficult to assess because of the unknown nature of the materials involved; their initial distribution on and in the sea; the dilution and advection rates; and the toxicity of these materials to organisms. In sea turtles, changes in water quality from the addition of anthropogenic chemicals may adversely effect their reproductive success, however the concentrations at which these impacts may be manifested are unknown. The same statement may be made of all of the anchialine and marine organisms residing in the waters fronting the Palima Point Site.

MAUNA KEA OBSERVATORIES (MKO)

Lighting. Except during night launches and fueling operations, the impact of facility lighting on Mauna Kea will be minimal. All temporary and permanent outdoor lights at the launch facility will conform with the Hawaii County Lighting Ordinance.

Radio Frequency Interference (RFI). Radar transmitters associated with Spaceport operations have the potential to cause interference to both optical/infrared and radio telescopes because of their high power levels. The maximum potential for interference will occur if a radar antenna is aimed directly at MKO. Such interference would be reduced by using "sector blanking."

Even when the radar antenna main beam is aimed away from the telescopes, it is possible for energy emitted in the antenna "sidelobes" to cause interference. Sidelobe emission from a Palima radar would not interfere with the electronics of an optical/infrared telescope during normal tracking activities. The same radar operating at Cape Kumukahi would interfere with MKO optical/infrared operations. Radars at both Palima and Kumukahi would exceed the VLBA system temperature threshold.

Particulate Contamination. Following a launch, a column of warm temperatures (relative to the surrounding atmosphere) will occur in the exhaust plume. The warm temperatures could interfered with measurements made in the IR energy spectrum. Light and heat from rocket exhausts, particulate and/or condensation trails during night launches, and any carryover remaining in the field of view after sunset, following the daytime launches, are of concern to UH IfA.

* **Effects From a Southern Launch.** The exhaust plume from a southern launch will be carried away from Mauna Kea both below and above the tradewind inversion but could be carried back into the field of view in the stratosphere. Assuming westerly winds with speeds in excess of 10 m/sec at the highest altitudes, the plume could take about seven hours to clear the field of view of MKO. The clearing is relatively slow due to the initial launch vehicle trajectory due south of the observatories and transport winds normal to this trajectory.

  A potential worst case situation occurs during January when winds from the south at 5 m/sec occur at an elevation of 20 km. The exhaust plume from a southern launch at that time could take 7 hours to clear the MKO field of view. In addition, the plume would be carried back over the observatories in the southerly winds.

* **Effects From an East Launch.** An east launch directed along a 90 degree azimuth flies away from the Mauna Kea observatories. During conditions when westerly winds at 10 m/sec occur, as assumed for the southern launch, the plume would take about three hours to clear the field of view. The clearing is faster than the south launch because of the assumed transport winds in the same direction as the launch trajectory and away from the observatory. Winds in a direction other than westerly and at speeds other than 10 m/sec would produce different clearing times. These will vary depending on the season.

  Based on upper air sounding data, the easterly winds that occur during July--most likely representative of the summer months--are in a direction that will carry the exhaust plume from an easterly launch back toward and to the south of the observatories. Because wind speeds during these conditions are relatively high, plume clearing times will be relatively short.

Mitigation Measures to Prevent Deterioration of the MKO Site.

- All temporary and permanent outdoor lights at the launch facility will conform with the Hawaii County Lighting Ordinance. The lighting inventory will be closely monitored to ensure that it does not differ significantly from that assumed in the EIS.

- There will be no night launches unless they are mission related and required by orbital mechanics. UH IfA will be given at least one month's advance notice of any night launches.

- Terrain shielding and management of radiated power level, sector blanking, sidelobe energy control, frequency coordination and reduction of out-of-band emissions will be implemented to reduce the potential for radio frequency interference to acceptable levels as specified by the International Astronomical Union for optical/IR telescopes and as specified by the National Radio Astronomy Observatory for radio telescopes. These mitigations will be strictly enforced.

  As the Spaceport moves to the design phase, continued coordination with UH IfA will be mandatory and enforced. Actual measurements of radar signal propagation will be necessary to establish acceptable locations and operating parameters. Guidelines for the location and operation of range instrumentation systems will be made in coordination with and approved by the UH Institute for Astronomy.

- There will be no launches--day or night--when there is a southerly component to the wind at any level, including upper-level winds.

- Launches will be restricted to times when the exhaust plume will be transported out of the field of view (sky above 15° elevation) within two hours of launch.

- All rocket launches will be coordinated with UH IfA. Calculations of plume clearing time will be made on a case-by-case basis in order to insure that there is no impact on observatory operations.

It may be necessary to pass special legislation to insure that the mitigating measures are enforceable.

SOCIOCULTURAL IMPACTS

Archaeological Sites. The largest concentration of sites recommended for preservation are located in and around the village complex of permanent habitations found in the area of the center launch pad. These sites (along with the chain of ahu interpreted as markers of a trail connecting this coastal settlement with the interior) are believed to represent a coastal village or hamlet. An explosion on the pad or a command destruct abort could damage these sites. Protective measures will be developed in coordination with the State Historic Preservation Division.

Social Impact. About 65 percent of the people responding in a 1991 key informant survey conducted for the EIS were opposed to the project. It is unknown whether additional information provided in the EIS and/or the decline of sugar and/or the slowed resort development on the Big Island would change any of their views. Although development of the launch facility will predispose Ka`u to numerous social changes, it may also serve to restrict the amount of growth and subsequent social changes that occur in the immediate region. As no development can occur within the specified boundaries of the population control zone, about 10,400 acres, the project area would be predominantly open space. From a social impact perspective, the launch facility

will induce fewer changes than development of the property for major resorts and associated housing development.

Shoreline Recreation and Subsistence Uses. Whenever there is a launch, the entire PCZ will be closed to the public from 6 pm on the preceding night until about 30 minutes to one hour after the launch. During the period of closure no one except authorized personnel will be admitted to the area. The closures will temporarily disrupt coastal access and use. Fishermen would be the primary user group affected by shoreline closures. Closures during weekends, the period of greatest use, would have greater impact than closures on weekdays. The intermittent effects of shoreline closure can be mitigated by limiting closures to weekday periods as much as possible.

Visual Impact. The complete facility will be visible from several locations in Pahala. Residents will see two 175 foot- to 225-foot-high mobile service towers along the coastline. The towers will be highly visible because the ocean will serve as a backdrop and the duration of the view will be continuous. Because the elements will be introduced into a landscape which is currently undisturbed by structures, the towers will intrude upon the middleground line form created by the shoreline. Visual impact will be high.

The launch facility will be highly visible from certain viewpoints along Highway 11, in areas characterized by a landscape of pasture/shrubland. The impact will be the highest for northbound motorists because the view of the facilities will be in front of the observer and within the field of view for a longer period of time.

An evaluation of visual impact is very subjective and depends upon individual preferences. Although the use of colors that blend into the surrounding terrain, non-reflective roofs, and appropriate landscaping around launch-site buildings should serve to mitigate most visual impact, the launch pad structures, radar and communications dishes are not as amenable to design mitigation. It is assumed that the degree of negative reaction will relate to the degree of acceptance of the project by the viewer.

HAWAII VOLCANOES NATIONAL PARK

Land Use. The National Park Service may not consider the proposed rocket launch facility as a compatible adjacent land use. It should be noted, however, that it is unlikely that the lands in question will remain undeveloped indefinitely. The PCZ was established to maintain a safety buffer zone for launch operations. Since no additional development will be allowed within the PCZ, the land in question will remain in its wilderness state as open space.

Recreational Uses. Launch facility operations are not expected to have a significant direct effect on recreational users of the HVNP, although rocket launches will occasionally disrupt the wilderness character of the backcountry portions of the park.

Visual Impact. The proposed launch site will be visible from various locations within the southern wilderness area of the Park. The entire Spaceport facility will be visible from areas near Pu`u Ulaula, just south of the southern boundary of the site. The primary user group that would experience these views is those Park visitors who are willing to hike several miles in order to experience a remote, serene ambience and are expecting to see an undisturbed landscape. The introduction of Spaceport facilities into this viewshed could have a significant impact on the users' wilderness experience.

Night Sky. From the Kue`e Ruins, approximately 9 km northeast of the Spaceport site, the proposed launch facility would produce a visible glow and could be observed directly due to

lighting associated with operations. This has the potential of reducing the number of stars visible to the naked eye in that part of the sky by about 20 percent. With proper lamp shielding, as required by the Hawaii County Lighting Ordinance, the sky brightness at a zenith angle of 75 degrees would be significantly less bright than a sky with just a first-quarter moon. Most of the sky would remain quite dark, and significant effects on the enjoyment of the night sky by Park visitors would be unlikely.

Noise. Natural quiet is considered an important park resource. The potential impacts on HVNP are:

- The proposed emergency diesel generator unit in the Technical Operations Facility even if muffled by 25 dBA, could be audible in the most southern end of the Park. Implementation of 40 to 45 dBA mitigation measures to the diesel unit are necessary to approach inaudibility in all portions of the Park.

- Noise from helicopter operations could affect the park if ingress and egress to Palima Point are within or near the Park boundaries. Restricting routes to those over the ocean and conducting all routine sweeps at distances greater than one mile from the Park boundary and preferably at lower altitudes should effectively mitigate this potential impact.

- There would be intense sound levels from rocket launches for several minutes with maximums of about 93 dB at the HVNP Visitor Center. At this distance, little high frequency noise will be heard. The sounds of a rocket launch will be similar to the rumble of distant thunder.

Transportation Spills.

* **Effects on Human Health.** Although the spills analyzed for the Park do not pose a significant cancer risk as defined by EPA, it is important that an emergency response team be available to accompany transportation vehicles. The results of the noncancer hazard analysis indicate that persons within 20 m (66 feet) of a spill of hydrazine or nitrogen tetroxide under unfavorable weather conditions could suffer severe adverse health effects, even if the HAZMAT team following the transportation truck is able to cordon off the spill area, contain the spilled product, and either cover the spill or remove it.

* **Effects on Sensitive Ecological Species.** For the worst case scenario assessed, the highest concentrations were estimated to be closest to the highway. Within 20 m of the highway, estimated concentrations of all three substances assessed - hydrazine, UDMH and nitrogen tetroxide - were above levels that have been found to produce adverse effects. The concentrations of these compounds, however, decreased with distance from the site. Only N_2O_4/NO_2 was still unacceptably high at 1 km from the site.

  While estimated concentrations of the three substances could potentially produce adverse effects to biota close to the highway (there have been reports of listed species within 1 km of the highway), the three most sensitive habitats within the Park are located farther away from Highway 11 and it is unlikely that they would be affected by spills.

* **Other Effects.** If an accident involving a hazardous propellant occurs--even if there is no leak or spill--a safety zone would be established to protect the public from danger. The extent of this zone would vary by type of accident and release. The duration would also vary; therefore, certain highway segments could be closed for hours, which is significant because there are no alternate roads to Highway 11. This type of closure is expected to be very infrequent.

ALTERNATIVES CONSIDERED

NO PROJECT

Ka`u without the Spaceport, resort development, or new subdivisions would retain its rural character and existing life-style. No project, however, does not mean that nothing about Ka`u will change. Ka`u will not remain the same, because other trends and forces, projected to be of greater significance than Spaceport development, will continue to exert their influences on the future of Ka`u.

Under existing conditions, without major new economic development projects, the rate and degree of social change in Ka`u is and will be determined by the build-out rates of existing and proposed subdivisions. It is unlikely that the entire inventory of former sugar lands in Ka`u would sit idle if the Spaceport is not developed. Other development options, including resort expansion and housing, are being considered.

If the launch facility is not developed, the risk of exposure to toxic chemicals would be eliminated or greatly reduced, as would the potential for property damage from accidents due to launch-related activities. The concerns relative to the effects of launch operations on global warming and depletion of stratospheric ozone would remain, as the launches would almost certainly take place elsewhere.

ALTERNATIVE SITES

The Palima Point and Kahilipali Point sites were compared on the basis of the following factors, listed in descending order of priority: (1) environmental resources, (2) land ownership and the practicality of assembling a site, (3) recreational resources, (4) natural hazards and (5) infrastructure. By all criteria evaluated--except for lava flow hazards--the Palima Point site was superior to Kahilipali. The environmental evaluations indicate that adverse impacts at the Kahilipali Point site would be more significant than at the Palima Point site. In addition, because of current land ownership and development conditions, it is anticipated that land at the Palima Point site can be assembled in a more timely fashion. The Palima Point site was therefore selected for the environmental impact analysis in this EIS.

ALTERNATIVES TO LAND-BASED LAUNCHES

Floating Platform. The floating platform option is a potential alternative that offers several advantages, however, current estimates indicate that a land-based option is less costly in terms of construction and maintenance. There is also some reluctance on the part of satellite and vehicle companies to place such valuable assets on an unfamiliar surface. No floating launch platforms have been constructed to date; however, some interest in the concept has been expressed. Several U.S. launch companies have performed feasibility studies. It is possible that this alternative may become viable at some future time although it is predicted that impacts on Hilo Harbor from a floating platform would be significantly greater than launch facility development at a Ka`u site.

Air Launch. Orbital Sciences Corporation and Hercules Aerospace Company have developed the "Pegasus" air-launched space booster. Pegasus is able to deliver approximately twice the payload over an identical ground launched booster. It is flown by a conventional airplane to an altitude of approximately 40,000 feet and released. Although the Pegasus vehicle is not expected to replace any of the medium-lift launch vehicles, it is one of the launch vehicles that OSI would like to attract to Hawaii. If a Palima Point launch site project is not developed, it is still possible that Pegasus could be flown from a Hawaii location if it is economically feasible. Most likely that location would not be Ka`u.

ALTERNATIVE TRANSPORTATION INFRASTRUCTURE

Barge Landing Facility. OSI evaluated potential harbor locations in Ka`u to off-load rocket supplies from barges. Sites at Honu`apo Bay, Waikapuna Bay, Kahilipali Point, and Ka`alu`alu Bay were considered to be feasible from an engineering standpoint. Wave analysis and barge motion studies were also conducted and results were used in conceptual design of structures and operational constraints. Construction costs, however, would range from $12 million for a pier, $29 to $32 million for breakwater-protected harbors, and $55 million for excavation into the cliffs.

The sites investigated were ranked according to engineering feasibility, operational efficiency, and cost of construction. Ka`alu`alu Bay has the most conducive natural features and best approach for barge and tow. In addition, the formation of the bay provides the most flexibility for orientation of the final configuration. Existing roadways could be improved to allow access to the site without significant excavation.

Detailed bathymetric charts and geotechnical studies of the study area are extremely limited. If construction of a barge landing facility is considered further, it is recommended that more detailed bathymetric charts be prepared and preliminary geotechnical work be performed.

On-Site Airport. OSI evaluated the feasibility of constructing an airport within the PCZ at both the Palima and Kahilipali Point sites. The airport would be used primarily for transportation of large rocket components to the site. It was assumed that there would be no service by commercial passenger aircraft.

OSI concluded that it is possible to provide a suitable airport facility at either of the sites. FAA criteria can be met except for minor penetrations of the horizontal and conical surfaces on the uphill side. Runways for large aircraft require fairly large graded areas with almost flat slopes. Providing this surface at the site will require significant amounts of expensive grading of hard rock. If a launch project is defined and the on-site airport is considered further, a reevaluation of site feasibility would be assessed with respect to the specific project siting constraints.

UNRESOLVED ISSUES

Unresolved issues will be addressed in future environmental documents, prior to the design, construction and operation of a launch facility at Palima Point. It is assumed that a Supplemental EIS will be prepared when an actual project is defined.

- The State must acquire control of the land for the launch facilities. This will include negotiations with the Office of Hawaiian Affairs for use of ceded lands.
- Intensive archaeological and botanical surveys of areas to be disturbed by project facilities and infrastructure must be made.
- Archaeological mitigation must be approved by the State Historic Preservation Division.
- Actual construction impacts must be determined and assessed once the facility is designed.
- Extensive meteorological monitoring (of a least one years' duration) from ground level to the upper atmosphere must be conducted--and toxic dispersion/diffusion, explosive overpressure and debris models must be run for each specific rocket that will be launched--before the launch facility becomes operational.

- Additional modeling of particulate transport in the stratosphere and troposphere must be conducted to evaluate potential impacts on astronomy observations at MKO and to determine specific launch restrictions.

- Modeling of plume transport and clearing times--based on each specific rocket--must be conducted prior to each launch.

- Explosive overpressure and debris effects must be reevaluated for the specific rocket(s) to be launched from the facility.

- Detailed operations and emergency response and evacuation plans must be developed and approved by the appropriate authorities prior to the operation of the facility.

- A detailed risk assessment (rather than hazard analysis) of propellant transportation of must be when the actual propellants to be used are known and when more specific statistical data is available. At that time, the "worst case" would be redefined and reevaluated.

- Flora and fauna surveys must be conducted in all areas within 1 km of the Highway from Hilo to Palima Point, except in developed areas.

- Analyses of the effects of spills on groundwater wells at various locations along the transportation route must be undertaken before any propellants are transported to the site.

- Potential impacts to Hilo Harbor must be assessed.

- The methods and hazards of transporting SRMs must be evaluated when the shipping container design and port landing configurations are determined.

- A management structure which will ensure state, county and community involvement in the facility must be developed and implemented prior to project implementation.

POLICIES AND PLANS

The proposed project is compatible with the Hawaii State Plan goals to enhance the economy, increase and diversify employment opportunities and promote a growing and diversified economic base. The State Plan emphasizes the promotion of Hawaii's unique geographical and technological advantages and the development of high-technology industries.

The economic goals and policies in the Hawaii County General Plan that relate to the proposed launch facility include: provide diversity and stability in its economic system, provide an economic environment which allows new, expanded, or improved economic opportunities that are compatible with the County's natural and social environment, provide an economic climate which provides its residents an opportunity for choice of occupation, strive for diversification of its economy by strengthening existing industries and attracting new endeavors, encourage the research, development and implementation of advanced technologies and processes in existing and potential economic endeavors, and identify and encourage primary industries that are consistent with the social, physical, and economic goals of the residents of the County.

Standards to guide the development of the County related to the economy are as follows:

- The island of Hawaii should be developed into a unique scientific and cultural model. The island should become a model of living where economic gains are in balance with social and physical amenities. Development should be reviewed on the basis of total impact on the

residents of the County, not only in terms of immediate short run economic benefits.

- New industries which provide favorable benefit-cost relationships to the people of the County of Hawaii should be encouraged. Benefit-cost relationships as used here include more than fiscal considerations.

The County of Hawaii General Plan contains "courses of action" for each of the nine districts in the County. There are courses of action for all of the thirteen program areas. There are six economic courses of action for Ka`u. These are:

- Resort development in Ka`u shall be kept in balance with the social and physical environment of the area. Provisions for orderly development, housing, and pollution control shall be implemented.

- The County shall assist the further development of agriculture in the area.

- The fishing industry, other ocean based industries, and aquaculture, located in Ka`u should be assisted by the County through a cooperative effort with State and Federal agencies.

- The County shall support efforts to stabilize and maintain the viability of the sugar industry.

- The natural beauty of the area should be recognized as a major economic and social asset. This resource should be protected through appropriate review processes when development is proposed.

- Preliminary to the consideration of any proposed space-related launch activities, the County shall require, in addition to standard EIS requirements, special impact assessments.

PERMITS AND APPROVALS

A list of applicable reviews, permits and approvals is given in Table S-1.

ABBREVIATIONS AND GLOSSARY

A list of abbreviations and a glossary of terms used in the EIS follows Table S-1.

Table S-1

APPLICABLE REVIEWS, PERMITS, AND/OR APPROVALS

Agency and Permit or Approval	Legislation or Regulation	Purpose
Federal		
Department of Transportation Office of Commercial Space Transport		
License to Operate CSLF	Commercial Space Launch Act of 1984, Public Law 98-575 14 CFR Ch.III, Part 400 Commercial Space Transportation Licensing Regulations	National interest, safety
Federal Aviation Administration		
Joint Use Restricted Area	Procedures for Handling Airspace Matters, 74400.2C, Part 7, Chapter 29	Closure of air space for safety during launches
United States Coast Guard		
Safety Zone Area	33 CFR Part 165	Closure of territorial waters for safety during launches
Office of Environmental Policy		
Environmental Impact Statement	National Environmental Policy Act 42 USC 4321 *et seq.* 40 CFR Parts 1500-1508 Guidelines	Environmental protection; Federal action is licensing

Table S-1 (cont'd)

Agency and Permit or Approval	Legislation or Regulation	Purpose
State		
Land Use Commission		
State Land Use Districts	Chapter 205, HRS	Reclassify site to Urban; Special Use Permit for PCZ
Department of Land & Natural Resources (DLNR)		
Land Lease	Chapter 171, HRS	Transfer control of State land to CSLF
Conservation District Use Permit	Chapter 183, HRS DLNR Administrative Rules, Title 13, Chapter 2	Temporary closure of coastal waters
State Historic Preservation Office Approval	Section 106, National Historic Preservation Act (16 USC 470) 36 CFR 800 Regulations Chapter 6E HRS	Protection of historic sites
Permit to Drill or Alter a Water Well	Chapter 174C, HRS State Water Code DLNR Administrative Rules, Title 13, Subtitle 7, Chapter 168	Develop new water source
Office of Environmental Quality Control		
Environmental Impact Statement	Chapter 343, HRS DOH Administrative Rules, Title 11, Chapter 200	Environmental protection Required by state action of land consolidation

Table S-1 (cont'd)

Agency and Permit or Approval	Legislation or Regulation	Purpose
Department of Health (DOH)		
Potable Water Systems	Chapter 340E, HRS DOH Administrative Rules, Title 11 Chapter 20	Provide safe drinking water, protect public health
Underground Injection Control Approval to Construct; Approval to Operate	40 CFR 122 and 156, Regulations; Chapter 340E, HRS DOH Administrative Rules, Title 11, Chapter 23	Groundwater protection
Aboveground Storage Tanks[1]	Clean Water Act (33 USC 1251 *et seq.*) Chapter 342D, HRS DOH Administrative Rules, Title 11, Chapter 55	Contain deluge water, accidental spills, prevent water pollution
Wastewater Systems Construct & Operate Private STP	Chapter 342D, HRS DOH Administrative Rules, Title 11, Chapter 62	Prevent water pollution, protect public health
Storage and Handling of Hazardous Wastes	Resource Conservation and Recovery Act (42 USC 6901 *et seq.*) 40 CFR 260 to 272. Chapter 342J HRS	Proper management of hazardous wastes
Air Pollution Control Permit: Authority to Construct or Modify a Facility; Permit to Operate	Clean Air Act (42 USC 1857h-7 *et seq.*) Chapter 342, HRS; DOH Administrative Rules, Title 11, Chapters 59 and 60	Air quality, odor control, public health

[1]New legislation on aboveground storage tanks is being considered by Congress.

Table S-1 (cont'd)

Agency and Permit or Approval	Legislation or Regulation	Purpose
Used Oil Transport, Recycling & Disposal	Chapter 342N, HRS	Proper handling of used oil
Lead Acid Battery Recycling	Chapter 342I	Proper disposal of used batteries
Hawaii County		
General Plan Amendment	Hawaii County Ordinance No. 761	Allow for industrial use
Change of Zone	Hawaii County Code, 1983, Chapter 25	Rezone portion of site for industrial use
Special Management Area Permit	Chapter 205A, HRS Rule 9, Planning Commission	Temporary closure of coastal areas
Grading, Grubbing, and Stockpiling Permit	Hawaii County Code, 1983, Chapter 10, Articles 2 and 3	Environmental impacts of earth moving activities
Building Permit	Hawaii County Code, 1983, Chapter 5	Health and safety
Outdoor Lighting	Hawaii County Code, 1983, Chapter 14	Restrict outdoor lighting
Electrical Permit	Hawaii County Code, 1983, Chapter 9, Article 5, Division1	Health and safety
Plumbing Permit	Hawaii County Code, 1983, Chapter 17, Article 2	Health and safety

ABBREVIATIONS

A-50	Aerozine-50
ACGIH	American Conference of Governmental Industrial Hygienists
AEL	Acceptable Exposure Level
AFB	Air Force Base
Al_2O_3	Aluminum Oxide
COC	Chemical(s) of Concern
DMNA	Nitrosodimethylamine
DoD	Department of Defense
DOT	Department of Transportation
EC	Endpoint Concentration
EEGL	Emergency Exposure Guidance Level
EIS	Environmental Impact Statement
ELV	Expendable Launch Vehicle
FDH	Formaldehyde dimethylhydrazone
FTS	Flight Termination System
GEMS	Graphite Epoxy Motors
GEO	Geostationary Orbit
GPD	Gallons per day
HCl	Hydrogen Chloride
HDOT	Hawaii Department of Transportation
HECO	Hawaiian Electric Company
HELCO	Hawaiian Electric Light Company
HPF	Hazardous processing facility
HPS	Health and protective services
IDLH	Immediately Dangerous to Life and Health
IIP	Instantaneous impact point
ILL	Impact limit line
km	Kilometer
l	Liter
LC_{50}	Lethal Concentration to 50% of animals exposed
LCC	Launch Control Center
LD_{50}	Lethal Dose to 50% of animals exposed
LEO	Low earth orbit
LH_2	Liquid Hydrogen
LOEL	Lowest observed effect level
LOX	Liquid Oxygen
m	Meter
mELV	Medium expendable launch vehicle
µg	Microgram (.001 or 10^{-3} gram)
µg/l	Microgram per liter

ml	Microliter (.001 liter or 10^{-3} liter)
MLE	Maximum Likelihood Exposure
MMH	Monomethylhydrazine
MST	Mobile service tower
N_2H_4	Hydrazine
N_2O_4	Nitrogen tetroxide
NASA	National Aeronautics and Space Agency
NIOSH	National Institute of Occupational Safety and Health
NO_2	Nitrogen Dioxide
NOAA	National Oceanic and Atmospheric Administration
NOEL	No observed effect level
NO_X	Nitrogen oxides
NPF	Non-hazardous Processing Facility
OCST	Office of Commercial Space Transportation
OSHA	Occuapational Safety and Health Administration
PCZ	Population Control Zone
PEA	Propellants and explosives area
PEM	Permissable Exposure Limit
PPA	Payload processing facility
ppb	Parts per billion (.000000001 or 10^{-9})
ppm	Parts per million (.000001 or 10^{-6})
PSB	Payload storage building
Q-D	Quantity distance
REL	Recommended Exposure Limits (for workplace exposures)
RF	Radio frequency
RfD	Reference Dose
RFI	Radio frequency interference
RSO	Range safety officer
sELV	Small expendable launch vehicle
SNARL	Suggested No Adverse Response Level
SRM	Solid Rocket Motor
TEC	Toxicological Endpoint Concentration
TLV	Threshold Limit Value
TOF	Technical operations facility
UDMH	Unsymmetrical dimethylhydrazine
UF	Uncertainty Factor
UPS	Uniterruptable power system
UT	Umbilical tower

GLOSSARY

a'a. Rough textured lava flow.

AEL. Acceptable Exposure Level.

Aerozine-50 (A-50). A 1:1 blend of hydrazine and unsymmetrical dimethylhydrazine (UDMH) hypergolic propellant fuel used in combination with an oxidizer to create thrust.

ahu. Heap, pile, collection, mass, altar, shrine; a trap-like stone enclosure made by fishermen for fish.

ahupua'a. A traditional Hawaiian land unit extending from the mountain to the sea.

ali'i. Hawaiian ruling class.

apogee. The point in the orbit of a satellite which is furthest from the Earth.

azimuth. An angle measured eastward from north in the plane of the horizon. For example, the azimuth of a point due west of an observer is 270 degrees.

ballistic flight. The path taken by an object moving under the influence of gravity.

bipropellant. Bipropellant propulsion systems use both a fuel and an oxidizer. booster. A launch vehicle engine or motor used to propel a launch vehicle. Usually refers to motors used to augment thrust of a first stage engine.

candidate launch vehicles. Launch vehicles analyzed for Palima Point launches.

clean room. A special facility for handling material in a sterile and dust-free environment.

command destruct. The destruction of an errant rocket by the range safety officer during flight.

conflagration. A launch failure involving the explosion of solid propellant.

cryogenic. Propellants that are liquid only at very low temperatures are referred to as "cryogenic."

deflagration. A launch failure involving liquid fuels reacting in an explosion.

dry bucket. A type of launch pad that does not include a water deluge system (used on some launch pads for cooling or sound suppression.)

dynamic spin balancing. A part of the payload processing wherein the assembled payload is spun under controlled conditions to attain proper balance.

EEGL. Emergency Exposure Guidance Level.

escape velocity. The velocity required to escape from the gravitational field of an object.

expendable launch vehicle. Also known as an ELV. Launch vehicle that is used only once and expended or consumed.

fairing. The cover used to protect the payload or vehicle components from the effect of atmospheric forces or heating.

flight termination system (FTS). A system to destroy errant rockets in order to protect people and property.

footprint. The outline of an area on a map used to define a boundary.

gaussian. A bell-shaped curve or distribution.

geosynchronous orbit. An orbit in the plane of the equator, in which a satellite moves at the same angular speed as the earth rotates. The result is that the satellite maintains its position above a point on the equator. The height of such an orbit is 22,238 statute miles.

graphite epoxy motor (GEM). A type of solid launch vehicle motor. Nine are used to augment the Delta II first stage thrust.

hazmat. Hazardous materials.

heiau. Sacred Hawaiian structure built for worship.

hybrid. A launch vehicle motor that uses a solid fuel and a liquid oxidizer.

hydrazine. A hypergolic propellant fuel used in combination with an oxidizer to create thrust.

hypergolic. A propellant mixture (fuel and oxidizer) which, upon mixing, causes spontaneous combustion.

Impact Limit Line (ILL). Lines on a map around a launch site beyond which no launch vehicle debris is allowed to fall. Impact limit lines must lie within a population control boundary to ensure that the public is protected from a launch failure.

inclination. Angle between the orbital plane of a satellite and the equatorial plane.

Instantaneous Impact Point (IIP). The point or area where a launch vehicle will fall in the event of thrust termination. IIP is computed several times per second during the initial phases of flight.

isopleth. A line on a map connecting points at which a given variable has a specified constant value.

isotropic. Exhibiting properties with the same values when measured along axes in all directions.

kipuka. An isolated area of vegetation surrounded by lava flows.

liquid hydrogen. Hydrogen in liquid form is used as a fuel; usually in combination with liquid oxygen.

liquid oxygen. Oxygen in liquid form is used as an oxidizer; usually in combination with liquid hydrogen.

low earth orbit (LEO). An earth orbit at an altitude of several hundred miles or less.

makaainana. Hawaiian common people.

makai. Toward the sea.

mass fraction. The percent of the launch vehicle mass that is comprised of propellant.

mauka. Toward the mountains.

mole. short for molecular weight.

monomethylhydrazine (MMH). A type of hydrazine hypergolic propellant fuel used in combination with an oxidizer (or a catalyst) to create thrust.

monopropellant. Monopropellant propulsion systems use a catalyst to cause propellant to decompose within the engine to release energy for thrust. nautical mile. 6,080 feet.

nitrogen tetroxide. A hypergolic propellant oxidizer used in combination with fuel to create thrust.

opihi. A type of shellfish popular for eating.

oxidizer. The oxygen bearing component in a bipropellant reaction motor, usually either liquid oxygen or nitrogen tetroxide.

pahoehoe. Lava flow with a smooth appearance.

payload. The instrument, device, satellite, spacecraft, or probe transported by the launch vehicle.

perigee. The point nearest to the Earth in the orbit of a spacecraft.

polar orbit. An orbit which travels over the north and south poles. Such an orbit has an inclination of 90 degrees.

population control zone (PCZ). A buffer zone around the launch site where access is controlled for safety reasons.

psi. Pounds per square inch.

quantity-distance (Q-D). Refers to criteria and related standards for storing and handling explosives.

real-time system. System which is designed to receive data and process it within a time frame so short that there is no significant delay within the system itself.

redundant. The provision of greater-than-minimum number of components or equipment, in parallel, so as to ensure continued operation after a single failure. satellite. An object which is in orbit about a more massive primary body.

skyscreen. An optical sighting device made of a frame with vertical wires used at liftoff to confirm the launch vehicle is following the proper trajectory.

solid rocket motor (SRM). A launch vehicle engine or motor used to propel a launch vehicle.

sounding rocket. A relatively small rocket which does not go into orbit.

spacecraft. Vehicle containing all the necessary subsystems to support the payload for the performance of a particular mission. It may be manned or unmanned.

specific impulse. A term for indicating rocket engine performance by measuring the amount of thrust produced when one pound of propellant is burned in one second.

SPEGL. Short term Public Exposure Guidance Level.

stage. A section or part of a launch system which fires for a certain time only and is then separated from the main system; when more than one stage is used the technique is called staging.

station keeping. Maneuvers used to keep a satellite precisely located in its assigned orbital position.

statute mile. 5,280 feet.

storable. Liquid propellants kept at room temperature, such as kerosene.

suborbital. Not in orbit; sounding rockets carry instrumentation which fall back to Earth after reaching a set altitude.
sun synchronous orbit. An orbit in which the satellite has a constant sun lighting angle for successive orbits so that photographic data can be compared from many orbital passes.

telemetry. Transmission of signal from the launch vehicle to ground stations to track progress, position, and status of the vehicle.

temperature inversion. An atmospheric condition where the temperature decreases with altitude to a certain height and then either remains constant or increases with height.

trajectory. The path of a launched vehicle.

transfer orbit. The launch vehicle places one of its upper stages in low earth orbit. The upper stage re-ignites at a predetermined location and burns until sufficient velocity has been added to "transfer" the payload into a new orbit.

transponder. A device which receives pulses from ground-based radar and transmits a strong return pulse for each pulse it receives.

unsymmetrical dimethylhydrazine (UDMH). A type of hydrazine hypergolic propellant fuel used in combination with an oxidizer to create thrust.

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A. GEOLOGIC HAZARDS - PALIMA POINT ROCKET LAUNCH FACILITY

B. GROUNDWATER RESOURCES INVESTIGATION - PALIMA POINT ROCKET LAUNCH FACILITY

C. BOTANICAL SURVEY - COMMERCIAL ROCKET LAUNCHING FACILITY

D. BIRDS AND MAMMALS OF THE PALIMA POINT SITE

E. PRELIMINARY INVENTORY OF MARINE, ANCHIALINE AND SEA TURTLE RESOURCES AND WATER QUALITY CONDITIONS

VOLUME IV - ARCHAEOLOGICAL SURVEY

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A. TRAFFIC IMPACT ANALYSIS

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VOLUME IX - SOCIOECONOMIC, SOCIOCULTURAL AND LAND USE ISSUES

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E. MECHANISMS FOR ACQUISITION AND CONTROL OF LANDS NECESSARY TO DEVELOP A COMMERCIAL SPACE LAUNCH FACILITY

F. CASE STUDIES OF ECONOMIC IMPACTS OF SPACE LAUNCH FACILITIES

VOLUME X - SPECIAL CONCERNS AND MANAGEMENT PLANS

A. EFFECTS OF THE PROPOSED COMMERCIAL SATELLITE LAUNCHING FACILITY ON OBSERVATORY ACTIVITIES ON THE ISLAND OF HAWAII

B. SUMMARY OF LIGHTING IMPACTS ON HAWAII VOLCANOES NATIONAL PARK

C. VOG AND LAZE

D. GLOBAL WARMING AND STRATOSPHERIC OZONE DEPLETION

E. STATE LAUNCH FACILITY (SPACEPORT) MANAGEMENT PLAN

F. CONCEPTUAL SHORELINE ACCESS MANAGEMENT PLAN

SECTION I: OVERVIEW

A. PURPOSE AND NEED FOR ACTION

A stated goal of the State is to diversify Hawaii's economy. The State Department of Business, Economic Development & Tourism (DBEDT) has been studying the feasibility of establishing a commercial satellite launching facility in Hawaii as one way to attain this goal. Although the project would be developed by the private sector, the State intended to facilitate the process by obtaining ownership rights to a site and applying for master development approvals and permits. The actions that "triggered" the State's role in the Environmental Impact Statement (EIS) process under Chapter 343 HRS and the EIS Rules (Section 11-200-5) was DBEDT's proposed future involvement in the land acquisition and permitting activities of the project.

Because there is no actual project proposed at the present time, the EIS is based upon the elements of a conceptual plan. Environmental and safety issues are assessed under a maximum capacity build-out scenario for a conceptual project. The accident scenarios for each rocket and propellant were developed to test the environmental and safety limits of the assessed activities. The acceptability or non-acceptability of the impacts disclosed--and the efficacy of the mitigating measures presented--is left to be determined by legislative and regulatory bodies and the community. The EIS is intended to provide factual data to be used as the basis for making informed decisions as to the environmental feasibility of locating a commercial launch facility at Palima Point, Hawaii.

After completion of the EIS, the State of Hawaii does not anticipate further active participation in the launch site initiative at the present time. A supplemental environmental impact statement--which would be the responsibility of the private developer--and various licenses, permits and agreements with State, County and Federal agencies would have to be completed before a launch facility could be developed at Palima Point. Development of such a facility by private industry would only occur if driven by sufficient demand for commercial launch services.

B. HISTORICAL BACKGROUND OF THE PROJECT

In the early 1980s, under the direction of the High Technology Development Corporation (HTDC), a statewide high-technology strategy was developed to identify and promote several niche markets that might be appropriate for Hawaii. To increase Hawaii's role in high-technology areas, Governor John Waihee directed the State to investigate potential space-related activities which would be most appropriate for Hawaii. His goal was designed to:

- Diversify and strengthen the economy of the State of Hawaii;
- Provide training and career opportunities in high-technology fields within the state for Hawaii's youth; and,

- Build on the existing space-related research at the Mauna Kea Observatories, at Haleakala, and at the University of Hawaii.

In 1987, DBED prepared a comprehensive evaluation of Hawaii's potential for space exploration and development. The study considered a broad range of economic, technical, environmental, social and cultural factors in making its recommendations (ADL, 1987). As one approach, the study suggested that the State facilitate the development of launch services for small and mid-sized commercial and scientific satellites.

A subsequent site selection study (ADL, 1988) evaluated seven sites on the Island of Hawaii for their potential to allow safe launches into both polar and equatorial orbits. Two of sites were identified as meeting the selection criteria: Palima Point, the preferred site and Kahilipali Point the alternate selection (Figure I-1.1). Based on preliminary studies at both sites, OSI determined that the EIS should focus on Palima Point. A discussion of the site selection process is presented in Chapter Nine of this EIS.

In July 1988 the State Legislature created the Office of Space Industry (OSI) within DBED with the mandate to "develop, coordinate, and monitor the progress of a strategic plan for Hawaii's space industry." An Interim Project Description was prepared in 1991; a Conceptual Plan and Revised Project Description was released by OSI in February 1993. Because it was necessary to begin impact analyses prior to release of the Conceptual Plan, the EIS is based primarily on the 1991 report.

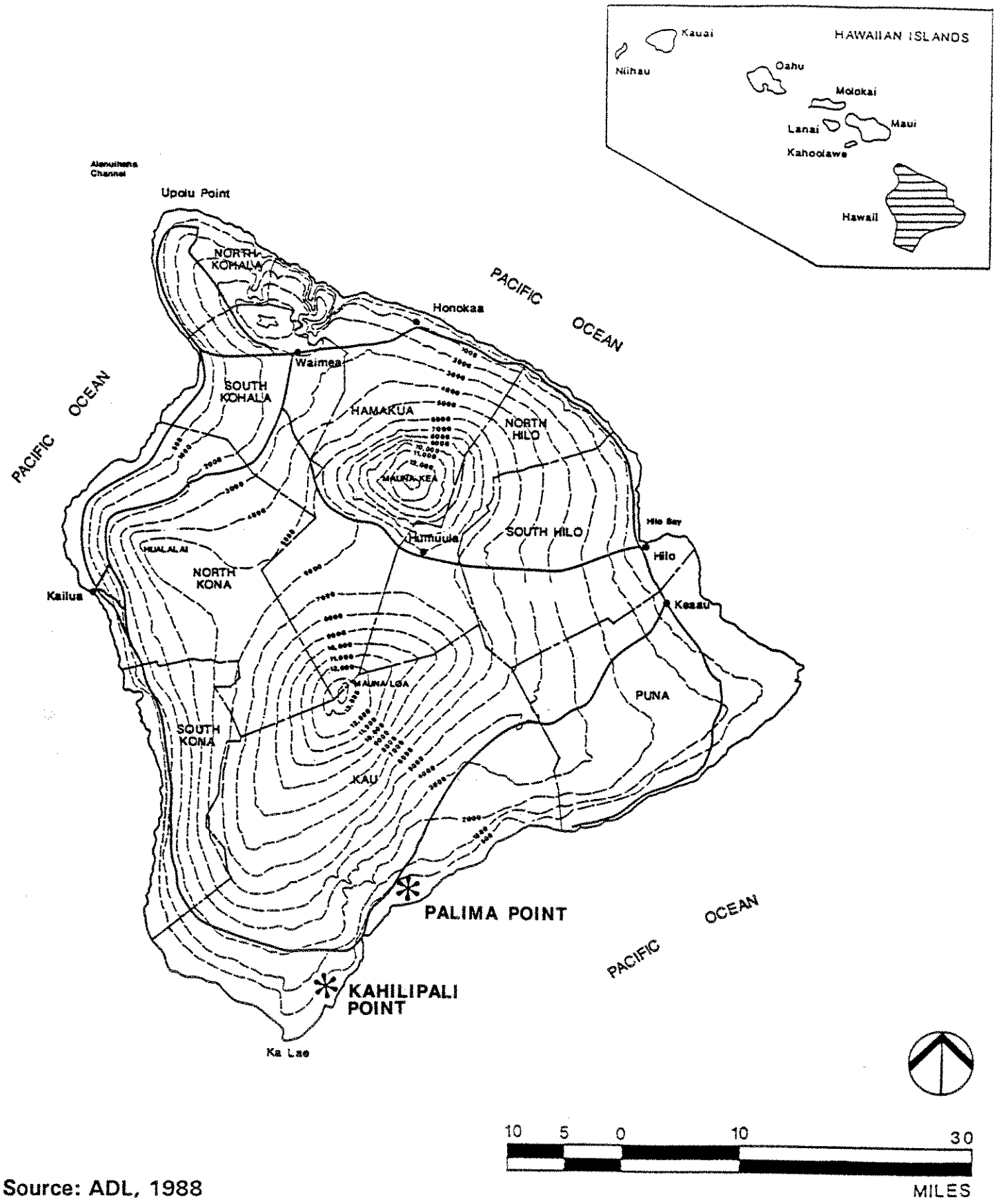
C. HAWAII'S ADVANTAGES AND DISADVANTAGES AS A COMMERCIAL LAUNCH SITE

Commercial satellite launching is an industry which offers substantial promise for economic diversification, and takes full advantage of Hawaii's unique mid-Pacific location. Hawaii offers the only place in the United States where satellites can be launched into any orbital inclination without overflying populated areas. Furthermore, Hawaii's low latitude increases fuel efficiency for launches into geosynchronous orbits--the closer a launch site is to the equator, the more it can take advantage of the earth's spin in launching into equatorial orbits. This advantage allows for heavier payloads and extended orbital lifetimes.

Since a launch facility in Hawaii would be a commercial enterprise rather than a military one, private launch companies would have greater control over their schedules, thereby reducing risk and expense for the launch customer. In addition, Hawaii's mid-Pacific location would encourage the formation of an international consortium facilitating foreign marketing, bilateral cooperation, and strategic alliances in the rapidly developing Pacific Rim.

The need to construct all of the range infrastructure (e.g., on-site roads, utilities, safety instrumentation, and support facilities) is a disadvantage inherent in a Hawaii site. At the national ranges, these costs were incurred by the U.S. Department of Defense (DoD); launch companies only pay the direct costs of their launch (e.g., cost of launch pads, use of the range safety instruments, additional maintenance costs, etc.). While the range infrastructure costs of a new Hawaii launch site must be amortized through launch fees, these facilities would have the advantage of being new and could be optimized for the greatest efficiency.

These advantages and disadvantages would be weighed carefully by any prospective launch operator. Environmental and safety constraints and restrictions, as recommended in this EIS, would also have a cost. The economic feasibility of the project would ultimately be determined by the prospective developer's analysis of the costs and benefits of operating in Hawaii.



Source: ADL, 1988

Figure I-1.1

PREFERRED AND ALTERNATIVE SITES

SECTION II: ENVIRONMENTAL COMPLIANCE

A. STATE ENVIRONMENTAL REQUIREMENTS

Although the State will not develop and operate a satellite launch facility, it does intend to acquire land and assemble a site; obtain the necessary land use reclassifications and permits; and, lease a permitted site to a consortium of launch operators. These actions, which will involve the use of state funds and lands, subject the state to the provisions of Chapter 343 HRS (EIS Rules, Section 11-200-5), which state:

> *"The applicability of chapter 343, Hawaii Revised Statutes, to specific agency proposed actions is conditioned by the agency's proposed use of state or county lands or funds. Therefore, when an agency proposes to implement an action to use state or county lands or funds, it will be subject to the provisions of chapter 343, Hawaii Revised Statutes, and this chapter."*

DBEDT determined that an EIS was required because the project could generate significant environmental impacts. An environmental assessment and notice of preparation of EIS (NOP), prepared under Chapter 343 HRS and the EIS Rules, was published in the Office of Environmental Quality Control (OEQC) Bulletin in September 1989. Comments that were received during the consultation period were addressed in the draft EIS to the greatest extent possible.

The EIS is intended to be a "full disclosure" document, prepared to fulfill the requirements of Chapter 343 HRS and the EIS Rules (Chapter 200, Title 11, Administrative Rules). The Final EIS contains revisions, additions and responses to comments received during the public review period of the draft EIS. If the contents of the Final EIS meet the requirements for full disclosure set forth in the EIS rules, the Governor will accept the document as adequately meeting the provisions of the law. It should be emphasized that the Governor does not approve the project when he accepts the Final EIS. It is up to the Legislature to either approve or deny funding and the regulatory agencies to approve, deny or condition the permits required for the development to proceed. As stated previously, after completion of the Final EIS, the State of Hawaii does not anticipate further active participation in the launch site initiative at the present time.

B. FEDERAL ENVIRONMENTAL IMPACT STATEMENT REQUIREMENTS

Because a Federal license is required before the facility can be operated, the State EIS process was coordinated with OCST to ensure that the issues assessed in the State document are consistent with those of the National Environmental Policy Act (NEPA) and USDOT guidelines. A supplemental environmental impact statement--which would be the responsibility of the private developer--and various licenses, permits and agreements with State, County and Federal agencies would have to be completed before a launch facility could be developed at Palima Point.

C. OTHER

There are other environmental requirements that require compliance on both the State and Federal levels. These requirements are discussed in Chapter Ten of this EIS.

D. LIMITATIONS OF THE EIS AND FURTHER WORK REQUIRED

The EIS is programmatic in scope. It should be considered as an informational guide to State decision-makers in determining whether or not the benefits of the project outweigh the potential environmental impacts and whether or not resources should be allocated to site acquisition, permitting and further analytical studies related to the commercial space launch facility initiative.

The draft EIS was prepared concurrently with the Conceptual Plan; most of the analyses were based on a preliminary project description dated June 1991. As findings of the technical and environmental studies became available, recommendations and mitigating measures were incorporated into the Conceptual Plan and Project Description. Because the process was interactive between the EIS studies and plan development, some of the assumptions that appeared in the technical appendices were subsequently revised and were, therefore, not consistent with the conceptual plan. Every effort was made to acknowledge these differences in the body of the environmental impact statement and evaluate their significance.

With the exception of the launch pad area, no intensive botanical and archaeological field surveys were undertaken. Once the project has reached the site planning stage of development, detailed surveys must be conducted to insure that no significant archaeological sites and threatened or endangered species are impacted. In addition, biological surveys may also be required along the transportation route from Hilo to the project site and within Hawaii Volcanoes National Park (HVNP) to insure compliance with all Federal requirements relating to endangered and threatened species.

The evaluation of launch operations and the transport of propellants are essentially hazard analyses, conducted to identify worst case scenarios that could impact the environment. They do not substitute for detailed risk assessments which include casualty expectations. Detailed risk assessments are more appropriately included in an operations plan, based on an actual project, which will set more definitive criteria to protect the health and safety of human and ecological populations.

In many cases, the EIS raises questions that cannot be answered with available data and/or project information. Unresolved issues are identified in Chapter Eight; it is intended that these issues will be resolved in a supplemental EIS which will be prepared when an actual project is planned.

SECTION III: ORGANIZATION OF THE FINAL EIS

The Final EIS incorporates all of the information submitted in the draft EIS with certain revisions as stated in responses to various comments. The technical appendices that were filed as part of the draft EIS (Volumes III through X) are incorporated by reference, they not being reprinted. Please see DBEDT responses to comments (Chapter Twelve) and Appendices A through D for additional technical information.

The ensuing Chapters of Volume I address the following topics:

- *Chapter Two* summarizes the elements of the Conceptual Plan/Project Description that are assessed in the EIS;

- *Chapter Three* describes the environmental setting of the proposed project;

- *Chapter Four* assesses impacts from natural hazards, construction activities and routine launch facility operations; and,

- *Chapter Five*, which discloses potential impacts from launch operations, transportation accidents and chemical spills, is organized by major groups of actions related to the following project elements: transportation of propellants and gases; launch events, including: normal launches and launch failures; hazardous operations including: propellant storage and handling, payload processing and accidental spills; and, special concerns, which includes analyses of project effects on the Mauna Kea and Mauna Loa Observatories and global and regional air quality. Chapter Five also includes an Addendum that includes replacement pages for the Health Risk Assessment (DEIS Appendix VIIIA).

- *Chapter Six*, which addresses economic, fiscal and housing impacts;

- *Chapter Seven*, which discusses sociocultural and recreation issues (including Hawaii Volcanoes National Park), and visual impacts;

Volume II includes:

- *Chapter Eight*, which evaluates the cumulative effects of the proposed action and presents a summary of adverse impacts; the relationship between local short term uses of man's environment and the maintenance and enhancement of long term productivity; and, irreversible and irretrievable commitment of resources; and unresolved issues.

- *Chapter Nine*, which addresses the alternatives considered, including: no project; alternative sites; alternative means of transportation; and, alternative economic scenarios;

- *Chapter Ten*, which discusses the relationship of the proposed project to policies, plans and controls for the area and includes a list of necessary approvals; and

- *Chapter Eleven* which lists agencies, organizations and individuals consulted during preparation of the draft EIS and includes copies of written comments on the NOP and DBEDT's responses to these comments.

- *Chapter Twelve* which includes copies of written comments on the draft EIS and DBEDT's responses to these comments.

- References cited and personal communications.

- *Appendix A*, compiled by Risk Sciences Associates, sets forth typical emergency response procedures for transporting and handling toxic liquid propellants for space operations.

- *Appendix B* is a summary of major elements of meteorological monitoring to support space launch operations compiled by ACTA Inc. and others.

- *Appendix C* is a report by Engineering-Science, Inc. entitled "Analysis of Stratospheric Wind Data to Determine the Frequency of Winds Toward the Mauna Kea Observatories."

- *Appendix D*, a September 1993 report by the DBEDT Office of Space Industry entitled "Financial Feasibility Studies Related to the Proposed Hawaii Spaceport."

- *Appendix E*, a written transcript of a video entitled "Spaceport-Benefit or Tragedy" submitted by William Hachmeister during the public review period of the dEIS.

Volumes III through X contain the technical appendices that were submitted as part of the draft EIS; they are incorporated into the Final EIS by reference. These reports address the subjects listed below. Please refer to DBEDT responses to letters from the State Department of Health, Office of Hawaiian Affairs and Ruth M. Bass and to the Addendum to Chapter Five for revisions to Volume VIIIA.

- *Volume III*, the Natural Environment, includes reports on geologic hazards; groundwater resources; botanical resources; birds and mammals; marine, anchialine and sea turtle resources; and, nearshore water quality.

- *Volume IV* presents findings of an archaeological survey of the Palima Point site.

- *Volume V*, Facilities Construction and Use, includes reports on traffic; climate and air quality; drainage and flooding; and, construction impacts.

- *Volume VI*, Launch Operations and Hazards (1), includes a hazard analysis for the transportation of propellants from Hilo to the site; accident risk assessments for handling and storage and payload processing facilities; and, an impact analysis of toxic spills, exhaust gases, and vehicles accident gases.

- *Volume VII*, Launch Operations and Hazards (2), includes reports on debris dispersion effects from an aborted launch; acoustical noise impact evaluations; a survey of potential sonic boom consequences; and, explosive overpressure hazards.

- *Volume VIII* presents human health and ecological risk assessments for transportation of propellants, normal launches and launch failures, and accidental spills.

- *Volume IX* reports concern socioeconomic, sociocultural and land use issues.

- *Volume X*, Special Concerns and Management Plans, includes reports on effects of the proposed facility on Mauna Kea and Mauna Loa Observatories; Hawaii Volcanoes National Park; regional vog and laze effects; global warming and stratospheric ozone depletion. It also includes a State Spaceport Management Plan and Conceptual Shoreline Access Management Plan.

SECTION I: OVERVIEW

This section is based on the "Conceptual Plan and Project Description for a Commercial Satellite Launching Facility", Office of Space Industry, February 1993 and the Interim Project Description, June 1991.

A. BASIC ASSUMPTIONS OF THE ENVIRONMENTAL ANALYSES

1.0 The Proposed Action

The EIS is based upon the elements of the Conceptual Plan rather than a specific project. In this case, the action that "triggers" Chapter 343 HRS and the EIS Rules (Section 11-200-5) is the State's proposal to enter into agreements with landowners to obtain an interest in the affected properties by purchase, lease and/or other mechanisms; and, to begin the land use conversion permit process. The application for a site and/or operator's license from OCST will be the responsibility of the private developer and/or operator and not the State. It is intended that supplemental statements, both State and Federal, will be prepared when an actual project is proposed.

2.0 The Project Site

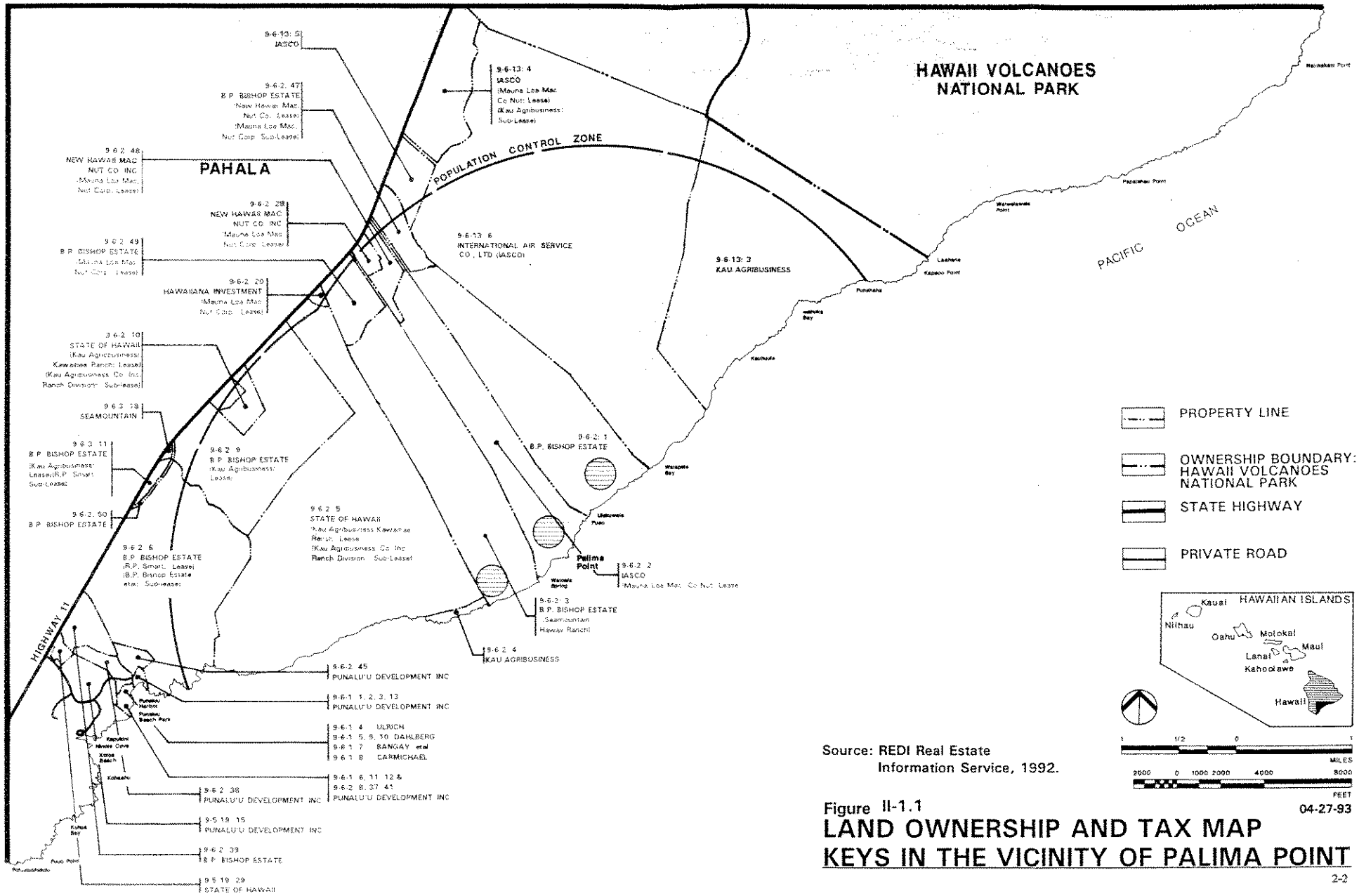
The preferred location for the project is at Palima Point, District of Ka`u, County of Hawaii (T.M.K. 9-6-2: portions of parcels 01-06, 09, 10, 20, 28, 47-49; and 9-6-13: portions of parcels 03, 05 & 06). Figure II-1.1 shows land ownership adjacent to and within the PCZ (REDI, 1992) with Tax Map Keys. Although development will only occur on about 1,000 to 1,200 acres, a total of about 10,400 acres must be controlled to insure the safety of the population during launch operations.

The assessment is based on a full build-out of the launch site. For the purpose of environmental analyses, it is assumed that all available launch pad space, three 1,500 foot diameter circular launch areas, is being utilized. It is also assumed that all support functions will be located on the spaceport. This approach yields the maximum number and size of buildings. Figure II-1.2 shows a conceptual layout of the proposed launch facility.

The State would not develop the site; it would be developed by a private operator or consortium. The State's role includes, but would not be limited to: land acquisition and land management; obtaining master land use permits and monitoring compliance to the conditions of approval; and monitoring environmental and safety concerns (DEIS, Appendices IXE & XE).

3.0 Launch Vehicles

Candidate launch vehicles would include suborbital sounding rockets and orbital launch vehicles (Atlas, Delta, Taurus and Scout). Atlas IIAS is the largest of the orbital launch vehicles being considered. The Atlas IIAS and Delta II are considered to be medium expendable launch vehicles (mELVs); Taurus and Scout are small expendable launch vehicles (sELVs). The environmental analyses focus on the "worst case" vehicle for a particular action or event being evaluated, therefore, the assessment deals primarily with potential environmental impacts of



Source: REDI Real Estate Information Service, 1992.

Figure II-1.1

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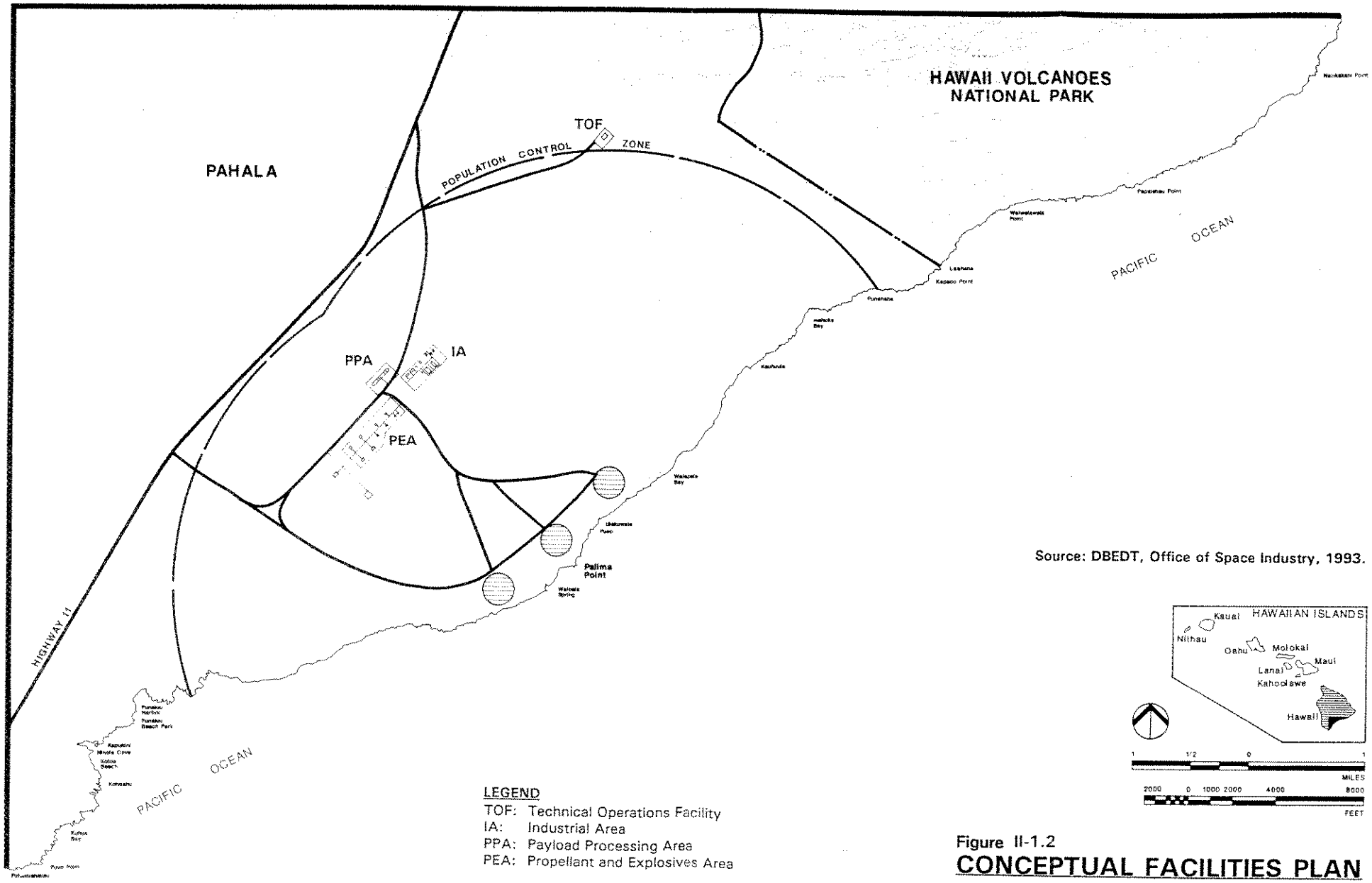
LAND OWNERSHIP AND TAX MAP KEYS IN THE VICINITY OF PALIMA POINT



Source: DBEDT, Office of Space Industry, 1993.

LEGEND
TOF: Technical Operations Facility
IA: Industrial Area
PPA: Payload Processing Area
PEA: Propellant and Explosives Area

Figure II-1.2
CONCEPTUAL FACILITIES PLAN

launching mELVs (Atlas and/or the Delta). The candidate launch vehicles are depicted in Figure II-1.3.

4.0 Payloads

There are six major commercial and scientific applications of space: communications satellites, weather satellites, remote sensing, navigation, materials processing, and space science. Early missions would probably be oriented toward either communications or earth observation including government weather satellites. Certain payloads, however, are prohibited by State law.

On June 19, 1990, Act 172 was signed into law by the Governor of the State of Hawaii. Section 201 states that:

> *Any vehicle launched into space from the land or ocean territory of the State shall not carry weapons of destruction, nuclear waste materials, or use radioactive materials as a power source.*

This Act is a statement of the intent of the State to use the commercial spaceport facilities for the peaceful exploration of space, and to prohibit those payloads which could cause harm or destruction. Some payloads related to the military could be launched, however, including weather, communications and navigation satellites.

5.0 Propellants

Solid Propellant Rocket Motors (SRMs). SRMs and small explosive charges would be stored at the launch facility in a storage area sized to contain two complete flight sets of motors for two mELVs and one sELV as well as sounding rocket and spacecraft apogee and perigee kick motors. All solid propellants are DoD Class 1.3 explosives.

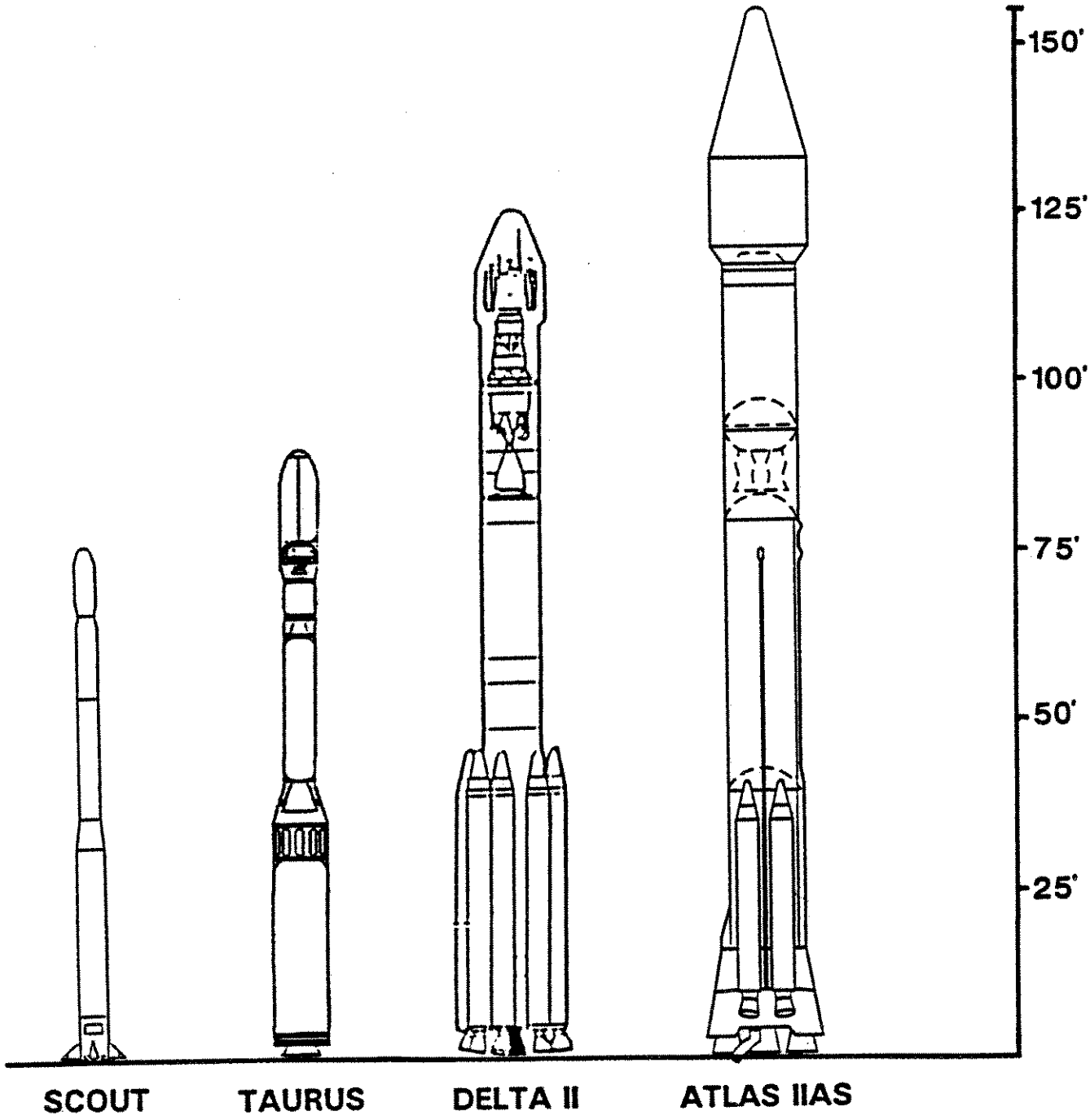
Hypergolic Propellants. Hypergolics are rocket propellant mixtures (fuel and oxidizer) that ignite spontaneously upon mixing. The hypergolic propellants Aerozine-50, Nitrogen Tetroxide (N_2O_4) and Hydrazine (N_2H_4) would be stored at a central location within a Propellant and Explosives Area (Figure II-1.1). Hypergolic propellant requirements by type and quantity are shown on Figure II-1.4. Storage of three times the required amounts would cover contingencies such as discovery of impure propellant.

Non-Hypergolic Liquid Propellants and Gases. Cryogenic propellants include liquid oxygen (LOX) and liquid hydrogen. RP-1 (kerosene), a hydrocarbon, is used as fuel in both the Delta and Atlas. Nitrogen and helium are utilized in both the gaseous and liquid form. It is assumed that these propellants are stored at the launch complexes.

Hazards associated with handling and storage of propellants are assessed in Chapter Five, Section IV and DEIS Appendix VIB.

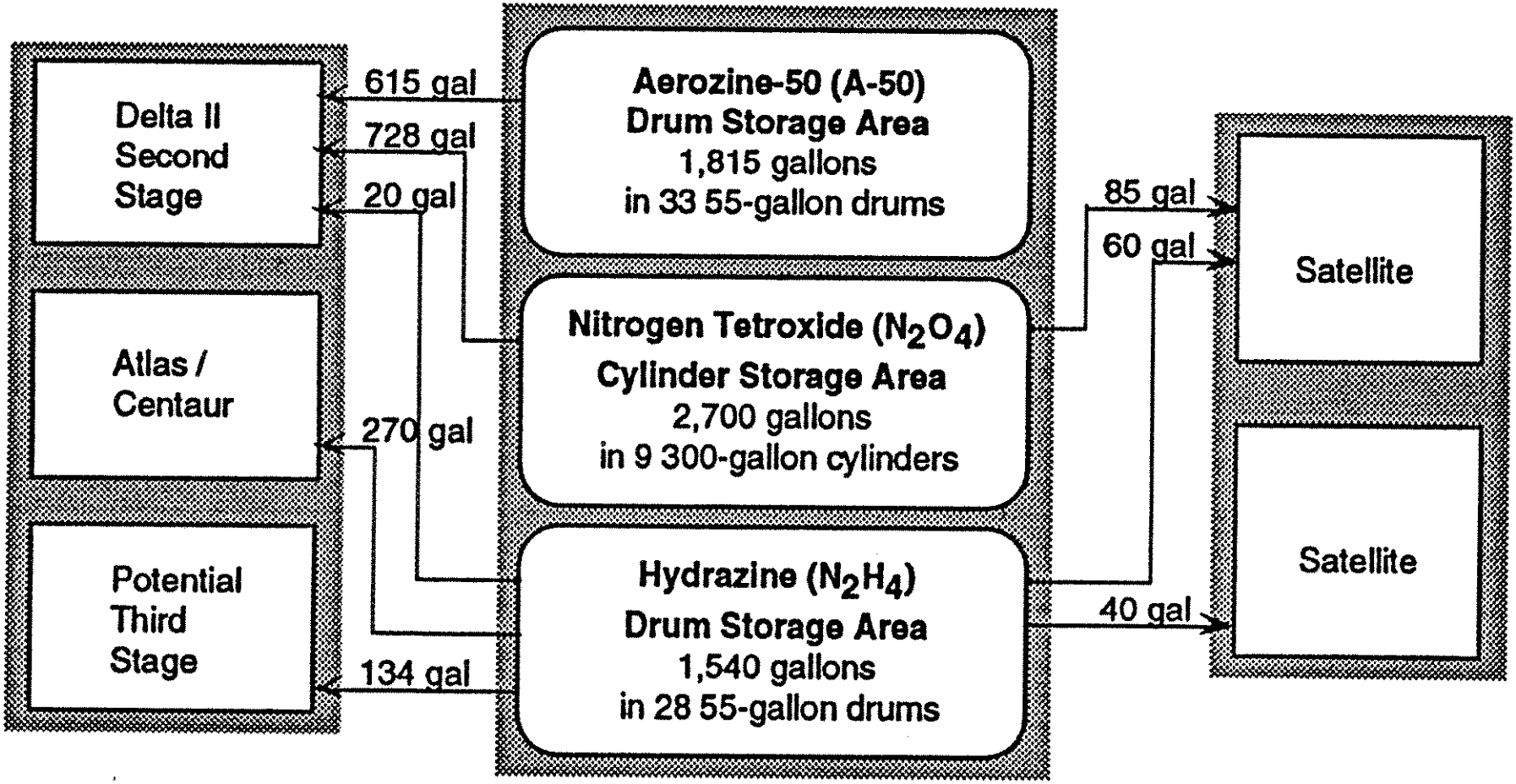
6.0 Launch Facility Development Schedule

Full build-out of the launch facilities is assumed to occur over a 3-year period after completion of permitting and land acquisition. Permitting includes completing all necessary agreements. After land rights and major development permits are obtained, an undetermined amount of time will be required to negotiate major agreements with the launch companies and the users.



Source: DBEDT, Office of Space Industry, 1993.

Figure II-1.3
CANDIDATE LAUNCH VEHICLES



Source: DBEDT, Office of Space Industry, 1993.

Figure II-1.4

HYPERGOLIC PROPELLANT REQUIREMENTS AT FULL BUILD-OUT

Construction of infrastructure, range instrumentation and support facilities would require two years. The first sELV launch could occur as early as 18 months after construction begins, with mELV operations commencing the following year.

7.0 Projected Launch Rates

Table 2.1.1 shows the launch rates assumed for the Palima Point launch facility. The number of orbital launches completed each year will depend on many factors, including the number and types of available launch pads, payload market demands and the time needed to prepare a rocket for launch.

A typical mELV would be on the pad for approximately two months prior to launch, therefore, it is assumed that an mELV pad could accommodate four to six launches per year. Because the sELVs considered as candidates for the Palima launch facility are less complex than the larger liquid propellant mELVs - on-pad time prior to launch is shorter - it is assumed that about eight to 12 sELV's could be launched per year.

Sounding rockets are normally launched from an elevated rail and require few support facilities. Short processing times could allow at least twelve sounding rocket launches per year.

8.0 Launch Windows

Most launches will occur during daylight hours; however, some will take place at night (about 20 percent at full development) because of particular, mission-specific launch window constraints.

B. GENERALIZED LAUNCH PROCESS

1.0 Transportation of Rocket Stages

Transportation of rocket stages from Hilo would be via Highway 11. The Delta first stage is 85 feet long and weighs 12,500 pounds; it requires a special van as does the second stage and fairing which are shipped together. Special vans also transport the upper-stage motor and each of the 28,800 pound solid propellant graphite epoxy motors (GEMS). The interstage is transported on a lowboy trailer; small containers holding the spin table and spare parts are carried in vans.

The 82-foot-long Atlas stage of the Atlas/Centaur is transported on a 92 foot flatbed trailer. The overall dimensions of the tractor/trailer are 116 feet long and 16 feet wide, requiring a vertical clearance of 13.5 feet on level road. Transporter gross weight is 45,000 pounds. The 33-foot-long Centaur stage is transported in a separate van.

The four-stage Taurus will utilize a Castor 120 solid propellant motor. Because the shipping enclosure, including the motor, weighs 137,000 pounds and is 9-foot-high by 29-foot-long, a special transporter would be designed to distribute the heavy load. This will allow existing bridges to be used without major modifications.

2.0 Transportation of Propellants

The types and quantities of chemicals that may be transported from Hilo Harbor to the launch facility are identified in Table 2.1.2. Most rocket fuels are classified by the USDOT as

Table 2.1.1 **PROJECTED LAUNCH RATES**

Year	Sub-orbital	sELV	mELV1	mELV2	Total Orbital
1995	2	0	0	0	0
1996	4-6	1-3	0	0	1-3
1997	7-9	4-6	1-3	0	5-9
1998	10-12	6-8	3-5	1-2	10-15
1999	10-12	6-10	3-6	2-3	11-19
2000	10-12	8-12	4-6	3-4	15-22
2001	10-12	8-12	4-6	3-4	15-22

Source: DBEDT, Office of Space Industry, Feb. 1993

Table 2.1.2 ROCKET PROPELLANT CHEMICALS AND TRANSPORT QUANTITIES

Substance	Chemical Abbr.	Use	Form	Transport Quantity
Propellants				
Hydrazine	N_2H_4	fuel	liquid	55 gal drum
Monomethyl Hydrazine	MMH	fuel	liquid	55 gal drum
Unsymmetrical dimethylhydrazine	UDMH	fuel	liquid	55 gal drum
Aerozine-50 (50% UDMH+50% N_2H_4)	A-50	stage 2 fuel	liquid	55 gal drum
Nitrogen Tetroxide	N_2O_4	stage 2 oxidizer	liquid	300 gal cylinder
Kerosene-like	RP-1	stage 1 fuel	liquid	4,000 gal
Hydroxol terminated polybutadiene	HTPB	propellant	solid	Castor motor, GEM
Cryogenics				
Liquid Hydrogen	LH_2	Centaur fuel	liquid	4,000 gal
Liquid Oxygen	LOX	stage 1 oxidizer	liquid	4,000 gal
Liquid Nitrogen	LN_2	pressurization	liquid	4,000 gal
Liquid Helium	LHe	pressurization	liquid	shipped as gas

Source: DBEDT, Office of Space Industry, Feb. 1993

hazardous materials because of their flammable and/or toxic properties. A hazardous material is defined as a substance or material in a quantity that may pose a risk to health and safety, or property, when transported in commerce. Trucks carrying hazardous materials will be escorted; the hazardous materials (HAZMAT) team will ride in the convoy transporting the propellants.

Solid rocket motors and segments may be shipped by highway, cargo aircraft or water. A low speed limit will be imposed on all trucks carrying solid segments on Hawaii's highways. SRMs are usually shipped without the motor igniter installed and without pressures being induced to the casing.

Hypergolic propellants (e.g., hydrazine, UDMH and Aerozine-50) would be transported in 55-gallon drums from Hilo Harbor to the launch site. Under USDOT performance standards, the design of a drum must be tested and officially certified. As regulated in Title 49 of the Code of Federal Regulations, 49 CFR, containers must be secured against movement in transit with the use of proper bracing.

Hazards associated with the transport of propellants are assessed in Chapter Five, Section II and in DEIS Appendix VIA.

3.0 Payload Processing

Processing a payload involves all of the activities required to make the spacecraft and its assist motor(s) flight-ready before they are placed atop the rocket at the launch pad. These operations are both hazardous and non-hazardous. The work areas for each are physically separated, with hazardous work areas located according to appropriate explosive siting criteria. Activities associated with payload processing are assessed in Chapter Five and in Appendix VIC.

4.0 Launch Processing

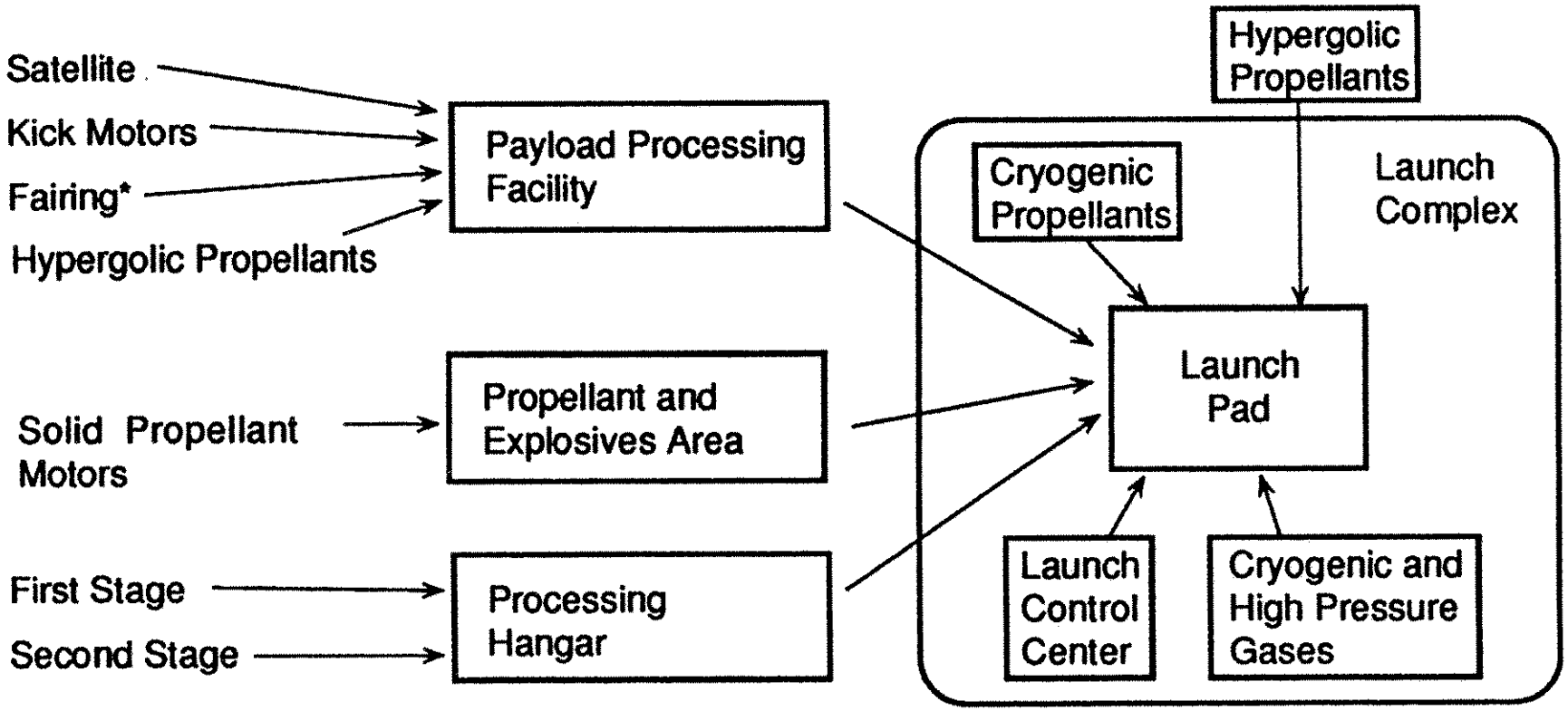
Launch processing includes all of the operations necessary to prepare a rocket for flight. The Conceptual Plan assumes conventional on-pad assembly for mELVS. Each launch pad would be designed to accommodate a specific type of rocket. The processing sequence for a rocket with liquid propellant first and second stages and solid rocket motor (SRM) strap-ons is shown on Figure II-1.5.

After a payload is mated to the rocket, and electrical and mechanical connections are made between the various stages of the rocket, an extensive series of tests are conducted to insure that all parts of the launch vehicle have been properly integrated. Assembly and checkout of the launch vehicle on the launch pad takes several weeks.

The vehicle is fueled from propellant storage tanks located near the launch pad. Cryogenic and high pressure gases such as helium and nitrogen may also be provided from storage tanks located at the launch complex. Hypergolic propellants are not stored at the launch complex. When needed, they are brought from a hypergolic storage area and loaded directly into the launch vehicle.

5.0 Rocket Launch

The launch is controlled from a launch control center (LCC) located either in a blockhouse near the launch pad or in an unhardened building at a safe distance from the pad. The LCC contains major systems such as propellant loading consoles, launch vehicle checkout equipment, vehicle environmental controls, launch sequencer, and countdown displays.



*Fairing may be installed at the launch pad

Source: DBEDT, Office of Space Industry, 1993.

Figure II-1.5

ROCKET PROCESSING FLOW

Count-down activities include: activation and verification of the guidance system, first stage propellant loading, radar beacon checks, destruct system checks, and pressurization of the vehicle propellant tanks. During the final minutes before launch, all ordnance is armed and the launch vehicle and spacecraft are switched to internal battery power.

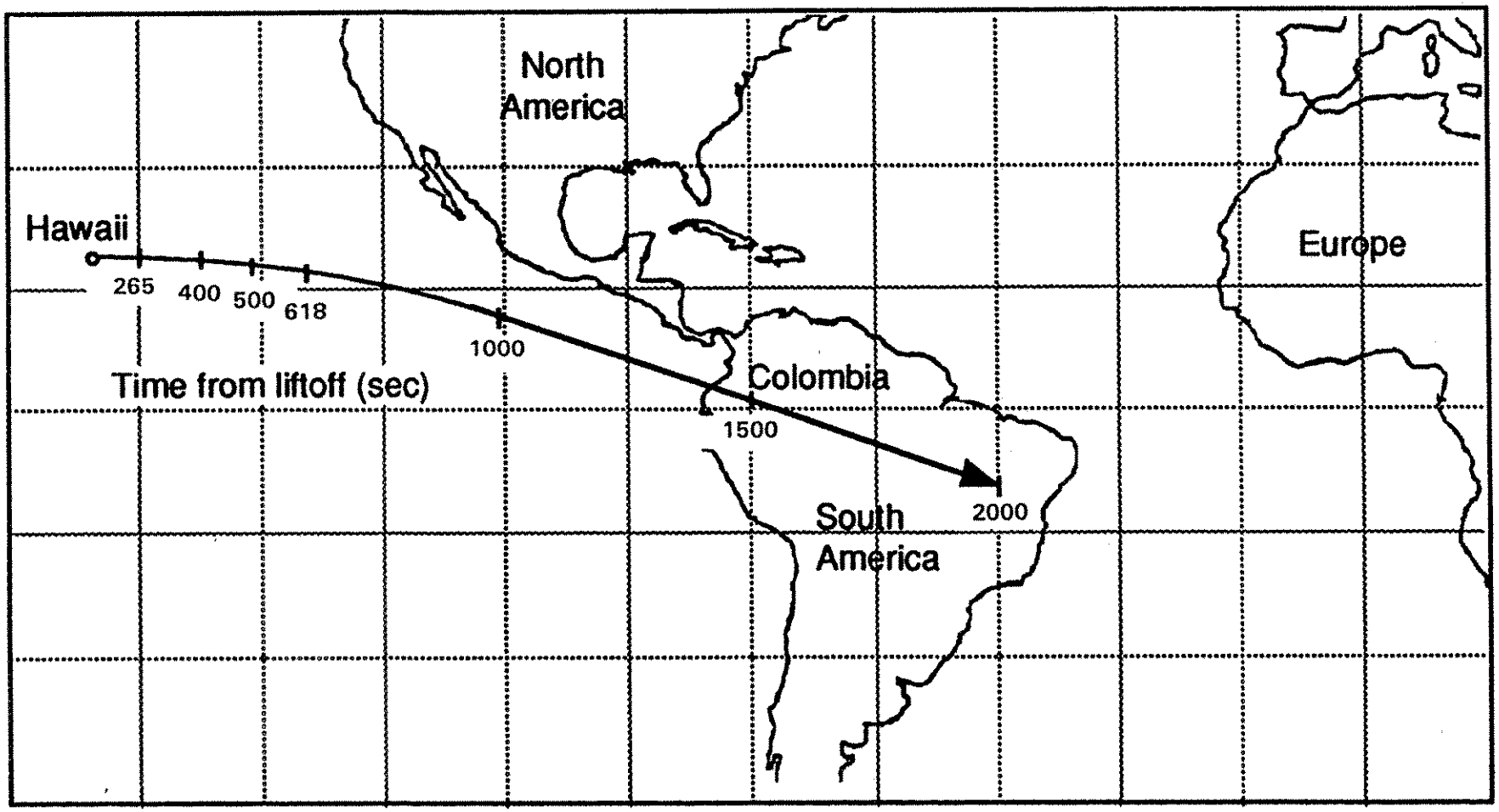
As the countdown proceeds toward launch, meteorological conditions are evaluated to insure that surface and upper winds do not exceed safe values. Range tracking instrumentation performance is verified to insure that the range safety system is functioning. If all of the vehicle, launch range and weather conditions are acceptable, the final launch sequence is initiated.

6.0 Rocket Flight

A rocket typically climbs several thousand feet almost vertically above the launch pad before it begins to pitch over and fly downrange, away from the launch site. Early in flight, tracking data is obtained from instrumentation located on or near the spaceport. Tracking and command/control links with the vehicle are maintained until the rocket is no longer a significant hazard to people or property. Figure II-1.6 shows a possible ground track of a Delta vehicle launched in an easterly trajectory from Palima Point.

7.0 Launch Holds (The "Safeing" Process)

When a rocket cannot be launched during its calculated "window", and must be held until the next launch period appropriate for the mission, the vehicle is "safed" and then left on the pad until the next launch attempt. "Safeing" a vehicle involves: disabling the vehicle's command/destruct system and the safe-and-arm devices, reducing the propellant tank pressures to pre-launch levels, reestablishing the flow of the environmental control system (ECS) to provide an inert atmosphere for defueling, returning the vehicle's power systems back to ground-supplied power, shutting off non-essential electrical elements, draining propellants, and reestablishing ECS with air to make the area safe for technicians. This process takes about two to four hours.



Source: DBEDT, Office of Space Industry, 1993.

Figure II-1.6

GROUND TRACK: EASTERLY DELTA LAUNCH

SECTION II: RANGE SAFETY

A. THE POPULATION CONTROL ZONE (PCZ)

A Population Control Zone (PCZ) extends 2.9 miles behind each launch pad. During launch operations, this area must be kept clear of all unauthorized personnel. The boundary of the PCZ for the Palima Point site is shown on Figure II-1.1. There are no homes within this zone at Palima Point. The PCZ is set back far enough from the pads so that all debris from a potential launch failure would land within the PCZ or in the ocean (See DEIS Appendix VIIA). A 6-mile-wide offshore shipping hazard area, which must also be clear during launch, extends for about 13 miles downrange.

B. SAFETY OPERATIONS

1.0 Meteorological Monitoring

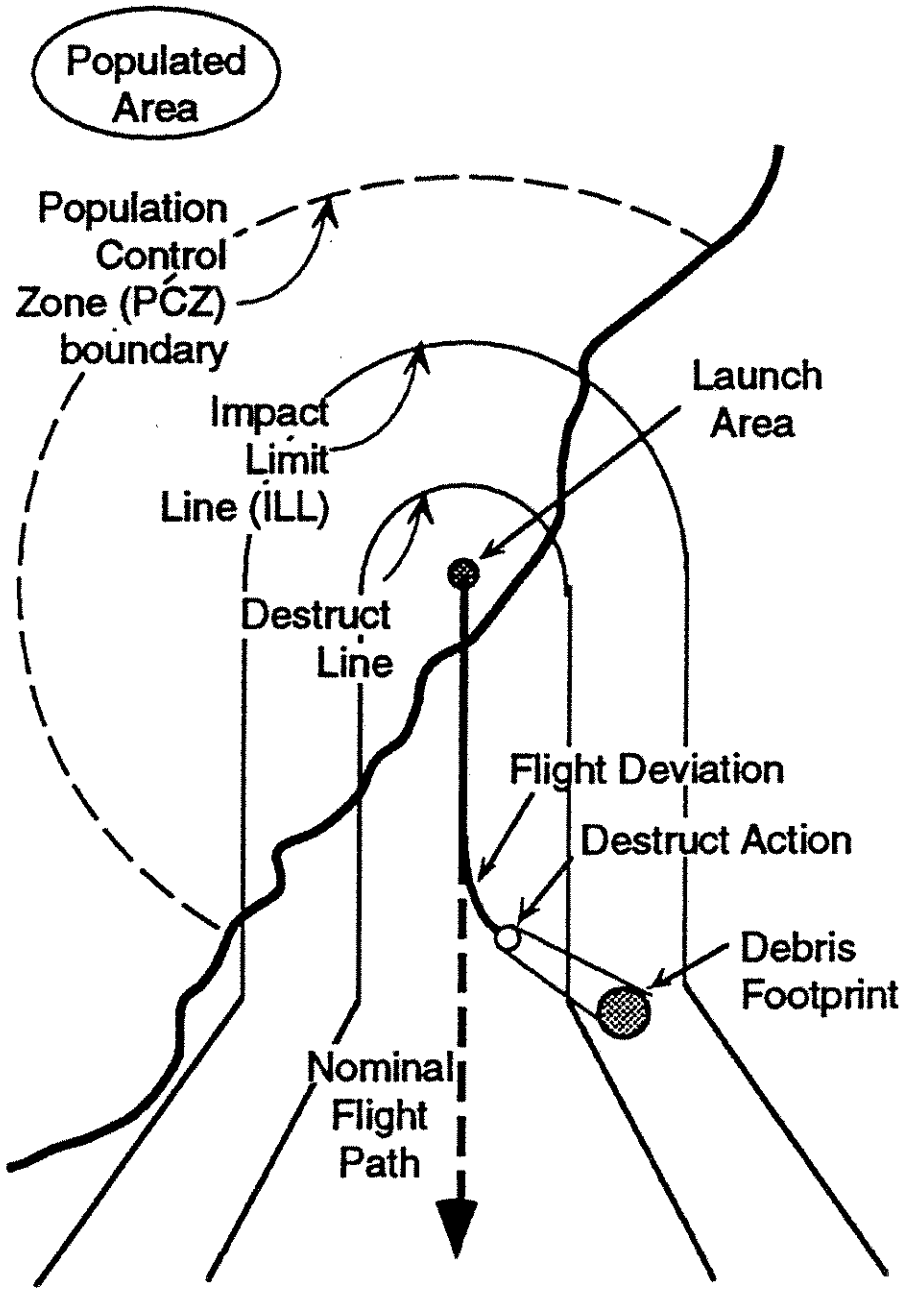
Prior to launch, surface and upper atmosphere winds are monitored to determine whether or not it is safe to fuel and launch the rocket. Air quality and meteorological measurements are conducted continuously to ensure rapid detection and response to elevated levels of hazardous vapors.

2.0 Launch Area Surveillance

Surveillance radar is used to verify that aircraft are clear of the rocket's flight path and that boats and ships are not within the danger zone close to the launch site. Prior to launch, notification is made to mariners and airmen that launch activities are scheduled and the affected areas of the ocean and airspace are identified.

3.0 Flight Safety Logic

The launch trajectory of the vehicle is designed so that the rocket will not fall into a populated area if the engines stop prematurely. Computer simulations are conducted to set the boundaries of the flight safety corridor the launch vehicle must fly within. Impact limit lines (ILL) define the boundary of the area beyond which no rocket debris will be allowed to fall. If the rocket deviates from its planned trajectory and heads toward the ILL, it will be deliberately blown up by a ground command. The rocket would be destroyed early enough in its flight so that all debris would be contained within the ILL. As seen in Figure II-2.1 the ILL lies inside the PCZ boundary to further ensure that the public is protected from a failure either on the pad or in flight. In addition to the ILL, destruct lines are defined for each flight. These are the lines which actually define the boundary of the vehicle flight corridor. The destruct lines are located so that if the vehicle is destroyed before crossing these lines, the debris will be contained within the ILL.



Source: DBEDT, Office of Space Industry, 1993.

Figure II-2.1
FLIGHT SAFETY LOGIC

4.0 Flight Termination

A Range Safety Officer (RSO), whose mission is to ensure the safe operation of the rocket during powered flight, is present for all launch operations. Because the primary responsibility of the RSO is flight safety, RSOs are independent of the rocket or payload manufacturer.

The RSO analyzes rocket performance to determine if the vehicle is flying safely. If is operating in a manner that may be dangerous to people or property, the RSO issues a destruct command and terminates the flight. Each rocket is equipped with a flight termination system (FTS) which can be activated by a coded radio signal initiated by the RSO. Small destruct charges on the rocket detonate in a pattern shaped to terminate engine thrust and rupture the propellant tanks. After the tanks of a liquid propellant rocket rupture, the liquid fuel and oxidizer mix and burn rapidly but generally do not explode.

Solid propellant thrust is terminated by explosively opening the "top" of the stage, thus allowing the exhaust to escape from both ends. A terminated stage will travel along a ballistic flight trajectory, tumbling and falling as remaining propellants burn up.

C. RANGE SAFETY INSTRUMENTATION

Range instrumentation is used to monitor and control the rocket during flight to ensure that it does not endanger the public. Instrumentation normally includes radars, command transmitters, telemetry receiving stations, computers for processing data in "real time," communication equipment and photographic or other optical instrumentation. These systems provide information for flight safety and post-flight evaluation.

The RSO must know where the rocket is at all times. Radar, optics, telemetry, and the vehicle inertial guidance system all provide information to the RSO about the rocket's position, velocity and performance. Tracking systems are integrated to provide optimum coverage from lift-off through completion of powered flight.

SECTION III: ELEMENTS OF THE CONCEPTUAL PLAN

A. CANDIDATE LAUNCH VEHICLES

1.0 Atlas IIAS

The Atlas IIAS is 156 feet in height. Its core vehicle configuration includes the following: (a) a booster section consisting of two Rocketdyne liquid oxygen-kerosene booster engines; (b) a sustainer section consisting of one Rocketdyne liquid oxygen-kerosene sustainer engine, one kerosene (RP-1) tank, and one liquid oxygen (LOX) tank; and, (c) an upper stage consisting of one Centaur module containing two Pratt and Whitney liquid oxygen-liquid hydrogen engines, one liquid hydrogen tank, and one LOX tank. The Atlas IIAS uses four Thiokol Castor IVA solid rocket strap-on boosters (SRBs), attached near the base of the vehicle, to augment the thrust of the liquid propellant engines.

The core vehicle also contains a small amount (less than 375 pounds) of hydrazine, which is used in small roll and reaction control engines. To be fully operational, a payload typically requires additional energy to raise orbit and maintain positioning. The payload usually contains small amounts of hypergols, often monomethyl hydrazine (MMH) and nitrogen tetroxide. A listing of Atlas/Centaur propellants and combustion products is given in Table 2.3.1; liquids and gases are listed in Table 2.3.2.

About a minute after the rocket is launched, the first pair of solid rocket boosters (SRBs) burns out and is jettisoned into the ocean approximately 10 nautical miles (nmi) from the launch site. The second pair of SRBs ignite 66 seconds into flight and burn for 56 seconds; the spent SRBs impact the ocean approximately 130 nmi downrange. After booster engine cutoff (BECO) at 153 seconds, the booster motors are discarded; the sustainer engine thrust continues until separation of the Atlas and Centaur stages at 275 seconds.

Missions to geosynchronous transfer orbit (GTO) require two Centaur engine burns. The Atlas phase and Centaur "first burn" places the Centaur/spacecraft combination in a slightly elliptical orbit; the second Centaur burn places the vehicle into a highly elliptical GTO. The spacecraft and Centaur stages are separated from each other 135 seconds after Centaur main engine cutoff (MECO2).

Atlas/Centaur carries two radio telemetry transmitters and a radar transponder located in the Centaur stage. The telemetry transmitters currently operating in the 2200-2300 MHz frequency band (S-band) during launches from Cape Canaveral may operate within the 2310-2390 MHz frequency range (commercial S-band) for commercial launches. The frequencies, output power and other characteristics of these emitters are listed in Table 2.3.3.

2.0 Delta II

The Delta II is 125 feet tall. A fully-fueled Delta II weighs approximately 513,000 pounds. The vehicle consists of five major assemblies: first stage, interstage, second stage, third stage, and payload fairing. The Delta II uses nine solid propellant, graphite epoxy motors (GEMS) to augment the thrust of the first stage liquid propellant engine which burns a mixture of RP-1 (highly refined kerosene) and liquid oxygen (LOX).

Table 2.3.1 **ATLAS/CENTAUR PROPELLANTS AND COMBUSTION PRODUCTS**

Stage	Motor	Propellants	Combustion Products
Strap-On *Boosters (Atlas* ***IIAS)***	***Castor IVA*** 4 solid propellant motors **with a** total of 22,300 lbs. of propellant	• HPTB (binder) • Ammonium perchlorate • Aluminum	• HCl • CO • CO_2 • H_2 • H_2O • N_2 • Al_2O_3
Atlas	***Liquid Propellant Engine*** 25,128 gal. of LOX, 15,676 gal. of RP-1	• Liquid Oxygen (LOX) • RP-1 (refined kerosene)	• H_2O • CO_2 • H_2O • H_2
Centaur	***Liquid Propellant Engine*** 2,775 gal. of LOX, 9,400 gal. of LH_2	• Liquid Oxygen (LOX) • Liquid Hydrogen (LH_2)	• H_2O • H_2 • Ar

Source: DBEDT, Office of Space Industry. Feb. 1993

Table 2.3.2 ATLAS/CENTAUR LIQUIDS AND GASES

Stage	Propellant or Consumable	Vehicle Qty.	Storage Qty.	Transportation
Atlas	Liquid Oxygen oxidizer (LOX)	25,128 gal.	A single 120,000 gal. storage tank will be used for both Atlas and Centaur.	If LOX arrives at the launch facility from outside then it will require 30 trips at 4,000 gal. per trip to fill the storage tank. LOX will be produced at the launch facility if an air liquefaction plant is built.
	RP-1 fuel	15,676 gal.	20,000 gal. at pad	Arrive at launch facility in five 4,000 gal. tank trucks thru Hilo.
Centaur	LOX	2,775 gal.	See above.	See above.
	Liquid Hydrogen fuel (LH_2)	9,400 gal.	40,000 gal. at pad	If LH_2 arrives at the launch facility from outside then it will require ten trips at 4,000 gal. per trip to fill the storage tank.
	Liquid Helium	3,000 gal.	—	Produced on site or shipped in as needed.
Atlas and Centaur	Hydrazine (N_2H_4)	270 gal.	Obtain from 715 gal. central storage	Arrive at launch facility in 55 gal. drums from port of Hilo. Stored at launch facility hypergolic propellant storage area.
	Gaseous Nitrogen (GN_2)	2,718,445 scf.	Nitrogen stored in liquid form and then converted to a gas at the required pressures. LN_2 capacity is 30,000 gal.	If LN_2 arrives at the launch facility from outside, then it will require five trips at 4,000 gal. per trip to fill the storage tank. LN_2 will be stored in liquid form and then converted to a gas at the required pressures. LN_2 will be produced at the spaceport if an air liquefaction plant is built.
	Gaseous Helium (GHe)	571,466 scf.	GHe will be stored in high pressure cylinders.	Will be shipped from mainland in high pressure storage cylinders.

Source: DBEDT, Office of Space Industry. Feb. 1993

Table 2.3.3 **RADIO FREQUENCY (RF) EMITTERS BY LAUNCH VEHICLE**

Stage	Emitter	Characteristics
Delta RF Emitters:		
First	Telemetry	• 245.5 MHz. • 4 watts • Omnidirectional beaming
Second	Telemetry	• 2241.5 MHz. • 4 watts • Omnidirectional beaming
	Radar Transponder	• 5765 MHz. • 1000 watts maximum • 160 pulses/sec. • 0.5 µsec. pulse width • Omnidirectional beaming
Third	Telemetry	• 2252.5 MHz. • 8 watts • Linear polarization • Omnidirectional beaming
Atlas/Centaur RF Emitters:		
Centaur	Telemetry 1	• 2202.5 MHz. • 3.5 watts • Linear polarization • PCM/FM Modulation • 101 kHz. deviation • 101 kHz. deviation • 267.55 kbps. data NRZ-L rate
	Telemetry 2	• 2215.5 MHz. • 2.2 watts • Linear polarization • FM/FM Modulation •1.26 MHz. deviation
	Radar Transponder	• 5765 MHz. • 1000 watts maximum • 160 pulses/sec. • 0.5 µsec. pulse width • Omnidirectional beaming

Table 2.3.3 **RADIO FREQUENCY (RF) EMITTERS BY LAUNCH VEHICLE (Continued)**

Stage	Emitter	Characteristics
Scout RF Emitters:		
Third	Telemetry	• 2230.5 MHz • 6 watts max
	Radar Transponder	• C-band • 6 watts max
Fourth	Telemetry	• 2205.5 or 2210.5 MHz • 6 watts max
Taurus RF Emitters:		
Third	Telemetry	• PCM/FM: 2252.5 MHz. • FM/FM: 2269.5 MHz. • 5 watts
	Transponder Transmitter	• 5565 MHz. • 400 W minimum • 0.5 ± 0.1 μsec. • pulsewidth

Source: DBEDT, Office of Space Industry. Feb. 1993

The first stage of the rocket consists of one liquid RP-1 fuel tank, one oxidizer tank, center body section, main engine section, and nine small SRMs. The major components of the GEM propellant includes ammonium perchlorate, aluminum powder, hydroxyl terminated polybutadiene, and dimethyl diisocyanate, which account for over 95 percent of the constituents in the propellant formulation.

The Delta II second stage motor contains 8,759 pounds of nitrogen tetroxide oxidizer and 4,640 pounds of Aerozine-50 propellant. The third stage is a 4,430 pound solid propellant motor. The Delta II vehicle contains the largest fuel loading of solid propellants and hydrazine class hypergols. In addition, the payload typically contains small amounts of hypergols to achieve and maintain a precise orbit. Delta II propellants, consumables and combustion products are listed in Tables 2.3.4 and 2.3.5. A typical Delta II flight profile is shown on Figure II-3.1.

Delta carries radio telemetry transmitters on all three stages as well as a radar transponder on the second stage. The characteristics of these emitters are described in Table 2.3.3. The telemetry transmitters currently operating in the 2200-2300 MHz frequency band (S-band) during launches from Cape Canaveral may operate within the 2310-2390 MHz frequency range (commercial S-band) for commercial launches.

3.0 Taurus

The Taurus sELV is a four-stage (Stage 0, 1, 2, and 3), inertially guided launch vehicle with a 0/1 Interstage. An interstage is an element in a vehicle which serves to structurally connect two powered vehicle stages. During the stage separation in flight, the interstage is separated from one or both of the stages it had joined, either by explosive bolts at the stage interface(s) or shaped charges which actually sever the structure.

The overall length of the Taurus is 88.5 feet; its gross lift-off weight is 156,700 pounds. The launch vehicle upper stages are from the Pegasus Air-Launched Vehicle and other proven launch vehicles. Stage 0 is the Stage 1 Peacekeeper rocket motor; Stages 1, 2, and 3 are the Pegasus Stages 1, 2, and 3 rocket motors.

The Taurus sELV would use solid propellants. Stage 0 Thrust Vector Control (TVC) will use Peacekeeper hot gas generator with a small amount (i.e., less than 50 pounds) of a similar solid propellant. A small amount of hydrazine would be included as part of the payload. Table 2.3.6 provides a detailed list of propellants used by the Taurus vehicles and the combustion products generated. A typical Taurus flight profile is shown on Figure II-3.2.

The Taurus carries two radio telemetry transmitters and a radar transponder. The frequencies, output power and other characteristics of these emitters are described in Table 2.3.3.

4.0 Scout

Although the Scout described in this EIS is no longer manufactured, a new version of the vehicle, which is expected to be similar in design and capability, is being developed. The current model Scout is a four stage solid propellant rocket which accelerates rapidly from the launch pad. The 75-foot-tall rocket is capable of placing a 450 pound payload into a 300 mile high orbit. A combination of jet vanes and aerodynamic surfaces control the Scout through the first stage burn. The fourth stage, including the payload, is spin stabilized at rates between 140 and 180 rpm. The dynamic balancing takes place at the launch site. Scout propellants and combustion products are listed on Table 2.3.7.

Table 2.3.4 **DELTA II PROPELLANTS AND COMBUSTION PRODUCTS**

Stage	Motor	Propellants	Combustion Products
Zero	***Graphite-Epoxy Solid Propellant Motors (GEMS)*** 9 GEMS contain a total of 232,263 lbs. of propellant	• Hydroxyl terminated polybutadiene • Dimethyl diisocyanate • Dioctyl sebecate 2 • 2-methylene-bis (4-methyl-6-t-butylphenol) • Di- and Tri-nonylphenol Malaeic anhydride • Triphenyl bismuth • Propylene imine • Adduct of isopthalic acid • Ammonium Perchlorate • Aluminum Powder • Isophorone diisocyanate • Ferric oxide	• Al_2O_3 • CO • HCl • H_2O • N_2 • $AlCl_3$ • CO_2 • H_2
First	***Liquid Propellant Engine*** 16,140 gal. of LOX, 9,946 gal. of RP-1	• Liquid Oxygen (LOX) • RP-1 (refined kerosene)	• CO • CO_2 • H_2O • H_2
Second	***Liquid Propellant Engine*** 728 gal. of N_20_4, 615 gal. of Aerozine-50	• Nitrogen Tetroxide (N_20_4) oxidizer • Aerozine-50 fuel is a 50:50 blend of hydrazine (N_2H_4) and unsymmetrical dimethylhydrazine [$CH_3(NNH_2)$]	• CO • CO_2 • N_2 • H_2O • H_2
Third	*Perigee Kick Motor* PAM-D, Star-48B. 4,431 lbs. of solid propellant	• Ammonium perchlorate • Aluminum Powder • Hydroxyl terminated polybutadiene • Isophorone diisocyanate • Propylene imine • Adduct of isopthalic acid	• Al_2O_3 • CO • CO_2 • HCl • H_2O • N_2 • H_2 • $AlCl_3$

Source: DBEDT, Office of Space Industry. Feb. 1993

Table 2.3.5 **DELTA II LIQUIDS AND GASES**

Stage	Propellant OR Consumable	Vehicle Qty.	Storage Qty.	Transportation
First	Liquid Oxygen oxidizer (LOX)	16,140 gal.	65,000 gal. at pad	If LOX arrives at the launch facility from outside then it will require 16 trips at 4,000 gal. per trip to fill the storage tank. LOX will be produced at the launch facility if an air liquefaction plant is built.
	RP-1 fuel	9,950 gal.	13,000 gal. at pad	Arrive at launch facility in three 4,000 gal. tank trucks thru Hilo.
Second	Nitrogen Tetroxide oxidizer (N_2O_4)	728 gal.	1200 gal. central storage	Arrive at launch facility in 300 gal. cylinders from port of Hilo. Stored at launch facility in hypergolic propellant storage area.
	Aerozine-50 fuel (A-50)	615 gal.	825 gal. central storage	Arrive at launch facility in 55 gal. stainless drums from port of Hilo. Stored at launch faiclity in hypergolic propellant storage area.
	Hydrazine (N_2H_4)	20 gal.	715 gal. central storage	Arrive at launch facility in 55 gal. stainless drums from port of Hilo. Stored at launch faiclity in hypergolic propellant storage area.
	Gaseous Nitrogen (GN_2)		LN_2 storage capacity is 20,000 gal.	If LN_2 arrives at the launch facility from outside, then it will require five trips at 4,000 gal. per trip to fill the storage tank. LN_2 will be stored in liquid form and then converted to a gas at the required pressures. LN_2 will be produced at the spaceport if an air liquefaction plant is built.
	High Pressure gaseous Helium (GHe)		100,000 scf. at 6,000 psig.	Will be shipped from mainland in high pressure storage cylinders.

Source: DBEDT, Office of Space Industry. Feb. 1993

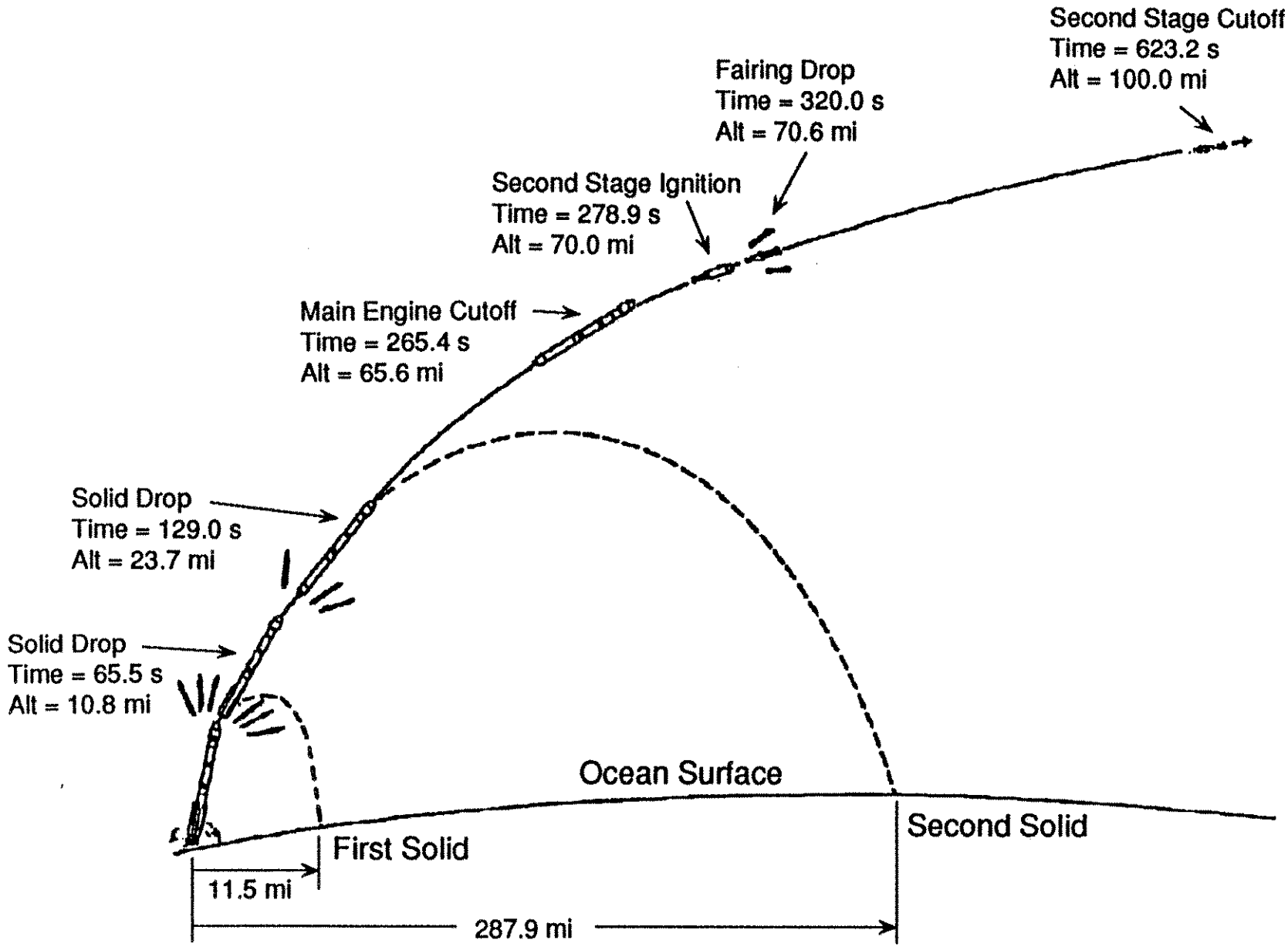


Figure II-3.1

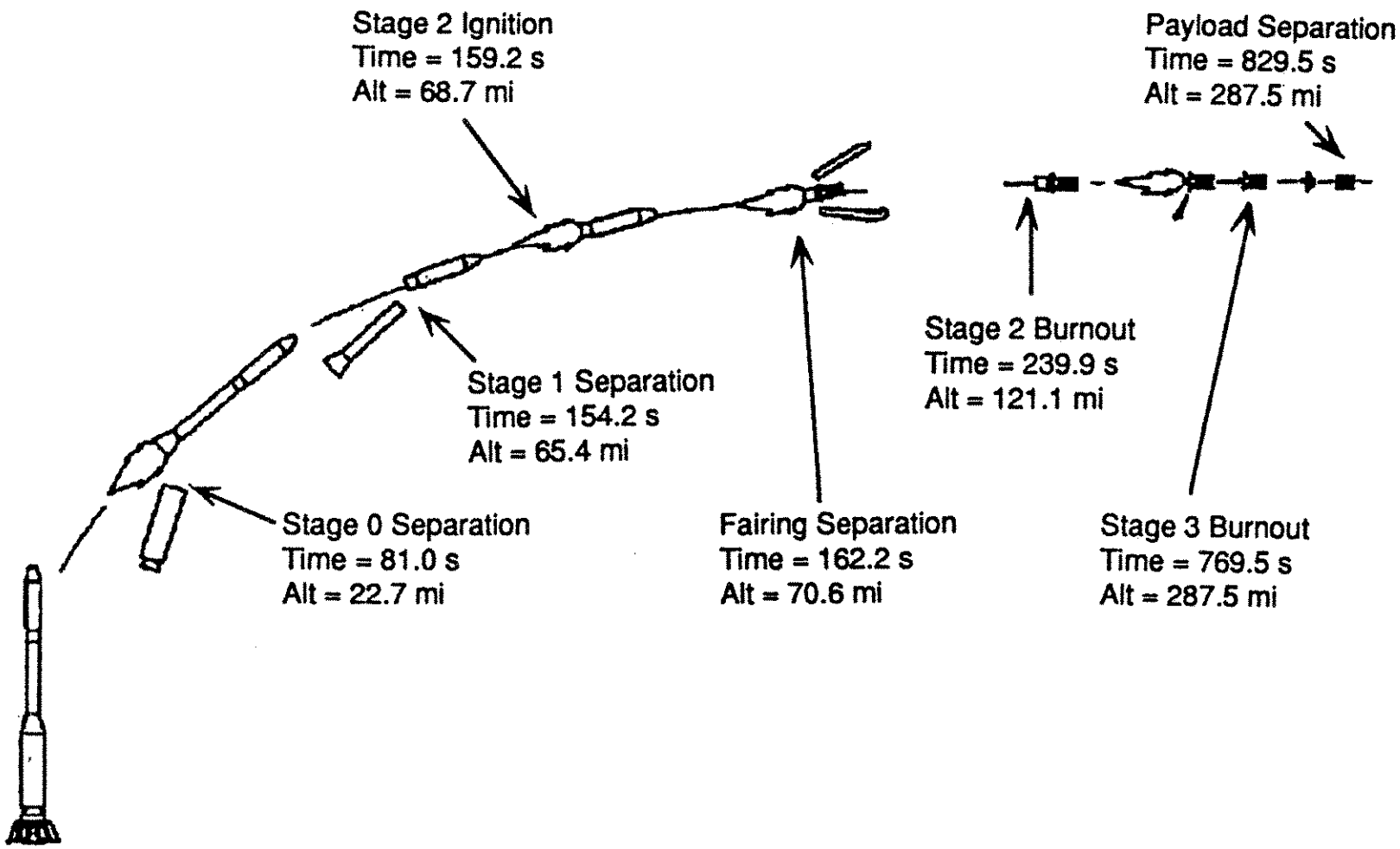
Source: DBEDT, Office of Space Industry, 1993.

TYPICAL DELTA II FLIGHT PROFILE

Table 2.3.6 **TAURUS PROPELLANTS AND COMBUSTION PRODUCTS**

Stage	Motor	Propellants	Combustion Products
Zero	***Castor 20*** Solid propellant motor with a **total of 108,000 lbs. of** propellant	• HTPB • Aluminum • Ammonium perchlorate	• CO • CO_2 • NOx • HCl • Al_2O_3
One, Two, and Three	***Hercules*** Solid propellant motors with **26,759 lbs., and 1,699 lbs. of** propellant for Stages 1, 2, and 3, respectively	• HTPB • Aluminum • Ammonium perchlorate	• CO • CO_2 • NOx • HCl • Al_2O_3

Source: DBEDT, Office of Space Industry. Feb. 1993



Source: DBEDT, Office of Space Industry, 1993.

Figure II-3.2

TYPICAL TAURUS FLIGHT PROFILE

Table 2.3.7 **SCOUT PROPELLANTS AND COMBUSTION PRODUCTS**

Stage	Motor	Propellants	Combustion Products
First	***Algol IIIA*** Solid propellant	• Aluminum Composite (fuel) • Ammonium Perchlorate (oxidizer) • Polybutadiene Acrylic (binder) • Total weight: 28,200 lbs.	• CO • CO_2 • H_2 • H_2O • N_2 • HCl • Al_2O_3
Second	***Castor IIA*** Solid propellant	• Aluminum Powder (fuel) • Ammonium Perchlorate (oxidizer) HC Polymer (binder) • Total weight: 8,300 lbs.	• CO • CO_2 • H_2 • H_2O • N_2 • HCl • Al_2O_3
Third	***Antares IIIA*** Solid propellant	• Aluminum Powder (fuel) • Ammonium Perchlorate (oxidizer) • HTPB (binder) • Total weight: 2,900 lbs	• CO • CO_2 • H_2 • H_2O • N_2 • HCl • Al_2O_3
Fourth	***Altair IIIA*** Solid propellant	• Aluminum Powder (fuel) • Ammonium Perchlorate (oxidizer) • Carboxy-Terminated Polybutadiene(binder) • Total weight: 663 lbs	• CO • CO_2 • H_2 • H_2O • N_2 • HCl • Al_2O_3

Source: DBEDT, Office of Space Industry. Feb. 1993

The launch complex of the Scout is designed to allow the vehicle to be assembled and checked out in a horizontal position and then launched in the vertical position from a dual purpose launcher/erector (Figure II-3.3). The first stage burns for 81 seconds and is jettisoned into the ocean at about 96 nmi downrange from the launch site. The second and third stages land 675 and 2,840 nmi downrange respectively. Orbit is achieved 650 seconds after launch when the fourth stage engine completes its burn.

The Scout carries two radio telemetry transmitters and a radar transponder. The frequencies, output power and other characteristics of these emitters are described in Table 2.3.3.

5.0 Sounding Rockets

Sounding rockets are used to launch payloads into the upper atmosphere and into space for brief periods of time; they are not powerful enough to achieve orbital velocity. Although small in size, the vehicles can carry payloads as heavy as hundreds of pounds. Sounding rockets usually use either a vertical tower or a steerable rail launcher. Figure II-3.4 shows typical sounding rockets and a typical sounding rocket rail launcher.

B. POTENTIAL PAYLOADS

Many types of satellites could be launched from the proposed facility. Most are similar in functional characteristics however they vary in size and appearance. Figure II-3.5 shows the configuration of a typical payload with assist motors. See Appendix VIC of the DEIS for tables showing the commercial licenses issued to launch agencies by USDOT through January 31, 1992 and NASA payloads that could conceivably be launched from the proposed Hawaii Spaceport.

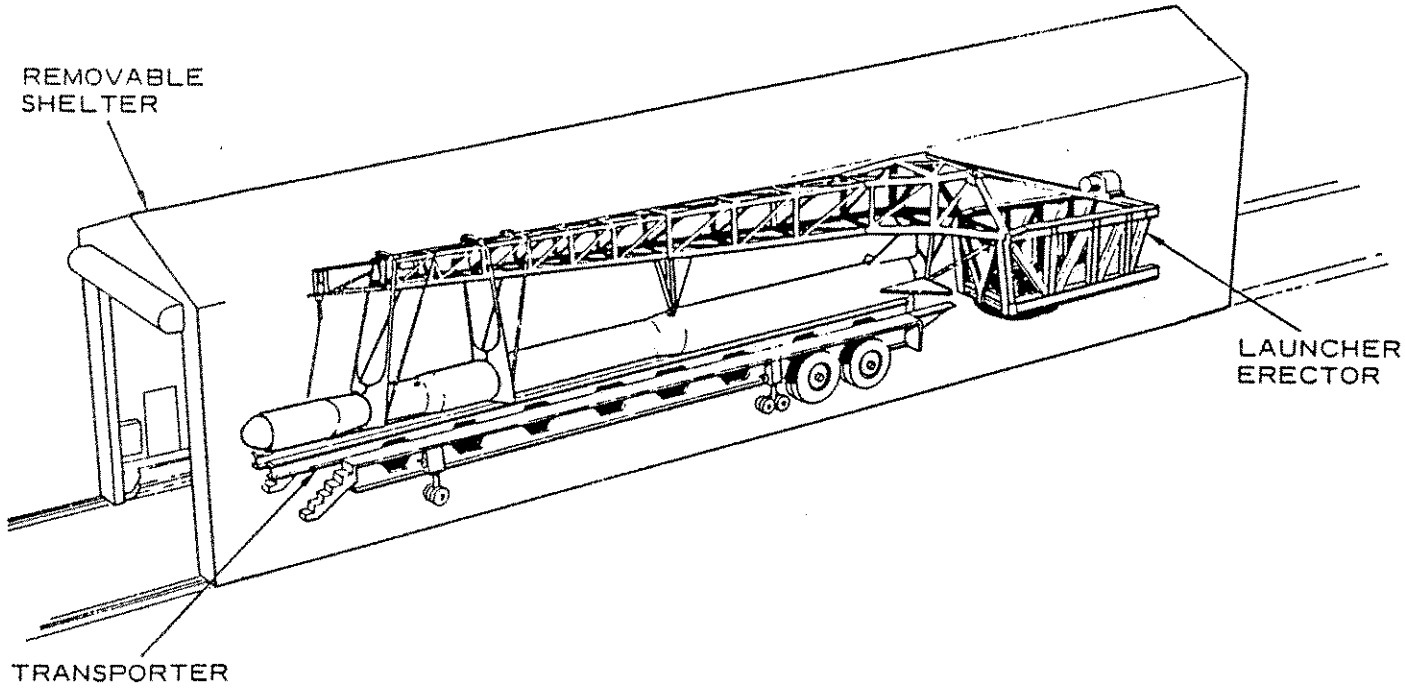
C. LAUNCH SITE FACILITIES

1.0 Siting Criteria and Design

Planning and design of the launch facilities will be closely coordinated with the County of Hawaii in order to insure compliance with County building and zoning codes. It will be the responsibility of the developer to apply for all required building permits and variances.

In addition to standard facility siting criteria (e.g. terrain, operational considerations, avoidance of endangered species and archaeological sites, geological considerations, and avoidance of flood and tsunami zones), hazardous operations facilities must be separated from other buildings by distances prescribed by standard quantity-distance principles. Because blast intensity is governed by the quantity of explosives and distance from the point of explosion, the radius of the danger zone is referred to as a quantity-distance (Q-D) radius. Figure II-3.6 shows the conceptual launch site facility areas with Q-D's for the launch pads, propellant and explosive area and payload processing.

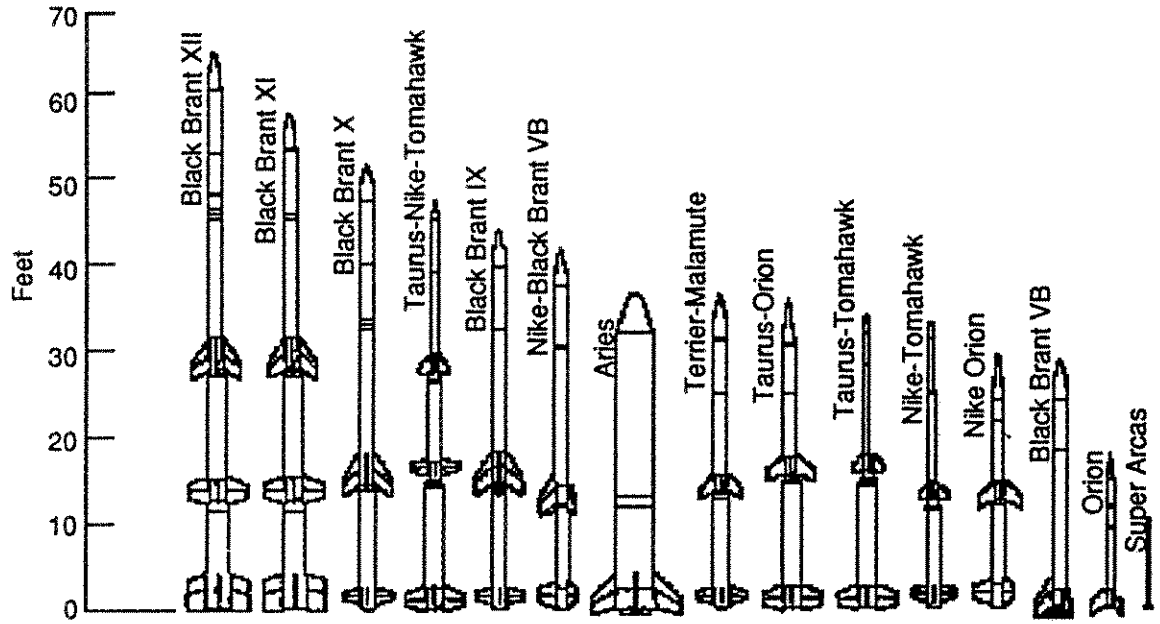
Explosives safety standards published by the Department of the Air Force are found in AF Regulation 127-100 which implements the Department of Defense Ammunition and Explosives Safety Standards outlined in DoD directive 514.4-S and agrees with OSHA Standard 1910.109. The safety standards used to develop the conceptual facility locations presented in this EIS are taken from AFR 127-100.

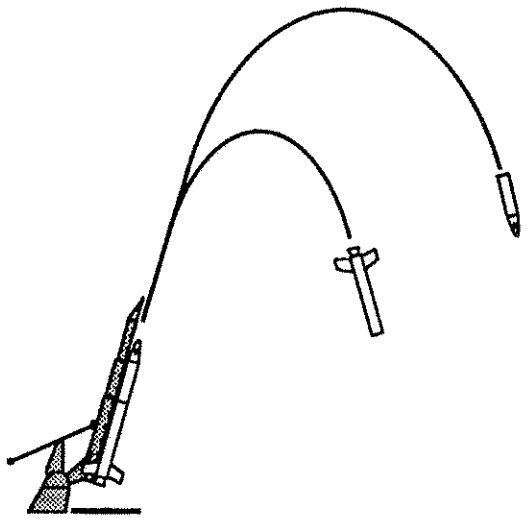


Source: DBEDT, Office of Space Industry, 1993

Figure II-3.3

TYPICAL SCOUT DUAL PURPOSE LAUNCHER

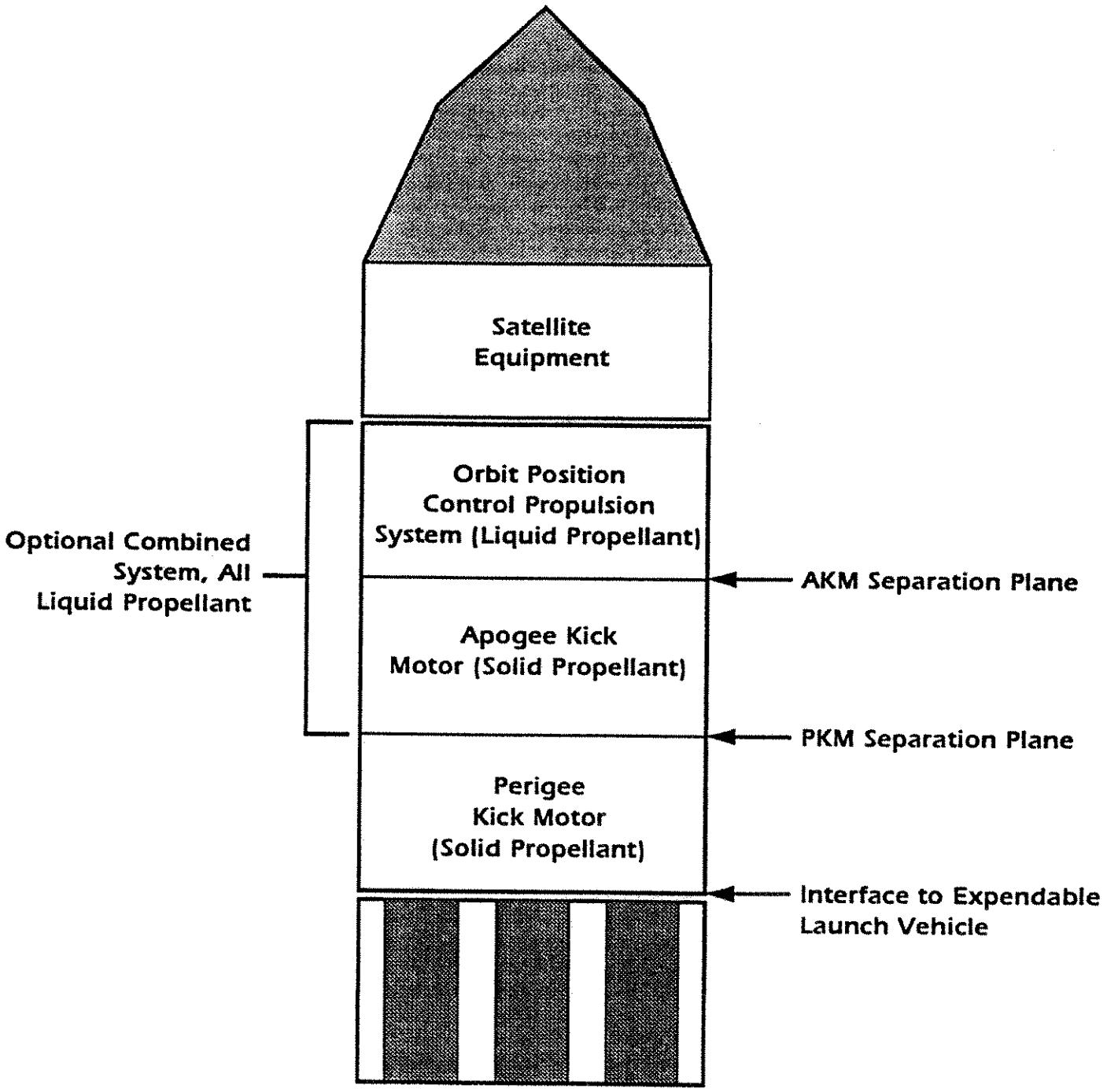




Source: DBEDT, Office of Space Industry, 1993.

Figure II-3.4

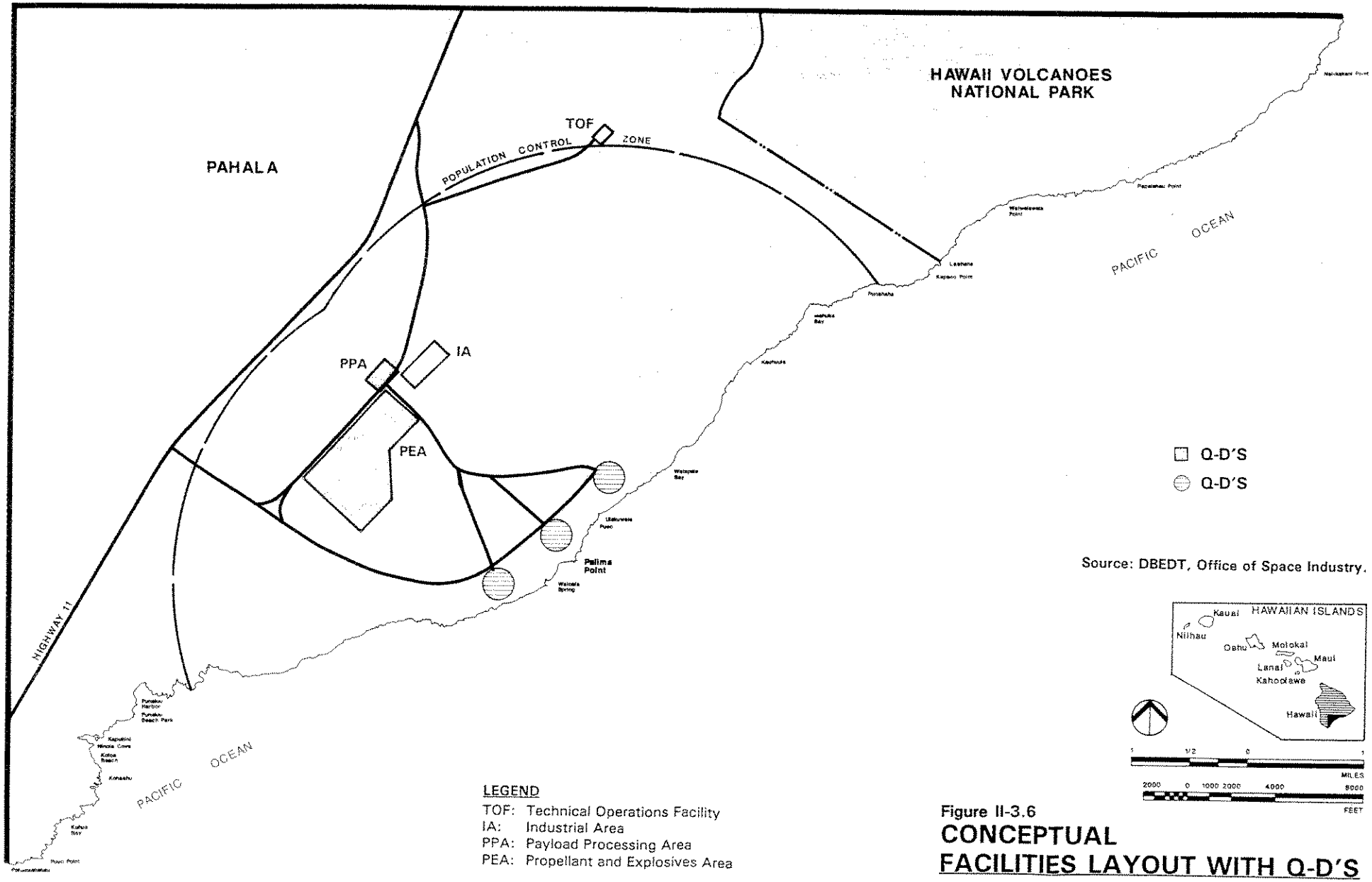
TYPICAL SOUNDING ROCKETS AND SOUNDING ROCKET LAUNCHER



Source: ACTA, Inc.,
DEIS Appendix VI-C

Figure II-3.5

TYPICAL PAYLOAD CONFIGURATION



Source: DBEDT, Office of Space Industry.

LEGEND

TOF: Technical Operations Facility
IA: Industrial Area
PPA: Payload Processing Area
PEA: Propellant and Explosives Area

Figure II-3.6

CONCEPTUAL FACILITIES LAYOUT WITH Q-D'S

Launch facilities are grouped into the following categories according to their use: Launch Vehicle and Payload Processing; Launch Complexes; Range Safety Instrumentation; Support; and, Infrastructure.

2.0 Launch Vehicle and Payload Processing

Each of the following areas is directly involved in processing and launch activities:

Payload Processing Area (PPA). A conceptual drawing of the 24-acre PPA is shown on Figure II-3.7. It has been sized to allow processing of between 15 and 22 payloads per year. The PPA consists of: a non-hazardous processing facility (NPF), hazardous processing facility (HPF), and payload storage building (PSB). The NPF would contain three satellite processing bays, as well as control rooms and offices. The HPF would contain three interconnected satellite processing bays, with one bay dedicated to spin balance. The PSB could store up to four spacecraft.

Hazardous operations are separated from other buildings by explosive resistant construction as well as by Q-D's. Hypergolic propellants would not be stored at the PPA; when needed for fueling operations they are delivered directly to the PPA from the hypergolic propellant storage area.

Toxic fumes released during fueling operations are captured and processed through scrubbers until air quality standards are met. The HPF airlock and spacecraft assembly bays would have hazardous vapor detection systems. A spill collection system consisting of floor trenches leading to hypergolic resistant piping and holding tanks will be constructed at each fueling bay. Liquid fuel and flush are channeled directly to waste holding tanks designed to meet toxic material safety standards. The diluted fuel-water and oxidizer-water mixtures are then shipped to an authorized disposal site.

Booster Processing Area. Liquid propellant rocket core stages would be processed at the booster processing area located within the industrial area (IA). Each type of liquid propellant rocket would be processed in its own specially designed hangar where inspection and testing of first and second stage components would also take place. These one-story hangars generally have a floor area of about 10,000 square feet; they are typically 25 to 30 feet high in order to accommodate a crane.

Propellant and Explosives Area (PEA). SRMs, hypergolic propellants and small explosive charges are stored at the PEA. Table 2.3.8 gives the minimum allowed separation between facilities in the PEA as derived from AFR 127-100. Figure II-3.8 shows a conceptual drawing of the PEA consistent with these minimum allowable distances.

Four SRM processing facilities would be available: two for mELV motors, one for sELV stages and one for sounding rockets. Each SRM processing facility would accommodate a single set of flight motors or stages.

Hypergolic propellants would be stored in their USDOT-approved shipping containers at a central location within the PEA. The storage area would consist of specially designed open sheds with concrete slab floors and metal roofs. The floors of the sheds would be constructed to divert toxic spills into an impervious containment system. The hypergolic storage facility and the fuel and oxidizer storage sheds would be separated from each other to the extent specified by Q-D requirements.

Hypergolic propellants are only transferred from storage containers into transfer units and transported to the launch complexes or payload processing facility when needed for launch

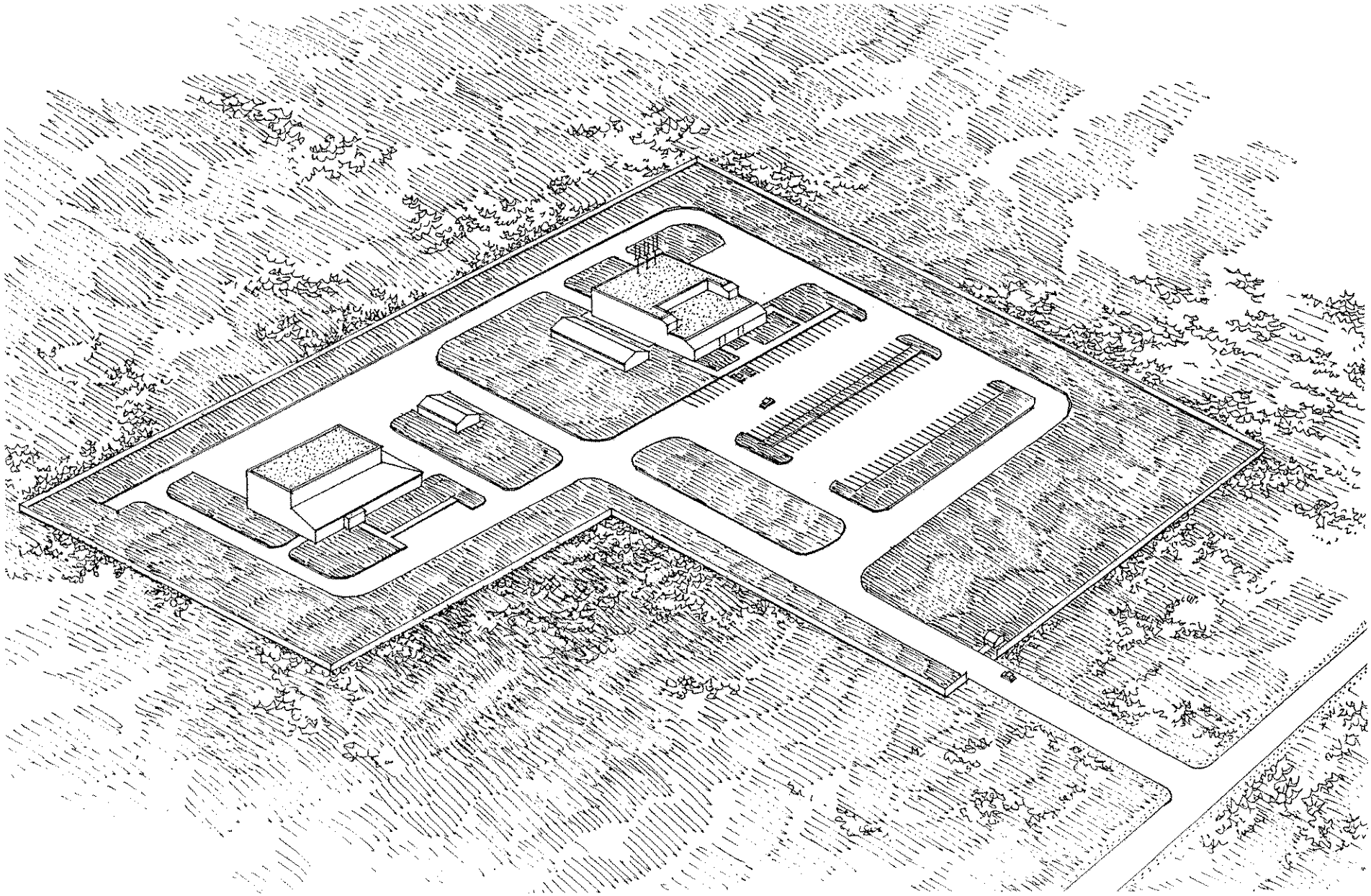


Figure II-3.7

Source: DBEDT, Office of Space Industry, 1993.

CONCEPTUAL PAYLOAD PROCESSING AREA (PPA)

Table 2.3.8 **PROPELLANT AND EXPLOSIVES AREA - SEPARATION DISTANCES**

Facility	Prop Wt (lbs.)	Prop. Class /Div.	IM* (ft.)	IB** (ft.)
SRM Storage Facilities				
MELV1	650,000	1.3	433	693
mELV2	650,000	1.3	433	693
sELV	350,000	1.3	353	564
Sounding	150,000	1.3	266	448
SRM Processing Facilities				
mELV1	325,000	1.3	344	550
mELV2	325,000	1.3	344	550
sELV	175,000	1.3	280	448
Other Facilities				
Cold Soak	10,000	1.3	108	173
NDTL	10,000	1.3	108	173
Class 1.1	200	1.1	–	1250

*Inter-magazine, **Inter-building

Source: DBEDT, Office of Space Industry. Feb. 1993

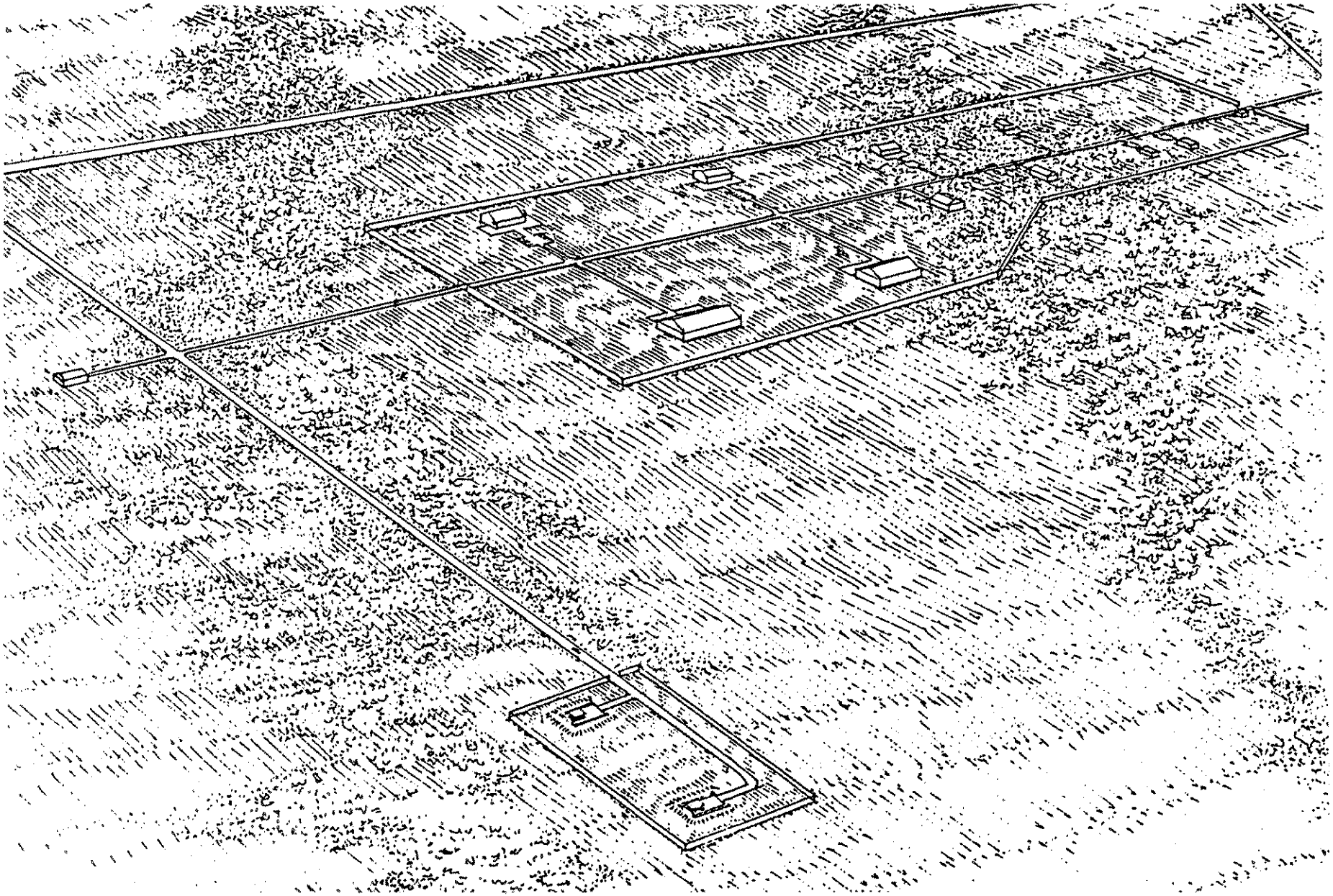


Figure II-3.8

Source: DBEDT, Office of Space Industry, 1993.

CONCEPTUAL PROPELLANT AND EXPLOSIVES AREA (PEA)

operations. Transfer operations always take place in an area equipped with a toxic waste containment system.

A toxic vapor monitoring system, sensitive to both hydrazines and nitrogen tetroxide, would monitor various locations at the hypergolic storage area. Visual inspections of the containers and equipment would be performed regularly.

3.0 Launch Complexes

The Conceptual Plan proposes three launch complexes, one for each of the candidate launch vehicles. Each complex will be accommodated within a Q-D defined, 1,500-foot-diameter launch area (Figure II-3.6).

A liquid propellant mELV launch complex generally consists of the launch pad, umbilical tower (UT), mobile service tower (MST), launch control center (blockhouse), and propellant storage tanks with various pumps, piping, and cryogenic equipment. The rocket would be assembled on the launch stand. The functions of the UT, which is located next to the launch stand, is to carry electrical power, control signals, pneumatic and propellant lines to the launch vehicle. During assembly and checkout the rocket is enclosed by a MST. The launch control center is located in a blockhouse within the complex. A typical mELV launch complex is depicted in Figure II-3.9.

The launch complex for solid propellant sELVs could be much simpler as it would not require liquid propellant handling equipment. The rocket would be transported from the assembly area to the launch pad on a combination transporter and strongback erector and erected over a flame deflector on a 200-square-foot concrete launch pad. A single-story launch control center, or blockhouse, would be located about 300 feet from the center of the launch pad. The only permanent utility installations required are power feeds and high pressure gas systems. Standby power generators and a water deluge system are not required.

A sounding rocket launcher configuration can range from a simple vertical rail to a steerable rail capable of supporting and aiming a large rocket. The Conceptual Plan assumes that the launcher is mounted on a concrete pad with the launch control equipment and personnel located several hundred feet away.

4.0 Range Safety Instrumentation

Instrumentation Facilities Layout. The primary siting criteria for radar, telemetry and command/control antennas are an unobstructed view of the launch complexes and satisfactory tracking geometry for the various flight trajectories. In order to prevent detonation of stored explosives, the radar antenna should not aim into or directly over the explosives storage area.

Tracking Radars. It is assumed that the Hawaii spaceport would utilize a conventional single-target radar located on or near the launch site. Additional instruments located "downrange" may also be necessary. The radar could be a small FPS-16 class system equipped with data handling systems to allow realtime interchange of designate data with other trackers. A larger radar (e.g., FPQ-14), could provide launch area support and provide long range tracking data from vehicles in flight and in orbit. Launch vehicles will be equipped with radar transponders to send out an "echo" pulse to a ground based radar.

Command/Control. More than one command control facility would be available to activate the launch vehicle flight termination system (FTS).

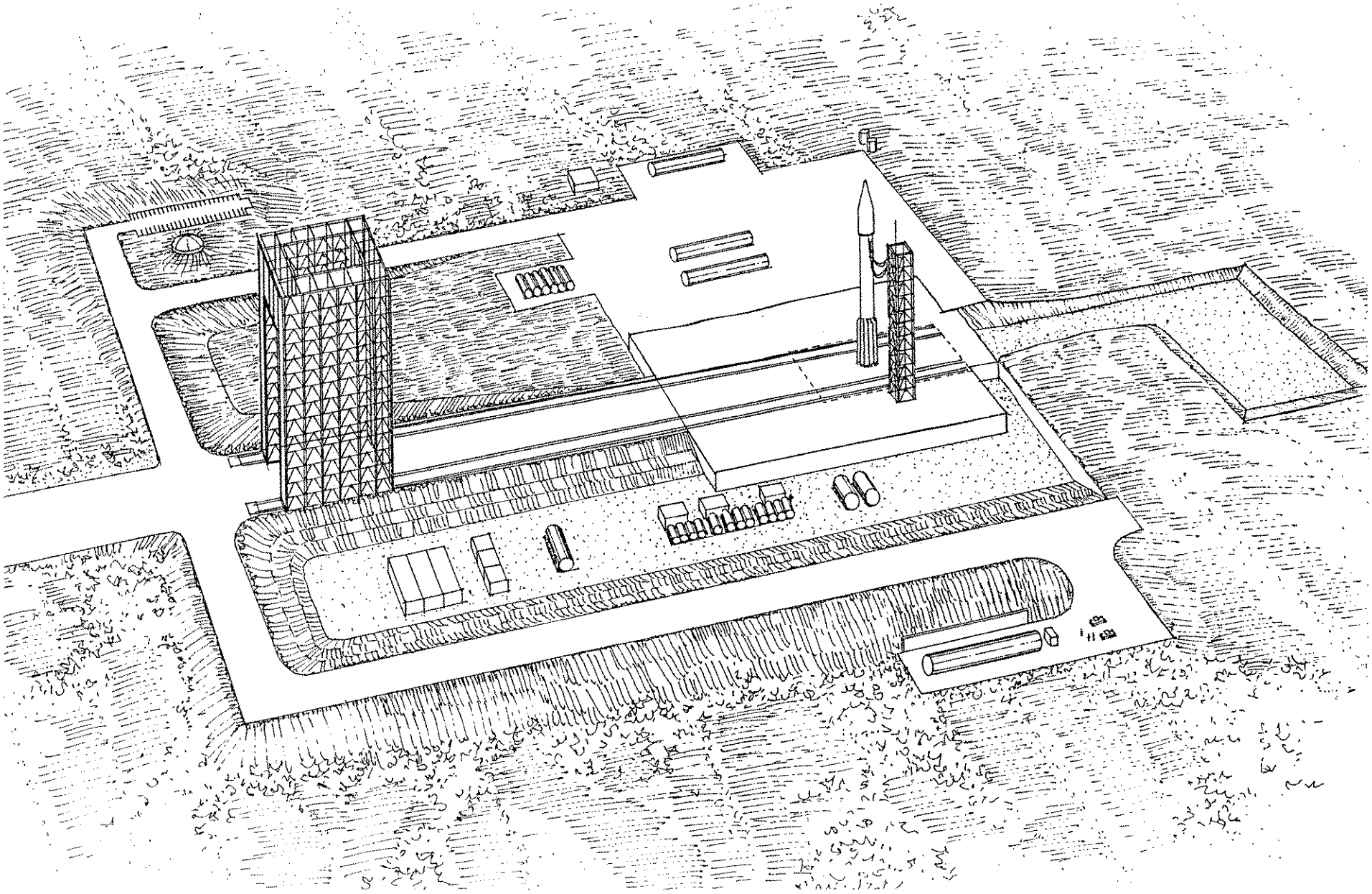


Figure II-3.9

Source: DBEDT, Office of Space Industry, 1993.

TYPICAL mELV LAUNCH COMPLEX

Telemetry. Telemetry signals would be received at a ground station. Inertial guidance and critical performance data contained in the telemetric data would be processed and routed to the range safety system. Global Positioning System (GPS) data could be used for determining rocket position.

Optics. Optical systems provide the main source of trajectory data during the early stages of flight. Intermediate-focal-length (10- to 240-inch) optical trackers process data from lift-off and early flight. Additional optical coverage may be provided by long-focal-length (200- to 500-inch), moderate-aperture (18- to 24-inch) telescopes. These instruments would provide long range coverage of vehicle staging events and high altitude flight.

Concrete pads would be located at various locations on the launch site for the mobile optical systems. These pads would be sited to afford a clear view of the launch vehicle flight path. The pads would be near roads and would require electrical power.

Meteorological Monitoring System. Atmospheric observations, from the surface to over 300,000 feet, involve the use of ground-based instruments as well as balloons, small weather rockets, and rawindsondes. Wind speed and direction, wind shear, temperature, dewpoint, relative humidity, pressure, density, speed of sound, refractive index, cloud height and precipitation are the parameters measured.

Surveillance Radar. A radar system would be operated to ensure that the downrange flight path is clear of ships and aircraft during launch operations. Additional data may be routed to the spaceport from FAA radars elsewhere in the State.

5.0 Technical Operations Facility (TOF)

The centralized TOF (Figure II-3.10), will house radar, telemetry, and command/control systems as well as the range safety real-time computers and the range safety display system (RSDS). A satellite earth station may be required to link launch site operations directly with users' facilities anywhere in the world.

The TOF would be a single-story building of approximately 21,000 square feet. The roof would support additional tracking instrumentation and small fixed telemetry antennas pointed toward each of the launch complexes. A separate utility building will house two 1000 kW diesel generators to operate all critical instrumentation at the TOF site. A 3,600-gallon above-ground fuel storage tank would supply the generators. Facility design will be coordinated with the County of Hawaii to ensure that it meets all County codes.

6.0 Industrial Area (IA)

The IA would be located near the boundary of the PCZ. Support functions, such as administration, health and protective services, technical support laboratories, and maintenance services would be located in the IA. A helipad with landing and parking space for two helicopters would be located within a few hundred feet of the health and protective services area of the IA. A hangar for helicopter storage and maintenance and a fuel tank/pump could be located adjacent to the helipad.

All buildings in the IA will be constructed according to Hawaii County Codes. Aesthetic considerations and appropriate landscaping will be incorporated in the design. Figure II-3.11 shows a conceptual drawing of the IA.

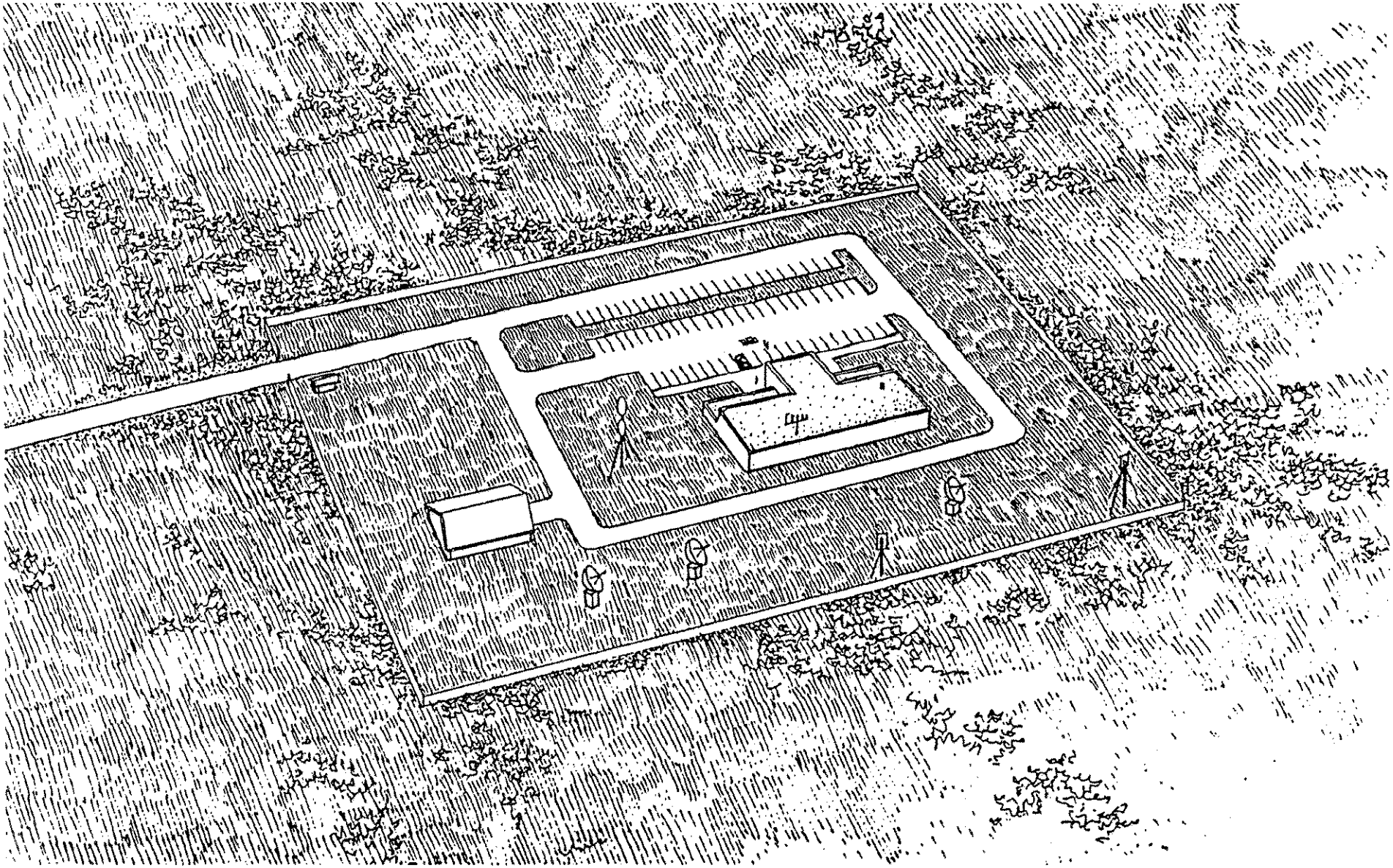


Figure II-3.10

Source: DBEDT, Office of Space Industry, 1993.

TECHNICAL OPERATIONS FACILITY (TOF)

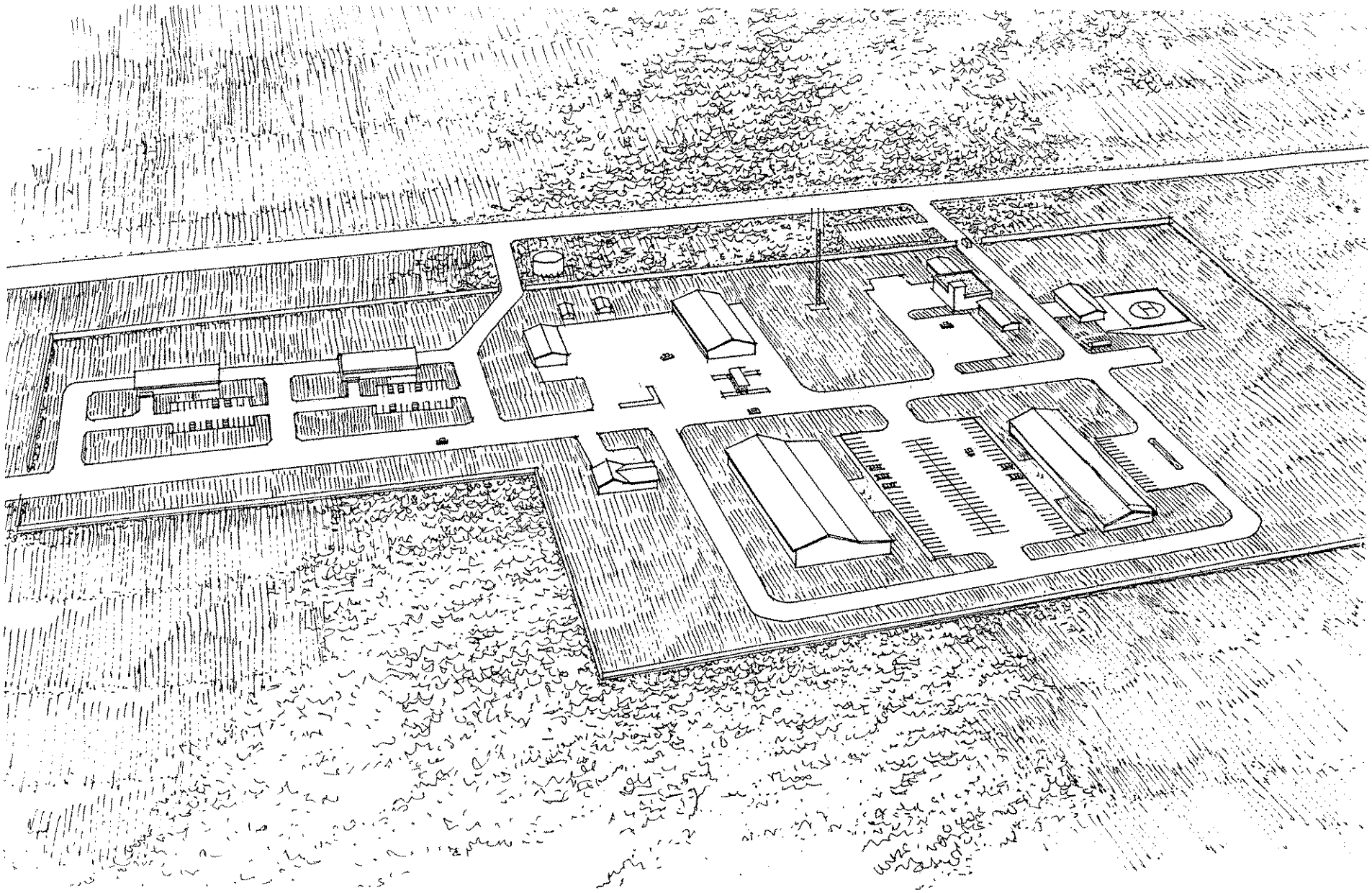


Figure II-3.11

Source: DBEDT, Office of Space Industry, 1993.

CONCEPTUAL INDUSTRIAL AREA (IA)

D. ON-SITE INFRASTRUCTURE AND UTILITIES

1.0 Roads

Approximately 15 miles of roadway will interconnect the various components at the launch facility. It is probable that all of the major roads will be built to County Standards and paved. Intersection improvements will be determined by State DOT requirements. Planning and design of roadways will be coordinated with the County of Hawaii.

2.0 Electrical Power

The spaceport will obtain its primary electrical power from the Hawaii Electric Light Company (HELCO) grid. Peak power demand at full build-out is expected to approach 10 MW, with an average requirement of about 7 MW. A new substation to step down power from the HELCO 69 kV transmission line will be constructed on site. On-site power lines could be overhead and/or underground, depending on County of Hawaii requirements. All electrical systems and lines will be constructed to industry standards.

Uninterrupted power systems (UPS) and/or emergency generators will be provided at the IA (UPS & 5 kW generator), TOF (UPS & 2 MW generator), and mELV launch complexes (UPS & 0.5 MW generator each) to ensure a continuous source of electricity during countdown and launch activities. The UPS is typically a large set of batteries which are kept charged and ready to assume critical loads for short time periods. The generators would be used infrequently, typically no more than a few hours on each launch day.

3.0 Lighting

Outdoor lighting at the launch facility will comply with the Hawaii County Lighting Ordinance which was established to protect the site qualities of the Mauna Kea Science Reserve. Two classes of lighting are permitted under this ordinance: Class I (repair and work areas where color rendition is important) and Class II (roadways, parking, security). Class I lighting may be incandescent; Class II must be low pressure sodium. Mercury-vapor lamps may not be used. Light fixtures must be shielded to block upward directed light except for small low-pressure sodium fixtures (90 watts).

Except for launch areas, the lighting throughout the launch facility is similar to that found in a light industrial area. The launch areas occasionally need true-color lighting. The ordinance allows incandescent work lights to be used, as long as they are shielded and are used only when required.

Outdoor lighting is used to illuminate parking lots, walkways, security areas, and some work areas. The total for this use is estimated at 3,000,000 lumens. Light levels recommended by the Illuminating Engineering Society (IES) and estimated low-pressure sodium lighting requirements for the launch facility by functional area are shown on Table 2.3.9a.

Illumination levels of incandescent lighting which may be used during fueling and launching range from 75,000 to 1,875,000 lumens. All lights will be aimed downward and will be shielded to prevent the emission of stray light upward. Lights will be operated at the minimum levels necessary to safely carry out pre-flight and launch operations. It is unlikely that more than a single launch area would require vehicle illumination lights on any given night. The range of illumination levels is shown on Table 2.3.9b.

Table 2.3.9a **GENERAL LIGHTING LEVELS BY AREA**

Area	Lighting (Lumens)
Industrial	600,000
Technical Operations	200,000
Payload Processing	500,000
Propellant Storage	800,000
mELV1 Launch Site	250,000
mELV2 Launch Site	250,000
sELV Launch Site	200,000
Misc.	200,000
Total low pressure sodium	3,000,000

Source: DBEDT, Office of Space Industry. Feb. 1993

Table 2.3.9b **RANGE OF ILLUMINATION LEVELS FUELING AND LAUNCHING**

Illumination (Ft.-Candles)	Total Lighting (Lumens)
10	600,000
25	187,500
50	375,000
75	562,500
100	750,000
150	1,125,000
200	1,500,000
250	1,875,000

Source: DBEDT, Office of Space Industry. Feb. 1993

4.0 Water

The water supply and distribution system will consist of storage tanks, pumps, and pipes which link buildings and functional areas that are located throughout the launch facility. Under most circumstances, water for fire protection is provided through outside fire hydrants (with sprinklers installed in inhabited buildings). A minimum 8-inch water line would be constructed to comply with Hawaii County Building Code requirements.

Water storage tanks would be located throughout the launch facility in the following manner:

TOF: A 60,000 gallon tank would be located at the TOF area since it is located some distance from other spaceport facilities.

IA, PPA & PSA: A shared 100,000-gallon capacity storage tank.

Each launch complex would have its own storage tank, with pipes and pumps designed to provide water at high flow rates as required at launch time. Water used during launches will be directed to a holding pond for treatment. Planned storage capacities are: sELV - 10,000 gallons; mELVs--60,000 gallons each. Total water storage capacity at the spaceport is estimated to be 290,000 gallons.

5.0 Domestic Sewerage

Domestic wastewater will be collected and distributed through pipes to treatment units; effluent will be discharged into the ground through leaching fields. The exact number and location of treatment units will be determined based on the final configuration of facilities. Separate packaged treatment units could be used at the propellant storage area, booster processing area, industrial area, technical operations facility, and the launch complexes. Domestic wastewater disposal for the facility at full build-out is estimated at 242,800 gpd.

6.0 Liquid Hazardous Waste Systems

Liquid hazardous waste containment systems will be located in three areas: the hypergolic propellant storage area; the Hazardous Processing Facility in the PPA; and, the launch complexes. A containment system, consisting of hypergolic fuel-resistant trenches surrounding fueling islands, will be constructed at each area. The trenches drain spilled hypergolics and flush water into underground holding tanks. Holding tanks are constructed to meet EPA and DOH standards for hazardous material containment. Hazardous liquid wastes will be neutralized with water and other chemicals prior to shipment off-site.

E. DIRECT EMPLOYMENT

Table 2.3.10 summarizes estimated employment at full build-out. The launch facility is expected to create about 270 jobs (plus or minus 60 or more). It is assumed that 120 of these jobs, primarily semi-skilled and labor jobs, could be filled by residents of Ka'u or nearby communities.

Transient workers - scientists, engineers and technicians from overseas organizations - will likely stay in Ka'u a few weeks at a time to assist in preparing payloads and launching rockets. An average of 150 of these workers are expected to be on-site at any one time.

Table 2.3.10 LAUNCH FACILITY EMPLOYMENT AT FULL OPERATION
(Potentially higher or lower by about 25%)

Item	Ka'u	Remainder Big Island	TOTAL Big Island
Jobs by Place of Employment			
Spaceport Jobs:			
Management and Highly-Skilled Jobs [1]	150		150
Semi-Skilled and Labor Jobs	120		120
Total Spaceport Jobs	270		270
Indirect Jobs Supported by Spaceport:			
Management and Highly-Skilled Jobs [1]	50	30	80
Semi-Skilled and Labor Jobs	200	140	340
Total Indirect Jobs	250	170	420
Total Spaceport and Indirect Jobs:			
Management and Highly-Skilled Jobs [1]	200	30	230
Semi-Skilled and Labor Jobs	320	140	460
Total Jobs Supported by Spaceport	520	170	690
Workers by Place of Residence			
Management and Highly-Skilled Workers [1]	200	30	230
Semi-Skilled and Labor Workers	290	170	460
Total Workers Supported by Spaceport	490	200	690
Transient Workers (average number of visiting workers)	150		150

1. Jobs filled by workers from the mainland and other islands.

Source: Decision Analysts Hawaii, Inc., Appendix IXA (DEIS)

SECTION IV: MANAGEMENT CONSIDERATIONS

A. SUMMARY OF THE STATE LAUNCH FACILITY MANAGEMENT PLAN

See Appendix XE of the dEIS for the complete plan.

1.0 Objectives

The objectives of the State Launch Facility Management Plan are to:

- Protect public health, safety, and personal property;
- Preserve and protect the environment, cultural resources, the shoreline, Hawaii Volcanoes National Park (HVNP), and the skies above Mauna Kea and Mauna Loa Observatories;
- Develop the facility to a level suitable for launching small to medium-sized rockets for placing satellites into earth orbit;
- Ensure that the necessary facilities and services are available to support the launch activities;
- Attract commercial users to the launch facility;
- Ensure that Hawaii reaps an equitable share of the diverse benefits that can accrue from the launch facility;
- Ensure job training for local residents to allow them opportunities to be employed at the launch facility;
- Provide adequate public access to and along the shoreline consistent with assuring public safety and conserving natural resources;
- Integrate the local community with the launch facility; and
- Provide public information services.

These objectives are to be accomplished through a joint effort between the State and private companies that will form a consortium to develop and operate the launch facility.

2.0 Development Approach

The Authority. The State Launch Facility Management Plan is based on the assumption that the State will: (a) purchase or otherwise acquire the land on which development is to take place; (b) obtain the controls needed to protect public health and safety on the remaining lands; (c) obtain the necessary major development approvals and permits; and, (d) provide the off-site infrastructure for the facility (such as road improvements and electrical power).

The State's interests will be promoted and protected through an Authority established by the Legislature. The Authority will make the land available for the facility and would have the power to represent the State in its dealings with Launch Companies and the Consortium.

Consortium. It is assumed that the State will lease land to one or more private companies ("the Companies") who will form a consortium ("the Consortium) to construct the launch facilities. The Companies may be launch companies only, or may be a combination of a launch company (or companies) and a large diverse corporation (or corporations) having experience in space-related endeavors, developing and/or constructing large facilities.

The Companies comprising the Consortium will take primary responsibility for developing and operating the launch facility under conditions mutually agreed to in writing with the Authority. The Consortium and the Companies will operate under their own management plans, and will execute separate agreements among themselves regarding how they share costs, revenues and profits, and their respective roles and responsibilities.

Common Facilities. As members of the Consortium, the Companies will share the cost of designing and constructing the commonly shared facilities. These common facilities will include shared tracking and control systems, technical support laboratories, maintenance shops, water and power systems, wastewater disposal systems, storage areas, a fire station, a medical clinic, a security office, a helipad and hanger, internal roadways, etc.

The Users. The "Users" will include launch companies and payload organizations that will launch payloads from the facility. The Users will include the launch companies that belong to the Consortium.

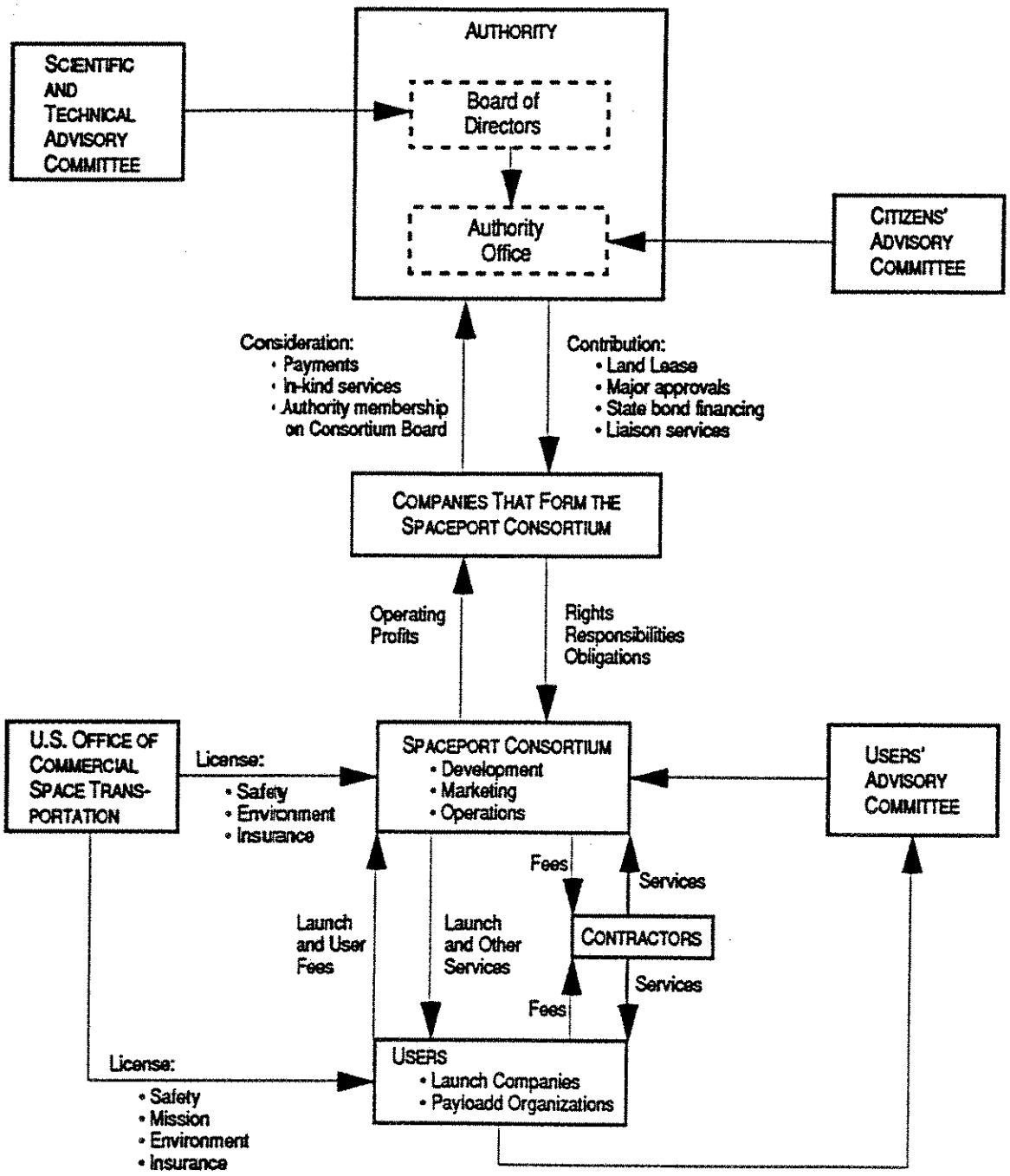
Users' Facilities. Individual launch companies--some of whom will be members of the Consortium--will fund the design, construction, and operation of launch complexes, which will be unique to each individual company's launch operations. These facilities will be called the "Users' Facilities," and will include the launch complexes for sELVs and mELVs; special rocket processing areas, storage areas, parking, etc. Platforms for the smaller sounding rockets may also be constructed as part of the Users' Facilities.

In addition, payload organizations which frequently use the launch services could build facilities at the Palima site, including their own building complex for processing payloads.

3.0 Proposed Organization

The principal participants will be: the Authority, which will represent the interests of the State; a Technical and Scientific Advisory Committee and a Citizens' Advisory Committee, which will make recommendations to the Authority; the Companies which form the Consortium, to develop and operate the launch facility; Users of the launch facility made up of launch companies and payload organizations; a Users' Advisory Committee to advise the Consortium; and, OCST, which will issue the necessary licenses and verify that operations are safe and that they serve the national interest.

The relationships among these entities, and their primary responsibilities, are presented in Figure II-4.1. Further details are discussed in Appendix XE of the dEIS.



Source: Decision Analysts Hawaii, Inc.
DEIS Appendix X-E

Figure II-4.1

ORGANIZATION CHART: STATE LAUNCH FACILITY MANAGEMENT PLAN

B. CONCEPTUAL SHORELINE ACCESS MANAGEMENT PLAN

The shoreline access management plan (DEIS Appendix XF) addresses issues regarding public access to the shoreline within the PCZ and proposes management strategies. It should be noted that the plan is conceptual; the final plan will not be adopted until exhaustive public and agency input has been received. The plan is shown on Figure II-4.2

1.0 Objectives and Guidelines for Public Access and Shoreline Use

The primary objective of the plan is to provide access to and use of the shoreline area, while at the same time insuring public health and safety during launches and other potentially dangerous operations and protecting shoreline resources and the launch site facilities. The planning guidelines which follow are derived from policies and objectives of various State and County plans, ordinances and laws, and from companion reports in the EIS and experience gained at other launch facilities.

- Provide adequate public access consistent with conserving the natural resources to and along the shoreline;
- Protect historic sites that must be preserved and those that must be avoided until data recovery can be completed;
- Protect, preserve and, where desirable, restore or improve the quality of coastal scenic and open-space resources;
- Preserve coastal ecosystems;
- Provide facilities and controls that will insure the health and safety of the recreational users;
- Provide security for the launch facilities.

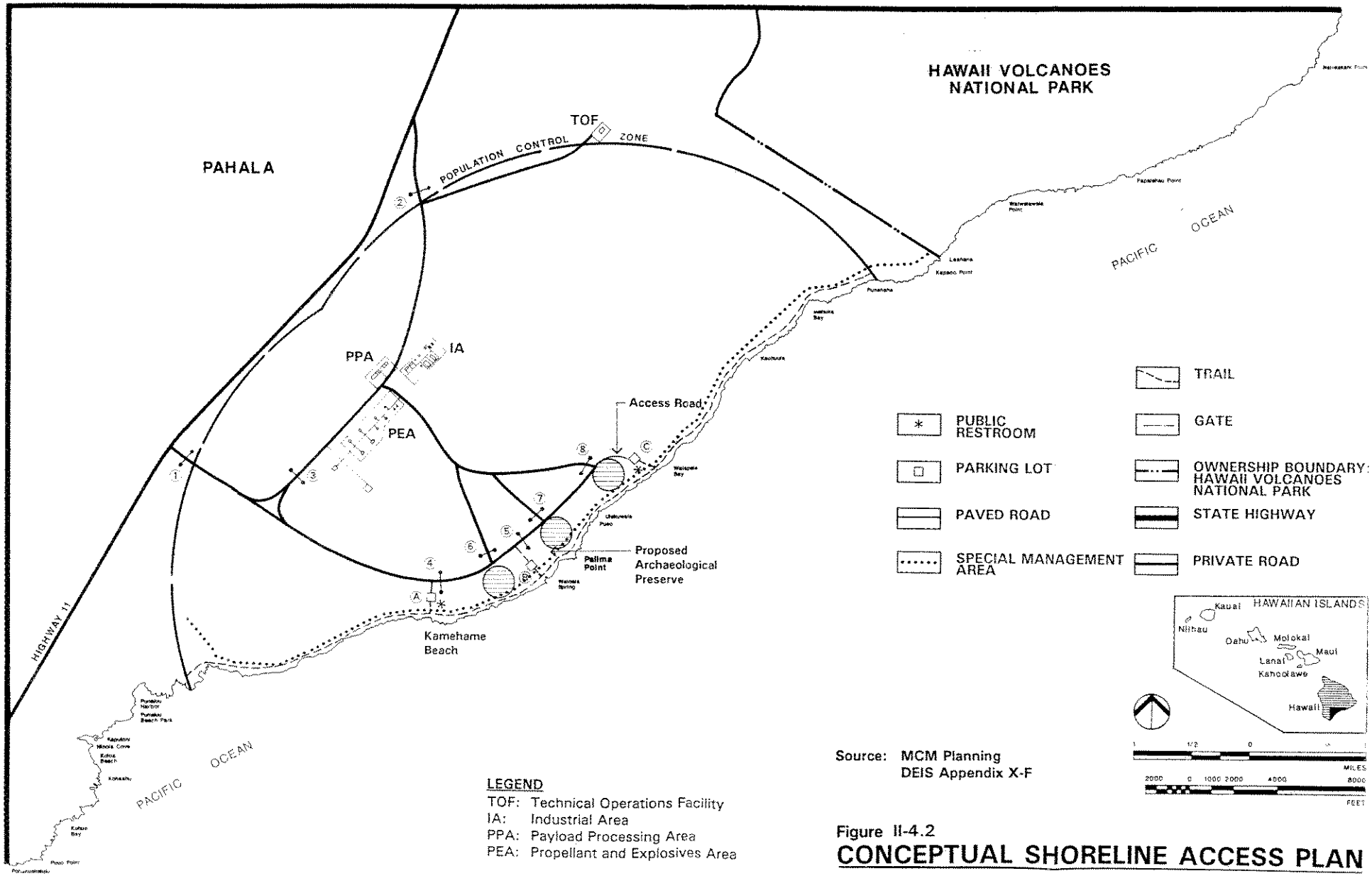
2.0 Management Jurisdictions

The plan is based on the management approach described in the State Launch Facility Management Plan. Organizations which will have jurisdictional responsibilities for the plan are:

The Authority. Provisions in the Authority enabling legislation will delegate to the Authority the responsibility and the necessary enforcement powers to manage and control public activities in the PCZ. The development of regulations will be coordinated with DLNR,the County of Hawaii and the USFWS. The Authority will also be responsible for maintaining the public areas, including trash collection and cleaning of all public areas.

The Consortium. One of the obligations of the Consortium will be to fund the construction, operation and maintenance of parking lots, restrooms, and public areas, and other activities of the plan. Funds for security facilities and for hiring the necessary security personnel will be provided by the Consortium.

Department of Land and Natural Resources (DLNR). Chapter 198D, Hawaii Revised Statutes, gives DLNR the authority to plan, develop, acquire land or rights for public use of land, construct, and engage in coordination activities to implement a Hawaii statewide trail and access system. Because DLNR may regulate the use of trails and accesses under its jurisdiction, this shoreline plan and proposed restrictions must be coordinated closely with them.



LEGEND
TOF: Technical Operations Facility
IA: Industrial Area
PPA: Payload Processing Area
PEA: Propellant and Explosives Area

Source: MCM Planning
DEIS Appendix X-F

Figure II-4.2
CONCEPTUAL SHORELINE ACCESS PLAN

The lands below the certified shoreline, the nearshore waters, and a portion of the State lands near Punalu'u are situated within the Resource Subzone of the Conservation District (Figure II-4.3). Uses in these areas must be approved by the State Board of Land and Natural Resources (BLNR) through Administrative Rule Title 13, Chapter 2, regulating uses in the Conservation District.

County of Hawaii. The Special Management Area (SMA) is shown on Figure II-4.2. An SMA Use Permit from the County will be required for uses and/or controls within the SMA. Section 46-6.5., Hawaii Revised Statutes, requires each County to adopt ordinances which require a subdivider or developer, as a condition precedent to final approval of a subdivision, to dedicate land for public access to the shoreline.

U.S. Fish & Wildlife Service (USFWS). The USFWS, Office of Endangered Species, by authority of the Endangered Species Act (P.L. 93-205, et seq.), has the authority to enforce regulations concerning endangered and threatened species and their habitats. In the case of the turtles, this function will be accomplished in coordination with the National Marine Fisheries Service (NMFS). Both agencies will be consulted during the development of the final plan in order to ensure that all of their concerns are addressed.

3.0 Public Access Restrictions

Site Access. Public access will be restricted to one gate located off of Mamalahoa Highway at the southernmost entrance to the site (Figure 2.4.2). Existing 4-wheel-drive trails from the highway to the launch pads will be closed.

Lateral Access. The access points on the shoreline at the northeastern and southwestern boundaries of the PCZ will remain open during designated public access hours. Temporary barriers will be erected to close the area at other times; security personnel will patrol these areas when access is restricted.

Hours of Public Access. Except during launch periods, public access to the PCZ will be allowed between 6:00 a.m. and 6:00 p.m. daily. When public access is closed, only authorized launch facility-related personnel will be allowed in the area.

It is possible that some time in the future, fishermen may be able to obtain overnight permits. These permits will not be valid on nights preceding a launch.

During hazardous-fuel operations, the PCZ will be closed 1/2 hour before the operation and reopened about 1/2 hour after it. During launch periods, the PCZ will be closed the night before the launch and reopened 1/2 hour to 1 hour after the launch. If the launch is delayed for an extended period of time, the PCZ will be opened after the rocket is safed (approximately two to four hours).

The shoreline will also be closed to the public during dangerously high surf, tsunami, flash flooding and/or when other natural conditions threaten the health or safety of the public.

Other. As shown on Figure II-4.2, vehicles will be restricted to improved roads; parking will be only allowed in designated areas. Launch pad and fuel-storage areas will be fenced, and the public will be restricted from these areas.

Archaeological sites waiting data recovery will have appropriate barriers around them. During turtle nesting periods, Kamehame Beach may be fenced or gated if deemed necessary.

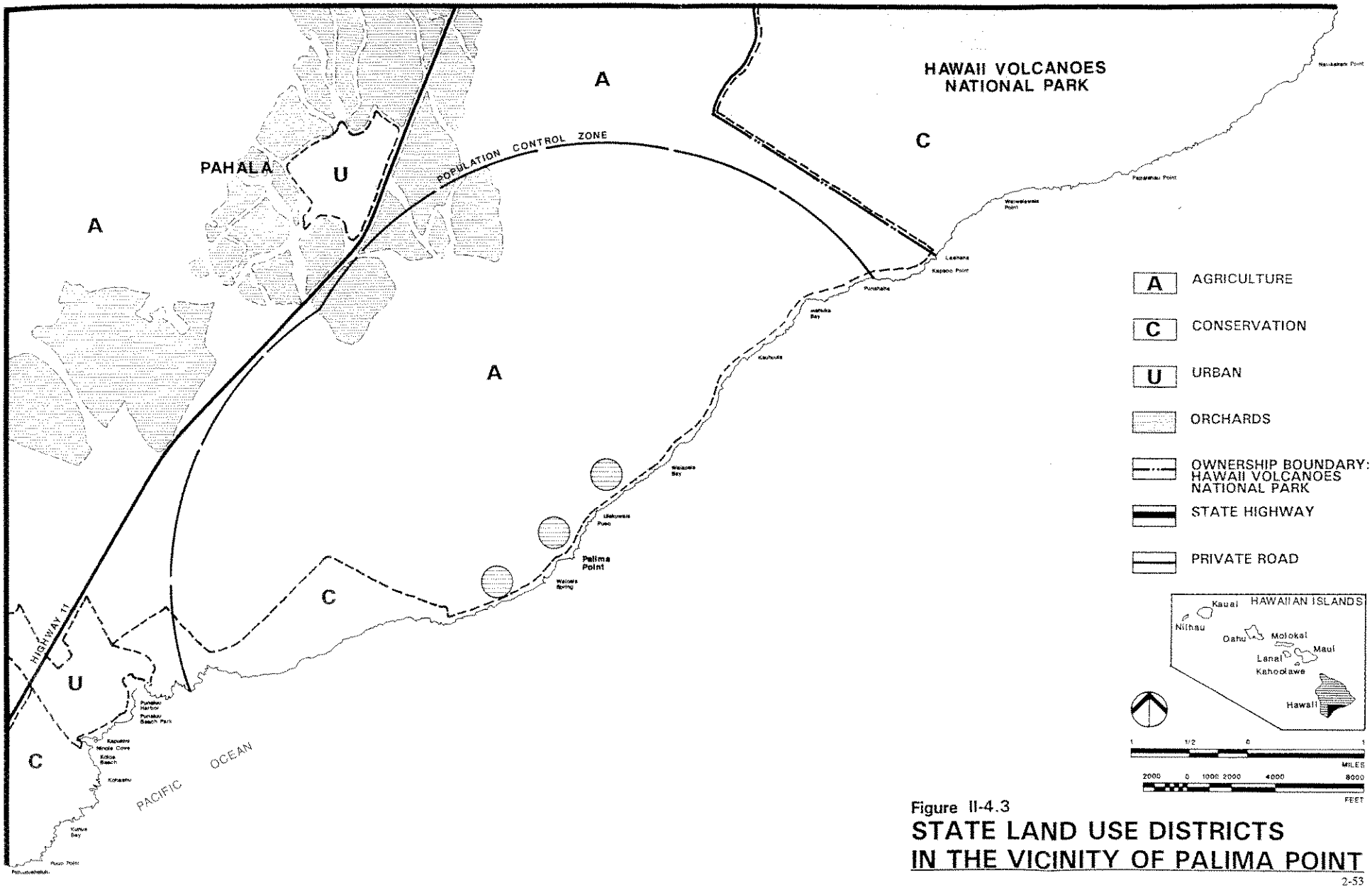


Figure II-4.3

STATE LAND USE DISTRICTS IN THE VICINITY OF PALIMA POINT

4.0 Permitted Public Activities

Daytime. Escorted visits by the general public to the the launch facility facilities; pole fishing, seaweed and shellfish gathering, spearfishing, and, throw-netting; picnicking; hiking; collecting; swimming (at Kamehame and Maue); and, scientific research (e.g., archaeology, geology, green sea turtles, HVNP, Hawaii Volcanoes Observatory).

Nighttime. Possible night fishing by permit only; and, special public events sponsored by the launch facility, if any.

5.0 Public Activities Not Permitted within the PCZ

Camping overnight. Fishermen who hold special overnight permits may be allowed. This restriction will be enforced rigorously and security officers will eject overnight campers who do not have permits.

Use of firearms or ammunition. Security officers will be authorized to confiscate all weapons and/or ammunition.

Others. This includes hunting of any kind, littering, disturbing archaeological sites, harassing or taking endangered species and driving of vehicles beyond the paved roads and parking lots.

6.0 Proposed Public Facilities

Shoreline parking areas, restrooms, trash cans, and drinking water will be provided (see Figure II-4.2). Paved roads will lead to the parking lots. The three designated parking areas are:

Area A. This parking area is provided primarily for visitors who would use the beach at Kamehame and/or the shoreline trail to Punalu'u, immediately to the west. Restrooms, water, trash cans and possibly picnic facilities will be located adjacent to the parking.

Area B. This parking area, located just south of the center launch pad -- near Palima Point, provides accessibility to a proposed archaeological preserve and the shoreline. No restroom facilities or potable water sources are planned for this area.

Area C. This parking area will be located near Pa`au`au Pali, north of the northernmost launch pad. It is anticipated that people who park in this area will be fishermen and/or hikers who will use the shoreline trail leading northeast towards HVNP. A restroom, drinking water and trash cans will be located nearby.

Eight gates are envisioned to control public access to the launch site facilities. These include:

Gate One. Located at the southwestern entrance on Highway 11, this gate will be used for public access (and for official launch facility business); a sentry will be present 24-hours per day.

Gate Two. Located at the northern entrance to the facility off of Highway 11. This gate will be used for official launch facility business only. Access will be controlled by launch site security personnel.

Gate Three. Located at the entrance to the Propellant and Explosives Storage Area. This area will always be closed to all except authorized personnel.

Gates Four and Five. These gates are located on the service roads to the launch pads. One or both of these gates will be closed when launch or fuel-transfer operations preclude public access.

Gates Six, Seven and Eight. These gates, which will be closed to all but authorized personnel, are located along the three roads leading from the launch pads to the industrial area to prevent unauthorized persons from driving through the launch site.

Signs will be erected throughout the area for purposes of information and control. The location, design and installation of all permanent signs will be determined by the Authority and the Consortium in coordination with DLNR, the County of Hawaii, and private landowners in the PCZ.

7.0 Enforcement

Regulations will be enforced by either a private security company retained by the Authority or by an on-site security force employed by the operator. Maintenance of the shoreline area and trash collection will also be the responsibility of the launch facility management.

The Authority will delegate its enforcement powers to security personnel. Round-the-clock sentries, hired by the Authority, will be on duty before and during launches at Gate One, at the shoreline, and at the shoreline access boundaries. At other times, security personnel will patrol the PCZ, particularly the shoreline areas, 24 hours a day and will eject anyone who is not abiding by the rules.

8.0 Monitoring and Plan Amendments

The management plan must be flexible; it must respond to changing conditions as the spaceport develops and expands. The situation will be monitored carefully and adjustments will be made to existing controls as required. The County of Hawaii, DLNR, USFWS, NMFS, Hawaiian groups, private landowners and the public will be included in all discussions concerning modifications to the Plan and will be notified in advance of any changes in the rules.

SECTION I: THE REGIONAL SETTING

A. STATE OF HAWAII

The State of Hawaii consists of a string of islands in the north central Pacific, about 2,400 miles west of San Francisco. The eight major islands are Kauai, Niihau, Oahu, Maui, Molokai, Lanai, Kahoolawe, and Hawaii. Honolulu, the State capital, is located on the island of Oahu, where over 75 percent of the State's population resides (Figure III-1.1).

1.0 Transportation

The State has seven commercial airports: two on the island of Hawaii and one each on Oahu, Maui, Lanai, Molokai and Kauai. Honolulu International Airport ranked 14th in the nation for enplaned passengers in 1989 (DBEDT, 1991). Almost all scheduled interisland travel is by air. In 1990, airlines and air taxis carried 9.9 million interisland passengers and 73,000 tons of cargo (Ibid.). There are eight deep water harbors statewide: two each on Oahu, Hawaii and Kauai and one each on Maui and Molokai.

2.0 Climate

Climate in the State is mild and semi-tropical. Hawaii lies within the belt of northeasterly tradewinds generated by the semi-permanent Pacific high pressure cell to the north and east. During the summer (May through September) when the Pacific high is at its northernmost position, northeasterly tradewinds are prevalent 80 to 95 percent of the time. During the winter (October through April), the State is north of the Pacific high. The northeast tradewinds however, still blow across the islands, but with a decreased frequency ranging from 50 to 80 percent. Wind speeds are also higher in the summer than in the winter, exceeding 12 miles per hour 50 percent of the time (USDOC, 1961).

Seasonal variations in average temperatures across the State are small; less than 9°F in locations below an elevation of 5,000 feet (USDOC, 1961). This can be attributed to the relatively small variations in solar energy received at this latitude, and the constant flow of ocean air across the islands.

3.0 Government

Hawaii has only two levels of government, State and County. The State Legislature consists of a 51-member House and 25-member Senate and meets annually. The four counties are governed by a mayor and council. The counties perform most services usually assigned to cities and towns (fire and police protection, refuse collection, construction and maintenance of streets, other public works). There are no separate municipalities or independent school districts. Public education, hospitals and courts are provided by State government.

4.0 Population

Since 1959, when Hawaii was admitted to the Union, the State has grown rapidly. From 1970 to 1980, the resident population grew by 195,800, from 771,600 to 967,400, an increase of 25 percent. Between 1980 and 1990, population growth continued but at a slower pace. The resident population grew by 146,100 to 1,113,500, a 15 percent increase (DBEDT, 1991).

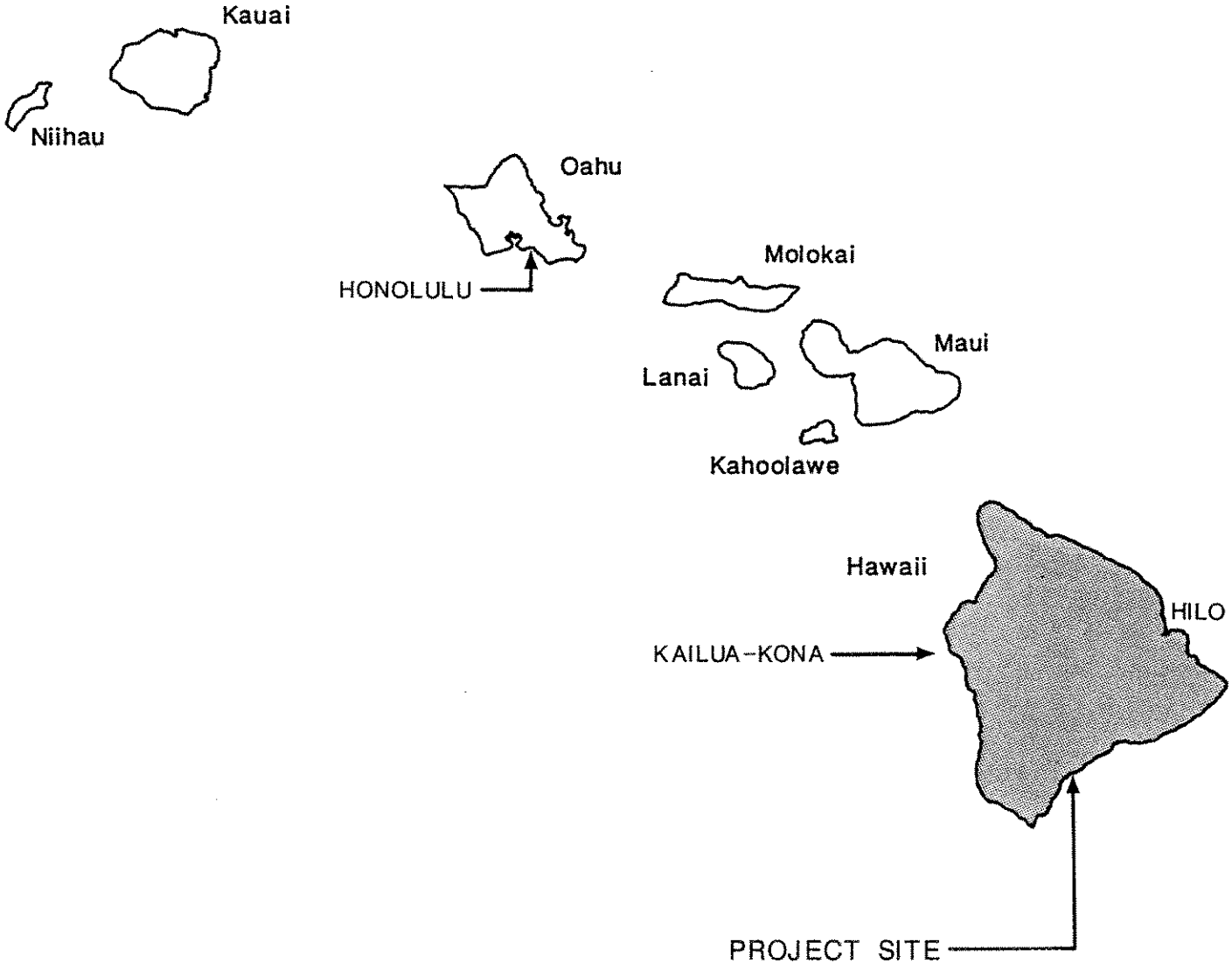


Figure III-1.1
STATE MAP

5.0 Economic Activities

Since Statehood, Hawaii's economic base has shifted from primarily agriculture to primarily tourism. Almost 7 million persons visited Hawaii in 1990, creating a $9.9 billion industry.

Hawaii also has important and strategic military installations. Federal defense spending in 1991 amounted to approximately $3.2 billion. Ten percent of the islands' population is comprised of military personnel and their dependents (DBEDT, 1991)

The State has recognized its need to diversify and create new industries to lessen its heavy dependence on tourism. In the early 1980s, a commitment was made to promote research and development and encourage the establishment and growth of high-technology enterprises. A number of these are on the Island of Hawaii.

B. ISLAND OF HAWAII

1.0 Overview

The Island of Hawaii, often referred to as the *Big Island*, is both the youngest and largest in area (4,035 square miles) of the Hawaiian Islands. It is about 1.6 times larger than all of the other major islands combined (Figure III-1.2). The island's climate and topography are diverse, ranging from dense tropical forests to the seasonally snow-covered mountain peaks of Mauna Kea and Mauna Loa. Ka Lae, located on the southern tip of the island, is the southernmost point in the United States.

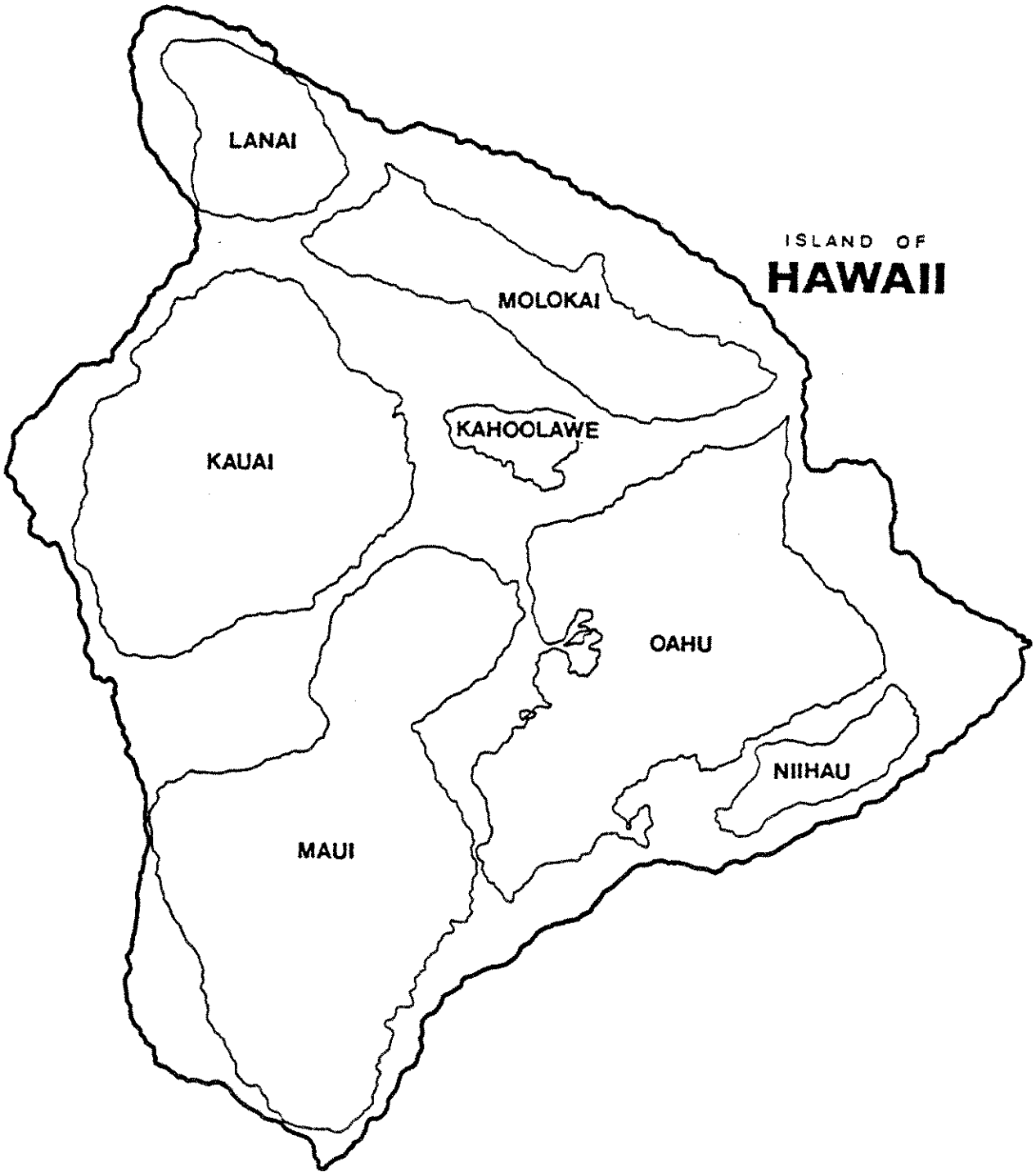
Hawaii's land mass was created by five volcanoes: Mauna Kea, Mauna Loa, Kilauea, Hualalai, and Kohala Mountain. Kilauea and Mauna Loa are still active today. The summit of Mauna Kea is the highest point in the Pacific basin, rising 30,000 feet from the ocean floor to the summit; the highest of its cinder cones (Pu`u Wekiu) towers 13,796 feet above sea level. Mauna Kea and Mauna Loa are the two most voluminous volcanoes in the world.

The County of Hawaii, which encompasses the entire island, is divided into nine administrative districts (Figure III-1.3) and is governed by an elected mayor and a 9-member County council. Hilo, which is located on the island's eastern coast, is the county seat and financial center. The County provides the full range of municipal services. These include police and fire protection; emergency medical care; public prosecutor; culture and recreation; sanitation; social services; water; planning and zoning; construction and maintenance of highways, streets and infrastructure; real property assessment and tax collection; and general administrative services. The University of Hawaii has a 4-year campus in Hilo.

2.0 Climate

Hawaii's weather is generally described in terms of wind direction; most often "tradewind" weather, with winds blowing from the northeast. Significant climatological patterns on the Big Island include persistent northeast tradewinds near the surface, localized sea/land breezes and occasional winter frontal systems.

"Kona" weather describes a period when large-scale pressure gradients and winds are weak. During such periods, the island's terrain influences wind flow and combines with the land/sea breeze to complicate the weather patterns. These conditions can produce winds that flow perpendicular to the shoreline at the proposed launch site. The land breeze (flowing seaward)



Source: DBED, 1985.

Figure III-1.2
ISLAND OF HAWAII: RELATIVE GEOGRAPHIC SIZE

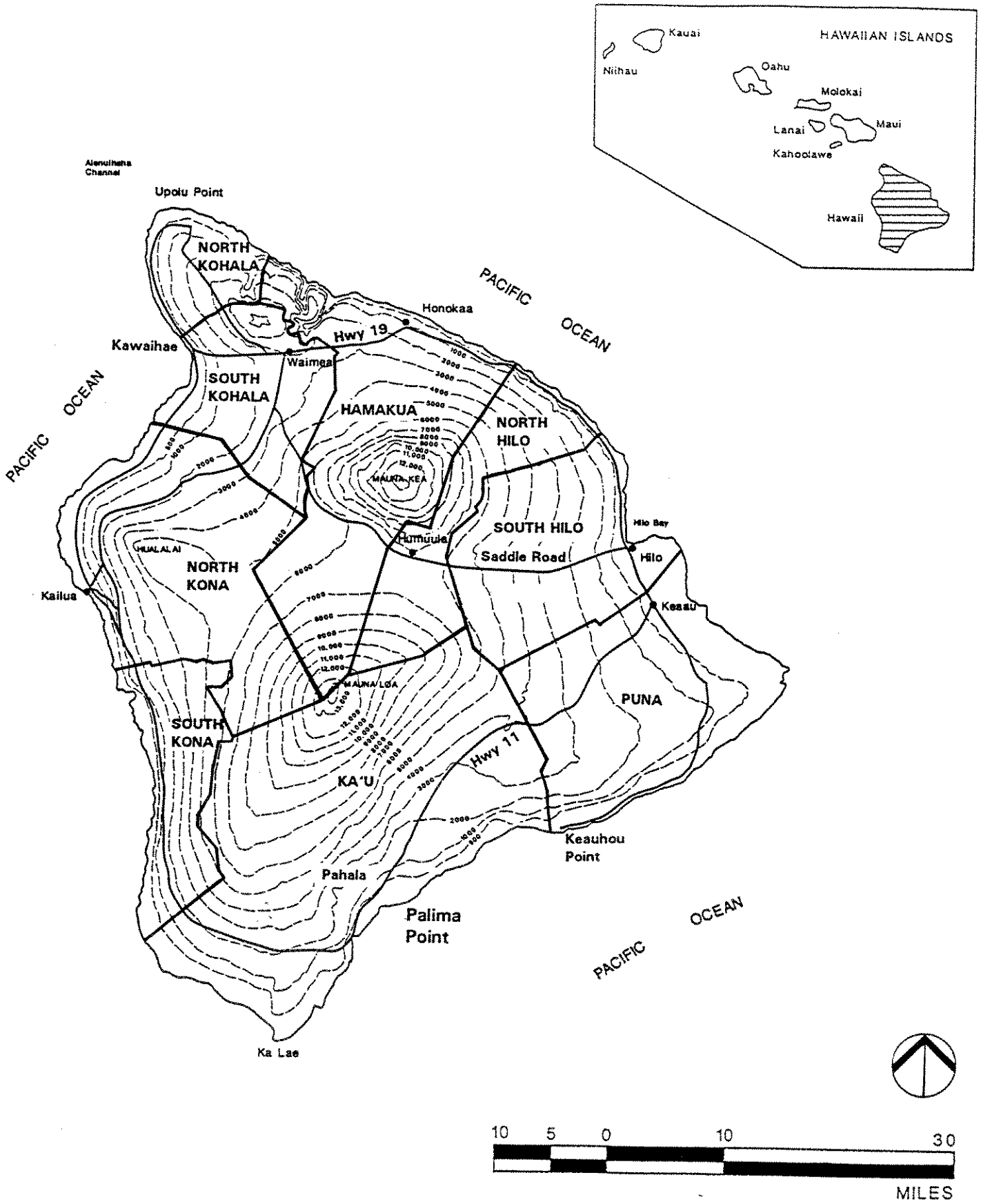


Figure III-1.3

COUNTY OF HAWAII LOCATION MAP

is strongest during the nighttime hours, prior to sunrise. Sea breezes (flowing inland from the sea) occur during the daytime and peak near sunset. Figures III-1.4 and III-1.5 show daytime and nighttime windflow patterns on the island of Hawaii.

Tradewinds bring warm air onshore from open ocean waters. In contrast, the Big Island's mountainous terrain generates cooler air that drains downslope, undercutting the warmer air and creating a low-altitude temperature inversion. This inversion is strongest in the early morning hours, when cool mountain air flows downslope to the sea. This inversion layer can occur at various heights up to several hundred feet.

A second inversion layer occurs at much higher altitudes. This tradewind inversion is present about 50 to 70 percent of the time and its height fluctuates between approximately 5,000 and 7,000 feet. On tradewind days, when the inversion is well defined, clouds develop below these heights with only an occasional cloud top breaking through the inversion.

Clouds are present over the island nearly every day. Cloudy and partly cloudy conditions occur in Hilo on the average of 330 days per year (USDOC, 1961).

3.0 Air Quality Monitoring

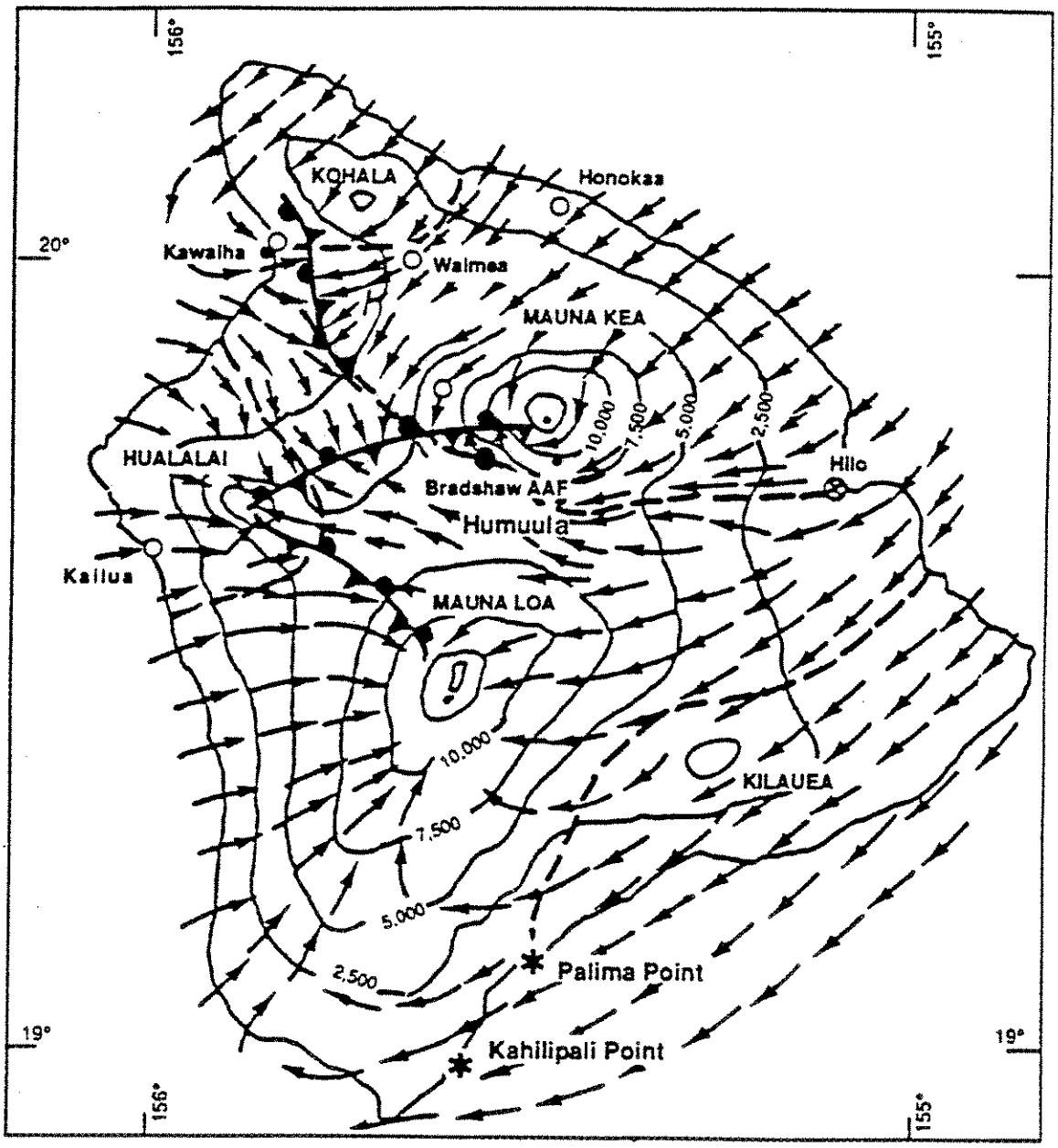
The State of Hawaii, the American Lung Association of Hawaii, the National Park Service and Hawaiian Electric Company, Inc.(HECO), have measured air-pollutant concentrations on the island of Hawaii. The monitoring locations include Hilo (2), Kona, Hawaii Volcanoes National Park (HVNP), Captain Cook, and Honu`apo (Figure III-1.6). The State monitored TSP and SO_2 at the University of Hawaii-Hilo Campus from January 1985 to October 1985 and at the Kona Health Center from June 1985 to September 1986. The State is not monitoring air quality on the Island of Hawaii at the present time.

The American Lung Association of Hawaii collected PM_{10} air quality data at Captain Cook and Hilo from July 1989 to June 1990 (Morrow et al., 1991). The air quality data collection is part of a three year study to investigate the impact of volcanic emissions on the island's air quality and on human health.

The National Park Service operates an ambient-air-quality monitoring station at HVNP near the Kilauea Caldera, approximately 22 miles northeast of Pahala (NPS, 1992). Ambient data have been collected at this site since the mid-1980s with a brief gap occurring approximately 2 years ago when the National Park Service acquired the station. Sulfur dioxide, O_3 and PM_{10} data are collected. Ambient-air-pollutant concentrations were also measured by HECO, under contract to DBEDT, at Honu`apo from 1989 to 1990 (HECO, undated). The air quality parameters monitored included SO_2 and NO_2.

The U.S. Environmental Protection Agency (EPA) and the State of Hawaii have promulgated ambient-air-quality standards to protect public health and welfare. Primary and secondary National Ambient Air Quality Standards (NAAQS) are specified in 40 CFR Part 50 for six pollutants. Similarly, State of Hawaii Ambient Air Quality Standards (HAAQS) are enumerated in Hawaii Revised Statutes, Chapter 11-59.

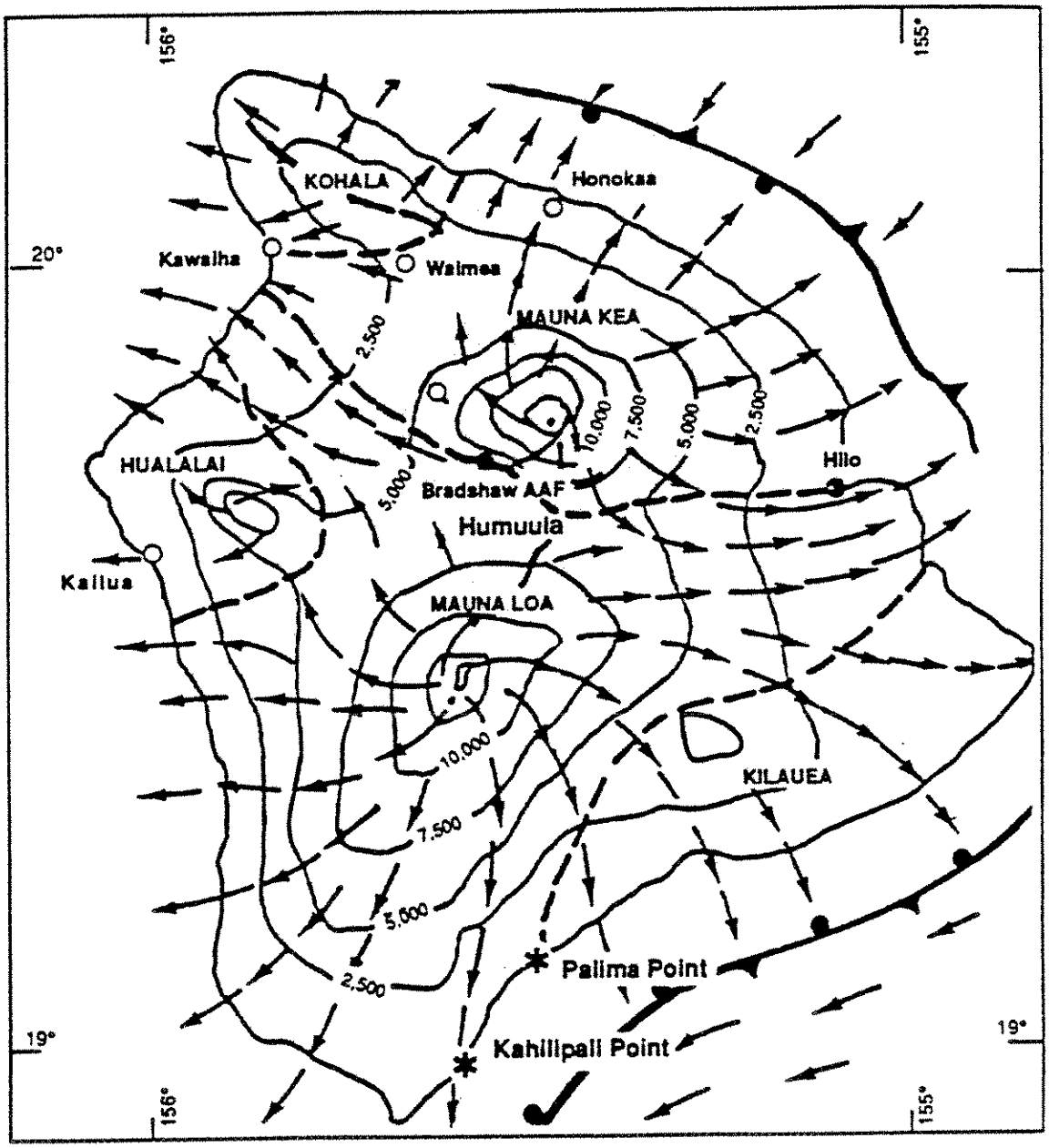
EPA has classified the State of Hawaii for each regulated pollutant as either "better than national standards" and/or "cannot be classified" (40 CFR Part 81.312). The Island of Hawaii is designated "cannot be classified" for TSP; "better than national standards" for SO_2; and "cannot be classified or better than national standards" for O_3, CO and NO_2. EPA has not made area designations for Pb. In addition, the State of Hawaii has not designated any areas in the State as meeting or not meeting HAAQS. See Chapter IV, Section III and



Source: DBEDT, Office of Space Industry, 1993.

Figure III-1.4

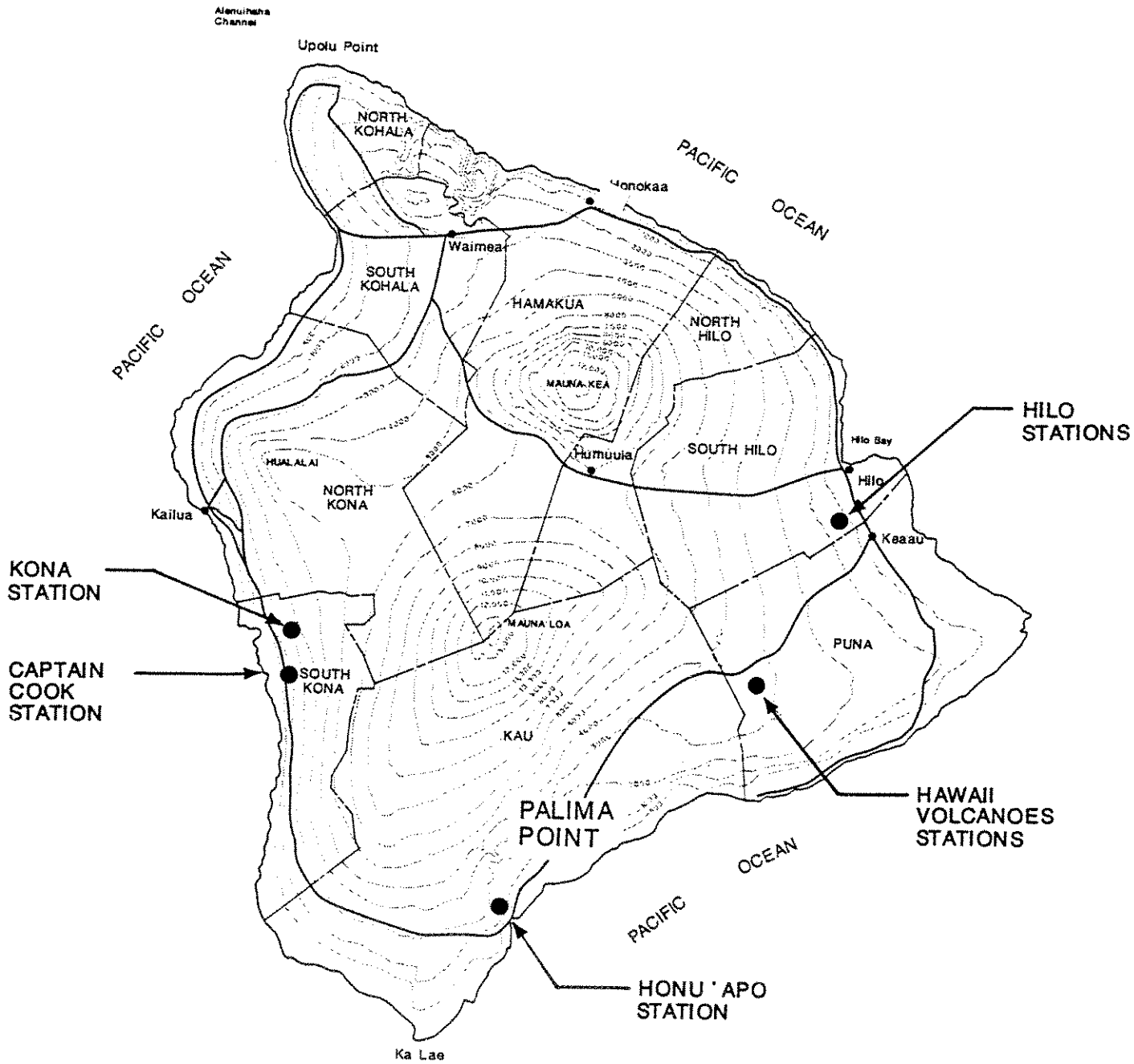
ISLAND OF HAWAII: DAYTIME TRADEWIND FLOW PATTERNS



Source: DBEDT, Office of Space Industry, 1993.

Figure III-1.5

ISLAND OF HAWAII: NIGHTTIME TRADEWIND FLOW PATTERNS



Source: Engineering-Science, Inc.
DEIS Appendix V-B

10 5 0 10 30
MILES

Figure III-1.6

ISLAND OF HAWAII: AIR QUALITY MONITORING STATIONS

Engineering-Science, Inc. (ES), Appendix VB, for summaries and discussions of EPA and State Air Quality Standards.

4.0 Population and Labor Force

As of 1990, Hawaii County had a resident population of approximately 120,300; slightly over half (54 percent) live on the eastern side of the island in the Puna and Hilo Districts. At 30.6 percent, Hawaii's rate of growth between 1980 and 1990 was over twice that of the Statewide growth rate of 14.8 percent (DBEDT 1991). The County anticipates that East Hawaii, with its abundant supply of reasonably priced land, has a future of continued varied commercial development while continued growth in West Hawaii will be closely tied to the visitor industry (Hawaii County, 1992).

The civilian labor force on Hawaii was approximately 67,600 in July, 1992. The unemployment rate was 7.1 percent, with 62,800 persons employed and 4,800 unemployed (FHB, 1992). The most recent figures on employment indicate that the trade and service sectors provided 47 percent of the jobs; government, 15 percent; manufacturing, 10 percent; agriculture, 10 percent; transportation, communication, and utilities, 6 percent; construction, 6 percent; and other, 6 percent (Ibid.).

5.0 Economic Activities

Visitor Industry. Hawaii attracted 1.2 million visitors in 1991, a marginal increase over 1990 (Ibid.). Length of stay, however, was 9.7 percent longer and visitor expenditures were 17.8 percent higher than 1990. In 1990, island hotels provided 6,250 direct and indirect jobs.

Construction. Construction is the major industry on Hawaii in terms of dollar valuation. Construction put in place in 1991 was valued at over $354 million and provided employment for 3,250 people.

Agriculture Industry. In 1990, 5,700 persons were employed in agriculture, which is still the dominant land use on Hawaii. Major changes are taking place within the industry, however, as sugar plantations are being replaced by diversified agricultural activities such as: macadamia nuts, guava, papaya, coffee, taro, beef and cattle, swine, dairy, flowers, nursery and other fruit and vegetables. The total value of agricultural production in 1990 was $286 million.

The future of the sugar industry, historically the foremost agricultural activity on the island, is uncertain. At the beginning of 1992, there were three sugar plantations in the County. In July 1992, one company announced plans to convert its operations to diversified activities. This could result in a loss of up to 450 jobs. Hamakua Sugar Company will close after a final harvest in 1993; up to 600 workers will be displaced.

Science and High Technology. This is a growing sector of Hawaii's economy. The Natural Energy Laboratory of Hawaii Authority (NELHA) is currently involved in research and development in energy, materials and aquacultural projects. It estimates the 1992-1993 economic impact of its tenants to be $30 million. In addition to the completion of the world's only open-cycle ocean thermal energy conversion (OTEC) plant in 1992, three additional major research projects are being considered, resulting in significant expansion of the industry at Keahole.

The other major high-technology activity on Hawaii is astronomy. There are eleven telescopes and one antenna facility either in operation or under construction on Mauna Kea. By the end of the decade, there will then be 13 telescopes and a antenna facility on Mauna Kea, representing an investment of over half a billion dollars. When all facilities are operational,

projected budgets will rise from the current $20 million a year to $40 million; between 300 and 400 people will be employed.

6.0 Infrastructure and Utilities

Transportation. The major highway system of the island is the Hawaii Belt Highway (Highway 11 along the southern half of the island; Highway 19 along the northern half). The only road which directly connects the east and west portions of the island is the narrow two-lane Saddle Road which the public is discouraged from using (Figure III-1.3).

Major transportation terminals in the County consist of harbors and airports. There are two deep-water harbors on the island, one at Hilo and the other at Kawaihae. There are also two commercial airports on the island at Hilo and Keahole-Kona. Although both airports are capable of handling overseas flights from the mainland and abroad, only Keahole-Kona operates these flights at the present time.

Water Resources. The Hawaii County Department of Water Supply maintains and operates 26 water systems on the island. The systems use both groundwater and surface water sources for their supply. Surface water is a significant source for irrigation and industrial uses. Groundwater is the primary source for the majority of users, municipal as well as private systems.

During drought conditions, the flow from streams and high-level sources may drop below the required rate. At these times, the County often supplies water to residents from water trucks. Domestic roof-catchment systems are present in some high-rainfall areas. The County discourages their use when other systems are available.

Sewerage. Hawaii County operates six municipal sewerage systems, one each in the City of Hilo, Papaikou, Kapehu, Pepeekeo, Kailua and Keauhou. In many areas throughout the County, municipal sewerage systems are nonexistent and private systems must be used. Major resort complexes and other developments along shorelines depend upon private sewerage systems, except where connection to existing nearby treatment facilities is feasible and in conformance with long-range plans for the County.

About 95 percent of the County's population and nearly all of the single-family residences in non-sewered areas utilize cesspools. The construction of cesspools has been severely restricted since January 1, 1990 and the County is working diligently to expand its sewage treatment plants and sewerage systems. There are numerous cesspools built before 1990 in use in rural areas of the Island of Hawaii, however, that will continue to be used into the future. The State Department of Health (DOH) and the County have jointly delineated Critical Wastewater Disposal Areas (CWDAs) throughout the island. No new cesspool construction will be allowed in these areas.

Utilities. Commercial electric power is provided by the Hawaii Electric Light Company (HELCO). The generation, transmission and distribution of electric power is characterized by relatively long transmission lines (as compared to Oahu) and their generation capacity is dispersed and varied. The primary source of power generation is oil, with some contribution from bagasse (the residue from sugar cane mills), wind power, hydroelectric generators, and geothermal power, which is anticipated to be a major contributor in the future.

Propane gas is used widely on the island. In some rural areas it is the only power source. Telephone service is provided by GTE Hawaiian Tel and other independent companies.

Solid Waste Disposal. The County operates two landfills - the Hilo Landfill and the Kailua-Kona Landfill - and 21 transfer stations located throughout the island. Residential, commercial, organic and agricultural wastes as well as construction debris and sewage sludge are disposed of at both landfills. There is also a federally-operated landfill site at Pohakuloa.

The present landfills do not meet the EPA regulations that will go into effect in October 1993 (RCRA, Subtitle D, 40 CFR, Part 258). Due to capacity constraints, the Kailua-Kona Landfill, located at Kealakehe, will be closed. It will be replaced with a new landfill at Puuanahulu; an area located south of Waikoloa Village between Queen Kaahumanu Highway and Mamalahoa Highway. Although the Hilo Landfill has additional capacity, continued operation under the new regulations will be prohibitively expensive.

A major question facing the County is what to do with the refuse now going to the Hilo landfill. The Hawaii County Integrated Solid Waste Management Plan notes that the new Puuanahulu Landfill in West Hawaii will have sufficient capacity for all County waste if the State diversion goals (25 percent reduction in waste entering landfills by 1995 and 50 percent by the year 2000) are met.

Transportation costs favor construction of two landfills, one in East Hawaii and one in West Hawaii. The solid waste management plan recommends that a study of the 40-acre quarry located next to the Hilo landfill be undertaken to evaluate its feasibility for use as a landfill. The alternative would be to construct a large regional transfer station to compact wastes for shipment by truck to West Hawaii.

C. DISTRICT OF KA`U

1.0 Background

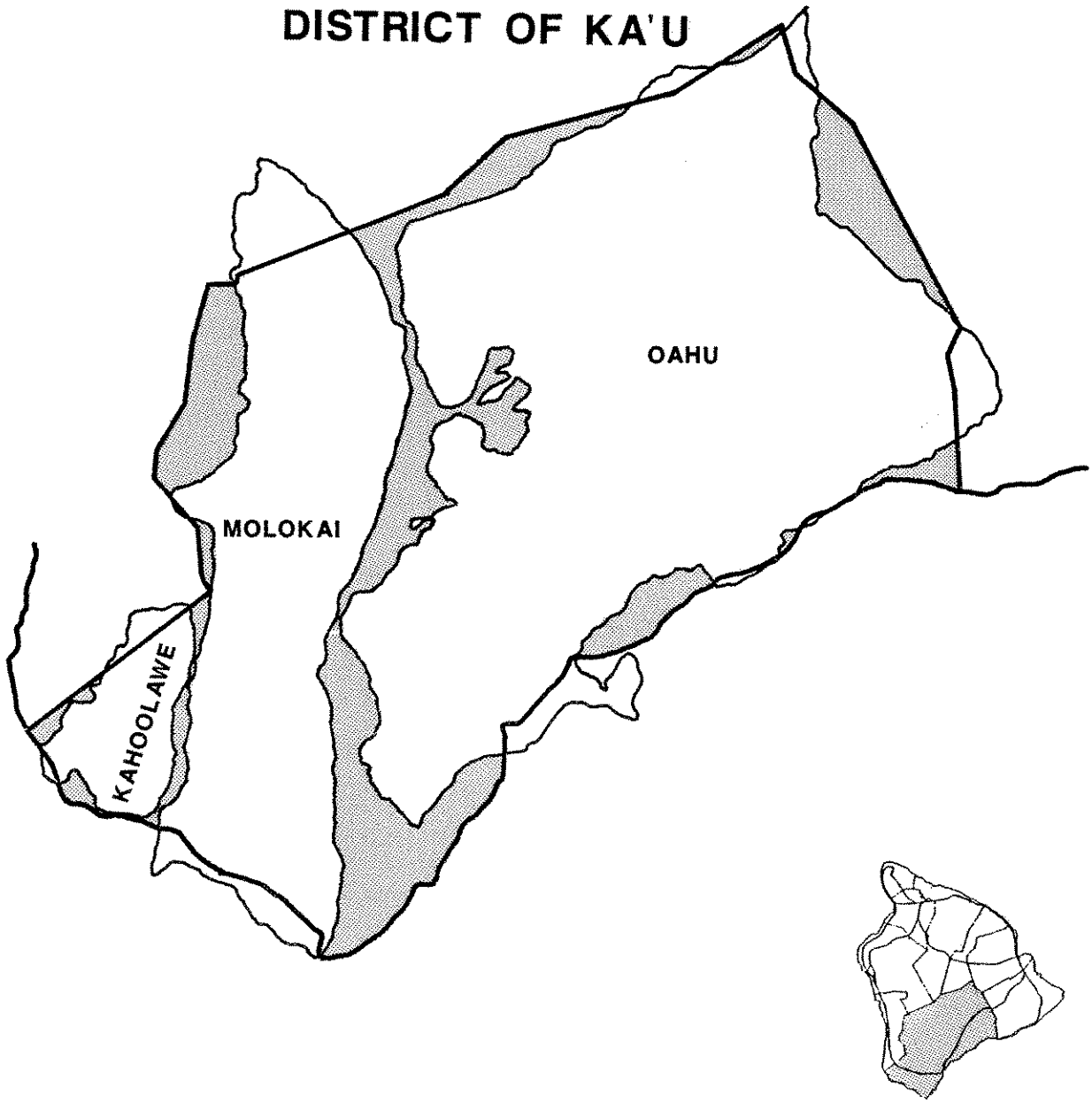
The Ka`u District is the largest on the Big Island, containing over 600,000 acres and 65 miles of shoreline. As shown on Figure III-1.7, the islands of Oahu, Molokai and Kahoolawe could be placed within its boundaries. Land elevations reach from sea level to 13,677 feet at the summit of Mauna Loa. The District is made up of barren lava fields, lush green sugarcane, extensive grazing lands, forest reserve lands and macadamia nut orchards. Most of Hawaii Volcanoes National Park (HVNP) lies within the District.

Descriptions of the cultural and historical background of the District of Ka`u are presented in reports by Cultural Surveys Hawaii (DEIS Appendix IV) and Jon K. Matsuoka (DEIS Appendix IXC).

2.0 Climate

Temperature. The average temperatures in the coastal area range from 70° to 80°F; upper elevations range from 50°to 75°F, dropping to 30°F at the summits of Mauna Kea and Mauna Loa.

Rainfall. Rainfall in the coastal areas ranges between 20 and 50 inches per year, averaging about 40 inches. Rainfall is highest during the winter season. Much of this rain falls during a few concentrated storms. The Ka`u District receives unusually heavy rains when winds turn southeasterly and are funneled between Mauna Loa and Kilauea. Flooding may occur north of Pahala along the Mamalahoa Highway.



Source: Elves Inc., 1992.

Figure III-1.7

DISTRICT OF KA'U: RELATIVE GEOGRAPHIC SIZE

Wind. Data collected at Honu`apo from February 1989 to April 1990 show a diurnal wind flow pattern (HECO, undated). During the daytime, northeast tradewinds dominate. Nighttime winds are from the north reflecting a drainage flow down the slopes of Mauna Loa. A wind rose of the Honu`apo data is presented in Figure III-1.8.

Cloud Cover. A low altitude inversion layer is present when cool air drains downslope from the mountains, undercutting the warmer air. This inversion is strongest in the early morning hours, when cool mountain air flows downslope to the sea. The height of this inversion layer can vary up to several hundred feet.

A tradewind inversion, which is present 50 to 70 percent of the time, occurs between 5,000 and 7,000 feet. When the inversion is well-defined, clouds develop below these altitudes with only an occasional cloud top breaking through the inversion. On days when there is no tropical tradewind inversion, maximum cloud development occurs along the mountain slopes up to 15,000 feet or more. The southeast flank of Mauna Loa has persistent cloud cover. During tradewind conditions, most of Ka`u is on the edge of this cloud.

3.0 Geologic Hazards

Volcanic Eruptions and Lava Flows. Figure III-1.9 shows the locations of major volcanoes on the Island of Hawaii; portions of two of them - Kilauea and Mauna Loa - are located in the District of Ka`u. The major features of Kilauea Volcano are a central caldera and two rift zones; the rift zones are fractures of the earth's crust where near-vertical dikes have transported magma to the surface.

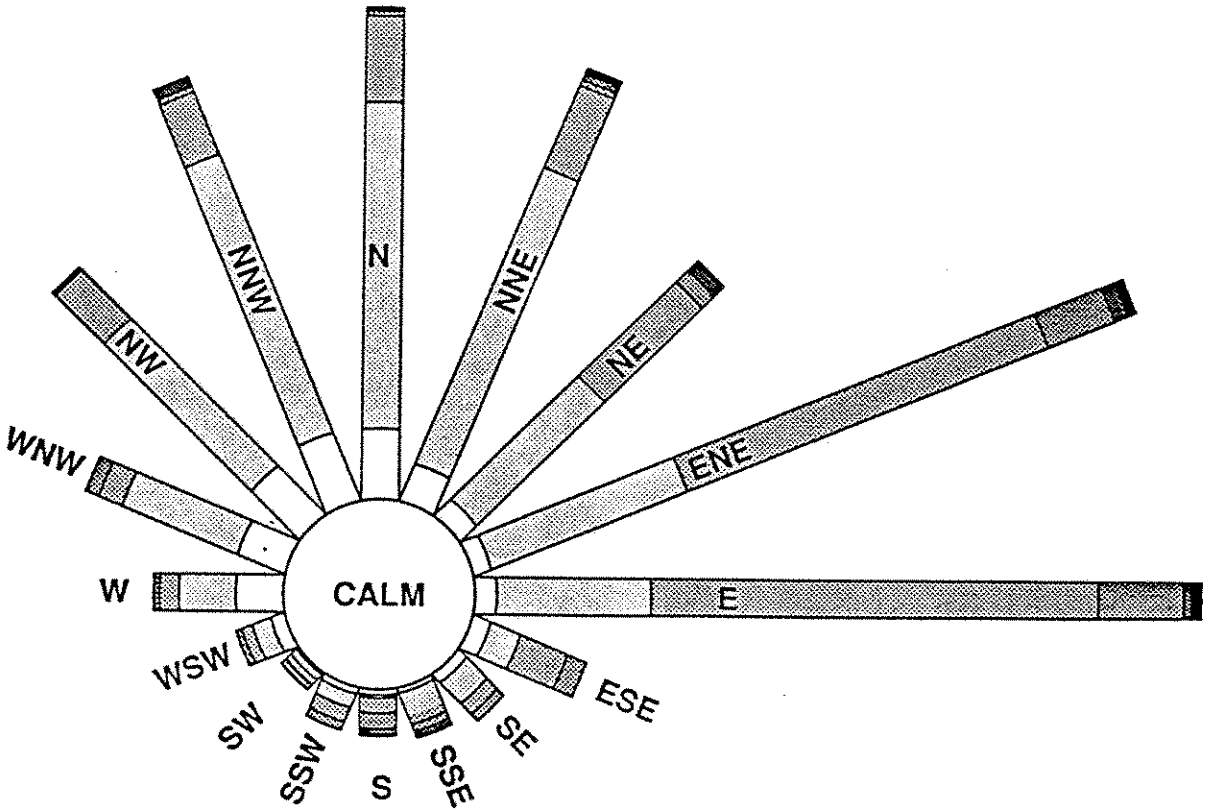
Both a'a and pahoehoe lava flows are present along Kilauea's southwest rift. Hawaiian lavas generally do not travel very fast; however, the 1823 flow from the southwest rift zone was said to have moved so quickly that a coastal Hawaiian village was overwhelmed (MacDonald and others, 1986). Pahoehoe lava flows can form extensive tube systems which enable the lava to travel long distances without losing much heat.

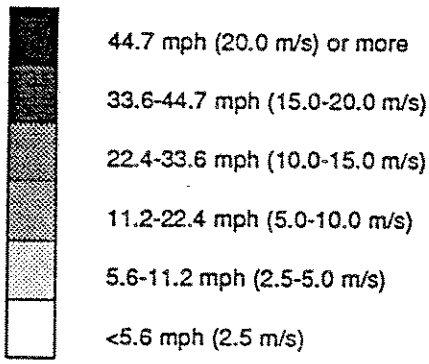
Lava flows from Mauna Loa tend to be more voluminous and faster moving than the Kilauea flows. Lava flows from Mauna Loa have been documented as traveling as far as 25 km (15.5 miles) in less than five days. Lava flows on Mauna Loa's northwest-facing slopes generally reach the ocean within 24 hours (Wright, 1990). These rates may not hold true for lava flows on Mauna Loa's southeast-facing slopes (upslope Ka`u).

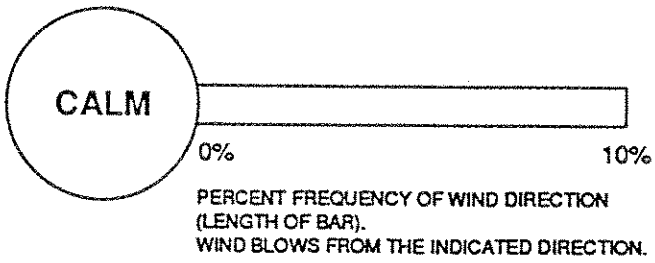
Tephra Falls, Volcanic Gases and Pyroclastic Surges. Most tephra fragments fall close to the vent, but some of the smaller particles can be transported great distances downwind. The primary threat from tephra is to man-made structures and machinery; however, smaller particles can irritate human lung tissue.

Volcanic gases are primarily made up of water vapor, however, they also contain combinations of sulfur, oxygen and hydrogen. Sulfur dioxide and hydrogen sulfide present the greatest risks to human health. Sulfur dioxide can form sulfuric acid in the presence of water and can be corrosive to human lung tissue. The sulfuric acid can be blown downwind from the eruption site where it could damage metal and man-made structures.

Pyroclastic surges consist of clouds of ash, rock fragments and gases which can travel laterally away from the volcanic vent at high speed. Pyroclastic surges from Kilauea 2,000 years ago and again in 1790 created deposits of debris 10 m (33 feet) thick locally and affected areas at least 10 km (over 6 miles) away (Mullineaux, 1987).

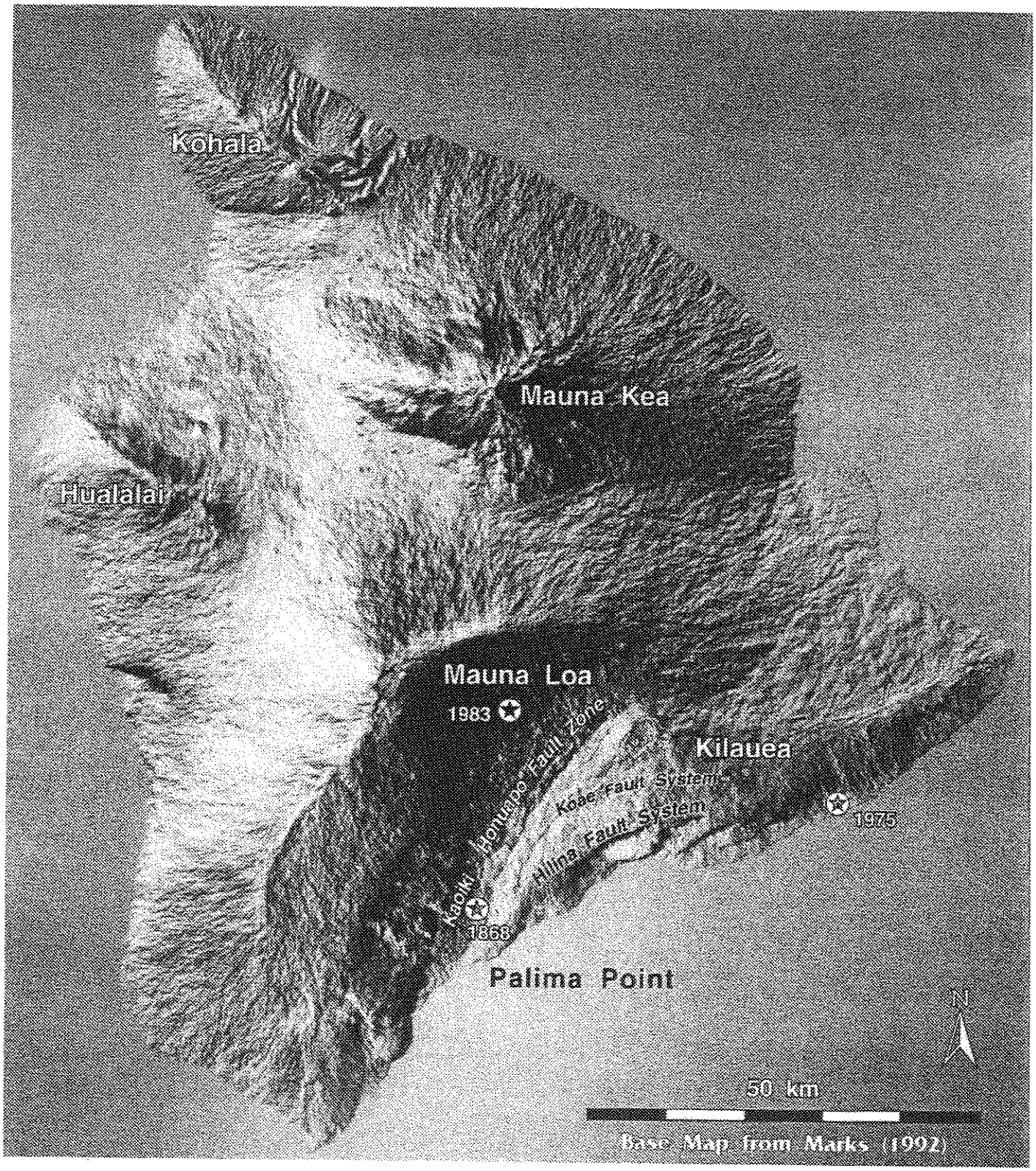






Source: Engineering-Science, Inc.
DEIS Appendix V-B

Figure III-1.8
HONU'APO WIND ROSE



Source: Harding Lawson Associates
DEIS Appendix III-A

Figure III-1.9

LOCATION OF MAJOR VOLCANOES, FAULT SYSTEMS AND HISTORICAL EARTHQUAKES

Ground Subsidence and Fracturing. The "Great Crack" along Kilauea's southwest rift zone, which is tens of feet wide and of unknown depth, may represent a linear zone of deep-seated subsidence, although its exact cause is not known. Subsidence on a larger scale is presently affecting the south flank of Kilauea. Repeated seaward movements of the flank have produced a series of stair-step, massive landslides around all of the major Hawaiian Islands. Some of these may have resulted from catastrophic failure of the volcanic slopes, such as Kilauea's south flank. A sudden downslope movement of Kilauea's south flank could expose low-lying coastal areas to inundation by tsunami and storm waves. Ground cracks are also associated with active volcanic vents and the underground movement of magma. Cracks can be several meters wide and several kilometers in length.

Earthquakes. The southern part of the island of Hawaii is very active seismically (Figure III-1.10). This seismic activity is generally related to the volcanic and tectonic activity associated with the active volcanoes on the island, particularly Mauna Loa, Kilauea, and Loihi. The latter is located beneath the ocean surface south of the island of Hawaii.

The largest historical earthquake known to have occurred in Hawaii occurred in 1868, prior to modern seismological instrumentation. Its Richter magnitude is estimated to have been approximately 8.0. On the basis of damage distribution, its epicenter was in the Ka`u District. Hawaii's largest earthquakes are believed to be caused by slippage toward the south on a near-horizontal plane about 10 kilometers (6.2 miles) below sea level. This was the case for the magnitude 7.2 earthquake at Kalapana in 1975. As a result, all locations in south Hawaii may be potentially equidistant from the source of a major earthquake. The characteristic maximum earthquake for the southern coast of Hawaii, particularly in Ka`u, is believed to be 8.0.

Tsunami. Tsunami are large, rapidly moving ocean waves caused by the abrupt movement of the ocean floor, by volcanism, or by landsliding. Locally generated tsunami are considerably more dangerous than those originating from around the Pacific Rim because of the very short time period between wave origin and inundation of coastal areas. Tsunami inundation of 20 to 40 feet has been reported along the Ka`u coast.

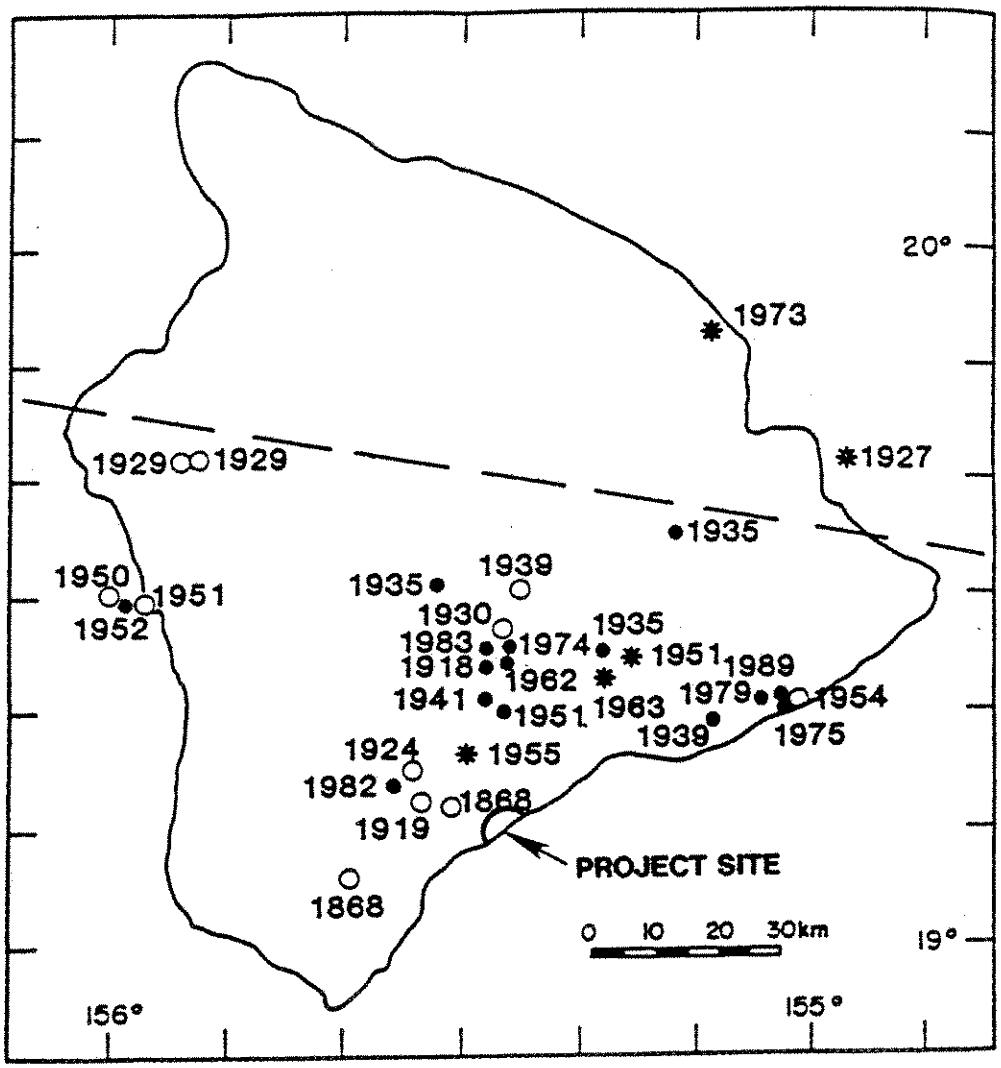
4.0 Flooding

The Ka`u region is subject to some of the most intense rainfall occurring on the island. The orographic nature of the area with its long sloping hills results in high peak runoff flows. Several precipitous clefts or gulches channel the flows. These drainage channels are dry except during heavy rains and most of them are not well defined due to the youthfulness of the site. A few of the more defined gulches, such as the Hi`onamoa, Pa`auau, Keaiwa and Ka`ala`ala, carry considerable amounts of water from Mauna Loa and the Kilauea Southwest Rift Zone slopes. Much flow is also channeled by the Great Crack.

Much of the flooding occurs north of Highway 11. During torrential rains, runoff quickly becomes sheet-flows and follows the gulches, which overflow frequently causing local flooding and/or damage to the highway and its culverts and bridges. These structures act as bottlenecks, causing the runoff water to back up.

5.0 Water Resources

Water for the Ka`u District comes from both ground and surface sources. Current water withdrawals and uses and future water needs and uses for the District are shown on Figure III-1.11. Water in the District is supplied to various users from municipal systems; agricultural irrigation systems; military systems; HVNP; private, domestic, commercial and industrial systems; and, native Hawaiian auwai systems (Kon, 1992).



LEGEND

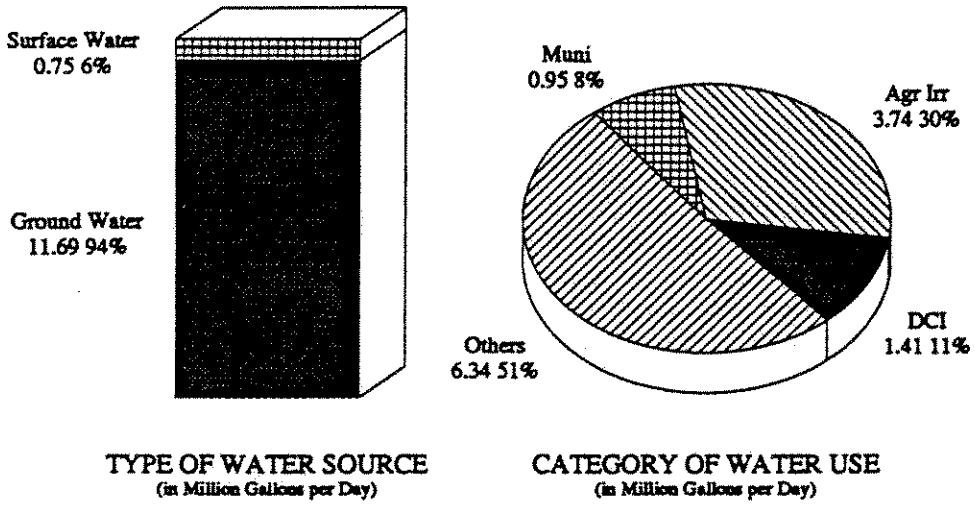
EARTHQUAKE EPICENTERS (WITH YEAR OF OCCURENCE)

- ○ Crustal Earthquake Located Macroseismically
- ● Crustal Earthquake Located Instrumentally
- ✱ Subcrustal Earthquake
- — — Northern Boundary of the Major Seismic Zone (MSZ)

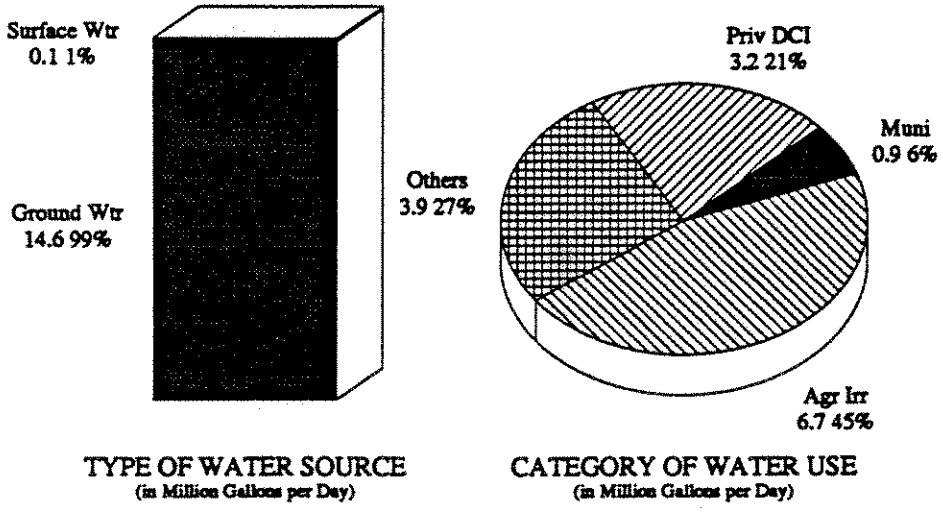
Source: Harding Lawson Associates
DEIS Appendix III-A

Figure III-1.10

MAJOR EARTHQUAKES IN SOUTH HAWAII



Total Water Withdrawals = 12.44 mgd



Total Future Water Needs = 14.7 mgd

Source: Kon, 1992

Figure III-1.11

KA'U: PRESENT WATER WITHDRAWALS (1990-91) AND ESTIMATED FUTURE WATER USES (2010)

There are two municipal systems in Ka`u: the Pahala system, which serves the village of Pahala; and the Na`alehu-Waiohinu system, which serves the Na`alehu, Waiohinu and South Point areas. The Pahala system relies on the Alii tunnel for its supply, supplementing it with water from the Pahala Well during dry weather. The Na`alehu-Waiohinu system depends primarily on the New Mountain House tunnel and Haao Spring for its supply, supplemented by the Na`alehu Well during dry weather. The two private agricultural irrigation systems in the District both use deep wells for their sources.

An extensive water catchment and storage system, operated by the military, serves the Kilauea Military Camp which is located within the boundaries of HVNP. In addition, the Park owns and operates a water catchment and storage system for its facilities including the hotel and visitor center.

The Punalu`u Resort development utilizes two water wells at Ninole. A number of ranches are supplied by their own wells or springs. The sugar mill in Pahala has two deep wells that supply water for industrial cooling and wash water. Several major subdivisions (approximately 470 households in 1990) depend on individual rainwater roof-catchment systems for their water.

Further study is required to determine if any requests for uses of spring and stream water in Ka`u that have been filed with the State Commission on Water Resources Management are native Hawaiian auwai systems.

According to Kon (1992), future needs for water can be met by developing existing groundwater sources. Groundwater of good quality can be retrieved, without excessive cost, in the vicinity of Pahala and Na`alehu.

During fiscal year 1990 to 1991, total water drawn for the Ka`u District was approximately 12 million gallons per day (mgd). Approximately 82 percent was used for irrigation or industry. Municipal systems obtained the majority of their water from surface water sources, but the numbers could reverse during any period. Municipal water sales have not changed significantly between 1985 and 1990, averaging 0.62 mgd.

6.0 Population and Land Use

The Ka`u District is characterized by many small communities, the largest of which are Pahala and Na`alehu (Figure III-1.12). In 1990, the population of Ka`u was 4,438 people.

The town of Pahala was built around a sugar mill, the largest employer in the area. Na`alehu is smaller than Pahala but contains a greater variety of commercial facilities. Waiohinu lies a few miles southwest of Na`alehu and contains a 14-unit hotel and a few small commercial establishments. Other clusters of residential and small commercial facilities include the Hawaiian Ocean View Ranchos and Estates and Green Sands subdivisions. Discovery Harbor, Mark Twain, and South Point are other subdivisions located in West Ka`u.

The Ka`u District has a total of 606,200 acres of land. The State owns 188,256 acres or 31 percent of this land, including 10,989 acres of Hawaiian Homes Lands. Only 2,972 acres of the District are designated for development in the Hawaii County General Plan: 2,062 acres for residential development, 206 for commercial, 525 for industrial, and, until 1991, 135 for resort. As noted earlier, the urban and rural centers are at Pahala, Na`alehu and Waiohinu. Industrial areas are located at Na`alehu, Pahala and Honu`apo. The two areas designated "Resort" in the 1989 General Plan are at the HVNP (including the Volcano House hotel complex and the Kilauea Military Camp) and Ninole-Punalu`u. The General Plan was amended in 1991 to provide for 3,244 acres of resort, medium and low density urban, industrial and open space for a major resort, the Hawaiian Riviera, in the Kahuku coastal area.

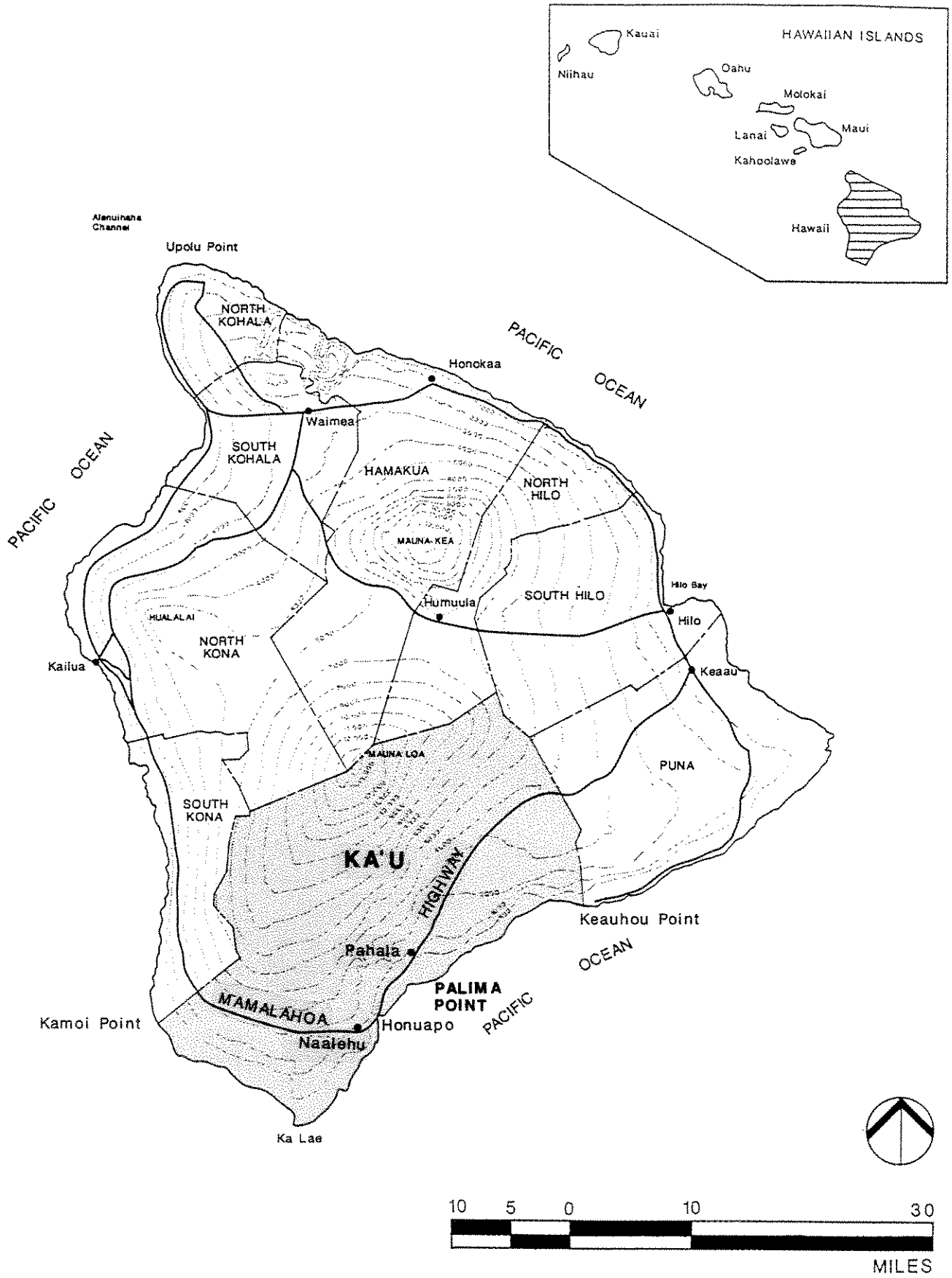


Figure III-1.12

DISTRICT OF KA'U: LOCATION MAP

portions of the road within HVNP. This segment, however, is maintained by the State Department of Transportation (HDOT). In addition, a segment of the highway, from Honu`apo to beyond South Point road, is maintained by the County of Hawaii, Department of Public Works.

Several areas along the highway are subject to flooding during heavy rains. An area near Pahala is signed for flooding. A ford area is located in the vicinity. Warning signs and poles along the shoulder of the road indicate dangerous conditions during flash flooding.

The Ka`u District does not have an aircraft landing field for commercial aviation. There are, however, several crop duster airstrips in the area. During World War II, South Point was an U.S. Army Air Corps base during World War II; remnants of the airfield still remain. There are no deep-water harbors in the Ka`u area.

Sewerage. The County has no sewerage system in the Ka`u District. A private system exists for the resort development at Punalu`u, but most residents are served by individual waste disposal systems. The cesspools in use in the Ka`u area apparently function adequately. Considering the low density and wide distribution of the housing units and the relatively small population growth anticipated, the existing individual treatment units will continue to be used. Portions of the District where cesspools could affect water quality have been designated as a Critical Wastewater Disposal Area (CWDA). Within these areas, other individual wastewater treatment systems must be utilized for new construction.

Water. Although, with additional storage, the existing municipal systems can meet estimated future needs, back-up wells are recommended as a safety measure in the event of an operational emergency or prolonged repair of the existing well. In addition, system improvements--particularly in the Waiohinu-Na`alehu System--are needed to provide better service to sparcely settled areas. Most of the water lines are old and have inadequate capacity (Kon, 1992).

Electrical Power. Transmission of electrical power from HELCO's main power generation plant in Hilo (Kaneoelehua) to the Ka`u District is via 69 kV and 34 kV lines. The 34 kV line terminates at the Pahala substation; the 69 kV line follows Highway 11 through the District, continuing to the Kona Coast, with substations at Kilauea and Na`alehu.

Communications. The Ka`u District is served by GTE Hawaiian Tel. The Pahala area is served by a Digital Central Office with a capacity for 812 lines. There are currently 675 lines in service (R. A. Saito, pers. comm.)

Solid Waste Disposal. Two solid waste transfer stations for household waste serve the District. Commercial operations transport their solid waste directly to the Hilo landfill.

SECTION II: THE PROJECT AREA

A. LAND USE AND ZONING

It is proposed that the project be located at Palima Point, District of Ka`u, County of Hawaii (T.M.K. 9-6-2: portions of parcels 01-06, 09, 10, 20, 28, 47-49; and 9-6-13: portions of parcels 03, 05 & 06). Figure II-1.1 shows land ownership (REDI, 1992) with Tax Map Keys. The launch pads would be located 3 to 4 miles south and south-southeast of Pahala and 3 to 4 miles from the northeast boundary of the Punalu`u Resort. The boundary of HVNP is about 3 miles away from the nearest launch pad.

Although development will only occur on about 1,000 to 1,200 acres, a total of about 10,400 acres must be controlled to insure safety of the population during launch operations. The 10,400 acres fall within the Population Control Zone (PCZ). Most of the area within the PCZ is classified Agriculture by the State Land Use Commission; some of the coastal areas are in the State Conservation District (Figure II-4.3). County zoning is Agriculture (A-20-a) and Open; the coastal portions of the site are located within the County of Hawaii Special Management Area (Figure III-2.1). There are no residences within the PCZ.

About 600 acres of land within the PCZ are planted in macadamia nut orchards and about 5 acres are planted in an experimental mango orchard. In addition, about 3,800 acres are being used for grazing cattle, while plans exist for about 1,600 of these acres to be used for a dairy. Also, tailwaters from the sugar mill flow onto lands within the PCZ. About 6,000 acres are vacant, most of which were used in the past for grazing cattle (DAHI, DEIS Appendix IXA).

B. LAND ACQUISITION AND CONTROL

1.0 Acquisition

In order to facilitate the development of the space launch facility, the State will need to acquire at least some of the lands upon which the project will be located. Acquisition of these areas is necessary in order to provide a suitable construction site for the facility and related improvements and to provide security and control access to these areas at all times. Once the land is acquired, current plans call for the State to lease this area to a Consortium for development and construction of the project (See Chapter Two, Section IV).

The most straightforward method by which the State could acquire these lands would be to purchase them. By statute, the State Department of Land and Natural Resources (DLNR) has exclusive responsibility for the acquisition of any lands by the State, and all such lands must be used for a public purpose. The costs of such acquisition plus the cost of consolidating and resubdividing these areas (which will be necessary if any improvements are proposed to be constructed across existing property boundary lines) must also be considered.

An alternative to acquiring the lands outright would be to enter into negotiations with the current landowners to obtain a long-term lease. This may not be a viable option if the project necessitates siting and construction of improvements over existing lot boundaries.

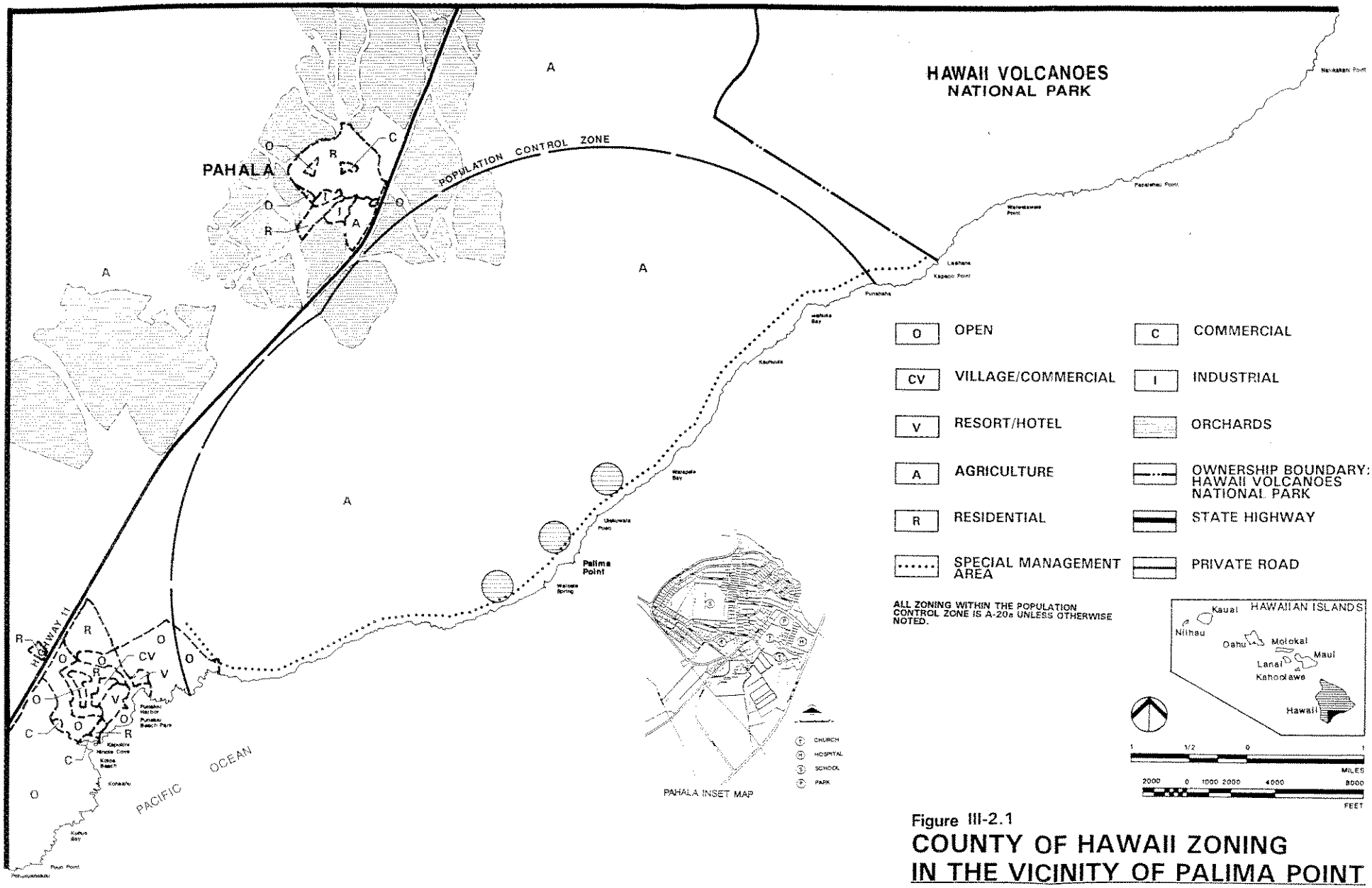


Figure III-2.1

COUNTY OF HAWAII ZONING IN THE VICINITY OF PALIMA POINT

The State might also consider exchanging other lands it owns for the required lands. The State would need to show that the value of the lands to be obtained is relatively equal to those it proposed to exchange. In addition, any proposed land exchange would be subject to disapproval by the Legislature upon a two-thirds vote of either the Senate or the House of Representatives or a majority vote of both bodies.

As a last resort, the State could choose to exercise its power of eminent domain. Although this would allow the State to force a sale or lease land from any owner who might otherwise be unwilling to enter into such a transaction, the State would still be required to pay a purchase price or lease rent which is equal to fair-market value.

If the State were to lease the lands necessary for the construction of the launch facilities to the Consortium, the lease would be subject to the provisions of Chapter 171 HRS. This means that the land would have to be awarded by public auction pursuant to detailed bidding procedures. The creation of an Authority, as discussed in Chapter Two, Section IV, would allow for the purchase and lease of real property for the specific purpose of developing the project. Examples of similar entities include the High Technology Development Corporation and the Hawaii Community Development Authority.

2.0 Other Controls

The vast majority of the lands needed for the project, including the PCZ, need not be acquired outright. The State would probably have to obtain easements for the construction of roads and utility lines to service the launch facilities. In addition, during actual rocket launches, the State and/or the operator of the Facility must have the authority to evacuate these areas and restrict access to them until such time as the launches are completed. During other times when launches are not occurring, current land uses which are consistent with the project could be continued. Development in these areas would need to be controlled in order to prevent uses which might be incompatible with the project in the future.

In order to accomplish these objectives, the State could use a variety of mechanisms to obtain the necessary interests in these lands to install the required infrastructure and control these areas consistent with the development and operation of the project. These mechanisms include easements, covenants, conditions, and restrictions (CC&Rs); and, licenses. Each of these interests, and the advantages and disadvantages of each, are discussed in Kaneshige, DEIS Appendix IXE.

C. CEDED LANDS TRUST

Upon annexation to the United States in 1898, the Republic of Hawaii ceded approximately 1.75 million acres of Government lands (lands set aside by Kamehameha III for the benefit of the chiefs and people) and Crown lands (lands personally reserved by Kamehameha III) to the United States. In 1959, title to the majority of these lands was transferred back to the State under Section 5 of the Admission Act, to be held in a public trust for specifically identified purposes. Subsequently, a public trust fund was created for the receipt of funds derived from the sale, lease or other disposition of the ceded lands. In 1978, the State Constitution was amended to specify that the ceded lands were to be held by the State in a public trust for Native Hawaiians and the general public and to create the Office of Hawaiian Affairs (OHA) which was given responsibility for management of the public trust fund covering ceded lands.

Since that time, there has been considerable controversy as to whether the State has complied with the provisions of the Act and the law in this area. OHA has made several claims, including filing a lawsuit which was appealed all the way to the Hawaii Supreme Court, seeking recognition of its right to the proceeds derived by the State from these lands. This issue remains unresolved, and OHA and the State are still trying to resolve this issue.

There is a strong possibility that the State-owned lands at the site are ceded lands. As a result, if the project is developed, it is likely that any proceeds the State receives from the development or operation of the project could be the subject of a claim by OHA.

D. THE PHYSICAL ENVIRONMENT

1.0 Geology, Topography and Soils

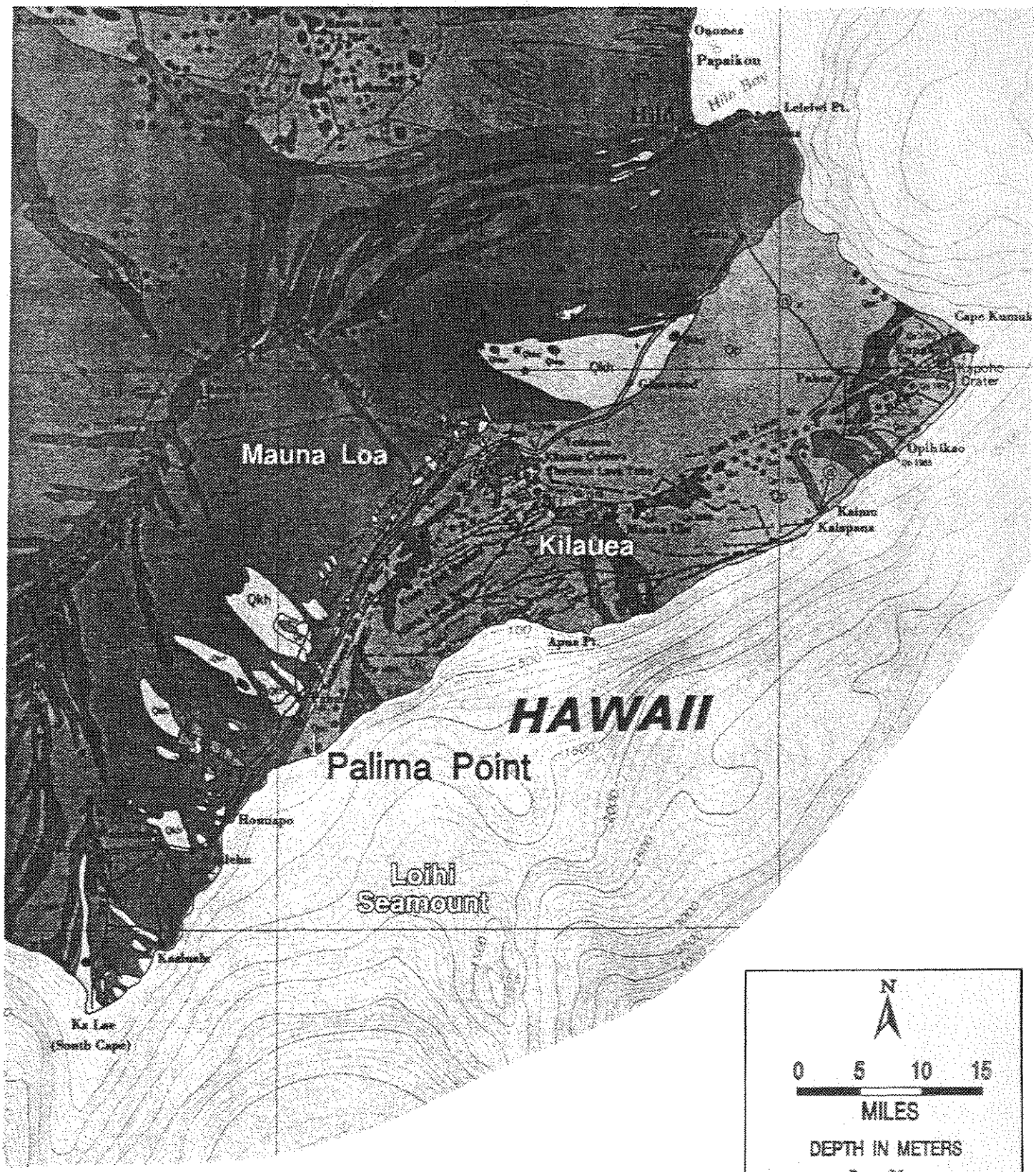
The proposed site straddles the southwest rift zone of Kilauea Volcano. Historically, eruptions on the southwest rift zone have been less frequent than on the east rift zone--the location of the current ongoing eruption. Five eruptive features, however, have been mapped on the southwest rift zone, in the near vicinity of the site. The most recent was 170 years ago in 1823; the oldest was 1,500 to 3,000 years ago. Most of the site is covered by Kilauea lava flows that are 600 years old or younger. These flows originated close to Kilauea caldera or at the caldera itself and flowed southwest to the site. In addition, a large portion of the site is underlain by a 1,300-year old lava flow from Mauna Loa. The location of major volcanoes near Palima Point is shown on Figure III-2.2; Figure III-2.3 shows lava flows on the site.

The land surface primarily consists of two types of lava: solidified a'a, with characteristic clinkery, hard and glassy sharp pieces piled in heaps; and, pahoehoe lava with a billowy glassy surface which is relatively smooth. In some areas the pahoehoe lava is broken and rough with pressure domes or sinkholes. The lava flows are generally barren of soil. The soil types Na`alehu Silty Clay Loam and Waiaha Rocky Silt Loam can be found along the northwestern boundary of the site (Figure III-2.4).

The site is generally evenly sloped downwards to the coastline with average slopes between five and ten percent. A few areas in the northern part of the site have slopes between 10 and 20 percent. Topographic maps show that the contour lines run generally parallel to the coastline. Elevations run from sea level to 1,100 feet above mean sea level (MSL) at the northern edge of the site. At Keone`ele`ele Flats, in the southern half of the site, the terrain is fairly flat at a 100-foot elevation (Figure III-2.5).

The coastline fronting the site is primarily comprised of pahoehoe lava which drops steeply away into the sea. Except for a few small coves and bays that serve as shelter (e.g., Punalu`u, Ninole, Honu`apo--all outside the study area), the shore is fully exposed to the northeast tradewinds. The lack of any reef development along the entire coast and the presence of deep water close to the shore results in little or no attenuation of open ocean swells prior to their impingement on the shoreline.

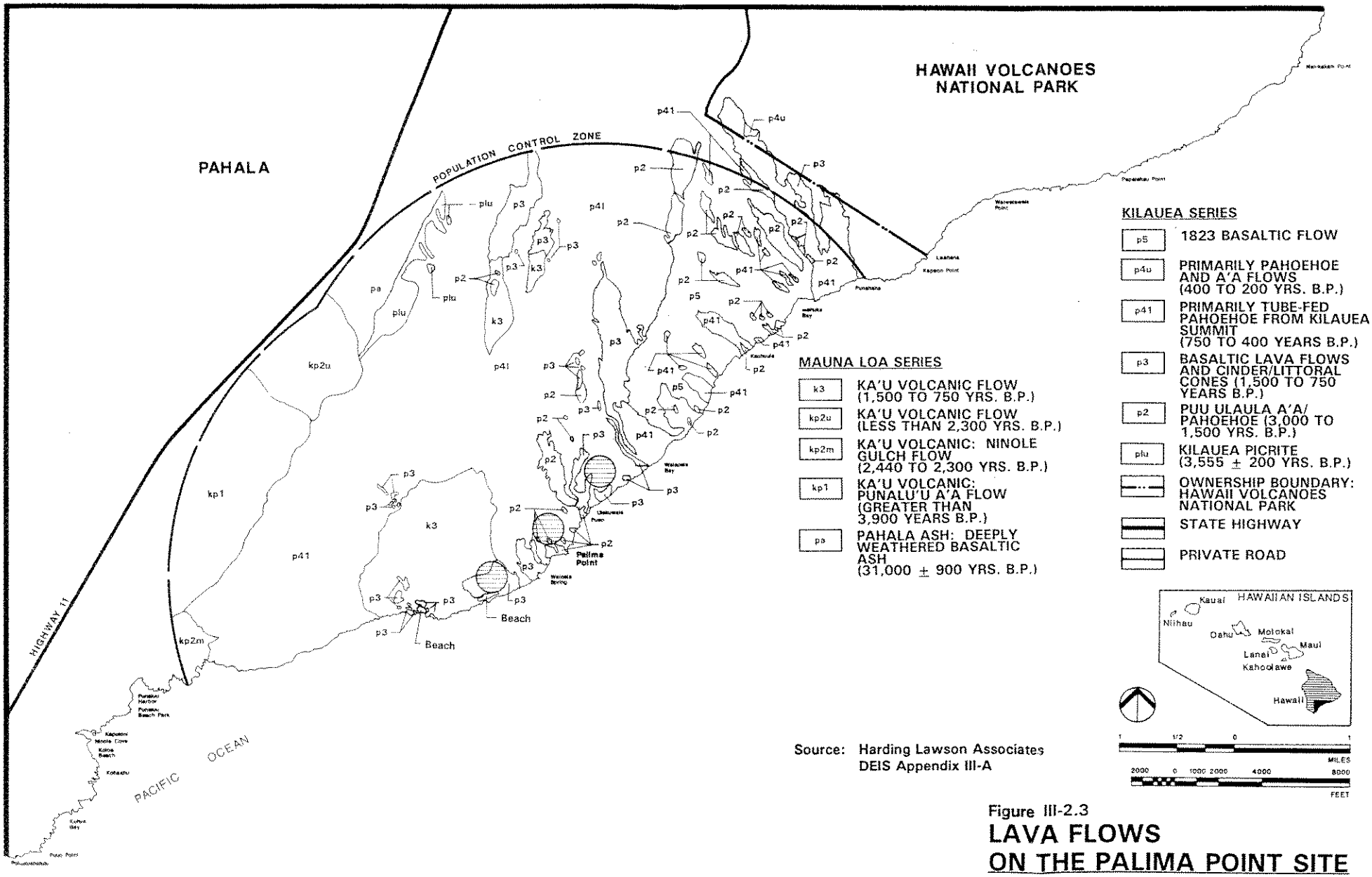
The shoreline fronting the proposed launch pads is a near vertical wall of pahoehoe ranging from 2.5 to 15 m (about 8 to 50 feet) in height, dropping in most cases to a narrow basaltic bench. This bench varies from 1 to 4 m (about 3.3 to 13 feet) in width; where the bench is absent, the vertical face is situated behind a basaltic boulder slope into the sea. Along much of the coastline, water depth at the foot of the boulder slope or basaltic bench is from 5 to 8 m (about 17 to 26 feet); boulders and smooth basalt comprise the subtidal substratum. The substratum drops quickly away into deeper water within 100 m (330 feet) from shore.



Source: Harding Lawson Associates
DEIS Appendix III-A

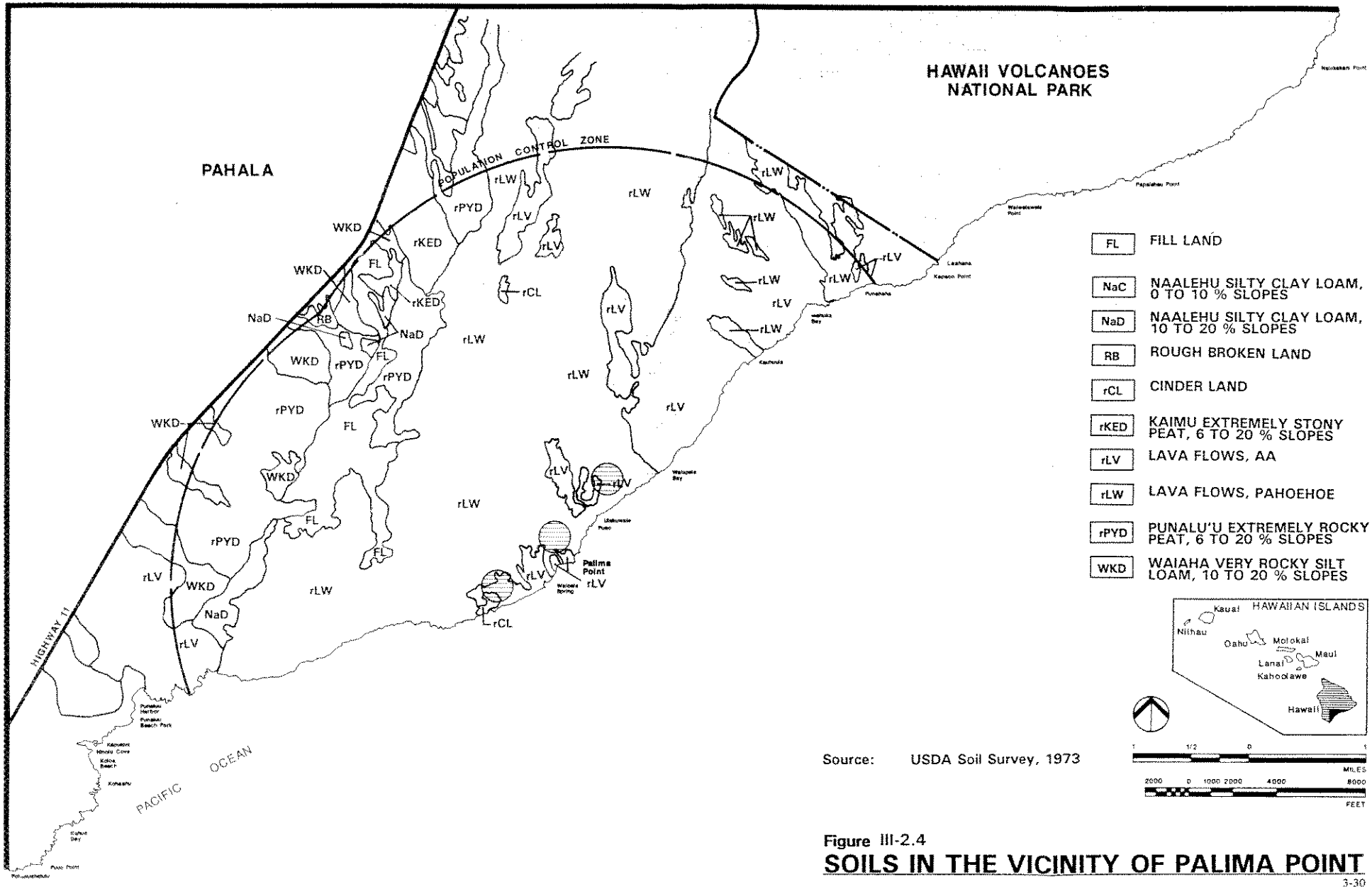
Figure III-2.2

LOCATION OF MAJOR VOLCANOES NEAR PALIMA POINT



Source: Harding Lawson Associates
DEIS Appendix III-A

Figure III-2.3
LAVA FLOWS ON THE PALIMA POINT SITE



Source: USDA Soil Survey, 1973

Figure III-2.4

SOILS IN THE VICINITY OF PALIMA POINT

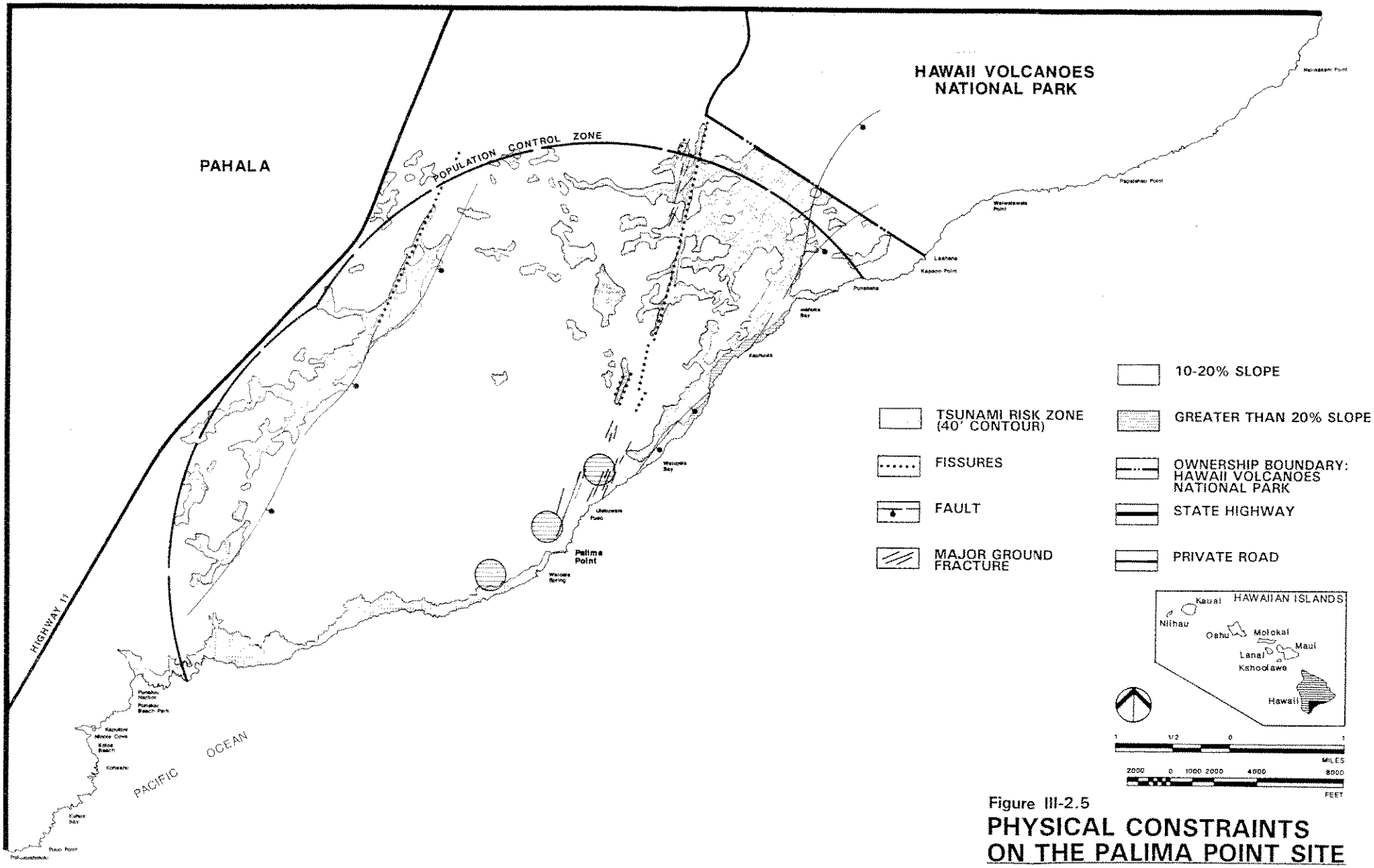


Figure III-2.5

PHYSICAL CONSTRAINTS ON THE PALIMA POINT SITE

Small spur and groove formations, which cut into the basalt, appear as channels having an orientation perpendicular to shore. The width and depth of these channels increases in a seaward direction until water depths of 8 to 15 m (from 15 to 30 m from the shore) are attained where they attenuate. The dimensions of the channels vary and they are variably spaced from 5 to 100 m (about 17 to 330 feet) apart. Occasional larger channels form "box canyons" that cut back into the shoreline. Between channels the basalt substratum is variably covered with loose boulders.

2.0 Water Resources and Water Quality

The Keaiwa aquifer (State Code 80804), with a system area of 90 square miles, has a potential sustainable yield of 17 mgd. This aquifer underlies the Palima Point site.

Considerable basal water discharges in the vicinity of the site and several large coastal springs of water are located in this same area with discharges greater than 35 mgd. It is believed that these springs are outlets of buried drainage systems of ancient valleys, now partly filled by more recent lava (Stearns and Macdonald, 1946). Chloride content of the springs ranges between 45 and 400 ppm. Brock, DEIS Appendix IIIE noted that there was evidence of groundwater percolation into the sea at many locations. Field salinities from water samples taken along the shoreline were often less than 34°/oo and freshwater intrusion could be seen.

A well which pumps good-quality basal water is located approximately 2.5 miles from the proposed launch site, at the 420-foot elevation. This well is relatively large--2500 gallons per minute (gpm)--and provides potable water and water for agricultural purposes. Limited on-site small-capacity water systems are also used in the area, principally by ranches. These systems distribute well water to small water tanks throughout the area.

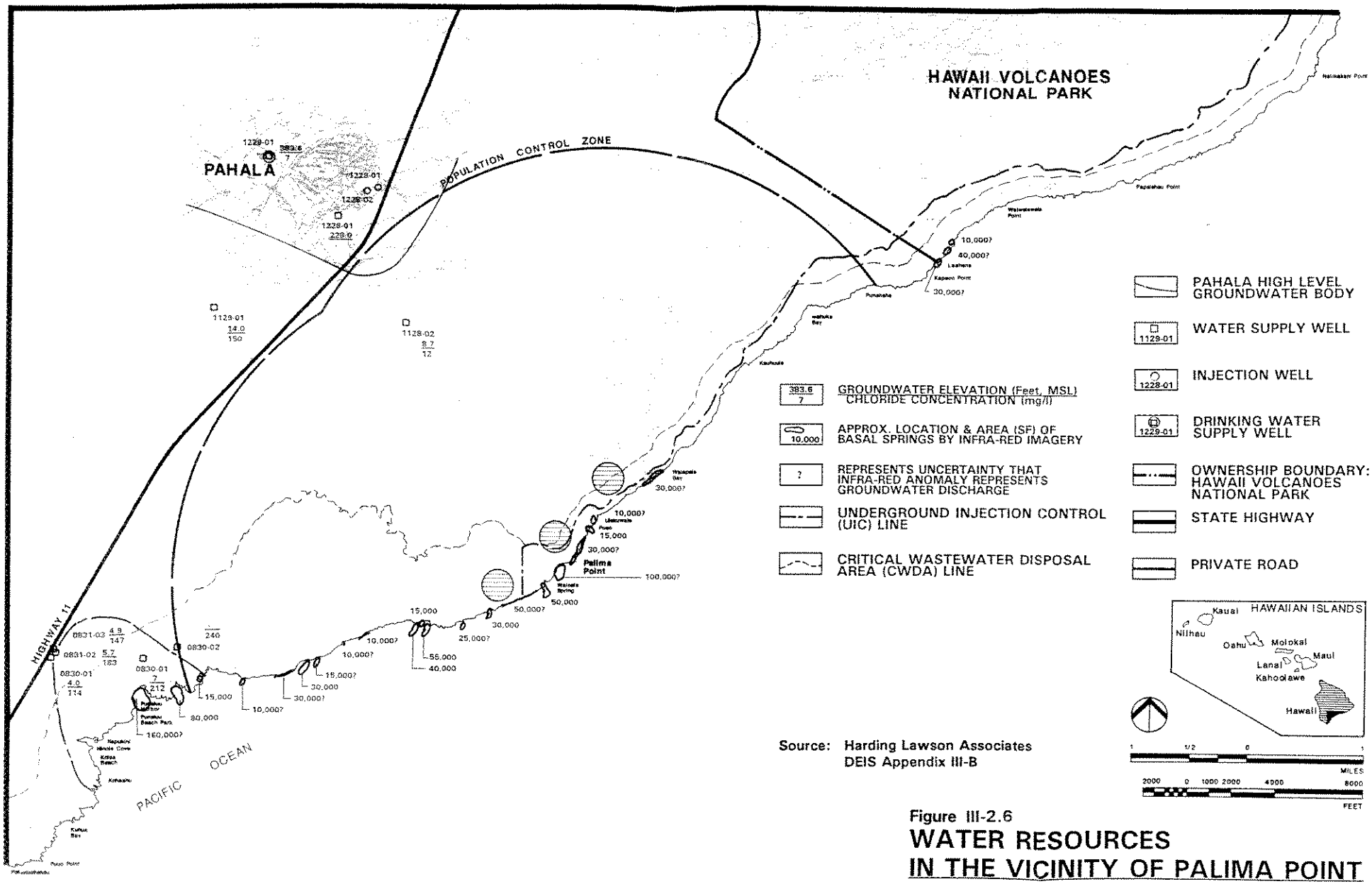
Figure III-2.6 shows the water resources on the project site; more detailed information is presented in Appendix IIIB of the dEIS.

3.0 Nearshore Water Quality

The waters fronting the project site are classified by the State DOH as open coastal waters. Table 3.2.1 lists the specific criteria specified by the DOH water-quality standards for open coastal waters and Table 3.2.2 gives a summary of the water quality parameters measured at 22 locations off the Palima Point site. Figure III-2.7 shows the locations of the water sampling sites. The results of water-quality sampling indicate that only the geometric mean for nitrate nitrogen exceeds the criteria specified for "wet" coastlines; ammonia nitrogen, total nitrogen as well as chlorophyll-a standards are exceeded for "dry" coastines. "Wet" coastlines are those receiving more than 3 mgd of freshwater discharge per shoreline mile. None of the parameters exceeded the DOH criteria of "not exceeding the given value 10 percent of the time".

4.0 Anchialine Pools

The DOH water-quality standards have exempted anchialine pools from meeting specific criteria including those for dissolved inorganic nutrients. Only one anchialine pool was located within the PCZ at Palima Point (Brock, DEIS Appendix IIIE). This pond is in the form of several large interconnected irregular cracks clustered together that parallel the shoreline in a broken fashion for approximately 800 m (nearly one half mile) and range from 20 to 80 m (66 to 264 feet) inland of the shoreline. All are situated in pahoehoe lava; the depth from the surface to the water ranges from 8.5 to 12 m. The width of these crevasses varies from complete occlusion by loose rock up to 3 m wide; however, in most areas it is less than 1.2 m wide. The primary crack is at least 700 m (over 2,000 feet) in length. Water depth is quite variable, ranging from 0.5 to at least 6 m. The southern terminus of the primary crack lies north of Punalu`u boat ramp and



Source: Harding Lawson Associates
DEIS Appendix III-B

Figure III-2.6
WATER RESOURCES
IN THE VICINITY OF PALIMA POINT

Table 3.2.1 **DEPARTMENT OF HEALTH WATER QUALITY STANDARDS CRITERIA FOR OPEN COASTAL WATERS**

Parameter	Geometric mean not to exceed the given value	Not to exceed the given value more than 10% of the time	Not to exceed the given value
Total Nitrogen (μg N/L)	150.00* 110.00**	250.00* 180.00**	350.00* 250.00**
Ammonia Nitrogen (μg NH_4-N/L)	3.50* 2.00**	8.50* 5.00**	15.00* 9.00**
Nitrate+Nitrite Nitrogen (μg[NO_3+NO_2]-N/L)	5.00* 3.50**	14.00* 10.00**	25.00* 20.00**
Total Phosphorus (μg P/L)	20.00* 16.00**	40.00* 30.00**	60.00* 45.00**
Chlorophyll-∂ (μg/L)	0.30* 0.15**	0.90* 0.50**	1.75* 1.00**
Turbidity (NTU)	0.50* 0.20**	1.25* 0.50**	2.00* 1.00**

* "Wet" criteria apply when the open coastal waters receive more than three million gallons per day of fresh water discharge per shoreline mile.
** "Dry" criteria apply when the open coastal waters receive less than three million gallons per day of fresh water discharge per shoreline mile.

Applicable to both "wet"and "dry" conditions:
(1) pH units shall not deviate more than 0.5 units from a value of 8.1.
(2) Salinity shall not vary more than 10% from natural or seasonal changes considering hydrologic input and oceanographic factors.
(3) Dissolved oxygen shall not be less than 75% saturation.
(4) Temperature shal not vary more than 1°C. from ambient conditions.

Orthophosphate was eliminated from the list of requirements in the revised 1988 document but, because of its biological importance, it was measured in this study. The old "wet" criteria was 7.00 μg/L and "dry" standard was 5.00 μg/L.

Source: Brock, Appendix IIIE (DEIS)

Table 3.2.2 **WATER QUALITY PARAMETERS AT SHORELINE SAMPLING SITES**

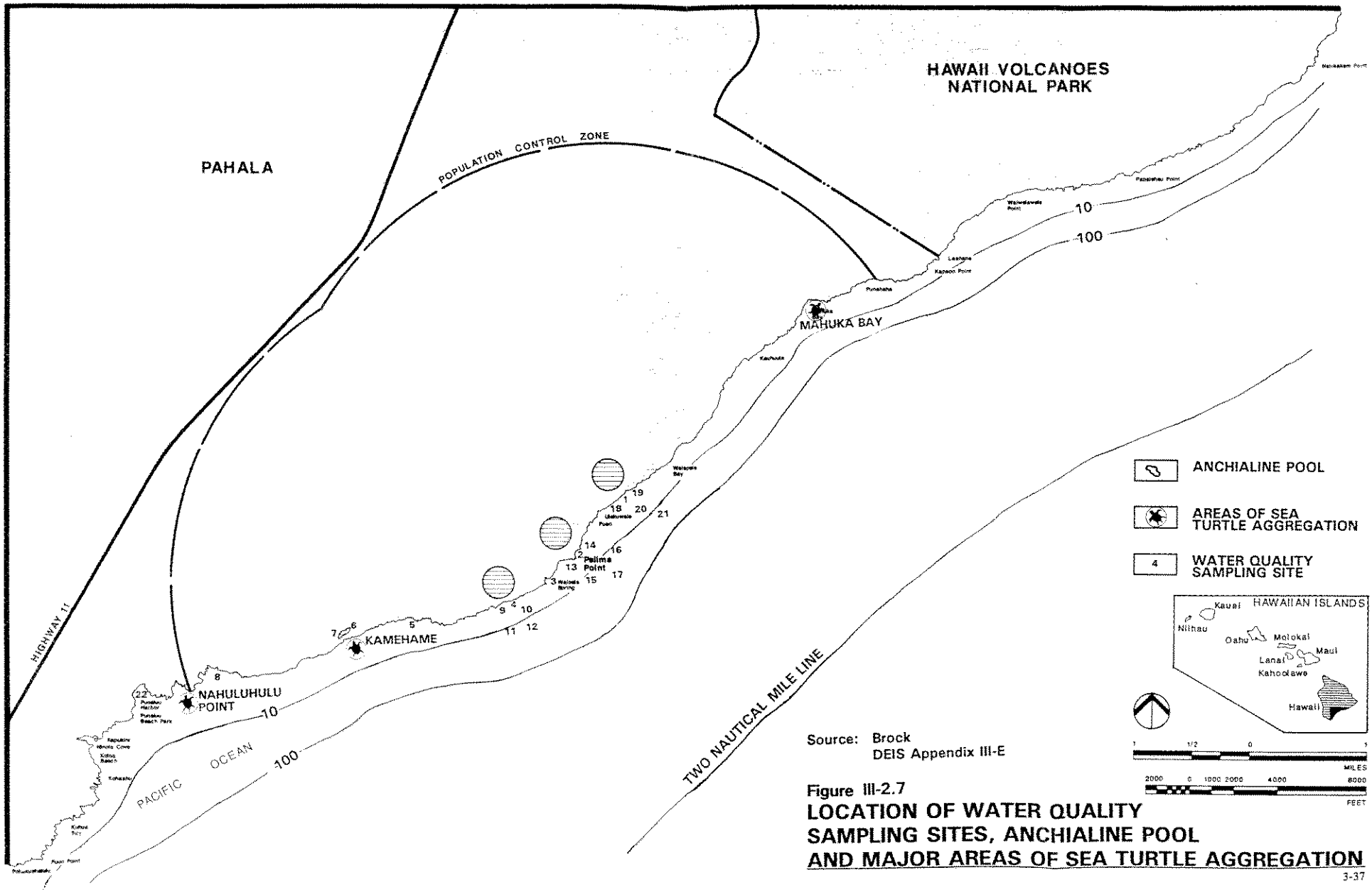
Station	Nitrate N	Ammonia N	Total N	Ortho-P	Total P	Silicate
1990 SHORELINE SAMPLES						
1	16.66	5.60	163.94	8.37	17.05	490.56
2	14.14	14.98	168.14	6.20	13.64	312.76
3	27.86	7.14	138.18	9.30	13.95	823.76
4	14.14	9.38	129.36	7.13	13.02	440.44
5	81.63	7.87	201.74	13.95	20.15	2,017.40
8	19.88	23.24	169.26	9.92	16.12	1,234.52
1993 OFFSHORE SAMPLES						
9	11.48	2.10	207.20	5.89	11.47	596.68
10	1.26	1.82	92.82	3.10	8.37	61.32
11	32.90	1.40	124.04	7.44	12.71	925.68
12	0.84	0.98	91.42	3.10	8.37	57.12
13	7.00	3.50	103.60	4.03	10.54	478.52
14	17.08	2.52	111.30	7.75	13.64	1,058.40
15	1.40	2.38	97.58	2.48	8.68	179.20
16	13.86	2.80	107.52	7.75	13.64	931.84
17	0.70	2.24	8.68	2.48	96.32	156.52
18	5.04	2.66	100.10	4.34	10.23	512.96
19	2.66	2.66	97.30	3.10	8.99	203.56
20	4.06	1.688	97.16	4.34	9.92	512.68
21	2.66	1.26	95.20	3.41	8.68	85.40
22	107.66	7.28	205.10	21.08	27.90	5,133.24
Geometric Mean						
(μg/L)	8.11	3.50	110.31	5.69	13.65	442.63
(μM)	0.58	0.15	7.88	0.18	0.44	15.81

Table 3.2.2 (cont'd)

Station	Turbidity (NTU)	Chl-∂ (μg/L)	Salinity (%)	Temp (°C)	Oxygen (% Sat)	pH	Total Alkalinity (meg/l)
1990 SHORELINE SAMPLES							
1	0.18	0.63	34.03	26.4	100.0	8.03	
2	0.11	0.40	34.24	26.5	100.4	8.21	
3	0.14	0.67	33.30	26.0	100.1	8.19	
4	0.16	1.07	33.87	26.1	100.3	8.20	
5	0.17	1.35	32.37	25.9	100.0	8.36	2.043
8	0.22	0.51	32.81	26.0	100.1	8.28	
1993 OFFSHORE SAMPLES							
9	0.12	0.096	34.043	24.4	103	8.15	
10	0.08	0.112	34.768	24.4	102	8.08	
11	0.06	0.112	33.544	24.2	102	8.15	
12	0.06	0.107	34.767	24.4	101	8.06	
13	0.07	0.064	34.237	24.1	105	8.28	
14	0.08	0.069	33.407	23.8	102	8.27	
15	0.07	0.104	34.638	24.2	102	8.13	
16	0.10	0.064	33.624	24.0	103	8.13	
17	0.07	0.105	34.666	24.3	100	8.05	
18	0.06	0.069	34.206	24.5	102	8.09	
19	0.08	0.082	34.615	24.5	100	8.07	
20	0.06	0.077	34.267	24.3	101	8.14	
21	0.06	0.100	34.747	24.5	102	8.12	
22	0.18	0.647	25.850	23.4	103	8.24	
Geometric Means	0.10	0.181	33.538	24.8	101	8.16	

Note: In the body of the table concentrations of dissolved nutrients are given in μg/L and μM; underlined values exceed "wet" State of Hawaii Department of Health water quality standards.

Source: Brock, Appendix IIIE (DEIS)



Source: Brock
DEIS Appendix III-E

Figure III-2.7
LOCATION OF WATER QUALITY SAMPLING SITES, ANCHIALINE POOL AND MAJOR AREAS OF SEA TURTLE AGGREGATION

approximately 3.4 km (about 2 miles) south of the center of the proposed southermost launch pad (Figure III-2.7).

The long axis of the pool parallels the shoreline and contains cold (18.5°C) low-salinity (1.27°/oo) water with no evidence of any vertical stratification. This suggests that the lava between the pool and the sea is relatively impervious at this site and/or that a large quantity of groundwater moves through the area in a seaward direction. A connection does exist, however, because changes in the water level in the pool closely follow tidal changes suggesting that the pool is not isolated from the sea. The substratum in this pool is comprised of basalt rock and boulders.

A badly degraded anchialine pool system is located at Punalu`u, just south of the southern border of the PCZ. The pools are situated in a low-lying pahoehoe field that is bordered by higher lava flows and in the seaward direction by the black sand beach. Exotic fishes have been introduced and have spread through the system precluding the existence of decapod crustaceans that are typically found in such systems. This series of pools was examined in February 1993 but because of the exotic fish and depauperate nature of the native fauna, was not examined further other than to collect a water sample in the most inland (mauka) pool and at the shoreline of Punalu`u Bay fronting the system to provide a comparison for groundwater chemistry in a nearby developed section of coastline (Brock, Ibid.).

5.0 Climate

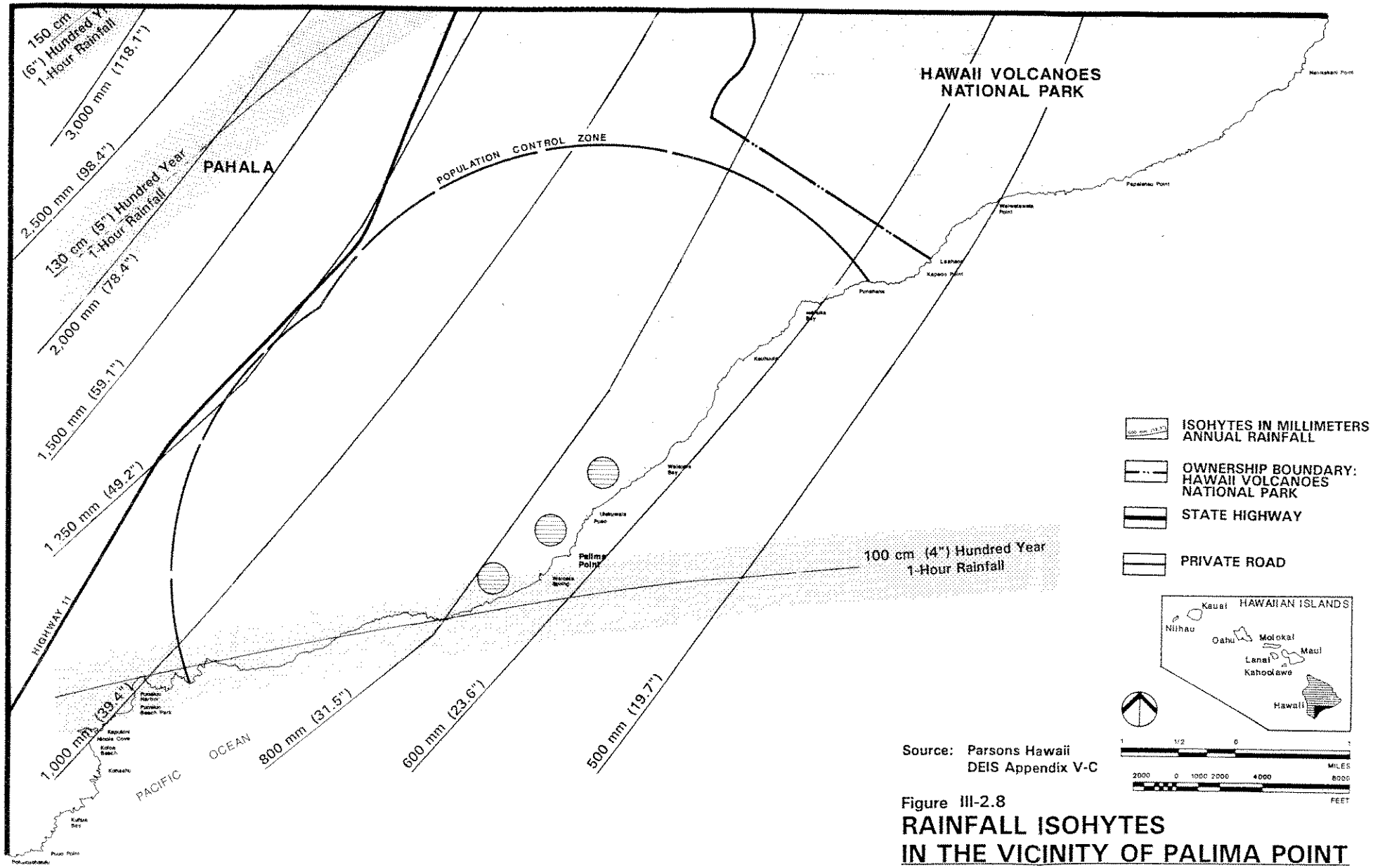
The Palima Point project site is located adjacent to the ocean and at the base of Mauna Loa and Kilauea Volcanoes. The proximity of the two volcanoes and the surrounding steep terrain strongly influence the climate at the site.

At Pahala, the annual average temperature is 71.3°F. Monthly average temperatures range from 68.8°F in winter to 74.0°F in summer (USDOC, 1961). Pahala is located approximately 3 miles northwest of Palima Point.

Data collected at three nearby stations (Honu`apo, Pahala and Moaula) show annual average rainfall of nearly 50 inches (USDOC, 1961 and HECO, undated). Historical data reveal that much of the rainfall occurs in the winter. Moaula is located approximately 3.5 miles west-northwest of Palima Point. Figure III-2.8 shows rainfall isohytes for the project site.

The prevailing wind at the site is from the northeast and is associated with the synoptic tradewind. This condition produces a flow from the site down the coast in the general direction of Na`alehu. "Kona weather" is characterized by a wind from the southeast and produces an onshore flow at the site. A Kona weather condition can result in an air flow that moves from the site across Highway 11 toward Pahala and possibly to the more distant and populated western coast of Hawaii.

Localized wind-flow patterns also occur at Palima Point as a result of the diurnal heating and cooling cycle on the nearby mountain slopes. During the nighttime, the ground cools by means of longwave radiation out to the night sky. The air near the ground cools and flows downhill producing what is called a nocturnal drainage flow. This layer is usually only a few hundred feet deep and is associated with a ground based temperature inversion. It is strongest on calm clear nights and is weakened by the presence of heavy cloudcover or synoptically induced nighttime winds. Solar heating on the slopes during the daytime produces the opposite effect, causing air near the surface to warm and rise creating an upslope flow. During the early morning hours a transitional period occurs when the localized flow changes from nighttime offshore flow to daytime onshore flow.



Source: Parsons Hawaii DEIS Appendix V-C

Figure III-2.8

RAINFALL ISOHYTES IN THE VICINITY OF PALIMA POINT

6.0 Meteorological Data Collection

A limited study was conducted to evaluate the surface winds at Palima Point and Honu`apo (Schroeder, 1991). Honu`apo is located about eight miles southwest of Palima Point (Figure III-1.6). Data were also obtained from atmospheric soundings, "rawinsondes", that measured relevant meteorological conditions to altitudes of up to 20,000 feet. Rawindsondes are recorded by launching a weather balloon that measures data such as wind speed, air turbulence, and air temperature and transmits it to a ground receiver.

During the months of April and May, 1989, at the request of the DBEDT Office of Space Industry (OSI), the U.S. Navy conducted hourly measurements over two 48-hour periods from Honu`apo Bay. In September 1991, additional soundings were taken from Pu`u Pili at Palima Point. These measurements were taken approximately every hour over two 3-day periods.

Dr. T. A. Schroeder, UH Professor of Meteorology, defined seven meteorological scenarios that would be characteristic of conditions that could occur at the Palima Point site, they are: (1) moderate tradewind conditions with 6 to 16 knot winds from the northeast; (2) somewhat stronger tradewind conditions, with 8 to 19 knot winds from the east to northeast direction; (3) weak to moderate tradewind conditions, with 2 to 12 knot winds from the east to northeast; (4) a tradewind decline (Kona weather) with 4 to 14 knot winds from the southeast; (5) a typical shallow surface layer offshore nocturnal drainage flow from the surrounding mountains; (6) transitional period conditions with surface winds shifting from nocturnal drainage flow to a tradewind condition; and, (7) a morning sounding revealing continuing transition to a prevailing tradewind. These profiles were used in the modeling of potential hazards from launch operations that are evaluated in Chapter Five of this EIS.

7.0 Ambient Air Quality

The existing air quality in the project area is affected primarily by air pollutants from natural sources, transportation sources and agricultural activities. Although there are no on-site ambient air quality monitoring stations, it is assumed that volcanic emissions at HVNP would have some effect in the area.

The National Park Service operates an ambient air quality monitoring station in HVNP near the Kilauea Caldera, approximately 22 miles northeast of Pahala (Figure III-1.6). Ambient data have been collected at this site since the mid-1980s with a brief gap approximately two years ago when the National Park Service acquired the station. Sulfur dioxide, O_3 and PM_{10} data were collected. Because of the close proximity to volcanic vents, both Federal and State ambient air quality standards for SO_2 have been exceeded (NPS, 1992).

Ambient air pollutant concentrations were also measured by HECO (under contract to DBEDT) at Honu`apo from 1989 to 1990 (HECO, undated). This site was located roughly 8 miles southwest of Palima Point (Figure III-1.6). Air quality parameters monitored included SO_2 and NO_2.

8.0 Drainage and Flooding

The Palima Point site is intersected by several precipitous clefts or gulches which meander through the flats and change position from time to time. A few of the more defined gulches carry considerable amounts of water during torrential rains. Much of the water carried through the gulches percolates into the highly porous lava before reaching the shore. "Red water," which is surface runoff water mixed with eroded soil particles, is very rarely observed offshore. Most runoff water does eventually reach the ocean via the water table and subterranean lava tubes.

During infrequent heavy rains, surface water runoff flows onto and across the proposed site. It appears that most of the water percolates into the ground as it flows across the relatively porous lava. Flooding is common at the upper portion of the site and is reported to be rare to non-existent at the lower edge adjacent to the ocean.

E. THE BIOLOGICAL SETTING

1.0 Terrestrial Flora

Cultivated macadamia nut orchards are located within the PCZ boundary, adjacent to Mamalahoa Highway. Uncultivated lands found within the proposed project boundaries support seven vegetation types: pasture-shrubland vegetation, mixed forest, Guinea grass-California grass community, Christmas berry shrubland, mixed grass-shrubland community, pioneer vegetation on lava, and coastal vegetation (Figure III-2.9). Only the pioneer vegetation on lava and coastal vegetation types have large populations and diversities of native plant species.

2.0 Terrestrial Fauna

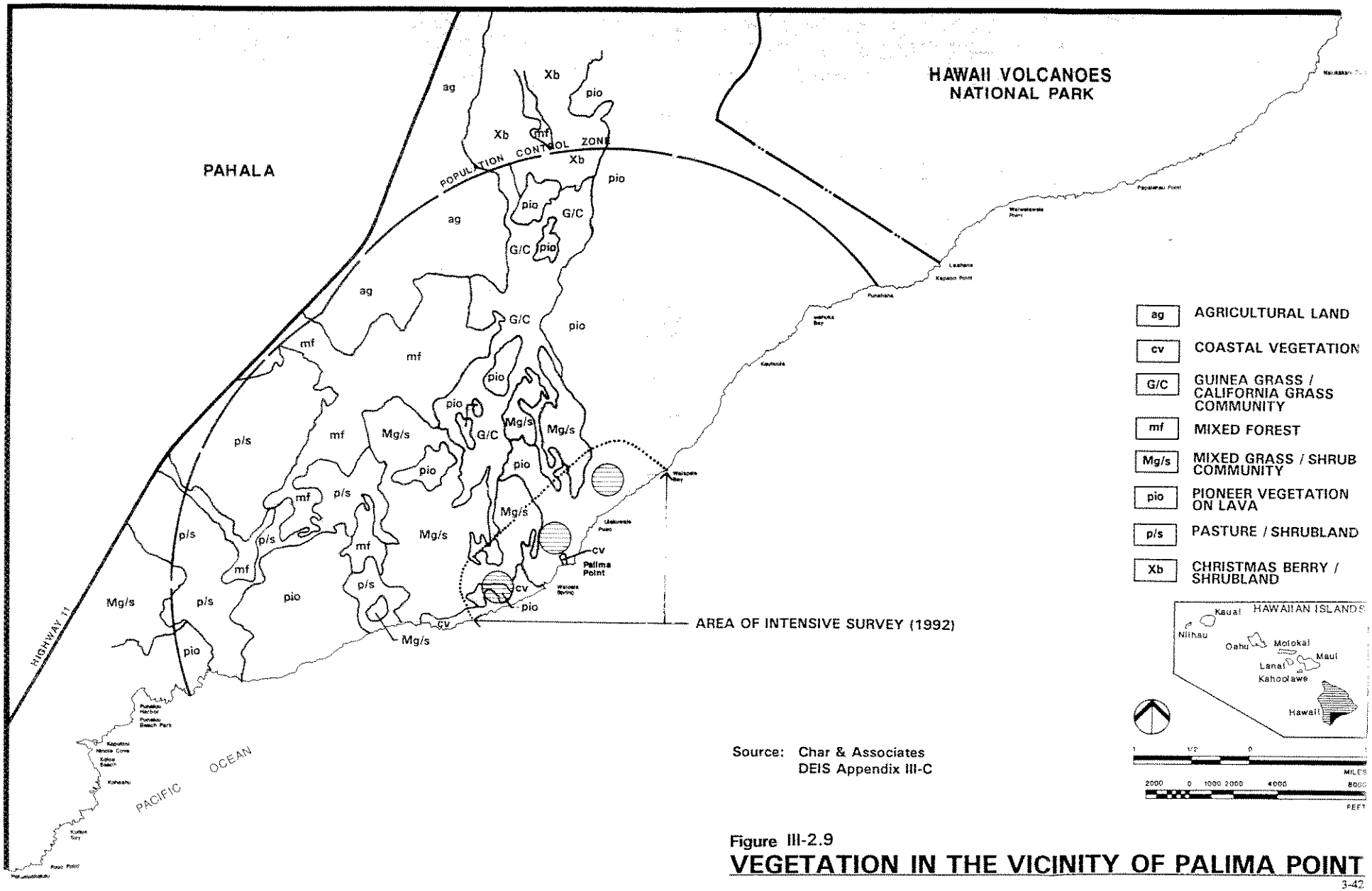
A field survey was conducted to identify birds and mammals on the project site (Freed, DEIS Appendix IIID). The survey, conducted in late-summer 1990, found one endangered species, the Hawaiian hawk (*Buteo soliarius*) present. An endangered mammal, the Hawaiian hoary bat (*Lasiurus cinereus semotus*), was seen in the vicinity of Punalu`u, just south of the western boundary of the PCZ. A species list and discussion of species found is included in Appendix IIID.

Birds. Two Hawaiian Hawk individuals were sighted close to Highway 11 (Figure III-2.10). They were flying over forested habitat--as is common to the specie--and would not be expected over the expansive open areas of lava with sparse vegetation that make up most of the site. A community of Black Noddy, a non-endangered resident breeder, was discovered in the sea cliffs between Kauhuula and Mahuka Bay. Pacific Golden Plovers, a non-endangered migrant bird, were common in the coastal and grassy areas and along the outflow stream. Eight species of introduced birds were seen on the site.

Although the Dark-rumped Petrel and Newell's Shearwater no longer breed at low elevations, the birds may fly over the site enroute to nests or feeding areas. There are also indications that the Band-rumped Storm-Petrel breeds on high elevations of northeast Mauna Loa; they might also fly over the site enroute to the ocean.

Mammals. Three species of introduced mammals are common and widespread on the project site: mongoose, feral pigs, and feral goats. Although no endangered Hawaiian Hoary Bats were detected on the study site, they were present at offsite locations sufficiently close to the site that bats may be expected, at least occasionally, in the forested areas on the site. The bats are also known to forage occasionally on aerial insects over the ocean. Small patches of mixed forest near Kamehame Hill may provide a location for over-water foraging in this portion of the project site.

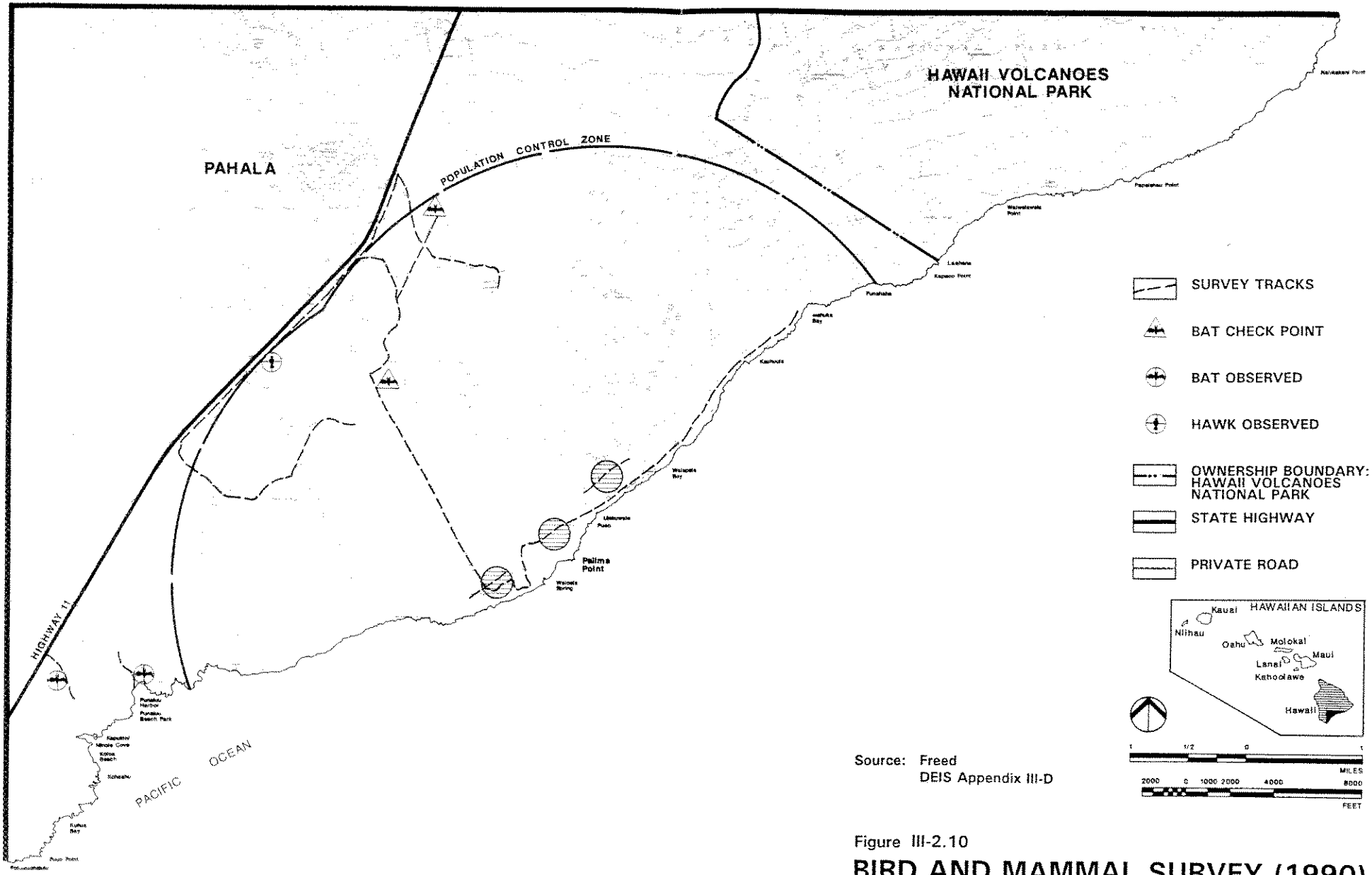
Terrestrial Invertebrates. The Island of Hawaii has several lava tubes in which a specialized subterranean fauna of insects and spiders has evolved. There are lava tubes on the project site and some of these may contain cave communities, including possible endemic species.



Source: Char & Associates
DEIS Appendix III-C

Figure III-2.9

VEGETATION IN THE VICINITY OF PALIMA POINT



Source: Freed
DEIS Appendix III-D

Figure III-2.10

BIRD AND MAMMAL SURVEY (1990)

3.0 Freshwater Biota

The biota in the anchialine pond (Station 6) was sampled by Brock (DEIS Appendix IIIE). Species present include the alga *Hildenbrandtia sp.*, shrimp opae`oeha`a (*Macrobrachium grandimanus*), o`opu`akupa (*Eleotris sandwicensis*), and an unidentified species of goby. The morphological characters of the shrimp (*Macrobrachium grandimanus*), show an interesting ecotype variation; individuals are sexually mature at an unusually small size and lack the robust characters usually seen in the species (e.g., walking legs). The biota seen at Station 7 (Figure III-2.7) include one mosquito larva, two o`opu`akupa (*Eleotris sandwicensis*) and a small amount of the alga *Hildenbrandtia sp.*; no other species were seen.

4.0 Marine Biota

The entire southeastern boundary of the proposed project site is made up of shoreline which intergrades into marine habitat types such as rocky intertidal, coralline encrusted rocks and boulders (with associated spurs and grooves), and other associated nearshore systems.

The rocky intertidal habitat is dominated by algal species (which include encrusting and some coralline varieties), aquatic invertebrates (particularly soft coral, mollusc, echinoderm, and crustacean species), and reef fish (typically juveniles). The largest biological diversity is found within the coral encrusted rocks and boulders and the associated spurs and grooves. The spurs and grooves found within this habitat are typically associated with natural freshwater springs.

The marine habitat contiguous to the proposed project site is suitable for the threatened green sea turtle and the endangered hawksbill turtle, particularly at Kamehame Hill, in the vicinity of Nahuluhulu Point, offshore of Kane`ele`ele Heiau, and at Punalu`u Bay (Brock, DEIS Appendix IIIE).

During field surveys, approximately 41 turtles were observed; 36 were offshore of the proposed project site. None of those observed were of the hawksbill variety. No turtles were encountered offshore immediately contiguous to the proposed launch pad locations, though it is assumed that they occupy these areas occasionally while foraging, or in transit from one location to another. Punalu`u Bay is a recognized turtle habitat that is about 350 m southwest and the PCZ. Figure III-2.7 shows the major areas of sea turtle aggregation identified by Brock (Ibid.).

The endangered humpback whale occurs in the ocean off the project site project region during its annual migration (arriving in December and leaving in April). These whales prefer calm waters less than 100 fathoms deep for mating and calving. The offshore area located contiguous to the proposed project site is not known to be an important humpback whale habitat since the waters are generally rough, and there is only a narrow band of shallow water adjacent to the coast.

In summary, the marine communities fronting the proposed launch facility at Palima Point are situated in a very high-energy area, exposed to the northeast tradewinds. The substratum is comprised of pahoehoe and basalt boulders with very little reef development present. This substratum drops away rapidly such that oceanic waters are within 200 to 300 m of the shoreline. The marine resources present in this area are representative of those found in other isolated, high-energy Hawaiian nearshore environments.

F. THE SOCIO-CULTURAL ENVIRONMENT

1.0 Historical/Archaeological Setting

Most archaeological resources are concentrated along the coastline. One exception is the northeast corner of the PCZ where a relatively low density of archaeological resources exists; it is associated with the 1823 lava flow. Kane`ele`ele Heiau is located outside of the PCZ. This site, which contains over 100 associated structures, comprises the major site complex in the area.

Complexes of sites occur in kipukas and small inlets along the entire length of coastline. These are assumed to be prehistoric Hawaiian fishing settlements. Many of the sites show historic use.

A complete (100 percent) archaeological inventory and limited subsurface testing were conducted for the proposed launch pad area (approximately 800 acres) by Cultural Surveys Hawaii (CSH, DEIS Appendix IV). Additionally, a planning reconnaissance was conducted at the northeast end of the PCZ to determine the relationships between archaeological sites on either side of the HVNP boundary. A total of 138 archaeological sites and site complexes were identified during the survey. Cultural resources are discussed in Chapter Seven, Section I of this EIS; see CSH, DEIS Appendix IV, for the complete survey results and significance evaluations.

2.0 Recreation and Subsistence Activities

Access to the shoreline portions of the site is difficult. Recreational or subsistence uses are limited. The focal point of shoreline activities is Kamehame Beach, a cobble beach, usually awash, cut into a cinder cone in the southwestern portion of the PCZ. Kamehame Beach can be reached on foot along a stepping-stone trail which runs from the northern end of the Kane`ele`ele Heiau complex. Several *mauka-makai* trails intersect the trail. The trail is used by hikers, fishermen, opihi pickers and turtle researchers who park at the Punalu`u boat ramp. A shoreline access management plan is presented in Chapter Two, Section IV of this EIS and in Appendix XF of the dEIS. Impacts of the proposed project on recreation and subsistence activities are discussed in Chapter Seven, Section III of this EIS and in DEIS Appendix IXD.

SECTION I: NATURAL HAZARDS

Natural hazards constrain the siting of facilities and can dictate structural design. In this context, the environment generates effects on the facility, rather than the facility generating adverse effects on the environment.

A. GEOLOGIC HAZARDS

Detailed information on geologic hazards is presented in HLA, DEIS Appendix IIIA.

1.0 Affected Environment

Southwest Launch Pad. The pad area includes Pu`u Pili, a cinder cone which was formed from lava flows reacting explosively with seawater. Surrounding the cone on three sides is an unvegetated a'a lava flow. The a'a flow appears to be associated with Pu`u Pili.

Palima Point Pad. The center of the proposed pad is marked by a 4-inch by 8-inch wooden post in the middle of a large tumulus. The tumulus is the highest topographic point in the area. The pad is surrounded by tube-fed pahoehoe flows. There are a number of linear cracks just to the south of the center of the pad. These cracks are up to a foot in width and at least 10 feet deep.

Northeast Pad. The center of the East Pad is underlain by flows of pahoehoe, partially vegetated with grass. A series of cracks with the same general trend as noted at the Palima Point Pad crosses through the site.

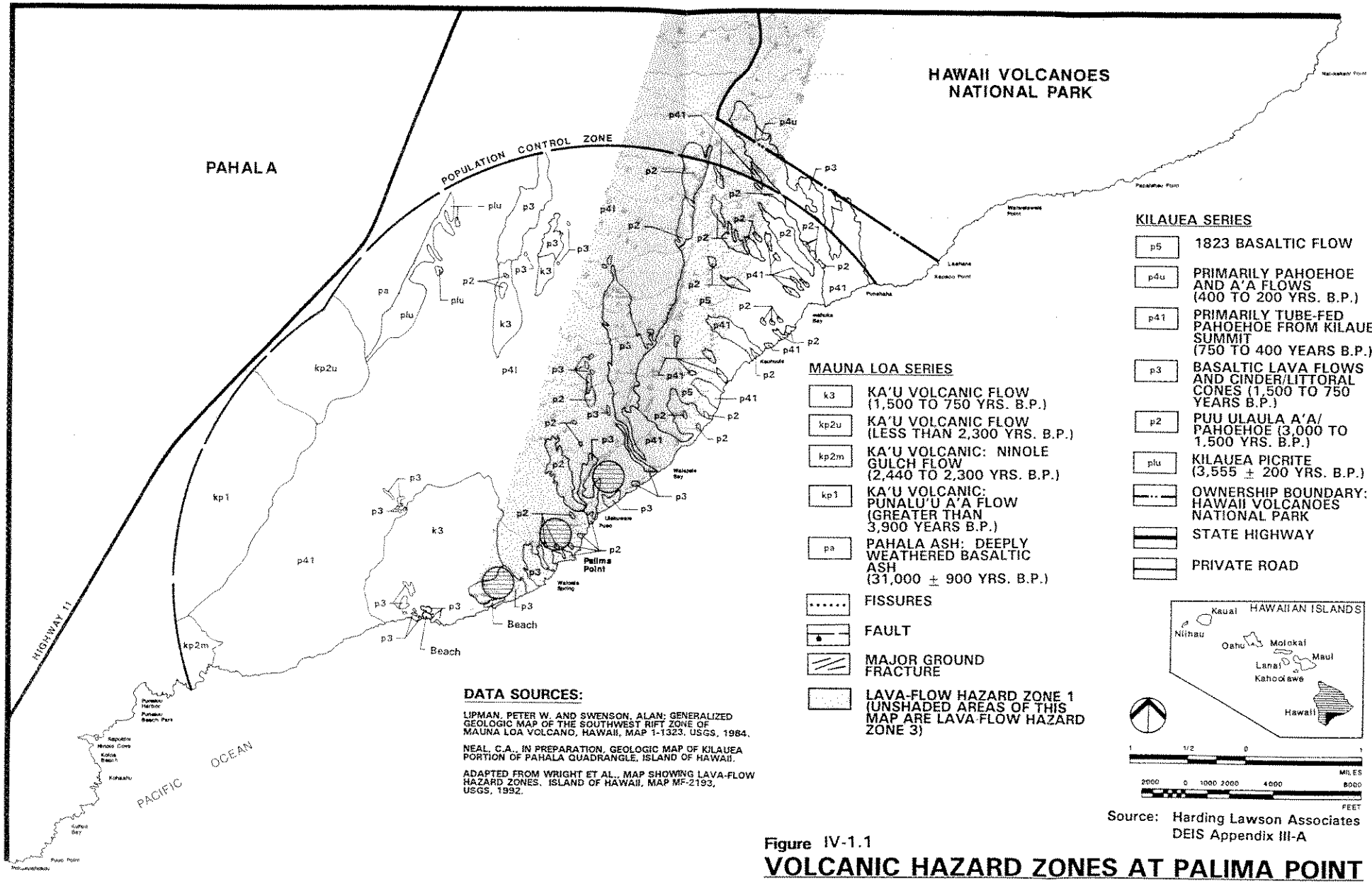
Support Facilities. The support facilities are proposed to be located approximately halfway between the launch pad sites and the town of Pahala. Presently, this area is completely overgrown with California grass, heavy brush, and larger trees such as mango. The topography slopes gently to the southeast. The area is underlain by pahoehoe lavas. The source of the lavas was near Kilauea's summit.

2.0 Volcanic Eruptions and Flows

Analysis. Figure IV-1.1 shows the U.S. Geological Survey (USGS) volcanic hazard zones for the site. The proposed launch pads are located within Hazard Zone 1. Zone 1 includes the rift zones of Kilauea and is, therefore, the most hazardous (Mullineaux, 1987; Heliker, 1990). Since 1800, 25 percent of the land area in Zone 1 has been covered by lava. In the last 750 years, more than 65 percent of the zone has been covered. Zone 1 contains the sites of most historical eruptions, and this trend will probably continue into the near future.

The edges of the southwest rift zone form boundaries on the hazard map between Zones 1 and 3. The support facilities are included in Zone 3. Zone 3 is gradationally less hazardous than Zones 1 and 2 because of increasing distance from recent active vents and because of local topography. Since 1800, only 1 to 5 percent of the zone has been covered by lava. However, in the last 750 years, 75 percent of the flanks of Kilauea have been covered, and 15 to 20 percent of the flanks of Mauna Loa.

Hawaiian lavas generally do not travel very fast, but there are exceptions. The 1823 flow



Source: Harding Lawson Associates DEIS Appendix III-A

Figure IV-1.1

VOLCANIC HAZARD ZONES AT PALIMA POINT

which issued from the southwest rift zone of Kilauea, northeast of the site, is reported to have moved so quickly that a coastal Hawaiian village was overwhelmed, and there may have been some loss of life (MacDonald and others, 1986). Pahoehoe lava flows can form extensive tube systems which enable the lava to travel long distances without losing much heat.

Potential Effects. A probabilistic analysis of inundation by lava flows was prepared (ACTA Inc. in HLA, DEIS Appendix IIIA). The analysis concludes that the risk of inundation by lava flow at the Palima Point site varies from high in the area downslope of the Kilauea Southwest Rift Zone (SWRZ) - the launch pad area - to moderate elsewhere. ACTA predicts that the area along and immediately downslope of the SWRZ has the highest potential for burial--about 50 percent during a 50-year time span. Recent intrusive activity along the SWRZ (1981-82) may signify that an eruption in this vicinity is very likely in the near future.

Upslope, to the north and west, lava flow inundation risk from the summit area of Kilauea volcano and the summit and upper southwest rift zone of Mauna Loa volcano is moderate. If an eruption occurs in these source areas, the probability of inundation at the Palima Point site varies from less than 10 to more than 30 percent. Considering the probability of major eruptions that generate long lava flows from these source areas, the probability over a 50-year time span is less than 5 percent.

It should be noted that there are differences in professional opinion as to the validity of the quantification of the risks of inundation that appears in the ACTA report. Although the values may be correct, the period of historic observation of lava flow activity on Hawaii is very short, therefore quantification may not be justified. The probabilities give a rough idea of the hazard, but are best regarded as semi-quantitative assessments and should not be considered as hard statistical data.

3.0 Ground Subsidence and Fracturing

Description and Analysis. The "Great Crack" along Kilauea's southwest rift zone may represents an eruptive center where lava poured onto the surface and flowed outward. It may represent a linear zone of deep-seated subsidence, although its exact cause is not known. The Great Crack terminates about 2,000 feet east of the Northeast Pad, but smaller cracks extending to Palima Point are very likely a continuation of this feature.

Subsidence on a large scale is presently affecting the south flank of Kilauea. Some of these may have been the result of catastrophic failure of the volcanic slopes such as Kilauea's south flank. Ground subsidence on a local scale can be caused by settling due to underground movement of magma. This process has produced pit craters which are abundant near Hawaiian volcanoes.

Normal faults on Kilauea's south flank are considered to be the scarps at the head of potential future slides. Similar scarps, now masked by young lava flows, have been mapped by Neal on the eastern portion of the project site.

Ground cracks are also associated with active volcanic vents and the underground movement of magma. Numerous cracks can be found in the eastern portion of the site, where the southwest rift continues toward the ocean. Some of the cracks are more than 2 km (about 1.25 miles) in length.

The hazard zones for ground subsidence and fracturing (Mullineax, 1987) divides the site into the same zones as the lava flow zonation map (Figure IV-1.1). The area east of the southwest rift lies in Zone 1, which includes the rift zones of Kilauea. The area west of the southwest rift is in Zone 3, where fractures and subsidence due to the underground movement of

magma occur less frequently than in Zones 1 and 2. Fissures, faults and major ground fractures on the Palima Point site are shown on Figure III-2.5.

Potential Effects. Large-scale subsidence can destroy man-made structures through tilting or shaking of the ground. A sudden downslope movement of Kilauea's south flank could expose low-lying coastal areas to inundation by tsunami and storm waves. Local scale subsidence can cause roofs of lava tubes and blisters to collapse, especially in pahoehoe lava flows where such large voids are common. Man-made structures near these types of subsidence can be damaged by tilting or differential settlement. The hazard from ground cracks to man-made structures is the same as from local ground subsidence.

4.0 Tsunami

Description and Analysis. Tsunami are large, rapidly moving ocean waves caused by the abrupt movement of ocean floor, volcanism, or landslides. The maximum recorded height of a historical tsunami in Hawaii is 16 to 17 m (about 53 to 56 feet). Tsunami generated locally are considerably more dangerous than those from around the Pacific Rim because there is very little time between the origin of the wave and its effects on coastal areas. There have been about 50 tsunami in the Hawaiian Islands since the early 1800s (Tilling and others, 1976).

Potential Effects. Tsunami are a hazard to people and structures because the force of the water can be sufficient to damage or topple buildings. Saltwater inundation can also damage metal, structures, and electrical systems. The actual effects of a particular tsunami are hard to predict because of the variability of local topography. Coastal inundation resulting from subsidence and tsunami is also likely to be a major regional earthquake-related hazard. For the proposed launch facility, areas below 20 m elevation (60 feet) may be affected, and historical run-up in excess of 12 m (40 feet) has been observed in the region.

The West Pad near Pu`u Pili is the most likely complex to be affected by tsunami run-up. The other launch pads and facilities are located at higher elevations, and therefore, less vulnerable to tsunami run-up. The estimated tsunami inundation zone on the Palima Point site is depicted on Figure III-2.5.

5.0 Earthquakes

A seismic risk assessment is presented in HLA, Appendix IIIA. This section discusses the primary earthquake-related hazards including ground shaking, ground failure and coastal inundation which could directly effect facility design. Earthquake-related hazards to off-site populations from hazardous launch operations at the Palima Point facility are discussed and evaluated in Chapter Five.

Description and Analysis. Three primary earthquake hazards are of concern at the Palima Point site: ground shaking; ground failure; and, tsunami. (Tsunami are discussed above). All parts of the Palima Point launch facility are located within 10 km (6.25 miles) of the Kaoiki-Honu`apo fault zone. Specific definition of the character and level of ground shaking expected at the site, including amplitude, duration and response spectra, requires further engineering analysis that is beyond the scope of this preliminary assessment.

Areas where thick deposits (>0.5 m) of Pahala Ash lie at the surface or under thin lava flows, e.g., along the northern edge of the site, may experience significant local site amplification. The site is gently sloping, in general, so that no topographic amplification effects are expected.

In general, earthquake-induced ground failures include liquefaction, slope failures, fault

rupture, and ground displacement. Except for areas underlain by saturated deposits of Pahala Ash, liquefaction-related ground failures are unlikely in the vicinity of the proposed Palima Point launch facility. Slope failures in sensitive ash near Pahala may occur; rockfalls along coastal bluffs and steep embankments are very likely. Collapse of hollow lava tubes may be common. Permanent ground displacements in the form of extension and contraction failures (cracks) along the southwest rift zone (SWRZ) are likely. Based on historical observations, extensions across new or existing cracks may exceed 1 m in width.

Potential Impacts. Rocket propellants stored at the proposed launch facility pose a hazard to people and the environment in the event that an earthquake causes a failure of containment. The three principal consequences of propellant releases are leaks or spills, fires and explosions. Any one of the three may result in the other two. The potential effects of spills to human health and ecological systems are evaluated in Chapter Five, Sections III and IV.

Fire and explosions may impact the local population and environment in several ways. Fires may spread through vegetation to neighboring communities, generating toxic or caustic gases as products of combustion. Explosions could cause large overpressures which may break windows and may scatter unburned propellant and debris over wide areas. Toxic or caustic gases can also be released into the atmosphere. Detailed analyses of these consequences are discussed in Chapter Five and in DEIS Appendices VID, VIIA, and VIIF.

The most conceivable worst case would be the occurrence of a major earthquake while a launch vehicle is fully-fueled on the pad prior to lift-off. This is the most vulnerable configuration of propellant storage due to large quantities of both fuel and oxidizer that are present in close proximity to each other. The launch vehicle has minimal lateral support to withstand earthquake forces and would be exposed to puncture via toppling or slamming against adjacent support towers. The Delta represents the most serious hazard because it contains the largest amount of toxic/explosive propellants. The effects of this scenario, and potential mitigating measures, are discussed in Chapter Five, Sections III and IV.

6.0 Mitigating Measures for Geologic Hazards

Lava Flows. The only mitigating measure is to build lava diversion structures around the launch pads. If the lower SWRZ of Kilauea should erupt, however, the launch pads would likely be inundated and destroyed. Lava diversion techniques would only be a temporary solution. For example, east rift zone eruptions of Kilauea in 1960 breached diversion barriers, and eventually buried most of the town of Kapoho.

Earthquakes. Risk to launch facilities can be partially mitigated by appropriate design. These measures will include:

- Employing seismic isolation bearings to isolate launch vehicles from strong earthquake-induced ground motion; verifying performance by dynamic analysis and testing.

- Designing structures to withstand the primary earthquake hazards (seismic-resistant design of structures is imperative); including flexible connections on pipelines and storage tanks; and implementing UBC Seismic Zone 4 building requirements. Connections between pipes and storage tanks must allow extension (or contraction) of the expected earthquake-induced displacements.

- Carefully preparing the foundation with fill. Avoiding lava tubes or other potentially unstable ground conditions. Base-isolation or reinforced foundations of critical or hazardous facilities may reduce earthquake-induced displacements.

- Building earthquake-resistant containment structures for propellant storage facilities.

- Providing sufficient anchorage of structures and appurtenances. Securing storage racks, tanks, pipes, other appurtenances to avoid breaking loose, toppling, or slamming against adjacent structures.

- Providing redundancy in design of critical components such as back-up power, communications and control equipment--back-up power and pumping facilities must be made seismically resistant to provide fire suppression and spill containment/cleanup capability following major seismic events. Insuring emergency communications equipment is able to withstand the earthquake and be operational and accessible when the shaking stops.

- Constructing fire barriers, such as berms, around all hazardous facilities. In addition, launch operators should consult and coordinate with the Hawaii County Fire Department to develop additional fire control methods.

The effectiveness of structural mitigations varies with regard to the particular mitigation. Quality control throughout the construction phase of the project must also be implemented to insure the full effectiveness of the design mitigation.

B. FLOODING

A preliminary drainage and flooding study is presented in Parsons Hawaii, DEIS Appendix IVC. The geological and soils characteristics of the project are shown on Figures III-2.3, III-2.4 and III-2.5. The geological characteristics of the development areas are discussed in Part A of this Section.

1.0 Description and Analysis

The project site is geologically young, and drainage channels are not as well defined as those above Highway 11. In some portions of the site the water spreads out in sheets and percolates into the ground. During heavy rainstorms surface runoff flows onto and across the proposed site. Information available at this time indicates that the water percolates into the ground as it flows across the relatively porous lava. Flooding is common at the upper portion of the site and reported to be rare to non-existent at the lower edge adjacent to the ocean.

Highway 11 currently serves as a flow control device to limit water from upland sources reaching the site at full flow. This is due to the apparent undersize of existing culverts and structures which cause water to back up on the uphill side of the road. It is reasonable to assume that in the future these restrictions will be eliminated. Thus the present peak flow rates reaching the project site may increase even if no other factors change.

As the region develops and grows, a higher percentage of the upland areas will be improved with housing, paved roads, parking areas, and so forth. These improvements will increase the run-off quantity reaching the site. Improvements at the site itself will also result in new concentrated flows being directed to downslope areas.

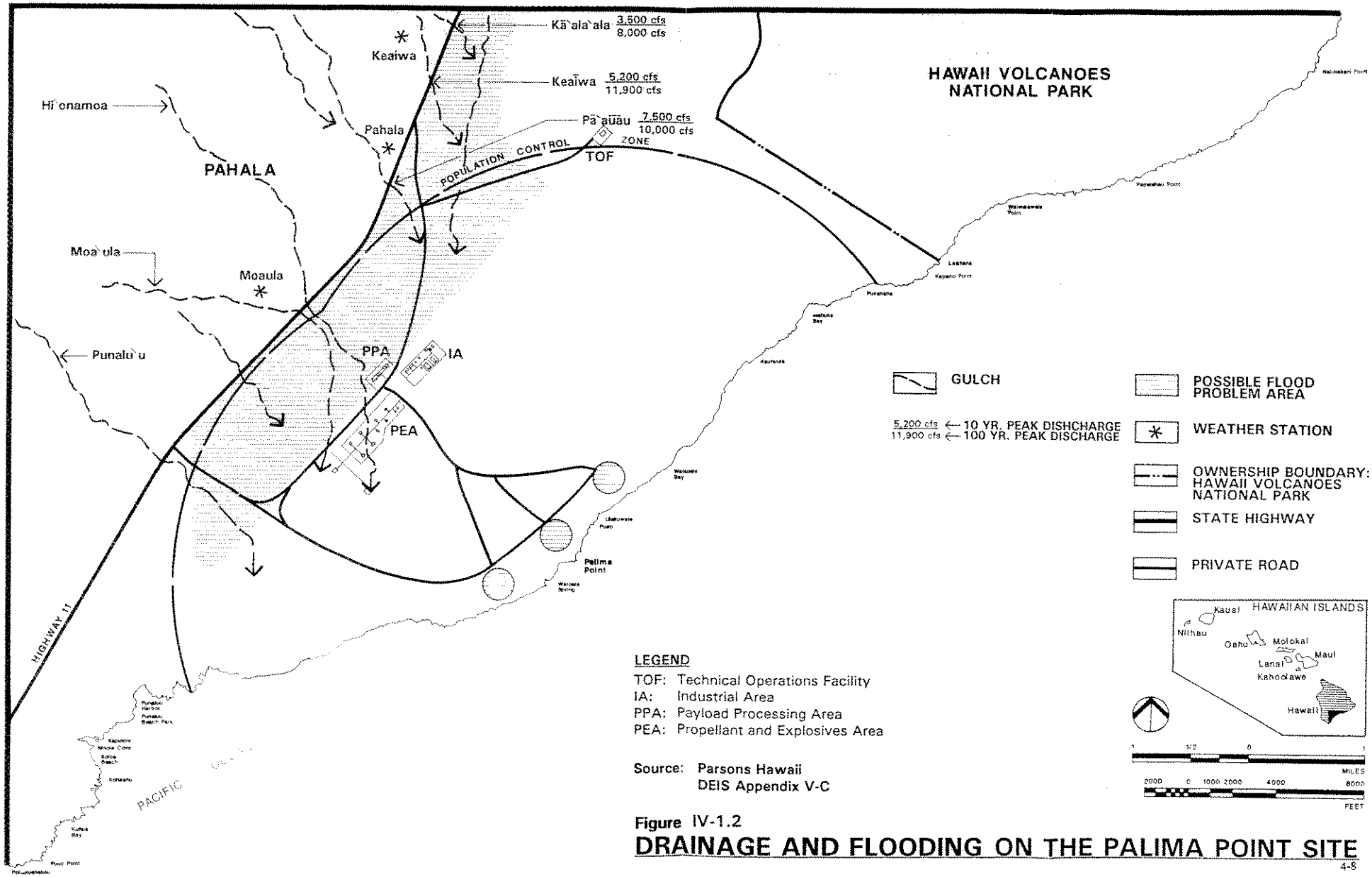
2.0 Impacts and Mitigating Measures

Although flooding can be extensive, it occurs infrequently. Site planning will consider

the existing and future impacts of flooding from high intensity storms. Wherever possible, permanent roads will go up and down the slopes following the highest ridge between adjacent low areas. Roads across the site, following the contour lines, will be kept to a minimum. Where short periods of closure during floods can be accepted, the crossings of flow paths could be constructed as fords rather than structures.

Buildings and other improvements will be constructed on individual fill pads with lower areas around each structure to divert water away from the facility. Wherever possible, sites will be developed with their long axis parallel to the flow line (upslope-downslope) to present the minimum obstacle to free flow around the facility.

The conceptual site plan shows drainage channels traversing the propellant and explosives storage areas (Figure IV-1.2). This area will either have to be relocated or structures will have to be constructed to divert the flow.



LEGEND

TOF: Technical Operations Facility
IA: Industrial Area
PPA: Payload Processing Area
PEA: Propellant and Explosives Area

Source: Parsons Hawaii
DEIS Appendix V-C

Figure IV-1.2

DRAINAGE AND FLOODING ON THE PALIMA POINT SITE

SECTION II: CONSTRUCTION ACTIVITIES

The EIS is based upon a conceptual plan, therefore, the discussion of construction impacts will of necessity be generic. Additional assessments will be required when the facility is designed.

A. DESCRIPTION

The developed area of the launch facility is expected to cover about 1,000 to 1,200 acres and to have about 275,000 square feet of building space. It is estimated that it will take about 2.5 years to construct the facility and to require an average of about 370 construction workers over the 2.5-year construction period. Peak employment is expected to reach about 600 workers. Most of the construction workers will not be on site during the entire construction phase, but only during particular phases, many of which may last only a few months.

Probable actions to be taken in the construction of the launch facility which may affect the localized environment and/or modify or change the environment of the area include: removal of vegetative cover; mass grading of the launch pads, support facilities, and access roads; heavy construction equipment operations and construction traffic along major roads; and, the presence of heavy equipment and construction workers on-site for a period of about 2.5 years.

The actual quantities of mass excavation and embankment are unknown. In locally high spots of the access roads, excavation will be necessary to achieve final grades. Excavation of the basalt lava rock may be difficult and may require ripping by heavy equipment or blasting. Excavated material meeting gradation requirements for structural fill can be reused as fill. Access roads will be constructed of natural materials obtained on site or imported from a nearby source. Trenching for buried electrical and data transmission cables will be necessary where access roads are at grade or in cut. The trenching activity is expected to be incorporated into the mass earthwork for the access roads.

Some negative impacts are expected as a result of the above actions; these are normal for any large construction project. Most of these effects will be short-term in duration and will end when the project is completed.

B. POTENTIAL IMPACTS AND MITIGATING MEASURES

1.0 Alteration of Landform

Because of the gradual slope of the terrain, the landform (absent buildings and structures) will appear little different than at present. Cuts and fills will be generally inconspicuous, aligned along the contours.

2.0 Erosion and Dust

The lava flows are not affected by surface runoff. Ground infiltration is expected to be rapid, resulting in minor erosional effects. The service roads will be graded to allow surface

runoff to flow away from fill slopes. Runoff from paved surfaces will be directed to lined channels which will conduct the water to collection basins and/or dry wells. This will allow runoff to percolate into the subsurface and thereby prevent downslope erosion.

Although dust generation is likely to be minimal, heavy construction equipment operations and construction traffic along the access roads may lead to temporary generation of dust particles. During windy periods, blowing dust may become a nuisance, especially if the wind is onshore and toward the town of Pahala. Dust control during construction at the site will be accomplished by: (a) exposing the smallest area practicable at any time; (b) sprinkling exposed surfaces with water; and/or (c) halting construction until winds dissipate.

3.0 Traffic

Construction-related traffic will include worker vehicles, deliveries of materials and supplies, and movement of various types of heavy equipment. Once mobilized to the site, the latter will likely remain for the duration of the construction period. Deliveries will usually be made during off-peak hours, and consequently the peak hour levels-of-service will not be degraded. Workers will likely "car pool" to some extent because of the commuting distances involved.

Measures to mitigate impacts will include encouraging car or van pooling by contractor personnel and scheduling of deliveries of supplies and materials during off peak hours.

4.0 Noise

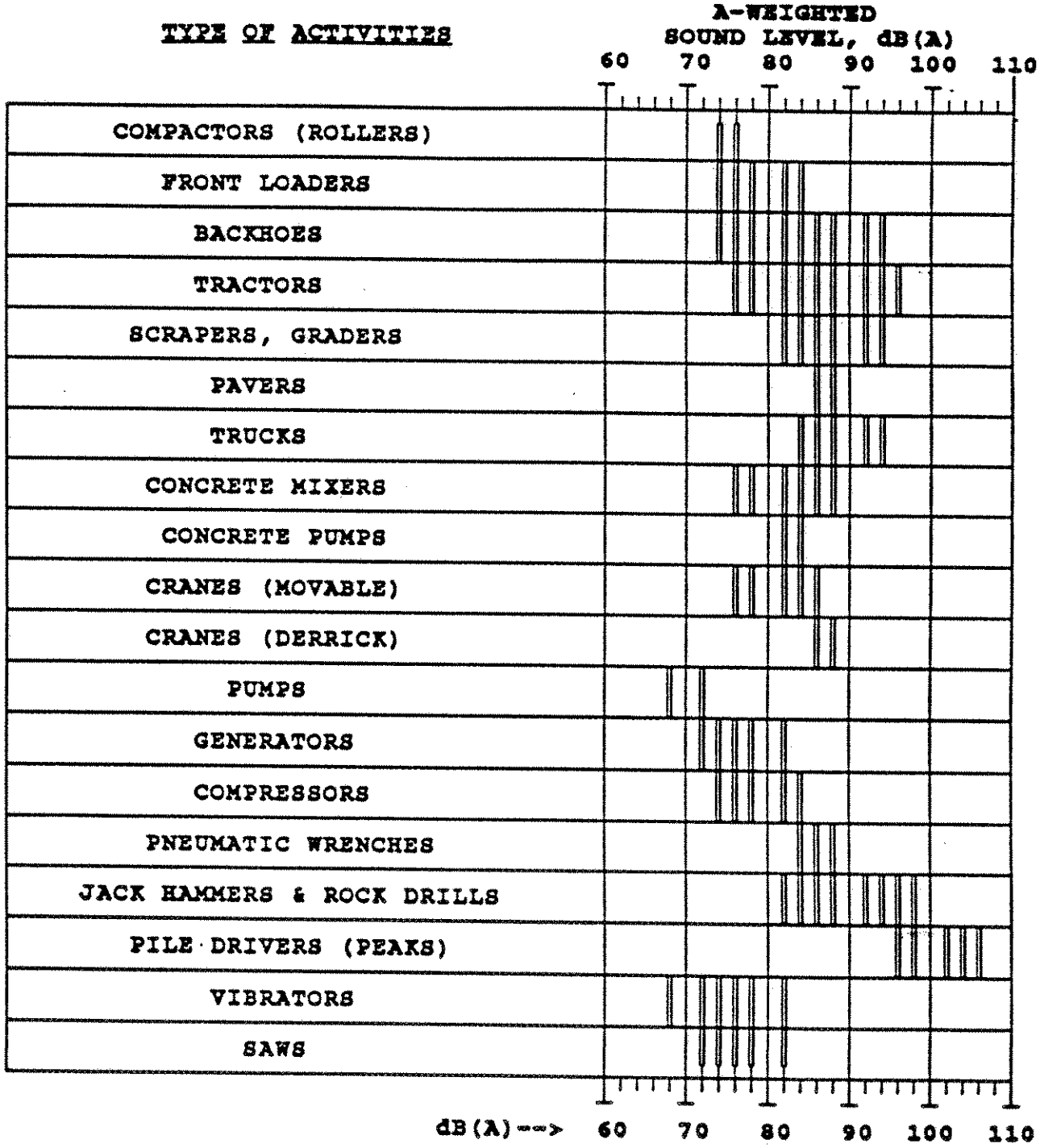
Description. Construction noise is discussed in Darby, DEIS Appendix VIB. Site development will involve excavation, grading and the construction of infrastructure and buildings. The various construction phases of the project could generate significant amounts of noise; the actual amounts are dependent upon the methods employed during each stage of the process. Typical construction equipment noise ranges in dBA are shown in Figure IV-2.1.

Impacts and Mitigating Measures. Pile drivers will probably be the loudest equipment used during construction. Noise from this activity could cause annoyance to persons in Hawaii Volcanoes National Park, Pahala, and Punalu`u on days with unfavorable sound propagation conditions.

Blasting, if required, could also have noise impacts. Blasting is usually accomplished by using numerous small charges detonated with small time delays. Wherever feasible, blast mats will be used to direct the explosive energy into the rock, control flying debris and muffle noise. With appropriate blast design techniques, the noise from blasting can be controlled within acceptable limits at the closest noise-sensitive areas.

Noise regulations have not been adopted by the County of Hawaii. If there are noise complaints from the public, the contractor should comply with Oahu regulations which regulate the operation of vehicles, construction equipment, power tools, and other machinery that emits noise levels in excess of the "allowable" limits. Oahu permit conditions for construction activities are:

> "No permit shall allow construction activities creating excessive noise...before 7:00 am and after 6:00 pm of the same day; No permit shall allow construction activities which emit noise in excess of 95 dB(A)...except between 9:00 am and 5:30 pm of the same day; No permit shall allow construction activities which exceed the allowable noise levels on Sundays and on...[certain] holidays; and, Activities exceeding 95 dB(A) shall [also] be prohibited on Saturdays" (Title 11, Chapter 43, "Community Noise Control for Oahu").



CONSTRUCTION EQUIPMENT NOISE RANGES @ 50 FEET
NOTE: BASED ON LIMITED AVAILABLE DATA SAMPLES

Source: Darby & Associates
DEIS Appendix VII-B

Figure IV-2.1

TYPICAL CONSTRUCTION NOISE LEVELS AT 50' DISTANCE

In addition, construction equipment and on-site vehicles or devices requiring an exhaust of gas or air must be equipped with mufflers; and, construction vehicles using traffic-ways must satisfy the DOH's vehicular noise requirements defined in Title 11, Chapter 42, "Vehicular Noise Control for Oahu."

5.0 Air Quality

Description. Engineering-Science, Inc. (DEIS Appendix VB), evaluated air quality effects for both the construction and operation phases of the proposed project. The major significant emission sources during construction of the launch facilities will be fugitive dust or particulate matter (PM), and construction equipment exhaust emissions associated with site preparation, road construction, and building construction. Emissions will vary substantially from day to day depending on the level of construction activity and weather conditions. Significant emissions from construction activities will occur only during the daily working hours for the duration of the construction phase of the project.

Fugitive Dust (PM) Emissions. Fugitive dust will be generated as a result of ground excavation, cut and fill operations, equipment traffic over temporary roads, and construction of the facilities. Fugitive dust emissions were calculated using an EPA-AP-42 uncontrolled emission factor of 1.2 tons/acre/month or 110 lbs/acre/day (EPA 1985, Volume I, Section 11.2.4). Control methods such as application of water/or soil binders to the work area will be required to reduce fugitive dust emissions. These controls were assumed in calculating the daily fugitive dust emissions (controlled emissions). The estimate is conservative because site work on basalt is likely to produce larger particles with less mobility.

Daily fugitive dust emissions (lbs/day) were calculated based on an assumed work area of two acres/day. The estimated daily controlled fugitive dust emissions during the construction phase is 110 lbs/day.

Construction Equipment Exhaust Emissions. Construction equipment includes, but is not limited to, heavy-duty trucks, construction worker light vehicles, industrial stationary sources, and heavy-duty construction equipment. Exhaust emissions from each include carbon monoxide, nitrogen oxides, sulfur oxides, particulate matter, and hydrocarbon pollutants. Exhaust emissions will be kept to a minimum by proper engine maintenance. In addition, emissions will be minimized through the use of low sulfur fuels.

Impacts and Mitigating Measures. All project construction emissions are temporary and will cease upon completion of construction. Impacts to air quality from construction activities will be short-term and localized. Although the level of particulate emissions could be significant on an hourly basis, the impact to ambient concentration is considered insignificant because of the averaging periods (24-hour and 1-year). Nitrogen oxide emissions from heavy machinery could conceivably be significant on an hourly basis, but in general, construction emissions would not be expected to violate National Ambient Air Quality (NAAQ) or Hawaii Ambient Air Quality (HAAQ) standards (Table 4.2.1).

Implementation of the following recommended measures during construction phase would reduce the emissions of all construction-related air contaminants:

- Water exposed surfaces as often as necessary or spread soil binders on exposed surfaces, unpaved areas, and parking areas to minimize fugitive dust emissions;

- Maintain construction equipment engines in proper mechanical condition and retard diesel engine timing to minimize nitrogen oxide emissions; and,

Table 4.2.1. **Federal and State Ambient Air Quality Standards**

Air Pollutant	Averaging Time	National Standards (NAAQS) Primary	National Standards (NAAQS) Secondary	Hawaii Standards (HAAQS)
Ozone	1 Hour	0.12 ppm (235 μg/m³)	0.12 ppm (235 μg/m³)	100 μg/m³
Carbon Monoxide	8 Hour	9 ppm (10 mg/m³)		5 mg/m³
	1 Hour	35 ppm (40 mg/m³)		10 mg/m³
Nitrogen Dioxide	Annual Average	0.053 ppm (100 μg/m³)	0.053 ppm (100 μg/m³)	70 μg/m³
Sulfur Dioxide	Annual Average	80 μg/m³ (0.03 ppm)		80 μg/m³
	24 Hour	365 μg/m³ (0.14 ppm)		365 μg/m³
	3 Hour	(0.5 ppm)	1300 μg/m³	1300 μg/m³
Total Suspended Particulates	Annual Average			60 μg/m³
	24 Hour			150 μg/m³
Particulates Less Than Ten Microns	Annual Average	50 μg/m³	50 μg/m³	
	24 Hour	150 μg/m³	150 μg/m³	
Lead	Calendar Quarter	1.5 μg/m³	1.5 μg/m³	1.5 μg/m³

Source: Engineering Science, Inc., Appendix VB (DEIS)

o Encourage ridesharing by construction personnel to minimize automobile exhaust emissions.

6.0 Vegetation

According to Char (DEIS Appendix IIIC) the vegetation on the site is dominated largely by introduced or alien species. Of the total 214 floral species inventoried on the site, 171 (80 percent) are introduced, 8 (4 percent) are originally of Polynesian introduction, and 35 (16 percent) are native. Of the natives, 24 are indigenous, that is, they occur throughout the Hawaiian Islands and elsewhere, and 11 are endemic, that is, they are native only to the Hawaiian Islands. A species list is presented in the referenced Appendix.

Important botanical resources, such as sensitive native plant communities or rare plants, were not found in the 850-acre "optimal band" (Figure III-2.9) surrounding the launch areas. None of the plants found during the field studies are officially listed as threatened or endangered species, nor are any proposed or candidate for such status. Similar results were reported in a botanical survey of the adjacent Punalu`u resort area (Char, 1984). Loss of vegetation due to construction of the launch pads will not result in significant impacts.

Additional botanical surveys for other facility locations must be conducted when final design and layout are known. These sites should be staked, flagged, and mapped before the surveys. Roadways and other corridors should also be surveyed, especially where they cross older a'a lava near the proposed TOF location.

7.0 Terrestrial Fauna

A shown on Figure III-2.10, only one endangered species was found on site during field survey conducted in late-summer 1990 (Freed, DEIS Appendix IIID)--the Hawaiian hawk (*Buteo soliarius*). In addition, the endangered Hawaiian hoary bat (*Lasiurus cinereus semotus*) was observed in the Punalu`u area, south of the Population Control Zone (PCZ).

Noise from construction might cause Hawaiian Hawks to forage further from the source of noise than they might otherwise forage, but these birds have substantial home ranges and it is unlikely that a temporary shift in foraging locations by a few individuals will affect either their survival or reproductive success. It is possible the birds may grow accustomed to the noise, as has been documented for many diverse species of birds elsewhere in the country. The Hawaiian Hoary Bat, which roosts during the day, may avoid areas where noise is the greatest.

8.0 Water Quality

The waters fronting the project site are classified as open coastal waters by the State DOH (Chapter 11-54); the standards for these waters are given in Table 3.2.1. The nearshore marine water chemistry is influenced by a relatively large input of low salinity groundwater. The volume of groundwater discharge along the coastline is high. Despite high wave activity, Brock (DEIS Appendix IIIE) found evidence of groundwater overlying the more dense seawater as far as 100 m (330 feet) from shore. High wave and wind activity serve to mix groundwater and seawater, masking the low salinity input; however, it was evident relatively far from shore suggesting a high volume of discharge. The water chemistry data suggest that the marine and groundwater are typical of those found along other high energy coastlines in the Hawaiian Islands.

Adherence to the Hawaii County Grading Ordinance, prompt paving and revegetation, and possibly scheduling site work during expected dry weather months will reduce sediment delivery to coastal waters. Other applicable standards which will be followed include:

- "Storm Drainage Standards," County of Hawaii, October, 1970, and as revised;
- Applicable standards and regulations of Chapter 27, "Flood control,' of the Hawaii County Code;
- Applicable standards and regulations of the Federal Emergency Management Agency (FEMA); and
- Applicable standards and regulations of Chapter 10, "Erosion and Sedimentation Control," of the Hawaii County Code.

NPDES permits under DOH Chapter 55 will be required for "Construction Activity Dewatering" and for "Discharges of Hydrotesting Waters" if either of these employed during construction. As the project would involve disturbance of more than five acres of total land area, an NPDES Permit for "Construction Activity" will be required.

9.0 Marine and Anchialine Biota

The marine and anchialine biota found on and fronting the project site are discussed in Chapter Three, Section II of the FEIS and in Appendix IIIE of the dEIS. There are several possible impacts to these biota due to construction activities. One potential problem is the possible input of terrigenous material due to heavy rainfall. Site preparation uncovers the soil leaving it vulnerable to erosion if a high rainfall event occurs during the period of time that it is uncovered. Erosion and runoff presently occur following heavy rainfall along this coast in the area between Punalu`u Bay and the anchialine pool (Figure III-2.7).

The levels of these impacts to marine communities could increase during the construction of the proposed facility. Appropriate measures (e.g., settlement/retention basins and the development of appropriate drainage systems) should be undertaken during the development of the site or sediment from the construction areas could be carried to the sea if a high rainfall event were to occur when vegetative cover was low or absent.

There are no impacts anticipated for turtles in the area as no launch facilities are planned to be constructed within 0.8 miles of the prime nesting site at Kamehame Beach. Construction activities at night that require bright lights will be discouraged during turtle nesting and hatching seasons.

10.0 Archaeological Sites

One hundred thirty-eight (138) archaeological sites and site complexes were identified during an inventory survey of the launch pad area (See Chapter Seven). Surface observations identified one confirmed burial site. Subsequent limited subsurface testing was conducted at both recurrent and permanent habitation sites, as well as at one of the probable burial sites.

Of the total 138 recorded sites in the launch pad area, a total of 90 sites were evaluated as having varied levels of archaeological significance; 30 sites are recommended for preservation. Descriptions of the sites and their significance evaluations are presented in DEIS Appendix IV; further discussion is also presented in Chapter Seven.

Although none of the sites recommended for preservation are located within the launch pad construction area, some sites within the area are recommended for inclusion in a data recovery plan to address scientific and informational concerns preceding developmental impact. In addition, some adjustment must be made to the southern launch pad location to avoid Pu`u Pili, a possible burial site.

Data recovery will take place prior to construction of the launch pads. In addition, other sites in the vicinity will be protected by rebars and flags to prevent inadvertent destruction during construction activity.

Once the road alignments and site plans for the other facilities are confirmed, intensive archaeological surveys will be undertaken for each area that may potentially be disturbed by construction activities.

11.0 Land Use and Public Access

Construction sites will be fenced and guards will be present at all times. Agricultural uses of the project area can continue throughout the construction period. From time to time during construction periods, some or all of the shoreline area may have to be temporarily closed to the public for safety reasons. Signs will be posted stating when the area will be closed during construction activities. The public will receive adequate advance notice of closings. See DEIS Appendix XF, Conceptual Shoreline Access Management Plan.

SECTION III: ROUTINE OPERATIONS

A. OVERVIEW

Launch facilities are grouped into the following categories according to their use: Launch Vehicle and Payload Processing; Launch Complexes; Range Safety Instrumentation; Support; and, Infrastructure. Hazardous operations and potential accidents at the Launch Complexes, Payload Processing and Propellant Storage Areas and human health and ecological risk assessments from these events are discussed in Chapter Five.

In addition to actual launches, day-to-day support operations include those common for any industrial facility, such as: maintenance, administration, technical and mechanical functions, and communications. About 270 full time employees, plus about 150 transient scientists, engineers and technicians from mainland and foreign organizations, will be on-site at any one time. Spaceport operations and personnel will consume water and electricity, generate solid waste, discharge domestic wastewater, generate noise, possibly generate hazardous waste, and increased traffic. Ambient air quality might also be affected. These actions could produce effects which may impact the natural and human environment of the area. Discussions of potential impacts from these actions and recommended mitigating measures follow.

As stated previously, the EIS is based upon a conceptual plan, therefore, the discussion of impacts of routine facility operations and use will also be generic. Additional assessments may be required when the facility is designed.

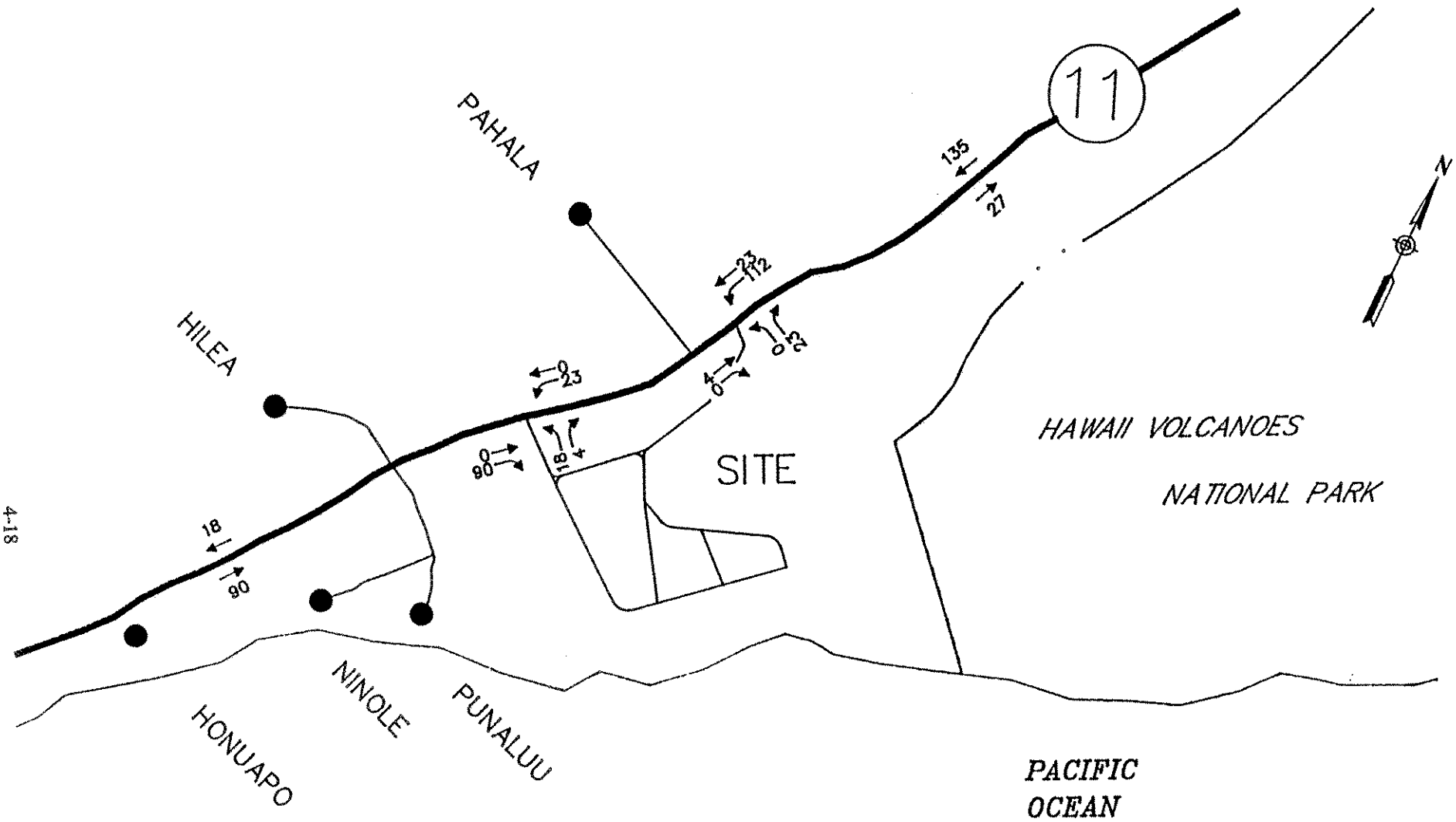
B. IMPACTS AND MITIGATING MEASURES

1.0 Traffic

Description. A traffic impact analysis report was prepared by Barton-Aschman Associates (DEIS Appendix VA). It is estimated that at full build-out the launch facility will generate 1,580 trips on an average weekday. AM peak hour total is estimated to be 272; PM peak is 251. A diagram showing projected AM peak hour trips is shown on Figure IV-3.1. Table 4.3.1 gives existing AM and PM peak hour traffic along Highway 11, by segment; future peak hour traffic volumes with the project are given in Table 4.3.2. Forecasted AM peak hour traffic in the vicinity of the site is shown on Figure IV-3.2.

Impacts and Mitigating Measures. Level-of-Service "E" is forecasted along one roadway section, however, the project does not affect the level of service. The projection indicates that some peak hour congestion can be expected with or without project. No mitigation measures are recommended. The intersections providing access to the project site will be designed to State DOT (HDOT) specifications. This will probably involve channelization and signalization.

Temporary congestion along the transportation corridor will occur when rocket stages and hazardous materials are delivered to the site. These deliveries, which could occur as frequently as once a week, will be by slow-moving vehicles accompanied by escorts. Although they will take place during off-peak traffic hours--between the hours of 9 am and 3 pm--traffic will be slowed



Source: Barton-Aschman Associates
DEIS Appendix V-A

Figure IV-3.1
AM PEAK HOUR VOLUMES

Table 4.3.1 **EXISTING TRAFFIC VOLUMES ALONG THE TRANSPORTATION CORRIDOR**

Location	AM Peak Hour Volume(1)(2)	PM Peak Hour Volume(1)(2)
1 FAP 19 Between Kamehameha & Silva	1160	1160
2 FAP 11 Between Kamehameha & Kilauea Ave.	1850	2220
3 FAP 11 Between Kilauea Ave & FAS 130	1910	1710
4 FAP 11 Between FAS 130 & Mountain View	630	500
5 FAP 11 Between Mountain View & Wright Rd.	310	360
6 FAP 11 Between Wright Rd & Volcano Park	180	240
7 FAP 11 Between Volcano Park & Punaluu	160	170
8 FAP 11 Between Punaluu & Waiohinu	160	200
9 FAP 11 Between Waiohinu & Keolia	160	1602

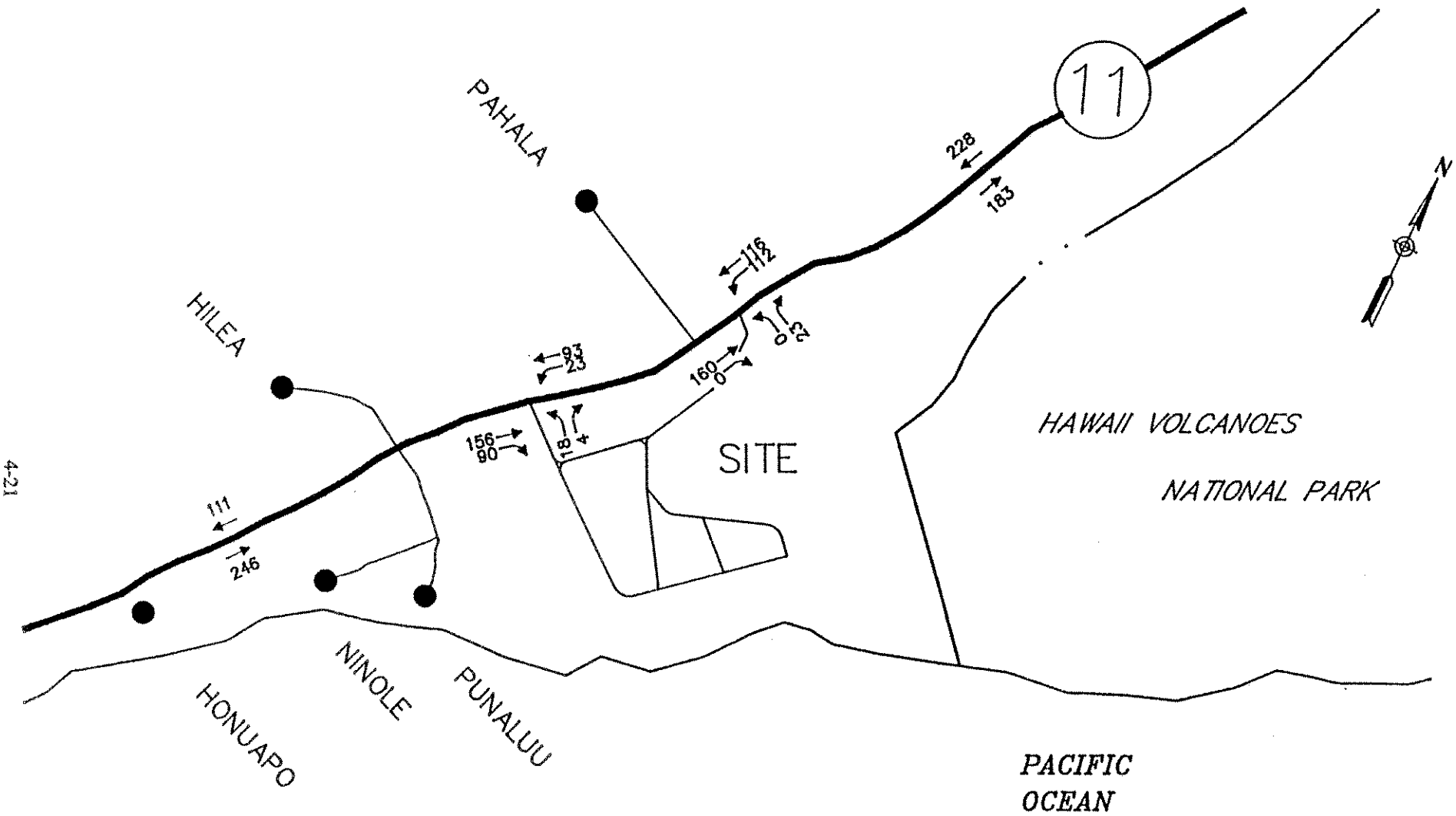
Notes:
(1) Volumes are two way peak hour traffic volumes.
(2) Source: Traffic Summary, Island of Hawaii
Hawaii Department of Transportation

Source: Barton-Aschman Associates, Appendix VA (DEIS)

Table 4.3.2 **PEAK HOUR TRAFFIC VOLUMES : 2005 CUMULATIVE PLUS PROJECT**

Location	2005 Traffic Volumes with Project			
	AM Peak Hour		PM Peak Hour	
	Volume	Los	Volume	Los
1 FAP 19 Between Kamehameha & Silva	1861	E	1858	E
2 FAP 11 Between Kamehameha & Kilauea Ave.	2990	B	3558	C
3 FAP 11 Between Kilauea Ave & FAS 130	3084	D	2764	C
4 FAP 11 Between FAS 130 & Mountain View	1144	D	929	D
5 FAP 11 Between Mountain View & Wright Rd.	646	B	712	B
6 FAP 11 Between Wright Rd & Volcano Park	443	B	525	C
7 FAP 11 Between Volcano Park & Punaluu	412	B	415	B
8 FAP 11 Between Punaluu & Waiohinu	357	B	411	C
9 FAP 11 Between Waiohinu & Keolia	358	B	349	B

Source: Barton-Aschman Associates, Appendix VA (DEIS)



Source: Barton-Aschman Associates
DEIS Appendix V-A

Figure IV-3.2

AM PEAK HOUR VOLUMES - CUMULATIVE PLUS PROJECT

along the narrower, two-lane segments of the highway. Some drivers will be highly annoyed and may resort to unsafe passing maneuvers; emergency vehicles may be temporarily slowed down. The days and times of the convoys will be announced in advance in order to minimize inconvenience to motorists.

Another source of congestion will be the launches themselves. Spectators will converge on the launch site, parking along the sides of the road--if allowed--to get a good view. It is recommended that a visitors' center and viewing area be developed outside of the PCZ so all traffic can be directed to one location. Strict "no-parking" regulations should be instituted prior to a launch (similar to those in place for the eclipse) to insure that the highway is not blocked. All launch and delivery operations will be coordinated with Hawaii County Civil Defense, HDOT and other appropriate agencies.

2.0 Noise

Description of the Acoustic Environment. In general, four distinct conditions or combinations of factors can be defined which affect the rate of attenuation of sound:

- *Condition 1 - Receiver Upwind.* The fact that wind speed increases with altitude causes the effective sonic velocity to decrease with altitude (or a negative gradient) and the raypaths are seen to bend above a receiver located upwind.

- *Condition 2 - Standard With Excess Attenuation from Shielding.* If there is no wind, and temperature is constant, the sound ray paths are straight. But if the ray paths are blocked by buildings, berms, and so forth, and/or graze over foliage, soft earth, a'a lava, and so forth, then noise levels are typically diminished.

- *Condition 3 - Inversion and/or Receiver Downwind.* A positive sonic velocity gradient causes the sound ray paths to bend over shielding elements and foliage such that there are only sound spreading losses and absorption losses in the atmosphere. Also, this condition often exists if the source is elevated such that the sound ray path is not near the earth and the sound rays are not sufficiently refracted to cause focusing.

- *Condition 4 - Caustic Focusing.* The wind and temperature conditions can cause a complex sonic velocity profile such that sound ray paths converge at a "caustic" where the receiver is located and elevated noise levels are possible. For a given geometry and terrain between the source and receiver, meteorological conditions can cause the sound level at the receiver to vary more than 30 dB.

Effects. The potential noise impacts from project operations which routinely occur between rocket launches were evaluated by Darby & Associates (DEIS Appendix VIIB). Normal truck movements and other activities at the Launch Pads should be inaudible in Pahala, Punalu`u and the National Park. Similarly, operations associated with the Payload Processing Area and the Solid Propellant Storage Area should not involve loud noise sources which are audible in any of the three mentioned areas, except possibly the occasional movement of diesel trucks in and out of the facility during certain sound propagation conditions. This noise, however, would not be distinguishable from similar types of trucks moving on the highway or on agricultural roads.

It was assumed for the analysis that most structures in the Complex would be air conditioned and the associated mechanical equipment (cooling towers, fans, pumps, compressors, and so forth) would be of conventional types that satisfy the interior noise requirements for typical offices, laboratories, and other work spaces. It was also assumed that the spaces immediately exterior to the buildings would have typical acoustical environments as found in

urban locations. Because of the relatively long distances to the residential areas and the National Park, basic mechanical equipment associated with air conditioning buildings should be inaudible in the noise sensitive areas. The following are facilities and/or operation that are potentially noisier and/or different in character.

Industrial Area. The conceptual location of the Industrial Area is about 6,500 feet seaward of Pahala and contains the following potentially significant noise sources:

Emergency Power Plant. A large unmuffled diesel generator could cause 100 dBA at 50 feet. The generator unit will be tested several times each month. Table 4.3.3 shows that estimated noise levels of 29 to 65 dBA will be heard in Pahala from an unmuffled diesel unit, depending on sound propagation conditions. An overall noise reduction of 25 dBA could readily be achieved by noise mitigation measures such as placing the unit in an enclosure with interior sound absorbing surfaces; providing duct silencers to provide ventilation air; and, providing a large "critical" engine exhaust silencer.

The measures described above would allow all OSHA noise exposure requirements (CFR, Title 29, Chapter XVII Part 1910, Subpart G, 48FR 29687, June 28, 1983) to be met and also make the generator essentially inaudible in Pahala, even during the worst case propagation condition. "Essentially inaudible" means that certain low frequencies of sound may be detectable for short periods of time when sound focusing causes a caustic to exist at the listener's location. It should be noted that noise from vehicles on the highway and agricultural roads will also be louder during the worst-case sound propagation Condition 4.

Heavy Vehicle Operations. At times, several heavy diesel trucks and/or a diesel powered crane may be involved in loading or unloading objects in the Industrial Area. Source noise levels of 85 to 90 dBA at 50 feet could readily occur during such operations resulting in noise levels could ranging from 14 to 55 dBA in Pahala. With typical background noise levels of 45 to 55 dBA in areas near the mill when it is operating, the heavy vehicle noise would generally be unnoticeable during all sound propagation conditions. When the mill is shut down and the ambient noise levels range from about 38 to 45 dBA, such operations could be heard during propagation Conditions 3 and 4.

The noise levels would generally be fluctuating due to the nature of the sources, as well as due to the sound propagation path, and would be similar to the sounds of heavy agricultural equipment operating at long distances. Such operations from the Industrial Area probably would not violate the DOH noise regulations because the allowable levels would not be exceeded for 10 percent of the time during any 20-minute period.

Public Address Systems and Sirens. Public address (PA) systems and sirens are usually 10 to 15 dBA louder than the higher noise levels in work areas. Table 4.3.3 assumes such sources at 105 dBA at 50 feet would be heard in Pahala during most propagation conditions. If this situation causes a problem, the PA systems can be configured with directive loud speakers and aimed away from town. Also, the speakers could be located to take advantage of shielding by buildings. By use of these techniques, sound reductions of 15 to 20 dB would be achieved. Sirens could be tested at the same time as the Civil Defense sirens and thus not be noticeable in town.

"Open" Machine Shops. Enclosed air-conditioned shops will contain noise sufficiently. There is a potential for exterior noise problems if a heavy, naturally ventilated machine shop that involved grinding, steam cleaning, pneumatic tools, large lathes, and so forth, is in operation. Noise level measurements from a large bus repair shop in Honolulu that had natural ventilation indicated an equivalent source level of 70 to 80 dBA at 50 feet.

Table 4.3.3 **ESTIMATES OF NOISE LEVELS IN PAHALA FROM THE PROPOSED INDUSTRIAL AREA**

Noise Source	dBA @ 50'	dBA at 6,500' Sound Propagation Condition 1	2	3	4
Diesel Engines and	100	29	43	55	65
Generators	90	19	33	45	55
	85	14	28	40	50
	75	4	18	30	40
PA Systems & Sirens	105	31	42	55	65
Directive Speakers	105	11	22	35	45
"Open" Machine Shop	70	2	10	22	32

Source: Darby & Associates, Appendix VIIB (DEIS)

Based on these "worst-case" levels, open machine shops would not be audible at Pahala and the other noise sensitive areas.

Tracking Facilities. Operations at the Tracking Facilities would have low exterior noise level output except for a 2 MW emergency diesel-powered generator unit in the Technical Operations Facility (TOF) which could readily cause 100 dBA at 50 feet if not muffled. If the unit was quieted by 25 dBA, it would still be clearly audible at the Park boundary for all but propagation Condition 1.

Further mitigation measures will reduce the diesel generator noise levels by 40 to 50 dBA making it essentially inaudible at the Park boundary even under condition 4. This effort could involve locating the unit as low as possible, using the Pu`u as a noise barrier, and more effective exhaust silencers and ventilation air duct silencers. Because of the longer distances to Pahala and Punalu`u, the generator at the TOF would not be heard there even if only the basic 25 dB attenuation is provided.

Launch Pad Areas. The major noise sources during non-launch periods are the 500 kW emergency diesel generators, PA systems and sirens. Noise from routine testing of the motor generators should be inaudible at locations outside of the Complex. This statement is based on the discussion of the emergency power plant in the Industrial Area which is much closer to noise sensitive locations. Similarly, sounds from the PA systems and sirens at the launch pads should be inaudible in consideration of the much greater separation distances.

Motor Vehicle Traffic Noise. The increase in traffic noise from Highway 11 that would be caused by project generated traffic was estimated (DEIS Appendix VIIB). The results indicate that the change in the hourly noise levels (HNL) due to the project are less than 1.5 dB at any of the locations. Such a small increase in noise level is not considered significant, particularly as compared to the increase in noise level predicted to otherwise occur (e.g., up to 5.7 dB increases due to future overall traffic noise increase without the project).

Aircraft Activity. No airstrip for fixed-wing aircraft is anticipated for the project, but helicopters would operate from the complex. The spaceport helicopter will be used primarily for surveillance during launch operations. Flights would be concentrated around times of launch operations, although there may be a quick sweep of the facility every couple of days. The helicopter would operate within the Industrial Area for a few hours prior to each launch, with a few landings and takeoffs. There also may also be some flights from Hilo or Kona to bring in dignitaries prior to a launch. The helicopter might also be used in case of medical emergency.

The few flights envisioned are estimated to average about one per day over a year and may be similar to (or less than) the average number of flights involved with agricultural spraying in the nearby areas. On the busiest day (rocket launch day), perhaps there may be 8 takeoffs and 8 landings. The Ldn 55 contours calculated for the project are about 760 feet long and 180 feet wide. They do not extend outside of the project area and will not impact residential areas or the National Park.

Mitigations for Fixed Sources. Technology exists to reduce noise emanating from all fixed sources to very low levels in sensitive areas. Basic techniques involve enclosing the source; absorbing as much internal sound energy as practical; and, if required, providing special sound retarding ventilation systems using acoustically lined ducts and/or duct silencers. Other methods include using earth berms and walls as noise barriers.

Sometimes implementation of high degrees of noise mitigation technology can negatively affect the intended function of the device which is the noise source; can reduce the reliability

of the device; can complicate the servicing and maintenance of the device; and can cause a significant amount of additional energy to be consumed. For these reasons, it is not practical to guarantee inaudibility of all fixed noise sources under all ambient noise and sound propagation conditions. Consideration should be given to establishing a set of noise level regulations for the Rocket Launch Facility which include allowable noise levels not to be exceeded for some percentage of the time based on the time of day similar to the intent of the Hawaii County "Geothermal Noise Level Guidelines."

3.0 Air Quality

Description and Analysis of Effects. The existing air quality in the project area is affected mostly by air pollutants from natural sources, transportation sources, and agricultural activities. Although there are no on-site ambient air quality monitoring stations to measure existing air quality in the project area, the State of Hawaii, American Lung Association, National Park Service, and HECO, have measured air pollutant concentrations on the island of Hawaii (Figure III-1.6).

Under normal operating conditions, fuel loading activities for the Atlas IIAS may result in minimal emissions of RP-1 (kerosene vapor), hydrazine, MMH, and nitrogen tetroxide. RP-1, the Atlas IIAS booster/sustainer propellant, will be vented from the storage tanks during propellant loading operations. Because RP-1 (kerosene vapor) has a very low vapor pressure, operational emissions to the atmosphere are expected to be very small.

Hydrazine, the fuel used for the roll and reaction control system of the Centaur upper stage, will be delivered to the launch pad in a mobile tanker or servicing cart and loaded into the rocket. Because hydrazine has a low vapor pressure and because only a small amount of hydrazine (no more than 375 pounds) will be used for a launch, emissions to the atmosphere will be minimal.

Emissions of trichloroethylene (TCE), which has been used historically as the Atlas rocket engine flush, may be generated during flushing/purging operations performed prior to launch. Emissions from the TCE flushing system could result in high maximum hourly hydrocarbon (HC) emissions. There are no ambient air quality standards for either TCE or HC emissions, but hydrocarbons are precursors to ozone formation.

It is anticipated that Atlas IIAS payloads will be processed at the PPA. Activities that may result in emissions during payload processing include the cleaning of the mating surface before mating of the payload with the mating adapter, and paint touch-ups. The hazards associated with payload processing activities are evaluated in Chapter Five of this EIS.

For the Delta II, small quantities of hypergolic propellants (e.g., hydrazine, MMH, unsymmetric dimethyl hydrazine, nitrogen tetroxide) or their vapors are sometimes released as a result of normal pre-launch operations. In addition, small releases may occur as a result of scheduled post-launch maintenance, when fuel and oxidizer filters are replaced. These releases occur only after the propellant lines have been purged with nitrogen gas to reduce emissions to the lowest practical levels. These small releases cannot be prevented as the system must be opened to change the filters. Releases of these small amounts of these chemicals and their vapors are not expected to result in significant adverse impacts to the environment.

Activities that may result in emissions during payload processing include the cleaning of the mating surface before mating of the payload with the mating adapter, and paint touch-ups.

Combustion products such as carbon monoxide, sulfur dioxide, nitrogen dioxide, particulates and hydrocarbons will be emitted from emergency power generators and other internal combustion engines. Launch vehicle processing, including surfacing and coating operations, could result in minor emissions of hydrocarbons.

Vehicular Carbon Monoxide. An analysis of vehicular carbon monoxide effects was also conducted to assess the impacts of employee vehicular trips on ambient air quality. The projected number of daily vehicle trips is equivalent to a 30 to 40 percent increase in traffic along Highway 11 near the site entrance during peak hours. Vehicles slowing to enter the site or accelerating while exiting the site may cause additional congestion. Impacts of the additional vehicle trips diminish as the distance from the proposed site increases.

Using this projection, the maximum carbon monoxide concentration at roadside between Honu`apo and one mile east of Pahala was estimated. Carbon monoxide emissions were estimated using the U.S. Environmental Protection Agency (EPA)-approved Mobile 4.1 emission model.

Roadside CO concentrations are also influenced by meteorological conditions. As a worst-case estimate, relatively stagnant meteorological conditions were assumed. Adding to the worst-case scenario, peak one-hour traffic volumes were used.

Using emissions predicted from the Mobile 4.1 model as input, the CALINE4 (June 1989 version), was used to estimate the maximum one-hour CO concentrations. Results of the CALINE4 modeling indicate that emissions generated by employee vehicles would increase the ambient concentration of CO less than 0.1 part per million by volume (ppmv) or 114 micrograms per cubic meter ($\mu g/m^3$). Additionally, the maximum incremental increase of CO generated by employee vehicles, together with cumulative increases related to general growth would be about 0.2 ppmv ($229.\mu g/m^3$). The 0.1 and 0.2 ppmv and concentrations represent one and two percent, respectively, of the more stringent one-hour $10{,}000.\mu g/m^3$ HAAQS.

The 8-hour average concentration will be less than the one-hour average concentration. The ratio is typically around 0.65. Even if the two concentrations were equal, however, the total 8-hour concentration of 0.1 ppmv ($114.\mu g/m^3$) and 0.2 ppmv ($229.\mu g/m^3$) would represent less than 5 percent of the more stringent 8-hour $5{,}000.\mu g/m^3$ HAAQS.

Potential Air Quality Impacts. Overall, emissions of the EPA Criteria Pollutants listed in Table 4.2.1 are not expected to exceed the prevention of significant deterioration (PSD) limit of 250 tons/year. Launch exhaust emissions are evaluated in Chapter Five. The effects of launch exhaust emissions on regional and global environments are presented in Chapter Five of the EIS and DEIS Appendices XC and XD. Overall, impacts to the ambient air quality from the Hawaii Spaceport are expected to be insignificant because the emissions are generated intermittently, and are of short duration.

For vehicular carbon monoxide, because Federal and State ambient air quality standards would not be expected to be violated, the air quality impact of mobile sources associated with the proposed project is considered insignificant. Model output and calculations are presented in DEIS Appendix VB.

4.0 Vegetation

The major impact to vegetation from Spaceport operations would be from fire. (The potential impacts of toxic exhausts are described in Chapter Five). Fire-fighting equipment should be available near all areas where substances could ignite, such as: launch pads, propellant and explosive storage areas, and the payload processing area. All personnel working in these areas should be trained in fire-fighting operations.

Native species already in the area should be used if landscaping is needed for the project. These native species are adapted to the environmental conditions of the site and would require little water or soil. (See DEIS Appendix IIIC for a listing of appropriate species).

5.0 Terrestrial Fauna

Noise. The Hawaiian Hawk and Hawaiian Hoary Bat may avoid areas where noise is the greatest, but these noisy areas are probably rarely, if ever, used by these species. The presence of the bat in Pahala indicates that it tolerates some amount of noise and people.

Light. The impacts of facility lighting are likely to vary among the species involved. Additional light would probably be beneficial for the Hawaiian Hoary Bat because lights attract the insects that bats eat. Bright lights might cause any Hawaiian Hawk that might be roosting and nesting in the project area to locate away from the light source.

Endangered and threatened seabirds are more likely to be affected by lights. Seabirds are known to be attracted and disoriented by lights, causing them to collide into buildings.

Structures. Construction of roads and buildings may damage cave arthropod habitats. A few Hawaiian Hawks might increase their foraging area to avoid buildings. There is a possibility that seabirds could collide with a building, fence, or other vertical structure even in the absence of disorientation caused by light.

Mitigation. Strict adherence to the Hawaii County Lighting Ordinance, which requires shielding of lights in the project area, may prevent attraction of endangered or threatened seabirds and thus reduce the probability of collision. Roads and buildings could be sited so as to avoid potential habitats. Chance collisions are by definition impossible to control and depend on the flight path of the birds. One way to minimize the exposure of the project infrastructure to unknown flight paths would be to orient the buildings relative to the potential flight paths. If the long axis of each building or structure was mauka/makai, a bird flying parallel to that axis has the narrowest portion of the structure with which to collide.

6.0 Water Quality

Liquids spilled during launch operations could reach the groundwater underlying the site and potentially effect the nearshore waters. The porous nature of the natural lava would allow spilled materials to reach the water table just a few meters beneath the surface in the vicinity of the coastal launch pads. Qualitatively, there appears to be a large groundwater input along much of the shoreline in the vicinity of the launch pads suggesting that spilled materials would quickly be delivered to the sea. Toxicity is a function of concentration; as soon as any material reaches the groundwater, concentration is declining. Once in the ocean the mixing processes are enhanced suggesting that a potentially harmful spill may not have an adverse impact (Brock, DEIS Appendix IIIE). Results of modeling of spills of two liquid propellants (Aerozine-50, which is miscible in water; and, RP-1 kerosene which is immiscible in water) are presented in Chapter Five of the EIS and in DEIS Appendix IIIB.

To insure that spilled materials do not reach the groundwater, all areas where such materials are handled will be completely contained and built to capture and reclaim any material that may be accidently spilled. Monitoring of concentrations of potential toxins in soils, groundwater and near shore coastal waters will also be undertaken. Water sampling should occur at least bi-monthly during construction and for five years after project operation begins. The testing frequency may be decreased if no adverse impacts are found after this length of time. Monitoring of biomass, biodiversity and species composition of the anchialine pool and the

near-shore habitat may provide early warning of significant impacts. If signficiant adverse effects occur, subsequent follow-up mitigation (appropriate to the situation) will be necessary.

7.0 Potential Impacts to Freshwater Biota

It is assumed that any spilled materials would be toxic to biota residing in either the groundwater or the anchialine pool located on the project site. Modeling shows that spills occuring in the launch pad area would not affect the pool. Because it is not located down-gradient from any other likely spill location, the pool would probably not be affected by spills from other launch facility areas.

The toxicity of anthropogenic materials to organisms residing in the groundwater or anchialine pools is essentially unknown; however, statistically significant increases in inorganic fertilizers (from treated sewage and dry fertilizers) on the Kona coast have had no quantitatively definable impact to these biota despite more than seven years of monitoring (Brock and Kam 1992).

8.0 Potential Impacts to Marine Biota

Sea Turtles. Human activities such as the proposed development potentially pose a threat to turtle populations and their habitat (Shabica 1981). These activities may affect turtles in a variety of ways ranging from direct impacts (such as the physical destruction of nesting beaches and eggs) to more subtle impacts which are chronic in nature. The latter include such things as chemical pollutants impacting the longevity and reproductive capacity of sea turtles. There is no ecotoxicological data for reptiles, therefore, the effect of launch site chemicals on turtles is unknown (DEIS Appendix VIIIB).

Human activities that affect nesting success as well as the survival of adults include the destruction or modification of beaches. No spaceport facilities are proposed near Kamehame Beach, therefore, the beach will not be destroyed or modified by launch operations. Increased controls, such as presented in the Conceptual Shoreline Management Plan (DEIS Appendix XF), will serve to control human activities near the turtle nesting sites and prevent poaching.

Increased artificial illumination may discourage adults from nesting (Brock, DEIS Appendix IIIE). Similarly, artificial illumination may disorient hatchlings as they move across the beach to the ocean. This disorientation may cause hatchlings to move away from the water to ultimately die of desiccation or predation.

Sea turtles nest on the beaches of the Cape Canaveral launch facility in Florida. To alleviate concern over the impact that light may have on nesting and hatchling success, the facility operation has reduced all unnecessary lighting near the beaches and employed low pressure sodium lights with shields. The proposed launch facility will also promulgate similar restrictions in order to comply with the Hawaii County Lighting Ordinance.

In the event of an evening launch, the Cape Canaveral Operational Plan allows lighting only in areas critical to operations and emergency egress. The lighting procedures are inspected by the USFWS for compliance. Restrictions such as these are also required at the Palima launch facility to protect the Mauna Kea Observatories from unnecessary light pollution. See Section VI of this Chapter for further discussion on lighting restrictions at the Hawaii Spaceport.

The only nesting area within the boundaries of the PCZ is at Kamehame. The hill itself is situated right on the shoreline and the nesting beach seaward of it; it is probable that Kamehame Hill will serve to block much of the light from inland sources. However, as a precautionary

measure, it is suggested that a light management plan similar to the Cape Canaveral, Florida facility be developed for Palima Point. This plan should be prepared in coordination with USFWS and the NMFS.

Nearshore Marine Communities. The marine communities fronting the proposed launch facility at Palima Point are situated in a very high energy area, exposed to the northeast tradewinds. The substratum is comprised of pahoehoe and basalt boulders with very little reef development present. The marine resources present in this area are representative of those found in other, high energy Hawaiian nearshore environments.

The development of a launch facility at Palima Point will probably alter the present coastal resource use patterns. If public access is increased, declines in marine resources can be expected. If the PCZ has controlled and limited access, then a decline in marine resources from the fishing public may not occur. More importantly, disturbance to turtle nesting would probably lessen. By virtue of coastal area closure, the Cape Canaveral launch facility in Florida has become an important wildlife preserve simply because coastal development in the area was arrested.

C. INFRASTRUCTURE, UTILITIES AND SERVICES

1.0 Potable and Process Water Supply and Distribution

The proposed rocket launch complex may require approximately 60,000 gallons of brackish water for each launch for the purpose of sound suppression and pad washdown (Parsons Hawaii, 1993). On the basis of two launches each month, an average of about 0.004 mgd would be required. If brackish water is unacceptable because of potential corrosion concerns, then fresh water would be required. Potable water supply for domestic and fire usages are estimated at 0.14 mgd (Parsons Hawaii, 1993). Thus total demand for water at the space facility is estimated to be no more than 0.15 mgd.

Nonpotable water, if used, will be sourced from on-site wells, stored in quantities specified in Chapter Two, and distributed through a dedicated system. Water samples collected from the anchialine pond on site indicate a salinity in the range of 1-2 ppt, well below the characteristic salinities of brackish aquifers in West Hawaii, but still above the potable limit of 0.25 ppt.

Potable water will be obtained either from the existing County system or from new wells. In either case, however, the ultimate source will be aquifers near the project site. Sustainable yield, the rate at which total pumpage can occur without changing the quality or quantity of the draw, has been estimated at 117 mgd for system aquifer system 80503 and 17 mgd for system 80804 (HLA, DEIS Appendix IIIB).

In evaluating the water resources available for the proposed project, future water demands for the Ka'u District were estimated (Figure III-1.13). Without the launch facility, the estimated future (year 2010) demand on Aquifer systems 80503 and 80804 is 12.3 mgd; with the facility at full build-out the estimated total future demand would be 12.5 mgd.

Future supply calculations do not include sustainable yields of both potable and nonpotable water or the accessibility of the water supply. The available data do not provide sufficient information to draw conclusions on the availability of potable water to the project site. If test wells determine that sufficient water is available on-site, a private water supply system

would be developed. A private supply system would need to be designed and operated in accordance with DOH regulations. Chapter Two describes the conceptual water storage and distribution system for the proposed project.

2.0 Electrical Power

Description and Analysis. Electrical power loads were calculated for general indoor lighting, air conditioning and ventilation, and equipment loads for eight areas: payload processing, booster preparation, industrial propellant storage, technical operations, and the launch complexes. Total power requirements are estimated to be 7.5 megawatts. The facility will also need standby diesel generators in case of HELCO system failures.

According to HELCO's projection of planned generation additions and deletions and the load forecast, the system can accommodate the 7.5 MW load addition from the launch facility. This may mean some readjustment in scheduled retirement of certain generating units if geothermal power is not realized according to planned schedules.

The capability of an electric transmission line (at specific voltage level) to deliver a given amount of power to a load point along its path is determined by the size and material of the conductors and the length of the transmission line. The size of the 69 kV transmission line conductors from the Kilauea substation to the Palima site limits the power transmission to 47.8 million volt-amps (MVa). The present load of about 7 MVa plus the projected electric demand of the proposed launch facility (7.5 MVa) would result in a load of 14.5 MVa. This is well within the limits of the conductors; however, the length of the transmission line (over fourteen miles) from the Kilauea substation is such that voltage regulation problems may occur well before the power carrying limits of the conductors is reached.

Portions of the 69 kV transmission line may need to be reconductored with heavy gauge conductors in order to avoid excessive voltage drop in the line (which would result in low voltage to the customers at South Point, for example). Alternatively, a new transmission line could be constructed from the Kilauea substation.

In either case, a new electric substation will be constructed on site. Equipment redundancy and reserve electric power capacity will provide the reliability required by the facilities and launch complexes. The substation will have two transformers, each capable of providing power to the entire complex to provide redundancy needed for reliable service. HELCO estimates construction costs for off-site line extension and a substation on the site to be $2.5 million (from Pahala) or $3.9 million (from the Kilauea substation). These costs would be shared by HELCO and the launch facility developer based primarily on the expected sale of electricity. Further study and analysis will be necessary to determine the best alternative.

A continuous supply of electric power is crucial during certain time periods, in particular during launch countdown and when a launch is in progress. Protection of costly payloads and range safety are of particular concern. Generators will be installed to provide emergency power to back up the range safety, telemetry, and radar complexes.

Potential Impacts and Mitigating Measures. Present HELCO customers will not be adversely affected by the project. New heavy gauge conductors will be installed in the 69 kV transmission line from Kilauea substation to avoid creating low voltage to downline customers. Alternatively, a new transmission line will be constructed from the Kilauea substation.

The standby diesel generators will require permits. An application for Authority-to-Construct permits must be filed with the Department of Health. Applications must

describe the project location, equipment specifications, fuel to be used (diesel, <2% sulfur), and operating schedule (including monthly testing). The application must also include an emissions discussion that quantifies the SO_2 and other air emissions over an annual period.

Appropriate energy efficient and conservation features suitable to reduce peak demand will be built into the project. These will include the use of energy efficient light sources and pumps, designing buildings for energy efficiency, and scheduling industrial loads during off-peak hours to the greatest extent possible.

3.0 Sewerage

The underground injection control (UIC) line, as administered by the State of Hawaii Department of Health (DOH) Clean Water Branch, separates the inland areas above underground sources of drinking water from seaward exempted areas. For much of the site, the UIC line coincides with the coast, so there is no exempted area (Figure III-2.6). DOH regulations require more stringent review and public hearings for sewage effluent injection wells inland of the UIC line.

It is unlikely that injection wells would be allowed in a "Critical Wastewater Disposal Area (CWDA)." As a result, injection wells do not appear to be a suitable choice for the project. Because there is no muncipal sewer system servicing the project site, individual packaged wastewater disposal units would probably be used in each functional area of the launch site (Chapter Two).

If leaching fields are proposed for sewage disposal, they should be placed outside of the CWDA, established by the DOH Wastewater Branch on a county-to-county basis. As shown on Figure III-2.6, the CWDA in the vicinity of the site includes "the coastal area 1,000 feet from shoreline or 100-foot-elevation, whichever is greater." The CWDA was established along the coastline "to protect the accessible, pristine shoreline waters."

4.0 Domestic Solid Waste

Disposal of domestic solid waste will be the responsibility of the launch site operators. Solid wastes are almost entirely nontoxic and can be disposed of at the local landfill. In Ka'u solid wastes are taken to transfer stations and hauled to the landfill in Hilo.

5.0 Industrial Waste Disposal

There are a number of hazardous materials associated with the operation of a rocket launching facility. The launch facility will be required to have available to the public a list of hazardous materials used on-site in accordance with SARA Title III, Community-Right-To-Know. These materials will require special handling and the wastes will need special treatment before disposal.

Hazardous wastes are defined as those that are ignitable, corrosive, reactive, or toxic as per RCRA CFR Part 261.3. Under these guidelines it is up to the waste generator to determine if the waste is hazardous. Hawaii County does not have a permitted hazardous waste disposal site. Currently, hazardous wastes are segregated, stored and disposed of by a certified contractor. Hawaii's hazardous wastes that cannot be neutralized are shipped to the mainland to be incinerated or landfilled.

Hazardous wastes generated by launch activities consist primarily of wastewater, solvents, paints, adhesives, oils, lubricants, fuels, propellants, contaminated rags, and process

chemicals. The greatest quantities of wastes generated by these activities consist of quench water from launch complexes and wastes from the cleaning facility.

There will be chemically active solid wastes requiring controlled disposal and discarded toxic substance containers (pesticides) and so forth. Chemical wastes must be disposed of by methods which are environmentally acceptable. These wastes are identified, segregated, and as applicable, directed to be biologically treated, incinerated, reclaimed or delivered to offsite contractors for disposal in accordance with EPA regulations. Radioactive wastes are considered a special category and are shipped offsite to a Federal repository.

Hazardous waste facilities at the launch site may include a sanitary sewage system, a landfill, freon recovery system, hydrocarbon recovery system, mercury and silver recovery laboratories, incinerators, and staging areas for those materials to be picked up by offsite contractors. Chemical wastes in the staging area will be sent off site for EPA-approved disposal, treatment, or processing by a vendor under contract to the facility.

SECTION I: METHODOLOGY

Most of the analyses that follow in this EIS were based on an Interim Project Description dated June 1991. As findings of the technical and environmental studies became available, recommendations and mitigating measures were incorporated into the Conceptual Plan and Project Description. Because the process was interactive between the EIS studies and plan development, some of the assumptions that appear in the technical appendices were subsequently revised and are, therefore, not consistent with the Conceptual Plan. Every effort has been made to acknowledge these differences in the body of the EIS and evaluate their significance.

A. APPROACH

1.0 Hazard Analysis

The analyses that follow in subsequent sections of this Chapter are primarily hazard analyses. A hazard is defined as an intrinsic property or condition that has the potential to cause an accident or an undesirable effect. In this context a normal launch, as well as an accident, could result in undesirable effects to off-site populations, ecosystems and property under certain conditions.

An accident is defined as an undesired consequence, often associated with an unwanted transfer of energy due to lack or failure of barriers and/or controls. A failure is the inability of a system, subsystem, or component to perform its required function. An event is defined as an internal or external occurrence involving equipment performance or human action that causes a system upset. Because this environmental assessment is on a conceptual project it is not the purpose of the analyses to determine quantitative probabilities of events or failures.

In keeping with the "full disclosure" requirements of the EIS process, worst credible scenarios were assessed. It should be emphasized that these are scenarios that could happen and not scenarios that will happen. This approach used the most conservative assumptions to produce the most extreme effects.

2.0 Limitations of the Analyses

The outcome of an action or accident is usually determined by the specific circumstances present at the time and location of occurrence. There are a number of variations in these circumstances (e.g., weather), however, that can lead to different outcomes. Although catastrophic or "worst case" failures are seldom observed, these extreme events pose the greatest concern for both the public and regulators, and serve as the basis for conservative design, improved management, and regulatory requirements.

Because of the potential risks and wide range of possible circumstances involved, computer modeling is employed to estimate consequences of launch-related failures. Consequences of observed or anticipated accidents are often modeled by extrapolation from small-scale tests, limited observations, simulations, and scoping calculations. Many of the models used in analyzing hazardous space operations have been developed over several decades and continue to be refined as more data becomes available. Models are integral to launch safety systems and operations at the national ranges.

The models used to analyze the various launch-related actions described in the Conceptual Plan were developed for use in real-time operations. They depend upon information that would ordinarily be available in an operating setting (such as equipment, interfaces, environment and procedures). In an operations application, the models are used to quantify the probabilistic impact of an event or failure and to identify conditions when it is unsafe to launch.

When dealing with models, it is important to understand the uncertainties, assumptions, and approximations that are intrinsic to a particular model. Because the EIS is based on a conceptual plan rather than an actual project, much of the information required to run the models was approximated. For this reason, the models were used only to identify if and when "worst case" hazards exist and to evaluate what various measures are available to minimize potential problems. When an actual launch project is known, and more specific statistical and empirical data is available, the "worst case" would be redefined and reevaluated. At that time, the modeling could conceivably produce different "worst case" results.

There may be honest professional differences regarding these assumptions and uncertainties. It is also likely that there will be differences of opinion concerning the evaluation of the effects and the impacts on various aspects of the environment. The preparers have attempted to present an objective evaluation of each scenario based on accepted standards and criteria. Every attempt was made to use the most conservative, thus the most stringent, criteria appropriate to the action being assessed. The reviewer is referred to the Technical Appendices for more detailed explanations of the models and evaluation criteria used in the analyses and the reasons for choosing them.

B. CHEMICALS OF CONCERN (COC)

The Delta 7925 and the Atlas II have been identified as candidate launch vehicles. Another vehicle being considered is the Taurus which is under development. The propellant types and transport quantities for each of these vehicles are given in Chapter Two, Table 2.1.2. Lists of propellants and combustion products for the Delta II, Atlas/Centaur and Taurus are given in Tables 2.3.4, 2.3.1 and 2.3.6 of Chapter Two respectively.

1.0 Solid Propellants

A typical solid propellant rocket motor is comprised of a rubber-like material surrounded by a case of heat-treated steel, titanium, or glass filament. The propellant, which is commonly referred to as HTPB (Hydroxl Terminated Polybutadine), is a DoD Class 1.3 explosive (mass fire). Aluminum powder and ammonium perchlorate are contained in the propellant mixture.

Solid propellants burn at over 6,000 degrees Fahrenheit (F). The material itself is not explosive; however, a solid propellant produces large volumes of gas upon burning, which can lead to rupture and/or explosion. Inadvertent ignition of a solid propellant is difficult when standard safety practices are used.

2.0 Hypergolic Liquid Propellants

Hypergols are rocket propellant mixtures (fuel and oxidizer) that ignite spontaneously upon mixing. Hypergolic propellants include: hydrazine, unsymmetrical dimethylhydrazine (UDMH), monomethylhydrazine (MMH), Aerozine-50, and nitrogen tetroxide. Hypergolic propellant requirements by type and quantity are shown on Figure II-1.4 in Chapter Two. Each of these propellants is discussed on the following pages.

The Hydrazine Fuels. The hydrazine fuels proposed for use at the Hawaii Spaceport include hydrazine (N_2H_4), unsymmetrical dimethylhydrazine (UDMH), monomethylhydrazine (MMH) and Aerozine-50.

Hydrazine. Propellant-grade hydrazine contains a minimum of 97.5 percent basic hydrazine, the remainder is primarily water. In addition to its use as a high-energy rocket fuel, hydrazine is used as a chemical intermediate in the production of pesticides, photography chemicals, pharmaceuticals, antituberculants, and textile dyes, as an oxygen scavenger for boiler waters, and as a polymerization catalyst (RSA, DEIS Appendix VIIIA).

At ambient temperature hydrazine is clear and oily. It has an odor similar to ammonia. Hydrazine has a molecular weight of 32.05, a boiling point of 236.3 °F or 113.5 °C, and a vapor pressure of 14.4 mm Hg at 25°C. Hydrazine gas (fumes) are extremely irritating, hygroscopic, and tend to condense or be adsorbed to surfaces (Ibid.). Exposure of hydrazine to heat, flame, or alkali may result in explosion. When heated to decomposition, this substance emits toxic fumes of nitrogen oxides (NO_x).

Hydrazine is a strong reducing agent. It is flammable in a broad range of concentrations from 4.7 to 100 percent and is hypergolic with some oxidants. Hydrazine is stable under the extremes of heat and cold and contracts on freezing. It will mix with water in all proportions.

The environmental fate and transport of hydrazine is not well understood. This substance and its derivatives are very soluble in water and therefore release of these substances to water may result in drinking water contamination (Ibid.). Hydrazine in soils containing a high percentage of organic carbon is degraded; it is absorbed in soils with a high clay content. It may leach into the groundwater in some soils. Biodegradation may occur at low hydrazine concentrations (Ibid.). Hydrazine undergoes rapid degradation by hydroxyl radicals, ozone, and nitrogen dioxides present in the atmosphere. Please refer to Appendix VIIIA of the dEIS for the results of experimental studies of degradation of hydrazine in the atmosphere.

Toxic effects due to acute exposure in animals involve damage to the lungs, liver, and kidneys, with the liver being the chief site of structural damage. Symptoms include fatty degeneration of the liver, respiratory tract irritation, anemia, anorexia, vomiting, and convulsions. The central nervous system is also affected by exposure to hydrazine.

Hydrazine has been shown to be carcinogenic in several animal species by various exposure routes. Hydrazine has also been shown to be mutagenic in both in vitro and in vivo studies (EPA 1992).

Exposure to liquid hydrazine by humans may result in absorption through the skin, gastrointestinal tract, and lungs due to vapor exposure. The target organs of hydrazine toxicity in humans are the central nervous system, the respiratory system, the skin, and the eyes. Toxic symptoms include respiratory tract irritation and pulmonary edema, eye and skin irritation, dizziness, convulsions, nausea, and vomiting. Kidney and liver damage has also been reported.

Hydrazine is classified by the EPA as a B2 (probable) human carcinogen based on the observation of increased tumors induced in mice, rats, and hamsters upon oral and inhalation exposure.

Unsymmetrical dimethylhydrazine. Propellant-grade unsymmetrical dimethylhydrazine (UDMH) contains a minimum of 98 percent UDMH, the remainder is related amines and water. The chemical is similar in appearance to the other hydrazines. The molecular weight of UDMH is 60.1. This substance is highly reactive and when heated to decomposition, emits toxic fumes of nitrogen

oxides (NO_x). The primary use of UDMH is as a component of liquid jet and rocket fuels. It is also used as an absorbent for acid gases, a plant growth control agent, and in photography and chemical synthesis.

UDMH is stable under ambient temperatures and is completely miscible with water, hydrazine, ethanol, and most petroleum fuels. It is a strong reducing agent, weakly alkaline, and very hygroscopic. UDMH is hypergolic with oxidants and may ignite when it contacts metal oxides. Materials absorbed with UDMH may cause spontaneous ignition. Vapors of UDMH can be exploded by an electric spark or by an open flame.

UDMH present in the atmosphere is expected to result primarily from emissions associated with its use as an aerospace propellant. It has been reported that combustion of rocket fuels based on UDMH and hydrazine produces exhaust gases containing only trace quantities of the unchanged fuel. Once present in the atmosphere, UDMH undergoes rapid degeneration due to reaction with ozone or NO_2. The major product of this reaction is N-nitrosodimethylamine (DMNA).

Toxic effects due to acute exposure to UDMH in animals include respiratory irritation, pulmonary edema, vomiting, convulsions, and hyperglycemia. UDMH has been shown to be carcinogenic in several animal species by various exposure routes. UDMH has also been shown to be mutagenic.

Exposure to UDMH by humans may occur via inhalation, skin absorption of the liquid, and ingestion. This substance is rapidly absorbed by all routes (lung, gastrointestinal tract, skin) and is excreted by the kidneys in the urine. Noncancer health effects from overexposure to UDMH via inhalation include respiratory irritation, pulmonary edema, nausea, vomiting, lethargy, neurological effects, and liver injury.

UDMH has been classified as a possible C, probable B carcinogen to humans by the U.S. EPA Carcinogen Assessment Group and others (RSA, DEIS Appendix VIIIA). The classification for carcinogenicity is based on sufficient evidence of carcinogenic risk in animals.

Monomethylhydrazine. Propellant-grade monomethylhydrazine (MMH) contains a minimum of 98 percent basic MMH, the remainder is primarily water. At ordinary temperatures, it is a clear, oily, white liquid with a fishy odor. It mixes readily with water, alcohol, and hydrocarbons and is stable under temperature extremes. MMH will freeze, but because it contracts upon freezing there is no danger to storage vessels. It is stable to friction and shock, however, catalysts such as iron oxide can cause decomposition and possible ignition.

It is a strong reducing agent, slightly alkaline, and very hygroscopic. It will react with carbon dioxide and oxygen in air. MMH is hypergolic with oxidants and vapors can be exploded by an electric spark or by an open flame. Spontaneous ignition can occur if materials absorbed with MMH are exposed to air (such as saturated rags) due to the heat evolved from oxidation with atmospheric oxygen. A film of MMH in contact with metallic oxides or other oxidizing agents may ignite spontaneously.

MMH is a volatile caustic liquid which can cause systemic toxicity by absorption through the skin, as well as by inhalation. It is a suspected carcinogen. Exposure can result in central nervous system convulsions, kidney damage, anemia, and hypoglycemia. Because of its alkalinity, it is irritating to both the skin and pulmonary tract.

Aerozine-50. Aerozine-50 (A-50) propellant is a 1:1 blend of hydrazine and unsymmetrical dimethylhydrazine (UDMH). At ordinary temperatures, Aerozine-50 is clear, oily and white with an

odor similar to ammonia. A-50 propellent is hygroscopic and mildly alkaline. The vapors react very slowly with air at ambient temperatures to form traces of several products. A-50 is not shock or friction sensitive and shows good thermal stability.

A-50 is flammable in a broad range of concentrations. It is hypergolic with some oxidants. A film of A-50 in contact with metal oxides may ignite as a result of the heat of chemical reaction. Fires may be supported by air or other oxidizers. Vapors of A-50 can be exploded by an electric spark or by an open flame. The liquid is not sensitive to impact or friction.

If spilled on the skin or eyes liquid A-50 can cause severe local damage or burns and dermatitis similar to hydrazine. In addition, it can penetrate skin to cause systemic effects similar to those produced when swallowed or inhaled. If inhaled, the reaction is similar to UDMH. The vapor causes local irritation of the eyes and respiratory tract and systemic effects. On short exposure, systemic effects involve the central nervous system; resultant symptoms include tremors. On exposure to higher concentrations, convulsions and possibly death may occur. Repeated exposures may cause toxic damage to the liver and kidney as well as anemia. Because both hydrazine and UDMH are suspected carcinogens, A-50 is also carcinogenic.

Nitrogen Tetroxide. Nitrogen tetroxide (N_2O_4) is a mixture of nitrogen tetroxide and nitrogen dioxide (NO_2). Propellant grades of mixed oxides of nitrogen are identified by percent weight N_2O_4 with no more than 0.17 percent water equivalent. Nitrogen tetroxide and nitrogen dioxide are used as oxidizing agents in rocket fuel.

Nitrogen tetroxide is a brown liquid under pressure that is an equilibrium mixture of NO_2 and N_2O_4; between -9.3°C and 135°C, the two gases are present as a mixture. Below -9.3°C, the oxides are composed completely of N_2O_4 while above 135°C, the gas is essentially NO_2. Exposure to nitrogen tetroxide due to rocket launching can produce identical symptoms as those from NO_2 and is treated in a similar manner. Reaction of nitrogen tetroxide and nitrogen dioxide with water causes formation of a mixture of nitrous acid and nitric acid. Reaction of nitrogen tetroxide with rocket fuel is explosive.

N_2O_4 is a powerful oxidizing agent containing about 70 percent available oxygen. The fumes are yellowish to reddish brown and have a pungent acidic odor. It is a corrosive oxidizing agent. In the presence of water the corrosiveness of the oxidizing agents are enhanced. Nitrogen tetroxide is very stable at room temperature. At 302 degrees F. it begins to dissociate into nitric oxide and free oxygen, but upon cooling it reforms into N_2O_4.

Liquid nitrogen tetroxide will not burn, but will support combustion. Nitrogen tetroxide may react with combustible materials. It is hypergolic the hydrazines but not with all combustible materials. Non-hypergolic mixtures present an explosion hazard, however, particularly when subjected to elevated temperatures, pressures, or impact. If containers leak the vapors may form explosive mixtures with fuel vapors, especially in confined spaces. There is a possibility that containers in proximity to a fire may pressure rupture and the released vapors form explosive mixtures.

Nitrogen tetroxide is a highly toxic gas with corrosive fumes. When released to the atmosphere it undergoes rapid photochemical degradation with a half-life of about two minutes. The products of this reaction are nitrogen oxide, which can react with moisture in the air to form nitric acid rain or with oxygen to form ozone, and atomic oxygen which can react with water vapor to form hydroxyl radicals.

Nitrogen dioxide has been reported to be absorbed through the lungs into the bloodstream from which it is disseminated to extrapulmonary sites in the body. It is lethal to laboratory animals in certain concentrations. Symptoms prior to death observed in these studies include: convulsions, seizures, change in motor activity, respiratory depression, and pulmonary edema and methemoglobinemia (RSA, DEIS Appendix VIIIB).

Exposure of experimental animals to NO_2 has also been found to result in increased susceptibility to respiratory infection by bacterial pneumonia or influenza virus. Studies indicate that susceptibility to infection is influenced more by concentration of NO_2 than by duration of exposure (Ibid.).

Nitrogen dioxide has been shown to be absorbed through the lungs in exposed humans and to react with blood to form methemoglobin. Acute exposure in humans has been shown to cause increases in airway resistance, which are reversible. Acute human health effects that may occur following human exposure to low concentrations of NO_2 or N_2O_4 include skin, eye and respiratory irritation. Asthmatic individuals are more sensitive than healthy adults in experiencing nitrogen dioxide-induced pulmonary function changes (Ibid.).

In liquid form, nitrogen tetroxide destroys body tissues. It is volatile, releasing yellowish to reddish brown vapors. Because it is corrosive, severe burns of the skin and eyes can result unless it is immediately removed.

The Clean Air Act (CAA) lists a National Ambient Air Quality Standard (NAAQS) for NO_2 of 0.053 ppm as an annual average level. This value has been developed to protect the public health against the chronic effects of NO_2 exposure with an adequate margin of safety, and provides some measure of protection against possible short-term health effects. Sensitive populations (young children and asthmatics) were considered in the establishment of this NAAQS (EPA 1992).

3.0 Non-Hypergolic Liquid Propellants

Cryogenic propellants include liquid hydrogen and liquid oxygen. RP-1 (kerosene), a hydrocarbon, is used as fuel in both the Delta and Atlas.

Liquid Hydrogen. High purity liquid hydrogen (LH_2), a cryogenic (-423°), is a transparent colorless odorless liquid. When observable it is usually boiling vigorously because of its low boiling point, and when exposed to the atmosphere it creates a cloud of condensed water vapor. Liquid hydrogen is non-corrosive. It will form combustible mixtures with oxidizers. Hydrogen gas is combustible with air over a wide range of mixtures. Liquid or gaseous hydrogen will ignite spontaneously with either liquid or gaseous fluorine and chlorine trifluoride.

Liquid hydrogen is chemically stable. Because of its low boiling point it is physically stable only when stored under suitable conditions. The low temperature of liquid hydrogen may cause frostbite when the liquid contacts the skin. In the gaseous form hydrogen can act as an asphyxiant if the concentration is high enough to significantly reduce the amount of oxygen normally present in the air.

A fire hazard always exists when hydrogen gas is present. Hydrogen-air mixtures containing as little as 4 percent, or as much as 75 percent hydrogen by volume, are readily ignited. Unconfined hydrogen-air mixtures generally burn rapidly, but without detonation, when initiated by heat, spark, or flame. Because hydrogen diffuses rapidly in air, it will not form persistent flammable mixtures in open areas. In confined areas, or when ignition of the hydrogen-air

mixture is caused by a shock source equivalent to a small explosive charge, the mixture can detonate. An explosion hazard also exists if liquid hydrogen is contaminated with solid oxygen or solidified oxygen enriched air.

Liquid Oxygen (LOX). Propellant-grade liquid oxygen contains a minimum of 99.5 percent oxygen (O_2), and is an odorless light blue transparent liquid. It boils vigorously at ambient conditions and insulated containers are usually frosted. In either gaseous or liquid form, oxygen is a strong oxidizer that vigorously supports combustion. Liquid oxygen is chemically stable. It is not shock sensitive and will not decompose.

The health hazards of liquid oxygen are associated with its very low temperature (-297°), which may cause frostbite when it contacts the skin. Oxygen gas will not cause toxic effects except that inhalation of very cold oxygen gas may cause some irritation to the upper respiratory tract.

Liquid oxygen does not burn, but vigorously supports combustion. It will cause liquid fuels to cool and freeze if both liquids are brought together. Such a mixture is shock sensitive and may react with the violence of a detonation. Two types of combustion reactions are possible, depending on the conditions of mixing and ignition. Thus fuel and oxygen may be mixed without a consequent fire, but detonation occurs upon ignition or mechanical shock of such a mixture.

When mixed with liquid oxygen, all materials that burn are explosive hazards. An explosion may be initiated by static electricity, mechanical shock, electrical spark, and other similar energy sources particularly when mixtures are frozen.

Kerosene (RP-1). RP-1, a hydrocarbon, is a clear liquid which is chemically stable and reacts only under the strongest oxidizing conditions or at extremes of pressure and temperature. It is flammable and the vapors can form explosive mixtures in air. RP-1 is a skin irritant and repeated contact can cause scaling and blistering. Inhalation can cause narcosis, however the effects are unlikely except in closed spaces without adequate ventilation. The primary health risk occurs if the propellant is swallowed. Introducing the liquid into the lungs by gasping or aspiration can cause chemical pneumonitis.

RP-1 hydrocarbon fuel vapors readily form mixtures with air that can be ignited by electric sparks, static electricity, open flames and numerous other sources. RP-1 fires may be supported by either air or an oxidizer. Air supported fires may be controlled by use of agents such as water, fog, foam, carbon dioxide, dry fluidized bicarbonate based powders or vaporizing liquids. Methods involving water-based agents may be used to control oxidizer supported fires.

If RP-1 propellant and oxidizers are allowed to mix, the resultant mixture can explode. This hazard exists for high vapor concentrations of the fuel and oxidizer as well as liquid mixtures.

4.0 Combustion and Decay Products

Aluminum Oxide. In powder form, aluminum is a component of missile fuel and chemical explosives. The molecular weight of aluminum oxide (Al_2O_3) is 101.94. This compound exists in a number of natural and synthetic forms and has been detected in rocket exhaust. Aluminum is the third most abundant element in the earth's crust, comprising 8.3 percent of its volume and ranging up to 10 percent of the composition of rock. Due to its ubiquitous presence in soil, air, and water, it is commonly found in food and drinking water. Thus, environmental exposure to this substance is virtually universal. The human average daily intake of aluminum has been reported to be 30-50 mg/day via ingestion (DEIS Appendix VIIIA). The average human body

burden has been estimated to be 100 mg (1.4 mg/kg).

The major sources of aluminum in the human diet include plant material and processed foods. Aluminum has been shown to be essential for some groups or species of plants although in excess it can also be toxic to plants causing overall stunting, dark green leaves, purpling of stems, death of leaf tips, and damaged root systems. In most plants, symptoms of aluminum toxicity appear first in the roots.

Upon inhalation, aluminum is deposited in the lungs where retention of 90 to 100 percent of inhaled Al_2O_3 particles down to 1 μg occurs. Plasma proteins bind 70 to 90 percent of the aluminum present in the body and gastrointestinal absorption of this substance may occur. The kidney is responsible for elimination of a major portion of absorbed aluminum via the urine.

Inhalation exposure of laboratory animals to dusts of aluminum oxide show that this substance is retained in the lungs. The initial physiological response appears to be proliferation of blood cells which may result in lipoid pneumonia. A pattern of bronchopneumonia, emphysema, and/or severe fibrosis due to inhalation of this substance has also been described. A one hour exposure of rats and mice to 478 $\mu g/m^3$ of Al_2O_3 did not result in mortality or serious signs of poisoning up to 10 days post-exposure (Ibid.).

In general, aluminum has largely been considered as nontoxic to humans although it can affect the absorption of other elements in the gastrointestinal (GI) tract and alter intestinal function. Aluminum toxicity appears to be limited to inhalation of the dust and oxide. Pulmonary damage in the form of fibrosis and emphysema with symptoms of cough and shortness of breath has been reported as a result of short-term exposures to high levels of Al_2O_3. Orally, a very high dose of aluminum may cause a toxic syndrome which involves irritation of the GI tract (Ibid.).

Hydrogen Chloride. Hydrogen chloride (HCl) is a strongly acidic substance with a molecular weight of 36.46. At high temperatures, this substance will decompose into hydrogen and chlorine.

Chloride, mainly as sodium chloride, is present in the following food sources: salt, breakfast cereals, breads, dried skim milk, teas, eggs, margarine, salted butter, bacon, canned meats, fish and vegetables, snack foods, and olives. Chloride is also present in water, at levels dependent upon the geochemistry of the surrounding area and the presence of contamination. At concentrations above the secondary maximum contaminant level (MCL) for this substance of 250 mg/l, water has a salty taste.

High levels of gaseous hydrogen chloride in air have been shown to adversely affect plants, with broadleaf plants being generally more sensitive than coniferous plants. Symptoms observed in broadleaf species include discoloration on leaf edges and spotting while symptoms observed in coniferous species include discolored needle tips. Grains and grasses also show symptoms of discoloration on tips and edges of leaves. The degree of damage due to HCl exposure is related to the dose of the gas in air and the relative humidity of the exposure environment. A relative humidity threshold exists for a given dose above which injury to plants will be severe and below which injury will be minimal (Ibid.). Hydrogen chloride also acts as a strong irritant to exposed animals.

Inhalation exposure of humans to hydrogen chloride gas may cause symptoms of coughing, choking, and inflammation and ulceration of the respiratory tract. Persons with respiratory problems may be more sensitive to low level exposures to hydrogen chloride gas or mist than

persons without such problems. Workers exposed to this substance have displayed symptoms of dermatitis, photosensitization, gastritis, and chronic bronchitis (Ibid.).

Atmospheric corrosion, in which damage to building materials, property, and pitting of metallic surfaces occurs, is dependent upon temperature, relative humidity, sunlight, and the presence and types of particulate matter and trace gases in the atmosphere. Chlorine and hydrogen chloride dissolved in water are very corrosive substances and, when present in the atmosphere, may initiate or aggravate property corrosion. The concentrations of HCl required to accelerate atmospheric corrosion, however, is not known (Ibid.).

Nitrosodimethylamine (DMNA). The commercial production nitrosodimethylamine (dimethylnitrosamine or DMNA) was suspended in 1976. It was used as an intermediate in the manufacture of UDMH.

DMNA is a liquid at room temperature with a boiling point range of 304 to 307 °F (151 to 153 °C) and a vapor pressure of 2.7 mm Hg at 20°C. The molecular weight of this substance is 74.08. DMNA is photochemically reactive. It is also combustible but when heated to decomposition it emits toxic fumes of nitrogen oxides.

DMNA has been detected in the ambient air of several large cities, in the passenger area of new cars, in smoke-filled rooms, in mainstream cigarette smoke, in sidestream cigarette smoke, and at a number of industrial sites. It is also present in a variety of foods including cheeses, soybean oil, canned fruit, meat products, fish products, and alcoholic beverages.
DMNA released to the atmosphere is not expected to be persistent but rather is rapidly decomposed by sunlight with an atmospheric half-life ranging from about 5 minutes to 7 hours.

Human exposure to DMNA may occur via ingestion of foods that contain it, ingestion of contaminated drinking water, inhalation of ambient air and cigarette smoke, and dermal contact. The symptoms that have been reported due to acute, short-term exposure to DMNA include nausea, vomiting, abdominal pain, diarrhea, headache, fever, and weakness. Case reports of acute exposure to high concentrations of this substance have shown liver toxicity, necrosis, and death.

Chronic noncancer health effects due to exposure to DMNA include jaundice and liver damage. This substance has also been reported to affect male and female reproductive capacity. The U. S. Environmental Protection Agency (EPA) has classified DMNA as a class B2 (probable human) carcinogen based on the induction of tumors at multiple sites in rodents and other non-human mammals exposed by various routes.

DMNA is rapidly absorbed from the gastrointestinal tract and lungs in exposed animals. Once absorbed, it is distributed throughout the body and excreted in expired air and urine with a biological half-life in rats, mice, and rabbits of approximately 4 hours. The acute health effects observed in animals exposed to DMNA by several routes of exposure include liver necrosis, internal bleeding, and jaundice. The 4-hour LC_{50} for rats is reported to be 78 ppm.

N-nitrosamine substances have been shown to be teratogenic, mutagenic, and carcinogenic in experimental animals. They are systemic carcinogens, meaning that they are effective by all routes of administration. Some n-nitrosamine substances are capable of inducing tumors after a single dose. DMNA is mutagenic in bacterial systems and is structurally related to known carcinogens. Evidence suggests that the carcinogenicity of this substance is dependent upon its *in vivo* metabolic activation.

Formaldehyde Dimethylhydrazone. Formaldehyde dimethylhydrazone (FDH) is a decay product of UDMH decomposition and exposure standards have not been established for this substance.

Toxicological information specific to FDH was not available from any data base with the exception of two citations which did not address the toxicological properties of this substance, but were limited to its identification as a decay product of UDMH. In the absence of toxicological information specific to formaldehyde dimethylhydrazone, it is assumed that the toxicological properties and acceptable exposure levels of FDH are equivalent to the properties and levels of its parent compound, UDMH.

5.0 Pressurization and Transfer Gases

Pressurization and transfer gases are used to transfer liquids, pressurize components and purge systems. Pressures range from 2 psig to 6,000 psig depending on the intended use. The two inert gasses evaluated in this section to be used for pressurization and transfer are Gaseous Nitrogen and Helium.

Gaseous Nitrogen. Nitrogen gas is colorless, odorless and tasteless. Gaseous nitrogen (GN_2) is inert and non-flammable and will not support combustion. Normally it will not combine with other materials and it is only slightly soluble in water. It is soluble in liquid oxygen and may be used to pressurize liquid oxygen in special cases if the contact time is short and the interface area is small. It is chemically stable.

Gaseous nitrogen presents no significant health hazards. It is non-toxic but may cause an oxygen deficient atmosphere if released in confined spaces.

There are no fire hazards associated with GN_2; it will not explode and may even be used to dilute an explosive atmosphere to below the lower explosive limit.

Gaseous Helium. Helium gas is colorless, odorless, and tasteless; it is inert and non flammable and will not support combustion or combine with other materials. It is only slightly soluble in water and is chemically stable. Helium gas is non-toxic but may cause an oxygen deficient atmosphere if released in sufficient quantity in confined spaces. Gaseous helium presents no fire hazard. It will not explode and may be used to dilute an explosive atmosphere to below the lower explosive limit.

C. MODELS USED IN THE ANALYSIS OF ROCKET EXHAUST AND LIQUID SPILLS

The Rocket Exhaust Effluent Diffusion Model (REEDM) was used to simulate buoyant exhaust clouds produced by the combustion of rocket fuels. Dispersion of non-buoyant chemical releases was predicted with the Air Force Toxic Chemical Dispersion Model (AFTOX). Detailed descriptions of REEDM and AFTOX are presented in Appendix VID of the dEIS. The migration of typical liquid propellants released over the ground surface was investigated using numerical modeling techniques (see HLA, DEIS Appendix IIIB).

1.0 Rocket Exhaust Effluent Diffusion Model (REEDM)

Cloud Rise and Dispersion Computations. Most gas diffusion models assume that the dispersing gas being dispersed is neutrally buoyant with respect to the surrounding air. The combustion of energetic rocket fuels produces large volumes of hot exhaust that do not cool quickly to the prevailing ambient temperature. Such a thermally buoyant cloud is acted upon by an upwardly directed buoyant force that tends to accelerate the cloud. As the cloud moves upward, it entrains ambient air that dilutes it and lowers its temperature thereby reducing its total buoyancy.

At some point during its rise, the temperature of the exhaust cloud reaches the prevailing ambient temperature. At this time, the cloud is considered to have stabilized. The rate of air entrainment and the rate of temperature chance in the vertical air column are key factors affecting the height to which a buoyant cloud will rise. The air temperature normally decreases with increasing altitude at a rate known as the temperature lapse rate. When the lapse rate is high, the atmosphere tends to be unstable in the sense that a parcel of air displaced upward into cooler air will tend to continue moving upward. A stable air mass results when the air temperature remains constant or increases with increasing altitude. The latter condition is known as a temperature inversion.

The presence of an inversion layer affects the dispersion of pollutants in the atmosphere by restricting vertical mixing to the region between the ground and the base of the inversion. A rocket exhaust cloud may possess enough thermal buoyancy to penetrate a low level inversion in which case the pollutants in the cloud will tend to be trapped above the inversion and not pose a hazard to people at around level. Inversions from 500 to several thousand feet above the ground can trap a buoyant exhaust cloud below the inversion and these conditions produce the greatest potential for hazardous ground level concentrations.

The REEDM program uses an iterative technique to compute the decay of exhaust cloud buoyancy and to estimate the final stabilization height of the exhaust cloud. Exhaust cloud material is placed above or below the inversion layer (if present) based on the relationships between cloud size, stabilization height and inversion base height.

Dispersion of exhaust materials are modeled starting from the position of the stabilized exhaust cloud. The REEDM program uses a Gaussian diffusion model to predict the ground level concentrations of the hazardous materials downwind from the source cloud. The dispersion coefficients that determine the rate of plume growth are based on measurements or estimates of vertical and horizontal turbulence. Since measurements of turbulence at altitudes above ground level are usually not available, it is typical to operate REEDM using a climatological model to estimate turbulence. This was done for the Hawaii REEDM test cases.

When an inversion is present, and exhaust material is located below the inversion, the diffusion calculations are based on the assumptions that the pollutants are reflected off the base of the inversion and the around. This method is conservative in that it produces the highest estimate of downwind concentrations.

REEDM Output. The model provides both tabular and graphical output. Tabular data lists the critical input parameters and computed values for total dosage, centerline peak concentrations, and time mean centerline concentration user specified intervals downwind from the source location. The species that can be tracked are: HCl, aluminum oxide, N_2O_4, UDMH, DMNA, FDH, CO_2 and CO. The graphical output displays meteorological profile data and concentration or dosage contours. The contour plots include a map background showing coastline, highway, and population center information, which provide a good visualization of areas affected by the exhaust plume.

Another way of presenting the predicted concentrations is to compute the peak centerline time mean concentration and determine the variation of concentration as a function of downwind distance. The centerline is a line that passes through the peak concentration point along a sequence of downwind distances. The REEDM dispersion model uses a classical Gaussian plume growth assumption to define the crosswind growth of the exhaust cloud as it advects downwind.

Figure V-1.1 illustrates the concepts of Gaussian material distribution and a centerline track applied to an exhaust cloud moving downwind. The centerline time mean concentration is computed by defining the peak instantaneous concentrations in the downward direction of the plume. As the Figure shows, the cloud of pollutants that emanates from a launch event travels in a downwind direction from the launch site with the highest concentrations in the center of the plume and the lowest on the sides. The concentration profile appears as a Gaussian or bell-shaped curve. By this method, the 30-minute time mean concentration (the concentration of pollutants averaged over 30 minutes) and predicted centerline peak instantaneous concentrations can be estimated at varying distances from a site.

Figure V-1.2 is a plot of the peak instantaneous concentration, 30-minute time mean concentration and dosage of HCl for worst case meteorological conditions and a normal launch exhaust cloud. Note that the peak values occur some distance downwind from the launch site. This is because the exhaust material rises above the ground to the cloud stabilization height (in this case, 458 meters, about 1500 feet) and then diffuses back to the ground as it is blown downwind.

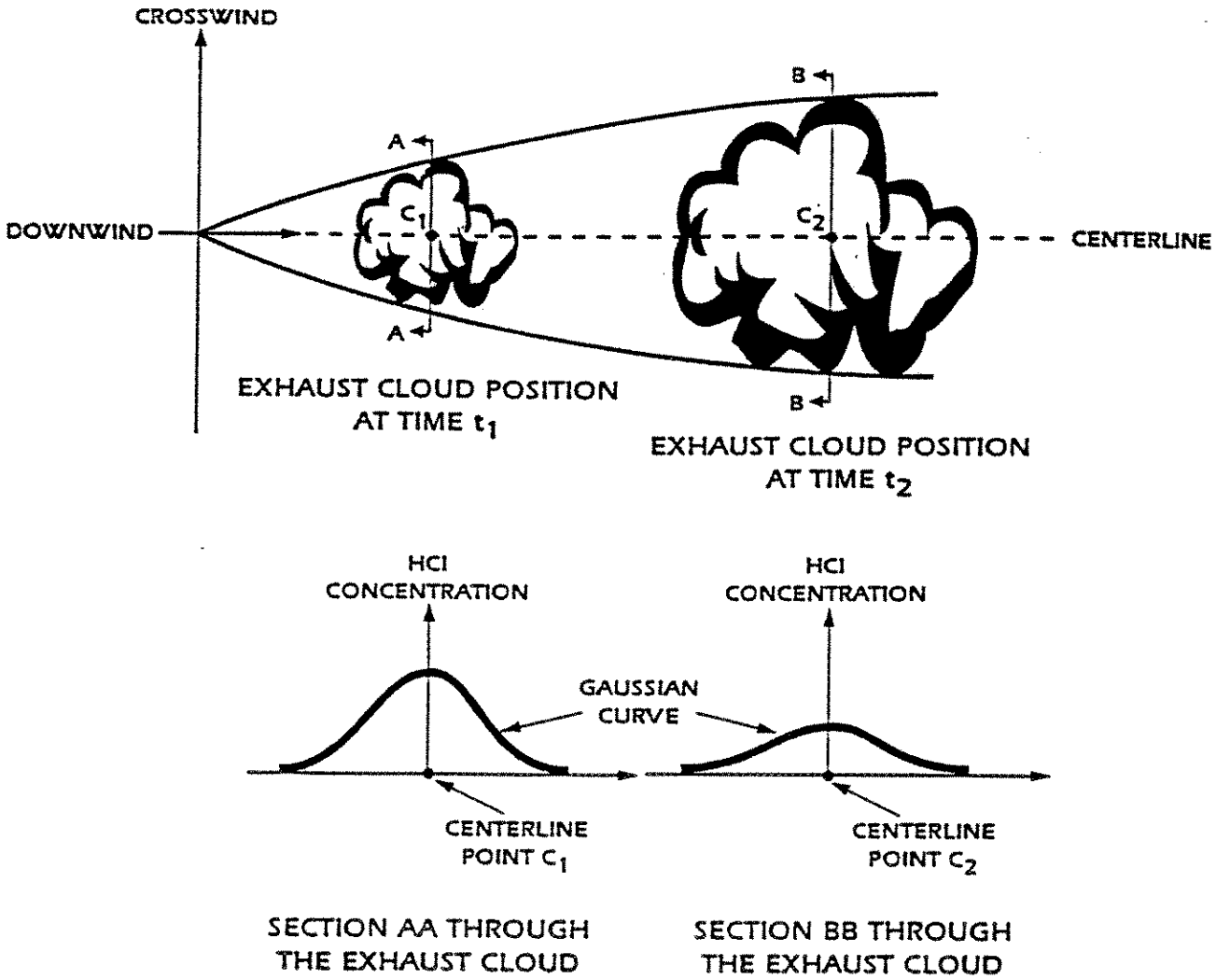
Windfield Solution Options. The above analyses are based on the assumption that exhaust cloud transport is along a straight line from the launch site to the receptor location. This type of analysis neglects the presence of the mountainous terrain of Hawaii and solves the dispersion problem as though Hawaii were a flat plain. To obtain an assessment of the terrain influence, four meteorological cases were run using the REEDM windfield solution option. The net effect of using the windfield information is a recomputation of the plume centerline position. The rate of dispersion, which is governed by the turbulence, is the same for both windfield and non-windfield solutions. Figures V-1.3 and V-1.4 show non-windfield and windfield solutions for the Kona weather case.

Dispersion of an exhaust plume in mountainous terrain is dependent upon interaction of wind and terrain. REEDM has an optional windfield solution module that attempts to solve the complex interaction between a uniform upstream windfield and mountainous terrain downstream. In order to use this windfield option, available rawinsonde soundings must represent the unperturbed uniform windflow over the ocean upstream from the island. For Palima Point this condition is satisfied in a Kona weather pattern and the tradewind cases are borderline. For those cases where windfield solution was appropriate, the option was used to predict the downwind location of the exhaust plume.

Without a more extensive set of upper level winds measured at various points around the island, it is difficult to assess the absolute accuracy of the windfield solution. Rather than taking the windfield solutions as being a highly accurate prediction of the wind/terrain interaction, it is recommended that the windfield solutions be viewed as a general indication of the channeling and deflection of the winds at some distance from the Palima Point site. The effect of complex terrain is to add an additional uncertainty to the prediction of the direction of transport of the rocket exhaust products. The conservative approach straight line transport to all identified receptors maximizes the predicted concentration because any deflected path produced by the windfield will require a longer travel distance of the exhaust cloud.

2.0 Air Force Toxic Diffusion Model (AFTOX)

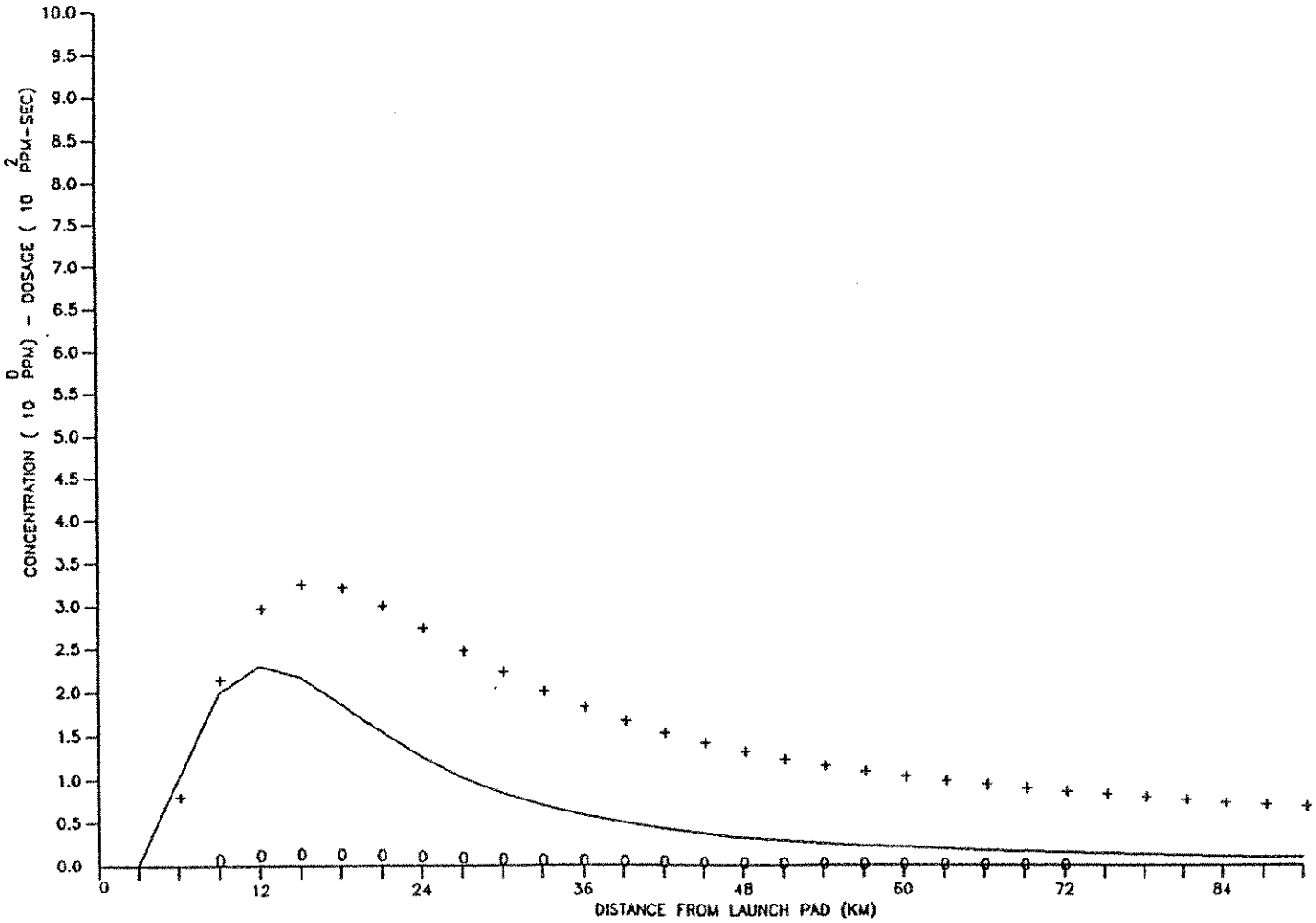
Accidental spills of propellants or cryogenic liquids can occur during routine handling and transportation operations at the launch facility. Typically only a single chemical is involved in an accidental spill thereby minimizing the likelihood of an explosive reaction. Under these conditions, the spill is characterized as a pool of evaporating liquid or as a gaseous cloud that is neutrally buoyant. A class of dispersion models, commonly known as cold spill models, were



Source: ACTA, Inc.
DEIS Appendix VI-D

Figure V-1.1

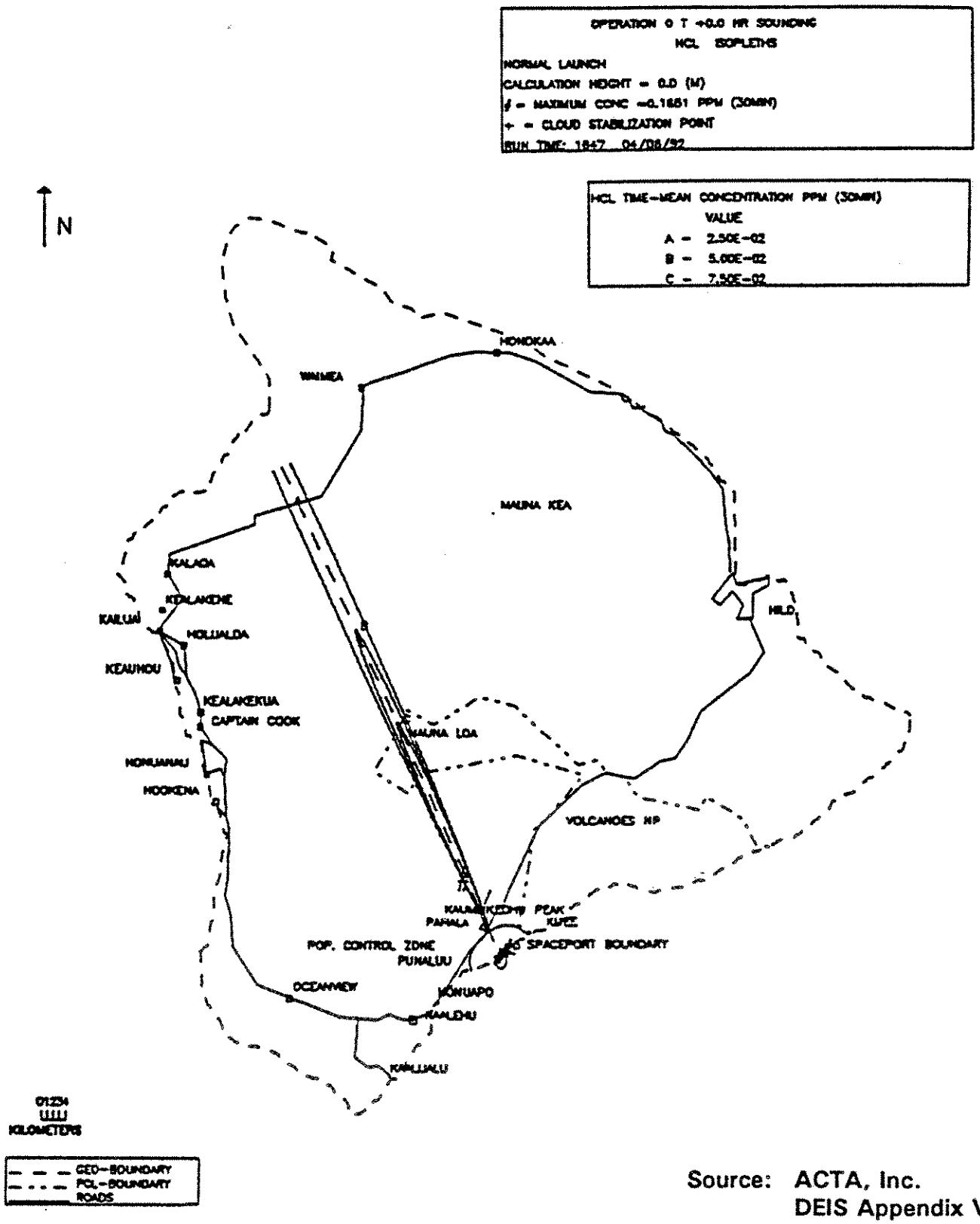
GAUSSIAN MATERIAL DISTRIBUTION AND CENTERLINE



——— Concentration
+ + + + Dosage
0 0 0 0 30-Min. Ave. Conc.

Source: ACTA, Inc.
DEIS Appendix VI-D

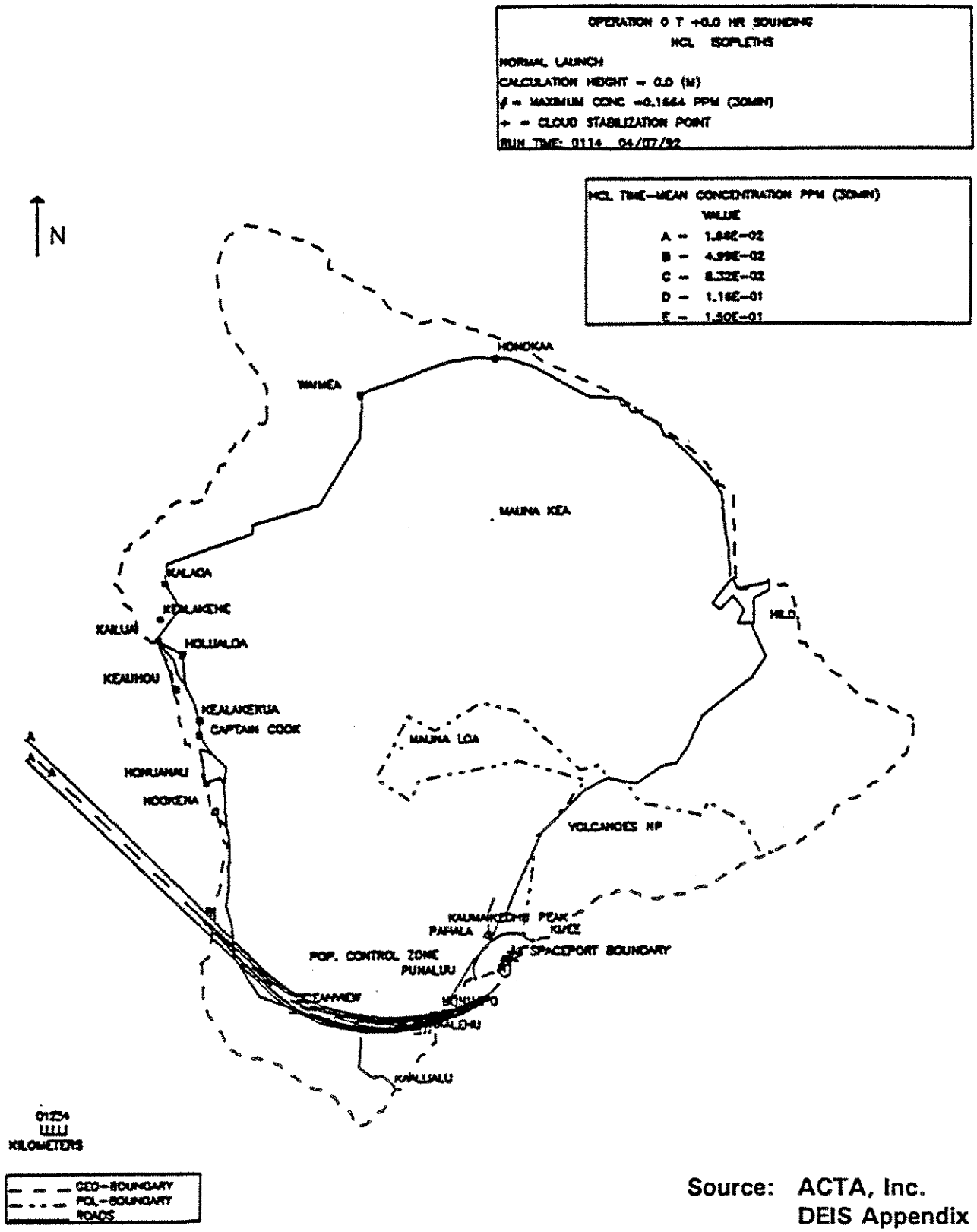
Figure V-1.2
PEAK INSTANTANEOUS CONCENTRATIONS AND 30 MINUTE TIME MEAN (AVERAGE) CONCENTRATIONS FOR HCl



Source: ACTA, Inc.
DEIS Appendix VI-D

Figure V-1.3

KONA WEATHER HCl ISOPLETH (NON-WINDFIELD SOLUTION)



Source: ACTA, Inc.
DEIS Appendix VI-D

Figure V-1.4

KONA WEATHER HCI ISOPLETH (WINDFIELD SOLUTION)

developed to model the dispersion of neutrally buoyant or denser than air gases produced from liquid spills or pipeline leaks. AFTOX was designed to model these types of releases and provide an estimate of downwind concentrations.

Like the REEDM program, AFTOX is based on the Gaussian puff dispersion equation. Unlike REEDM, AFTOX utilizes only a single surface wind to represent flow at the spill site. The program has been evaluated against diffusion test experimental data from field tests. The program was officially endorsed by the Air Force in 1988.

It should be noted that the field tests which provided data to validate AFTOX only measured concentrations out to 8 or 10 kilometers from the source point. Although it is generally accepted that the model provides acceptable predictions over downwind distances of 5 to 10 kilometers - in homogeneous terrain and under persistent meteorological conditions - for purposes of this EIS, the model was applied to locations out to 50 kilometers from the source. The predictions at distances greater than 10 kilometers are believed to be conservative, because the model is applied in a manner that errs toward over estimating concentrations at these outer locations. For an EIS, it is appropriate to consider that the winds could at some time carry the dispersing chemicals toward the receptors of interest. This is a different problem than attempting to provide an accurate prediction for a downwind receptor on a given day, using specified wind measurements at the spill source.

Worst case conditions for accidental spills were defined in terms of surface wind speed, ambient temperature, time of day, and spill pool area. Worst case conditions generally occur at night, under light wind conditions, with a low level thermal inversion present in the lower atmosphere. Spill quantities used in the model simulations were based on maximum vehicle tank volumes or individual storage and transportation container sizes.

3.0 LEACHM and MOC

Assumptions of the Analysis. Conceptually, it is expected that propellants released over the ground surface will infiltrate, percolate downward through the unsaturated zone to the groundwater surface, and then migrate horizontally with the groundwater either as a solute (in the case of miscible liquids) or a floating separate-phase liquid. Groundwater in the area of the proposed spaceport generally flows seaward and discharges from the subsurface at the shore of the ocean as dispersed fresh or brackish springs.

Among various rocket propellants that may be used, one liquid propellant that mixes with water (miscible), Aerozine-50, and one liquid propellant that does not mix with water (immiscible), RP-1 (kerosene) were chosen for modeling.

Miscible Propellant. The maximum amount of Aerozine-50 in a single vessel without secondary containment would be 615 gallons in a fully fueled vehicle on a launch pad. The spill scenario assumes that the entire 615 gallons could be released in a sudden accident and would infiltrate the subsurface in a small area near the launch pad.

Immiscible Propellant. The maximum amount of RP-1 at risk would be 15,676 gallons in a fully fueled Atlas. The spill scenario assumes that the entire 15,676 gallons could be released in a sudden accident and would infiltrate the subsurface in a limited area near the launch pad.

For the purpose of numerical modeling, the subsurface was assumed to be fresh, layered basalt with a hydraulic conductivity of 3,000 feet per day, porosity of 0.1, longitudinal dispersivity of 328 feet and transverse dispersivity of 98 feet. Based on measurements of wells in the region, the hydraulic gradient in the aquifer is about four feet per mile towards the sea.

The effects of propellant releases to the atmosphere above the site from exploding vehicles were also considered. For modeling purposes, it was assumed that half of the vehicles propellant capacity would be released and would reach the ground surface in a roughly circular area, about 1,000 feet in diameter (covering 18 acres), at an elevation of 500 feet and 3,000 feet from the shore.

LEACHM. The vertical migration of liquid propellants through the unsaturated zone was simulated by use of a finite difference model (LEACHM). Major assumptions upon which the simulation is based include:

- Homogeneous and isotropic aquifer permeability;
- No lateral migration in the unsaturated zone;
- The propellants do not dissolve or volatilize in the subsurface; and,
- The propellants infiltrate uniformly.

MOC. The horizontal migration of propellants in the saturated zone was simulated by use of a two-dimensional solute transport model developed by the U.S. Geological Survey called MOC. The model assumes that:

- Changes in chemical concentration within a dynamic groundwater system are primarily due to convective transport and mechanical dispersion, while molecular and ionic diffusion are negligible;

- Homogeneous and isotropic aquifer permeability; and,

- Fuels do not volatilize in the subsurface.

The model was developed to simulate transport of dissolved contaminants (miscible chemicals), but can also be applied to thin layers of immiscible liquids that are less dense than water and float on the groundwater surface. This application is an approximation for estimation of the quantity of kerosene leaving the aquifer at the shore.

D. METHODS USED IN THE COMPUTATION OF DEBRIS EFFECTS

1.0 Description of the Event

Range safety systems are designed to contain rockets or debris from destroyed rockets within boundaries so that people and property are protected. The destruction of a rocket during launch produces a breakup either due to explosive charges or by aerodynamic and inertial forces. The exact boundary of the debris pattern cannot be predicted absolutely because of the uncertainties in the wind, drag, velocity imparted by the explosion, vehicle dynamics at the time of destruct, etc. Consequently, a probabilistic debris pattern is computed whose boundaries express a probability of non-exceedance of impacts of debris.

The debris pattern is dynamic, that is, it changes progressively during the flight. Very early in the flight, because of the low altitude, the spread of debris is limited. As the vehicle rises, the debris can spread over a larger area. The wind becomes a bigger contributor to drift as the altitude increases. Pieces of debris with lower weight to drag ratios (e.g., pieces of sheet metal versus more massive pumps) fall at a slower velocity and thus are more influenced by the wind. The debris pattern, therefore, is computed for a range of ballistic coefficients. The most convenient way is to select distinct categories of ballistic coefficients

(W/C_dA or "weight to drag" where W is the weight, C_d is the drag coefficient, and A is the cross-sectional area). "Weight to drag" is also represented by the beta symbol (ß).

2.0 Computation of the Debris Pattern

The LARA (Launch Risk Analysis) model was used to analyze debris patterns for both intentional and unintentional in-flight rocket destruction. LARA is currently used at Vandenberg AFB; Cape Canaveral AF Station is adopting the same conceptual model.

The debris pattern computation accounts for both the nominal (mean) impact points for the debris and the potential dispersions around these nominal impact points. The nominal impact points (like the dispersions) must consider the aerodynamic characteristics of the debris. The major sources of uncertainty are: (a) dispersion of the debris due to wind; (b) uncertainty due to lift effects on falling debris; (c) dispersion of the debris due to velocity imparted by an explosion; (d) uncertainty in the impact point prediction due to uncertainty or variability in the predicted coefficient or the spread of the ballistic coefficients in the particular debris category; (e) behavior of the vehicle in the period from the time of observation to the time of destruct; and, (f) position (state vector) uncertainty due to instrumentation and filtering errors. (The state vector uncertainty due to instrumentation is expected to be relatively small and is not implemented).

The results from the mathematical analysis for impact dispersion are expressed in the form of a bivariate (x,y) normal distribution describing the likelihood of impact of a single fragment having a particular ballistic coefficient. From this density function, elliptical contours of equal probability density are determined to show the likelihood of impacting within a particular region. The contours represent a specified probability that no more than one fragment will exceed the contour in a direction critical to safety. (See ACTA Inc., DEIS Appendix VIIA for a complete discussion of the debris dispersion methodology).

E. METHODS USED IN ESTIMATING ACOUSTICAL NOISE IMPACT

1.0 Assumptions

The analysis considered the acoustic environment that could be generated by the "most energetic" of any one of four possible booster systems: an Atlas II AS, Delta II, Taurus or Scout booster rockets, augmented, where applicable, by strap-on Solid Rocket Motors (SRM). The launch trajectory was assumed to be made either due East or South. The analysis includes an estimate of the acoustic power generated by each rocket system, an evaluation of their sound power spectrum and the apparent directivity of a moving rocket noise source during launch. Propagation effects considered include the atmospheric absorption of sound at high altitudes using typical weather profile data for the site augmented by an ISO Standard Atmosphere model above 20,000 feet.

Also considered were ground and typical refraction effects on sound propagated close to the ground during the first part of the launch. As sound waves move through the atmosphere, the energy of the waves are weakened (attenuated) as the distance from the source increases. The factors affecting the amount or level of attenuation include distance traveled, the frequency of the sound waves, the relative humidity, temperature, wind velocity, and the elevation of the source and receiver, as well as the characteristics of the ground surface between the source and the receiver in some cases.

In general, four distinct conditions or combinations of factors can be defined which affect

the rate of attenuation of sound. These conditions, which are illustrated in Figure V-1.5, are described as follows:

Condition 1 - Receiver Upwind. The fact that wind speed increases with altitude causes the effective sonic velocity to decrease with altitude (or a negative gradient) and the raypaths are seen to bend above a receiver located upwind.

Condition 2 - Standard With Excess Attenuation from Shielding. If there is no wind, and temperature is constant, the sound ray paths are straight. But if the ray paths are blocked by buildings, berms, etc., and/or graze over foliage, soft earth, a'a lava, etc., then noise levels are typically diminished.

Condition 3 - Inversion and/or Receiver Downwind. A positive sonic velocity gradient causes the sound ray paths to bend over shielding elements and foliage such that there are only sound spreading losses and absorption losses in the atmosphere. Also, this condition often exists if the source is elevated such that the sound ray path is not near the earth and the sound rays are not sufficiently refracted to cause focusing.

Condition 4 - Caustic Focusing. The wind and temperature conditions can cause a complex sonic velocity profile such that sound ray paths converge at a "caustic" where the receiver is located and elevated noise levels are possible. For a given geometry and terrain between the source and receiver, meteorological conditions can cause the sound level at the receiver to vary more than 30 dB.

2.0 Prediction Model

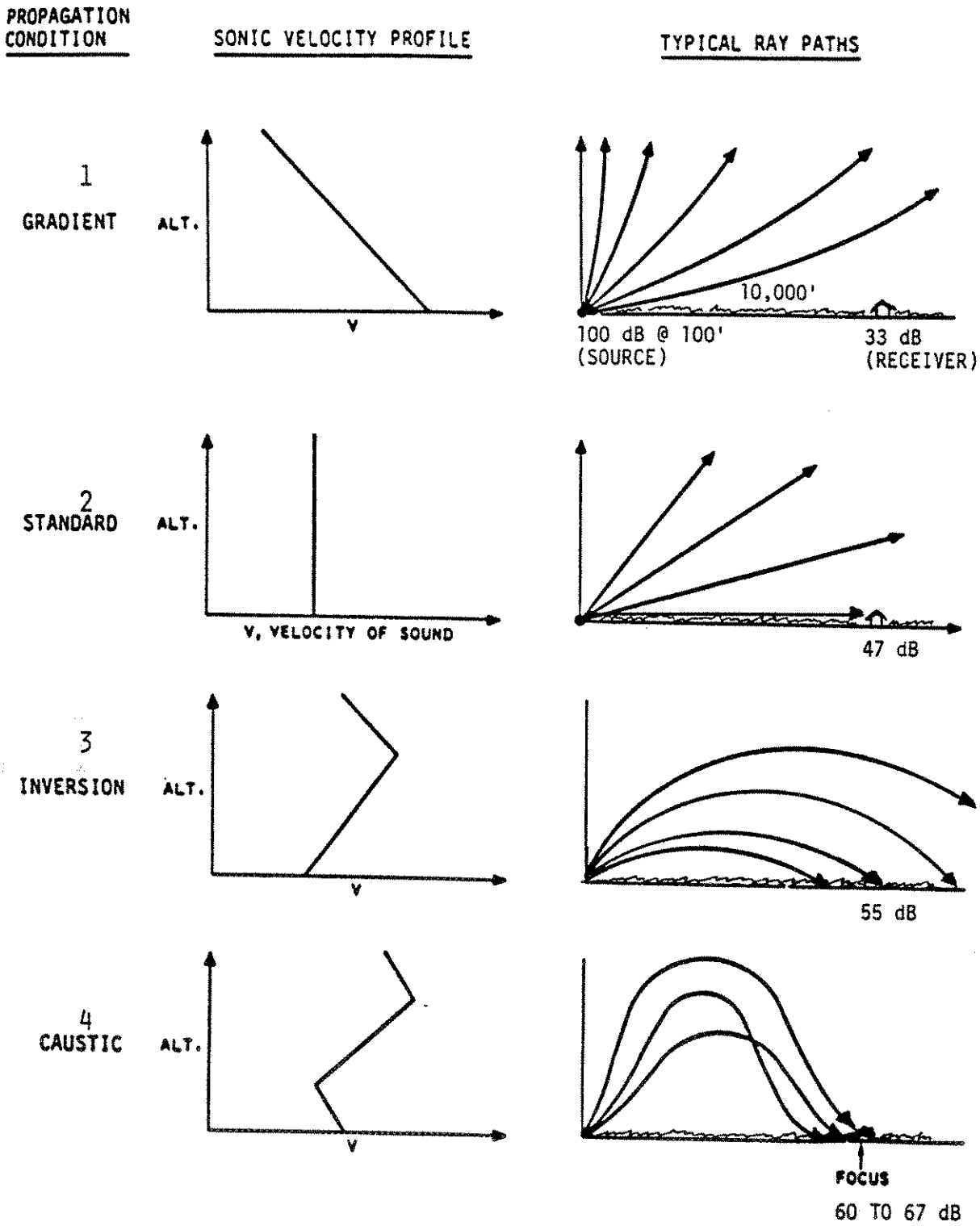
A prediction model was developed to estimate the time history of the overall sound levels at any position on the ground for launch operations either due East or South of the launch pad; and, the octave levels on the ground at the time of this maximum overall sound level. The prediction model was found to be reasonably consistent with available measured Saturn S-I launch data. Examples of measured, weather-induced short and long-term fluctuations in launch noise levels are illustrated but no attempt is made to incorporate these additional weather parameters into these initial estimates of the environment.

F. METHODOLOGY FOR EVALUATION OF EXPLOSIVE OVERPRESSURE HAZARDS

1.0 Blast Wave Propagation

The major elements of blast wave propagation are temperature, wind, dewpoint and pressure. The most severe condition for significant shock wave overpressure occurs when the atmosphere acts as an acoustic lens which focuses the shock wave energy at particular locations. This creates a "caustic focusing" conditions, described under Condition 4 in Part E of this Section.

The simple "ray theory" used to predict shock wave propagation breaks down in a caustic focusing condition. This is because countless ray paths arrive at the same point, which results in "infinite" amplification. In reality, infinite amplification never occurs but strong amplification in the focusing region is observed. The ray theory can predict where such focusing would occur and provides the basis for the BLAST program model. The actual overpressure levels predicted by the BLAST model, however, are based upon empirical attenuation results from airblast overpressure field tests.



Source: Darby & Associates
DEIS Appendix VII-B

Figure V.1.5
SOUND PROPAGATION CONDITIONS

2.0 BLAST Damage Assessment Model

The principal inputs to the BLAST damage assessment model are meteorological data for the launch site, explosive yield and location of the launch vehicle, terrain elevations surrounding the launch site, and (if available) window survey data showing the numbers and locations of windows in the nearby communities. The model computes overpressure versus distance, the expected window breakage at each distance and a casualty estimate based upon the number of windows broken. The expected casualty estimate is also based upon the conditional probability that the launch vehicle has failed at or immediately above the launch pad, such that its impact with the ground results in a high order explosion. In the operations version, real-time meteorological input and model results are used to identify unacceptable conditions that may result in a launch hold.

Seven locations on the island were identified as "noise sensitive areas" for launch impact considerations. Blast wave propagation was performed in the direction of each of these locations for each of seven given wind conditions. At each of these locations the expected overpessure due to a blast was computed, as well as the probability of window breakage, if applicable.

G. HUMAN HEALTH RISK ASSESSMENT

1.0 Description

A human health risk assessment (HRA) is a procedure by which potential or possible adverse health effects (illness) are assessed and quantified. It does not assess the probability that exposure will occur but instead assumes that some exposure will occur. The HRA assesses the chance - given this exposure - of adverse health effects occurring in people living on the Big Island. A health risk assessment consists of four parts: (1) hazard identification; (2) dose-response evaluation; (3) exposure assessment; and (4) risk characterization.

2.0 Procedures Used

An assessment of the health risks associated with all aspects of launch activities (spills from transportation accidents, storage and handling operations, normal launches, and launch failures) was prepared by Risk Science Associates (DEIS Appendix VIIIA), following procedures recommended by the EPA. The EPA methodology was chosen for use in the risk assessment because it is conservative and most likely overestimates dosage and risk, assuring that risks are not underestimated. The model allows for consideration of multiple factors and the incorporation of the most recent data on exposure assessments.

3.0 Steps in the HRA

Hazard Identification. The first step, hazard identification, consists of determining if a hazardous substance is present. In the case of rocket launches or propellant spills, several hazardous materials are present and/or emitted. These substances are described in Part B of this Section.

Dose-response Evaluation. The second step in a risk assessment, dose-response evaluation, addresses the toxicity of the substances of concern. Toxicological profiles describing the toxicity and concentrations which might be harmful are found in Appendix VIIIA. It should be noted however that hydrazine, UDMH, MMH and A-50 are all derived from hydrazine and have similar characteristics. UDMH and MMH are analogs of hydrazine; A-50 is a 50-50 blend of

hydrazine and UDMH. Because hydrazine is the most toxic substance in the hydrazine family of fuels, much of the analysis in the HRA is based on worst case hydrazine concentrations. Worst case events involving UDMH, A-50 or MMH are not expected to produce a greater hazard than identical events involving hydrazine.

Exposure Assessment. The exposure assessment step is very important as it includes identifying and characterizing how people come into contact with the toxic substances emitted from the rockets or stored and/or transported to the site. The exposure assessment also determines how much of a toxic substance a person contacts. It must be noted that the mere presence of a toxic substance does not indicate that a hazard or risk to people exists. Contact with a sufficient amount is necessary to cause a risk to be present. The exposure assessment methodology is that recommended by EPA, as presented in the Risk Assessment Guidance for Superfund (RAGS; EPA 1989).

Based upon predominant wind direction and meteorological conditions of the Palima Point area, residents of the areas north and southeast of the facility site, and the Kona coast north to Kailua, may potentially be impacted by toxic substances present in rocket exhaust during normal launches, from the release of rocket fuel during launch failures (explosion on the pad or in the air), or from spills of rocket fuel stored at the site.

To determine the location of sensitive receptors within the study area, U.S. Geologic Survey (USGS) topographic maps were reviewed for the entire study area. Additionally, street maps, telephone directories, and county officials were consulted to determine locations of sensitive receptors. Sensitive receptors are considered individuals who might be particularly susceptible to increased exposure of pollutants. They may include individuals with respiratory problems, infants, the elderly, or the infirm. Sensitive receptor locations generally include hospitals, convalescent homes, schools, day care centers, and water supply sources. Sixty-six sensitive receptor locations were identified. These sensitive receptor locations were modeled for ground level pollutant concentrations.

Estimates of short-term airborne concentrations of chemicals emitted from rocket exhaust during a successful launch, conflagration and deflagration episodes during a launch failure, leaks of rocket fuel from on-site storage tanks, and leaks of rocket fuel during transportation accidents were prepared by ACTA Inc. (DEIS Appendices VIA and VID). The emissions were modeled to predict dispersion and deposition of pollutants in the region surrounding the project site and along the transportation corridor. Additional modeling was conducted to estimate long-range transport to distant receptors on the Kona side of the island.

The predicted ground-level pollutant concentrations are computed in two ways. In the first method, estimates of toxic concentrations are made for a defined place (e.g. Pahala) for each of eight meteorological scenarios. In the second method, the centerline time mean concentration is computed by defining the peak instantaneous concentrations in the downward direction of the plume (See Figures V-1.1 and V-1.2). As shown on the Figures, the cloud of pollutants that emanates from a launch event travels in a downwind direction from the launch site with the highest concentrations in the center of the plume and the lowest on the sides. The concentration profile appears as a Gaussian or bell-shaped curve. By this method, the 30-minute time mean concentration (the concentration of pollutants averaged over 30 minutes) and predicted centerline peak instantaneous concentrations can be estimated at varying distances from a site.

The modeling results were used to estimate potential human exposure to contaminants through a variety of pathways, including direct inhalation, soil ingestion, skin absorption of contaminated soil, and ingestion of contaminated local supplies of drinking water. A hypothetical Reasonable Maximum Exposure (RME) scenario was used to estimate potential adverse

health effects to an individual at highest risk from the proposed project emissions. In addition, estimates were made of health risks to the population within a study area surrounding the project site and along the Kona coast.

Reasonable Maximum Exposure (RME) is defined by EPA as the highest exposure that is reasonably expected to occur. The RME is intended to estimate a conservative exposure case that is within the range of possible exposures. For multiple exposure pathways, the RME must be estimated for each potential pathway. The exposed resident under the RME exposure scenario is defined as that person who spends 24 hours/day 7 days/week, 52 weeks/year for 70 years at the receptor site for which exposure is modeled.

Because it is assumed that only healthy, properly attired individuals would be authorized to remain within the PCZ during a launch, the facility worker was not modeled as a discrete receptor as were the residential receptors described previously. Rather, at the time of a launch or spill, the worker is assumed to be located somewhere within the population control zone (4.7 km inland radius from the launch pads). The evaluation of potential health risks to workers involves determination of a hazard index based on occupational exposure limits. In this health risk assessment, the strictest occupational exposure limits are used for each substance.

Risk Characterization. The final step in the HRA consists of quantifying the risk or hazard to the population.

Cancer Risk. Cancer risk refers to the chance that someone might contract cancer as a result of exposure. Cancer risk is defined as the additional probability of an exposed resident contracting cancer due to exposure to carcinogenic (cancer-causing) rocket propellant. The risk is expressed as a probability function in terms of, for example, one chance in one million of getting cancer. It does not mean that someone will actually get cancer. It only means that if one million people were exposed every second of every day for 70 years to the same airborne concentration of a carcinogen, one excess cancer case in the population would be expected. Because the cancer incidence rate in the U.S. is 25 percent or 250,000 per million, a risk of one in one million due to rocket fuel means that instead of expecting 250,000 cancer cases per million people, 250,001 would be expected.

The Committee on Technology of the National Research Council has published two technical documents that set the standards for airborne contaminants. Emergency Exposure Guidance Levels (EEGLS) are ceiling limit concentrations that are applied to unpredictable, rare, single exposure events usually of 60 minutes or less duration. Exposure for less than 24 hours at the EEGL is expected to not cause substantial decrements in performance during an emergency. EEGLs for carcinogenic substances are estimated to result in no more than 1 cancer in 10,000 exposed persons.

Short-term Public Emergency Guidance Levels (SPEGLs) are guidance concentrations for the exposed public in emergencies (civil defense, fire fighting situations, etc). SPEGLs are similar to EEGLs in that the level and associated degree of acceptable risk depends on each substance and the adverse effects or causes.

Short-term acceptable exposure levels (AELS) used in the risk assessment and based on the National Research Council's 1985 SPEGLs and EEGLs are shown in Table 5.1.1. The NRC's 1985 SPEGLs and EEGLs for some of the chemicals of concern are more stringent than current standards, however, the more conservative 1985 values are considered to be reasonable for this assessment.

Noncancer Hazard. The term "hazard" is used to address illness other than cancer (termed noncancer adverse effects). These adverse effects could include such minor and transitory

Table 5.1.1 **ACCEPTABLE EXPOSURE LEVELS (AELS) FOR ACUTE AND CHRONIC CANCER AND NONCANCER HEALTH EFFECTS**

Substance	Mol. Weight	Acute Short-term 1 hour or less		Acute Short-term 1-24 hours		Chronic Noncancer Average Annual		Chronic Cancer	
	g/gmol	μg/m³	ppm	μg/m³	ppm	μg/m³	ppm	μg/m³	ppm
Aluminum Oxide (Al_2O_3)	101.94	15,000	3.6	---	---	500	0.12	---	---
Unsymmetrical-dimethylhydrazine (UDMH)	60.1	590	0.24	25	0.01	---	---	2.0E-3 (.002)	8.3E-07 (.0000083)
Hydrazine (N_2H_4)	32.05	160	0.12	6.5	0.005	---	---	2.0E-04 (.0002)	1.6E-07* (.0000016)
Nitrogen tetroxide (N_2O_4)	46.01	1,900	1.0	75	0.04			---	---
Formaldehyde dimethylhydrazone	72	590	0.20	25	0.01	---	---	2.0E-3 (.002)	8.3E-07 (.0000083)
Dimethylnitrosoamine (DMNA)	74.08	160	0.05	6.5	0.0005			2.2E-04 (.00022)	7.2E-08** (.0000072)
Hydrogen chloride (HCl)	36.47	5,000	3	7	0.0047	7	0.0047	---	---

Source: Risk Science Associates, DEIS Appendix VIII-A (Revised August 1994)

g/gmol = grams per gram-mole
* 16 parts per 10 million

μg/m³ = micrograms per cubic meter
** 72 parts per 100 million

ppm = parts per million

effects as irritation of the respiratory tract or more serious effects such as liver damage.

The possible occurrence of adverse noncancer health effects as a result of exposure to toxic air emissions is evaluated through the determination of a Hazard Index. Noncancer health effects include adverse reproductive or developmental effects, central nervous system effects, respiratory effects, and so forth.

The hazard index approach is used to evaluate long-term and short-term noncancer exposure effects. The chronic and acute hazard index is the calculated exposure level of each contaminant compared to its chronic and acute acceptable level for noncancer effects, or, expected exposure compared to acceptable exposure. The basic toxicological concept of the hazard index method assumes additivity of dose. The hazard index used in this assessment is conservative and would tend to overestimate risk. The acute and noncancer acceptable exposure levels are listed in Table 5.1.2. A hazard index of less than one is considered to be a nonsignificant risk.

A description of the methodology and algorithms used to develop both the AELs for carcinogens and the noncancer hazard index, as well as the assumptions used for each scenario, are contained in DEIS Appendix VIIIA.

Health Risks To Facility Workers. The evaluation of potential health risks to workers involved determination of a hazard index based on occupational exposure limits. The federal Occupational Safety and Health Administration (OSHA) publishes enforceable Permissible Exposure Limits (PELS) for substances to which workers may be exposed in the work place. The National Institute of Occupational Safety and Health (NIOSH) publishes RELs, Recommended Exposure Limits for work place exposures while the American Conference of Governmental Industrial Hygienists (ACGIH) recommends Threshold Limit Values (TLVS) for U.S. work places. TLVs and RELs are not enforceable standards but are generally more strict that the OSHA PELS. The strictest occupational exposure limits for each substance are used in the health risk assessment. These levels are listed in Table 5.1.3.

H. ECOLOGICAL RISK ASSESSMENT

1.0 Description

The purpose of an ecological risk assessment (ERA) is to address the potential effects on biota of exposure to emissions from launch operations. The assessment used procedures recommended by the EPA. Conservative (ecosystem-protective) assumptions were applied in all cases to ensure that potential risks were not underestimated. The complete ecological risk assessment is included in DEIS Appendix VIIIB.

2.0 Summary of Procedures

Procedures recommended by the EPA (1989; 1991) and EPA Region IX (for Hawaii, California, Arizona, and Nevada) were followed. Conservative (ecosystem-protective) assumptions were applied in all cases to assure that potential risks were not underestimated.

Potentially exposed receptors were identified by consulting the Nature Conservancy of Hawaii, the U. S. Fish and Wildlife Service, and other published accounts. Ecological receptors selected for inclusion in the risk assessment consist of species that are federally listed as endangered or threatened, or are candidates for listing.

Table 5.1.2 **NONCANCER ACCEPTABLE EXPOSURE LEVELS (AELS) USED IN THE RISK ASSESSMENT**

Substance	**Acute Inhalation** ($\mu g/m^3$)	**Chronic Inhalation** ($\mu g/m^3$)	**Chronic Inhalation** (mg/kg/day)*	**Chronic Oral** (mg/kg/day)*	**Chronic Dermal** (mg/kg/day)*
Unsymmetrical-dimethylhydrazine (UDMH)	5.90E+02 (590)	2.00E-03 (.002)	5.71E-07 (.000000571)	5.71E-07 (.000000571)	5.71E-07 (.000000571)
Hydrazine	1.60E+02 (160)	2.00E-04 (.0002)	5.71E-08 (.0000000571)	5.71E-08 (.0000000571)	5.71E-08 (.0000000571)
Nitrogen Dioxide (NO_2)	1.90E+03 (1900)	7.50E+01 (75)	2.14E-02 (.0214)	2.14E-02 (.0214)	2.14E-02 (.0214)
Formaldehyde dimethylhydrazone (FDH)	5.90E+02 (590)	2.00E-03 (.002)	5.71E-07 (.000000571)	5.71E-07 (.000000571)	5.71E-07 (.000000571)
Nitrosodimethylamine (DMNA)	1.60E+02 (160)	2.20E-04 (.00022)	6.29E-08 (.0000000629)	6.29E-08 (.0000000629)	6.29E-08 (.0000000629)
Hydrogen chloride (HCl)	5.00E+3 (5000)	7.00E+00 (7)	2.00E-03 (.002)	2.00E-03 (.002)	2.00E-03 (.002)

Source: Risk Science Associates, Appendix VIIIA. (Revised August 1994)

* milligrams per kilogram (body weight) per day (24 hours).

Table 5.1.3. **OCCUPATIONAL EXPOSURE LIMITS**

Substance	Molecular Weight	ACGIHTLV (ppm)	ACGIHTLV (µg/m³)	OSHA PEL (ppm)	OSHA PEL (µg/m³)	NIOSH REL (ppm)	NIOSH REL (µg/m³)	NIOSH IDLH (ppm)	NIOSH IDLH (µg/m³)
Hydrogen chloride (HCl)	36.47	5	7,000	5 (ceiling)	7,000	5 (ceiling)	7,000	100	148,857
Aluminum oxide (Al_2O_3)	101.9	2.4	10,000						
1,1-Dimethylhydrazine (UDMH)	60.1	0.01	25	0.5	1000	0.06 (2-hour REL)	150	50	1.23E+05
Hydrazine	32.05	0.01	13	0.1	100	0.03 (2-hour REL)	40	80	1.05E+05
Nitrogen dioxide (NO_2)	46.01	3 5 (STEL)	6,000 10,000	1 (STEL)	1,800	1 (STEL)	1,800	50	9.39E+04
Formaldehyde -dimethylhydrazine (FDH)	72	0.01	25	0.5	1,000	0.06	150	50	1.47E+05

Note: All concentrations are 8-hour time weighted average concentrations (TWAs) unless otherwise noted.

ACGIH TLV American Conference of Governmental Industrial Hygienists Threshold Limit Values (ACGIH 1986)
OSHA PEL Occupational Safety and Health Administration Permissible Exposure Limit (NIOSH 1990)
NIOSH REL National Institute of Occupational Safety and Health Immediately Dangerous to Life and Health Limit (NIOSH 1990)
NIOSH IDLH National Institute of Occupational Safety and Health Recommended Exposure Limit (NIOSH 1990)

Ceiling Limit Ceiling concentrations must not be exceeded during any part of the workday
STEL Short-term exposure limit; a 15-minute exposure concentration that should not be exceeded at any time during a workday
Source: Risk Science Associates, Appendix VIIIA (DEIS)

Estimates were made of short-term airborne concentrations of chemicals emitted from rocket exhaust during a successful launch, conflagration and deflagration episodes during a launch failure, spills of rocket fuel from on-site storage tanks, and spills of rocket fuel during transportation accidents. The emissions were modeled to predict dispersion and deposition of pollutants within a 15 km region surrounding the project site (termed the zone of ecological concern) and along the transportation corridor. The results of this modeling were used to estimate potential biotic exposure to atmospheric contaminants.

Risk was characterized by comparing predicted exposure concentrations to toxicological endpoint concentrations selected from the eco-toxicological literature. Uncertainty factors were applied to provide a conservative screening-level assessment of risk. If the exposure concentration was found to be greater than the toxicological endpoint concentration (TEC) adjusted with an uncertainty factor, it was concluded that there is a high potential for an adverse effect under this exposure scenario. In contrast, if the exposure concentration was less than the toxicological endpoint concentration (TEC) adjusted with an uncertainty factor, it was concluded that there is a very low probability that an adverse effect would occur with exposure.

3.0 Steps in the ERA

The ecological risk assessment consists of four parts: problem formulation, exposure assessment, toxicity assessment, and risk characterization.

Problem Formulation. This step provides an overview of the Palima Point area and the transportation route from Hilo to Palima Point. It includes a physical and biological description of the site, identification of potentially exposed ecological receptors and the chemicals of concern (COC). (Note: Chemicals of Concern are described in Part B of this Section). Ecological receptors selected for inclusion in the risk assessment consist of species that are federally listed as endangered or threatened, or are candidates for listing. Because little ecological or toxicological information exists for each individual species, species were grouped taxonomically (e.g., related species were grouped together) and risk was characterized for each taxonomic grouping. These ecological receptor grouping are plants, reptiles, birds and mammals.

Exposure Assessment. The exposure assessment estimates the potential exposure of ecological receptors to toxic chemicals that may be released due to site activities. To adequately characterize exposure the following should be identified (EPA 1991): contaminant release, migration and fate; potential exposure pathways; ecological receptors; and exposure point concentrations.

Contaminant Release, Migration and Fate. Launch site activities that might lead to a release of toxic substances are described. These activities include successful launches, conflagration and deflagration accidents, spills from storage and handling on-site, and spills resulting from transportation accidents.

The extent of contamination and the probability that ecological receptors will be exposed to COCs depends on the frequency of the contamination events, as well as the physical and chemical properties of the compounds. Migration is the movement of a COC from one medium to another (e.g., water to soil), from one location to another within the same medium (e.g., wind transport of fugitive dust), or the transport of COCs into biota. All of the launch activities that release toxic substances would produce volatilized clouds of COCs; therefore, the primary medium of contamination would be air.

Through migration, COCs in the air could theoretically contaminate surface water, ground

water, soil, and biota through deposition. Only particles such as aluminum oxide are capable of dry deposition on vegetation, soil and water. The other COCs exist as vapors in the atmosphere. Wet deposition can occur before a plume has reached a receptor, thus reducing the concentration of contaminant to which a distant receptor is exposed; however, closer receptors would have higher exposures.

Biota can also act as a migration route. Some compounds are particularly bioaccumulative. When a plant or animal is exposed to these compounds they can accumulate them in their tissues and then transfer them to consumers and predators through food-chain pathways.

The fate of a contaminant refers to its ultimate disposition, e.g., does it degrade into a toxic or nontoxic compound or does it remain stable? Physicochemical parameters give an indication of the persistence of COCs in the environment and their ability to bioconcentrate and/or bioaccumulate in plant and animal tissues (DEIS Appendix VIIIB). Nonpersistent chemicals, such as gaseous compounds, are not readily retained in the soil after deposition and are lost through volatilization, photodegradation, and biodegradation. Except for aluminum oxide, all the substances of concern are gases or liquids and are extremely short-lived, being readily degraded in the air, on the land, or in the water.

Potential Exposure Pathways. Ecological receptors could be exposed to toxic compounds through the following potential exposure routes: air, surface water, soil and biota. Potential exposure pathways are included in an exposure assessment when the following four requirements exist (EPA 1989): potential for chemical release to the environment, transport of the contaminant to the point of exposure, a point of potential contact with a receptor to the contaminant, and an exposure route at the contact point such as inhalation or ingestion. Potential pathways for which any of these four requirements are absent are excluded from the exposure assessment.

The exposure pathways for each of the possible media described in the previous section were subjected to an Inclusion/Exclusion analysis. The only pathway deemed complete in animals is exposure through inhalation, and for plants dermal exposure and uptake through the surface of the leaf. Pathways excluded for animals include dermal exposure to airborne contaminants and biotic pathways. Exposure routes via surface soil and water were also excluded because exposure and risks are trivial compared to potential exposure via inhalation. (See RSA, DEIS Appendix VIIIB for the rational behind these conclusions).

Characterization of Sensitive Ecological Receptors. The third component of an exposure assessment is to characterize the species that may be potentially affected by launch site activities. Due to the extreme isolation of the Hawaiian Islands and their volcanic origin, all *native* Hawaiian flora and fauna are descended from species that were able to disperse and successfully colonize the islands. Due to this constraint, many taxa are missing.

It is impossible to assess the toxic effects of potential COCs on all ecological receptors, therefore, a subset of potential receptors is evaluated. The species of highest ecological concern are those that are State and Federally listed or are proposed candidates for listing as endangered, threatened, rare or a species of special concern. On the Big Island, the majority of the native vertebrate fauna are listed or are candidates for listing and have been used in other studies as indicators of the health and status of native Hawaiian ecosystems. Because of their legal importance and their role as indicators of ecosystem health, listed Hawaiian flora and fauna were selected as ecological receptors in the ERA.

Little ecological or toxicological information exists for each individual species; therefore, species were grouped taxonomically (e.g., related species were grouped together), and

risk was characterized for each taxonomic grouping. These receptor groupings consist of the following: plants (all of the listed and candidate plants); reptiles (the green and hawksbill sea turtle); birds (Hawaii creeper, akepa, akiapola`au, alala, I`o, nene, Hawaiian Duck, band-rumped storm petrel, Hawaiian dark-rumped petrel and Newell's Townsend's shearwater; and mammals (the Hawaiian hoary bat).

Quantification of Exposure Concentrations. The final step of an exposure assessment consists of quantifying the amount of COC to which ecological receptors are exposed in different media; this is termed the exposure point concentration (EPA 1991). ACTA Inc. (DEIS Appendices VIA and VID) modeled the ground level concentrations of the COCS in the atmosphere. Exposure point concentrations for the normal launch and accident scenarios were modeled for the eight different Palima Point meteorological cases.

The exposure point concentrations were presented in two ways. In the first, the concentration of the COCs released for each weather case for each of the 66 sensitive human ecological receptors identified was estimated (DEIS Appendix VIIIA). In the second method, the peak centerline time mean concentration was computed by defining the peak instantaneous concentrations in the downwind direction of the exhaust plume, which can be visualized as the peak of the bell-shaped curve.

The cloud of pollutants that emanates from a launch event travels in a plume in the downwind direction from the launch site with the highest concentrations at the center of the plume and lower concentrations extending to either side of the plume such that the concentration profile appears as a Gaussian or bell-shaped curve. The centerline concentrations in the downwind direction represent the maximum ground level concentration that occurs at a given distance from the launch site. By this method, the 30-minute time mean (average) concentrations and the predicted centerline peak instantaneous concentrations can be estimated at varying distances from the launch site. Because the ecological receptors of concern are distributed in different geographic areas from the sensitive human receptors, the most appropriate ecological exposure point concentrations are the peak centerline average (Figure V-1.1) and predicted centerline peak instantaneous concentrations (Figure V-1.2).

Toxicity Assessment. The adverse effects associated with the release of COCs due to activity at the proposed commercial spaceport are characterized. In this step, toxicity profiles of the COCs are summarized and a toxicological endpoint concentration or TEC (Suter 1993) is chosen. The selection criteria for the TEC is based on the following conservative criteria:

- o if eco-toxicological data from the same species are unavailable, data from surrogate species will be used. Surrogate species will be those that are the most closely related taxonomically to receptors;
- o NOEL or LOEL values will be selected over LC_{50} values;
- o data from tests that used exposures comparable to those predicted for Palima Point (e.g. acute 30 minute to 60 minute exposures).

The most common toxicity data are LD_{50} and LC_{50} values (dose or concentration that is lethal to 50 percent of the population tested). These values are useful for comparing relative toxicities but are not useful in potential adverse effects aside from lethality. More appropriate data consist of NOEL and LOEL values (no observed effect and lowest observed effect level, respectively) and dose-response data (testing where an animal is exposed to a number of different doses or concentrations and the responses to these exposures are noted). Unfortunately, NOEL and LOEL cannot be easily estimated from LD_{50} and LC_{50} data.

Another problem with most eco-toxicological data is that they focus mainly on laboratory animals, none of which are ecological receptors at Palima Point. Because even closely related species such as rats and mice may have divergent responses to different compounds it can be impossible to extrapolate from one species to another. There are no data on reptiles and very little on birds.

Given the lack of eco-toxicological data, data from surrogate species were used. Although there are many uncertainties inherent in using surrogate data, due to a great difference in sensitivities to toxins seen between species, it can at least give some information on the range of values that produce adverse effects in other species.

Risk Characterization. The final step in the ERA is the characterization of risk. This is an integrative step because it combines the data presented in the environmental setting, exposure assessment and toxicity assessment chapters to identify and characterize potential ecological risks to sensitive ecological receptors.

To characterize risk, the toxicological endpoint concentrations (TECs) selected in the toxicity assessment are compared to the predicted worst case exposure point concentrations (ECs). Because the available toxicity data are not directly applicable to the species of concern found on the Island of Hawaii, uncertainty factors (UFs) are applied. An uncertainty factor of 0.01 is used when extrapolating between animal species, a factor of 0.1 when extrapolating between plant species, and a factor of 0.1 is used when extrapolating between LC_{50} and NOEL values. Conservative factors are used because of the extremely sensitive status of the ecological receptors of concern. Using this approach, the following conclusions can be drawn:

* if the EC < TEC (UF) than it is very unlikely that adverse effects will occur.

* if EC > TEC (UF) than there is a high potential for adverse effects.

* If EC ≡ TEC (UF) than there is a slight potential for adverse effects.

Risks are characterized for launch and accident scenarios in Sections II, III and IV of this Chapter and in Appendix VIIIB of the dEIS.

I. ORGANIZATION OF SUBSEQUENT SECTIONS IN THIS CHAPTER

- *Section II.* Potential Impacts From Propellant Transportation Accidents.

- *Section III.* Potential Impacts From Normal Launches and Launch Failures.

- *Section IV.* Potential Impacts From Hazardous Operations including: Payload Processing, Fuel Storage and Handling, and Accidental Spills.

- *Section V.* Special Concerns: Mauna Kea and Mauna Loa Observatories, Vog and Laze, and Global Warming and Stratospheric Ozone Depletion.

- *Section VI.* Addendum: During preparation of the response to Department of Health comments, RSA discovered an error in their cancer risk calculations for UDMH and FDH. RSA has no explanation for this error except that it was most likely a typographical error made early in the preparation of the risk assessment that was unfortunately carried through. The corrected pages for DEIS Appendix VIIIA are included in this Section. It should be

emphasized that the computational error did not affect the overall conclusions that were presented in the draft EIS and the Health Risk Assessment (DEIS Appendix VIIIA).

Sections I through V identify potential hazards and impact producing actions; describe the various aspects of the local and regional environment affected by the actions; briefly describe the specific methodology used, results of the analyses and standards and guidelines used to evaluate the effects; and, assess potential adverse and beneficial impacts of the action on various aspects of the local and regional environment. In addition, mitigating measures to minimize or eliminate potential adverse impacts are described.

All relevant tables and text in Chapter Five have been revised to reflect the corrected calculations in DEIS Appendix VIIIA that are presented in the Addendum.

The following supplemental information related to the analyses presented in this Chapter is appended to Volume II of the Final EIS:

- *Appendix A.* "Typical Emergency Response Procedures for Transporting and Handling Toxic Liquid Propellants for Space Operations," compiled by Risk Sciences Associates.
- *Appendix B.* "Major Elements of Meteorological Monitoring to Support Space Launch Operations," compiled by ACTA Inc. and others.
- *Appendix C.* "Analysis of Stratospheric Wind Data to Determine the Frequency of Winds Toward the Mauna Kea Observatories," by Robert Baxter, Engineering-Science, Inc.

SECTION II: PROPELLANT TRANSPORT ACCIDENTS

See ACTA Inc., DEIS Appendix VIA, for a detailed hazard analysis of transportation risks and RSA, DEIS Appendices VIIIA and VIIIB for human health and ecological risk assessments along the transportation corridor.

A. INTRODUCTION AND OVERVIEW

Most rocket propellants are classified by the U. S. Department of Transportation (USDOT) as hazardous materials because of their flammable and toxic properties. A hazardous material is defined as a substance or material in a quantity that may pose a risk to health and safety, or property, when transported in commerce. These materials and their potential effects are described in Section I of this Chapter. This Section of the EIS addresses the potential hazards associated with the transportation of these materials from shipboard at Hilo Harbor to the storage facility at the proposed Palima Point Spaceport site.

B. AFFECTED ENVIRONMENT

The intended transportation route for rocket stages and propellants from Hilo Harbor to Palima Point is via Highway 11. The total distance of this route is about 52 miles (Figure V-2.1). Representative potential accident locations considered in the analysis are also shown on the Figure. Table 5.2.1 summarizes the weather conditions specific to each location.

The transportation route starts at Hilo Bay and goes through Hilo, Mountain View, Pu`u Makaala, Volcano, Ka`u Desert, Wood Valley, and Pahala. In Hilo, the route passes within one-half mile of Wailoa River, a perennial stream that empties into the Bay. Intermittent streams are found along the rest of the transportation route.

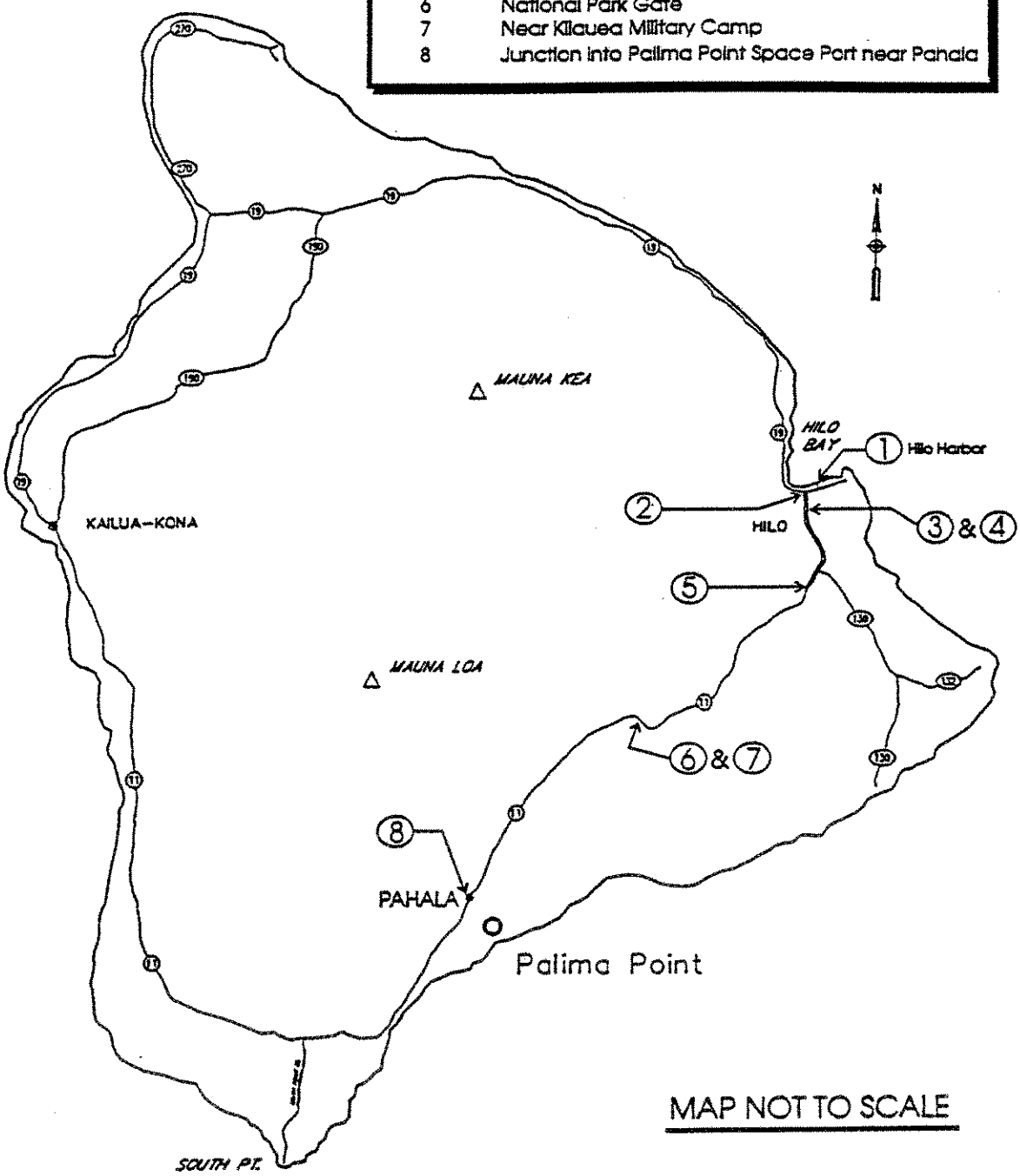
The area considered for the purposes of characterizing ecological risk is a 1 km (0.62 mile) corridor along either side of Highway 11. Data from the Nature Conservancy were used to compile information on the habitats and species found within the corridor. Hawaii Volcanoes National Park is an especially sensitive area along the transportation route. The sensitive species and habitats that have been identified within 1 km (about 0.6 miles) of Highway 11 are listed in Table 5.2.2 and illustrated in Figure V-2.2.

C. TRAFFIC ANALYSIS

A traffic analysis was performed by Barton-Aschman Associates, Inc. (DEIS Appendix VA) to provide roadway features along each road segment and accident data for 1988 and 1989. Available data indicates that accidents are more likely to occur at or near intersections with high volumes of traffic; close-by populations; and road features such as road changes from 4-lane divided highway to 2-lane roadway and road elevation. The representative potential accident locations used in the analysis (Figure V-2.1) were selected based on one or more of these factors.

An accident rate per road segment was calculated from accident statistics for all vehicle

Loc. #	Accident Location Description
1	Hilo Harbor (between ship & truck)
2	Junction of Kalanianaole Ave and Hwy 11
3	Shopping center at Hwy 11 and Puainako St.
4	Waiakea Waena School in Hilo
5	Keaau, road changes from 4 lanes to 2 lanes
6	National Park Gate
7	Near Kilauea Military Camp
8	Junction into Palima Point Space Port near Pahala



Source: ACTA, Inc.
DEIS Appendix VI-A

Figure V-2.1
REPRESENTATIVE ACCIDENT LOCATIONS ON TRANSPORTATION ROUTE

Table 5.2.1 **WEATHER CONDITIONS RELATIVE TO ACCIDENT LOCATION**

Location	Description	Conditions: Day		Conditions: Night	
1	Hilo Harbor	Temperature Windspeed Wind Direction	= 26.5°C = 2.8m/s = 40°	Temperature Windspeed Wind Direction Inversion Height	= 22.5°C = 2.0m/s = 250° = 200m
2	Junction of Kalanianaole Ave & Hwy 11 in Hilo				
3	Shopping center in Hilo	Temperature Windspeed Wind Direction	= 27°C = 3.0m/s = 40°	Temperature Windspeed Wind Direction	= 21.5°C = 2.0m/s = 255°
4	Waiakea-Waena School				
5	Hwy 11, where road changes from 4 to 2 lanes in Keaau				
6	Military camp at Kilauea	Temperature Windspeed Wind Direction	= 20.5°C = 3.0m/s = 50°	Temperature Windspeed Wind Direction	= 15°C = 2.0m/s = 360°
7	National Park Gate				
8	Spaceport turnoff, Pahala	Temperature Windspeed Wind Direction	= 29°C = 7.0m/s = 100°	Temperature Windspeed Wind Direction Inversion Height	= 24°C = 3.5m/s = 360° = 150m

Source: ACTA Inc., Appendix VIA **(DEIS)**

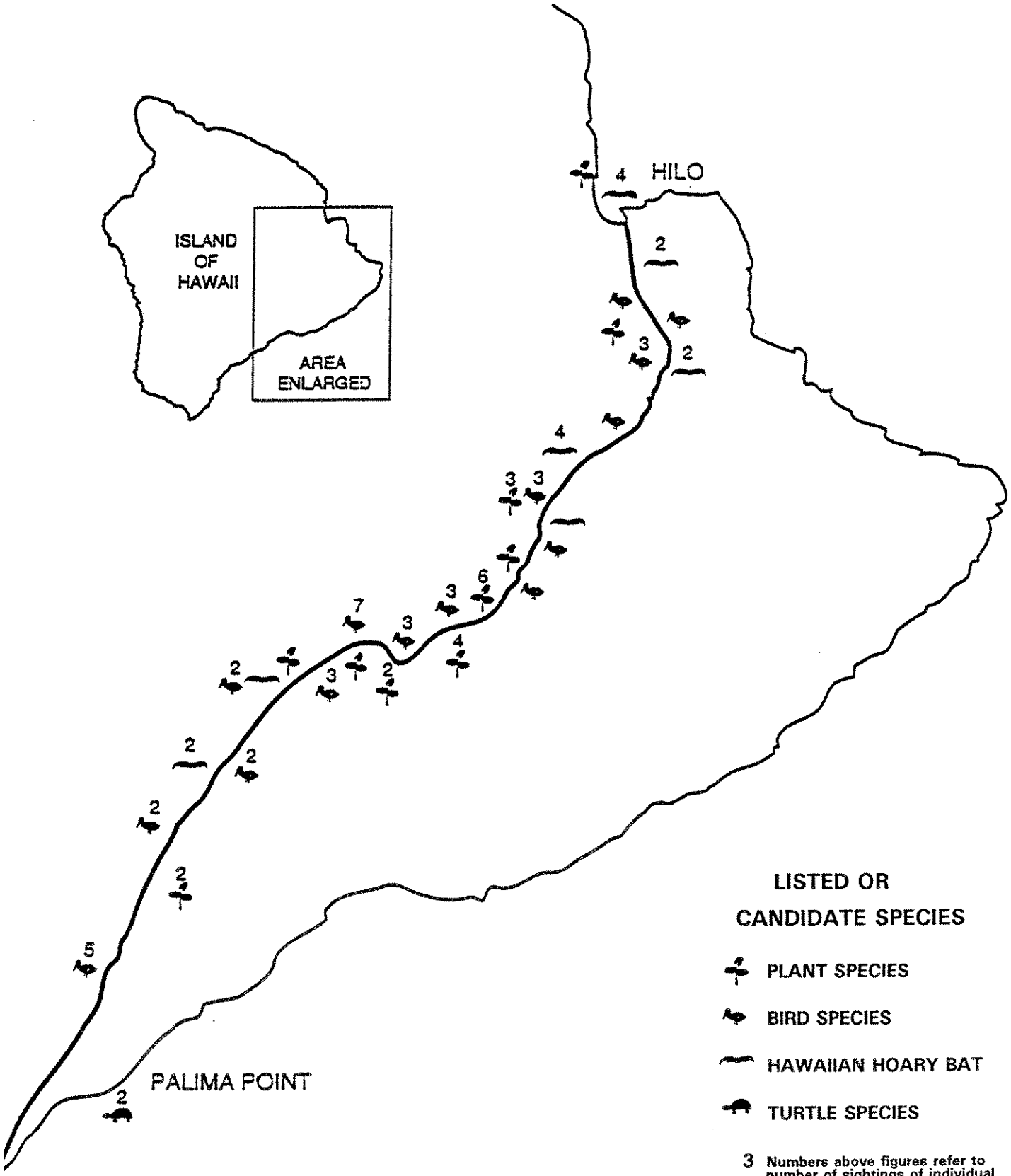
Table 5.2.2 **LISTED SPECIES FOUND WITHIN ONE KM OF THE TRANSPORTATION ROUTE**
(From the Nature Conservancy 1992)

Scientific Name	Common Name	Federal Status
Plants		
Clermontia peleana spp. peleana	'Oha, 'oha wai	C1
Cyanea platyphylla	'Oha, haha,'oha wai	3C
Cyanea copelandii spp. copelandii	'Oha, haha, 'oha wai	C1
Cyanea giffardii	'Oha, haha, 'oha wai	3A
Cyrtandra giffardii	Ha'iwale, kanawao ke'oke'o	C1
Eurya sandwicensis	Anini, wanini	C2
Ischaemum byrone		C1
Joinvillea ascendens spp. ascendens	'Ohe	C2
Neraudia ovata	Ma'aloa, ma'oloa 'oloa	C2
Melicope zahlbruckneri	Alani	C2
Pleomele hawaiiensis	Halapepe	C2
Scaevola kilaueae	Naupaka	3C
Silene hawaiiensis		
Stenogyne angustifolia		
Stenogyne scrophularioides		3C
Trematolobelia grandifolia		C2
Animals		
Eretmochelys imbricata	Hawksbill Sea Turtle	FE
Buteo solitarius	'Io Hawaiian Hawk	FE
Corvus hawaiiensis	'Alaia Hawaiian Crow	FE
Hemignathus munroi	'Akiapola'au	FE
Loxops coccineus coccineus	Hawaii 'Akepa	FE
Nesochen sandvicensis	Nene Hawaiian Goose	FE
Oreomystis mana	Hawaiian Creeper	FE
Psittarostra psittacea	'O'u	FE
Lasiurus cinereus semotus	'Ope'ape'a Hawaiian Hoary Bat	FE
Sensitive Community		
Hawaiian Continuous Perennial Stream		

LISTING STATUS

FE: Species formally listed as endangered by the federal government.
C1: Category 1 candidate. Species USFWA proposes as endangered or threatened.
C2: Category 2 candidate. Species USFWA proposes as possibly endangered or threatened.
3C: Species no longer considered for listing as endangered or threatened.
3A: Species considered extinct.

Source: Risk Science Associates, DEIS Appendix VIII-B.



SOURCE: Nature Conservatory 1992

Figure V-2.2

SENSITIVE SPECIES ALONG TRANSPORTATION ROUTE

types. The statistics were not broken down into truck accidents and miles driven, however, and consequently the overall vehicle accident rate was used as an estimate of that for trucks. This is likely to be an overestimate of the truck accident rate. Historically trucks carrying hazardous materials have a lower accident rate than that for other vehicles (ACTA Inc., DEIS Appendix VIA). The vehicle accident per mile-year associated with each of the road segments analyzed is given in Table 5.2.3.

D. LIQUID PROPELLANT TRANSPORT AND HANDLING

The transportation of liquid propellant chemicals is regulated by USDOT. Hazardous material drums and cylinders must conform to DOT specifications. Human error, such as improper packing, loading and unloading, rather than poor container design, causes the majority of releases involving small packages (drums and cylinders). The Office of Technology Assessment (OTA) shows that more than 60 percent of hazardous material releases involving small packages are attributable to human error. Vehicle accidents cause another 5 percent of all hazardous materials spills.

Hazardous material spills can occur during routine handling (i.e. loading and unloading). In order to properly define the potential for a spill during this phase, handling operations are broken down into separate events. Liquid propellants will probably be shipped to the site in the following types of containers:

- 3,000 or 4,000 gallon tank truck (liquid oxygen, liquid helium, liquid nitrogen and LHe);
- a 55-gallon drum (hydrazine, UDMH, Aerozine-50, MMH);
- a 300 gallon cylinder (nitrogen tetroxide).

Propellant types and quantities for the candidate launch vehicles assessed in this EIS are given in Chapter Two, Table 2.1.2. The characteristics of propellants and transfer gases and their potential effects are discussed in Section I of this Chapter.

Accidents could occur during the following handling operations:

- transfer of 3,000 and 4,000 gallon tanks from ocean barge to a truck, transporting the tanks to the site, and transferring the tanks from trucks to storage at the launch facility;
- transfer of 55 gallon drums from shipboard to a truck, transporting the drums to the launch facility, unloading the containers from the truck, and placing the drums in a central storage area at the launch facility; and,
- transfer of 300-gallon cylinders from shipboard to truck, transporting the cylinders to the launch facility by truck, unloading the cylinders from the truck, and placing the cylinders in a central storage area at the launch facility.

Some of the handling operations could potentially result in an accidental spill. Typically, only a single chemical is involved thereby minimizing the likelihood of an explosive reaction. The main concerns are that a container may be dropped from a crane, a drum may fall from a truck, a valve may be left open, or a hose may fail causing a potentially hazardous situation, primarily a toxic cloud.

Table 5.2.3 **VEHICLE ACCIDENT RATE PER MILE-YEAR**

Segment/ Location No.	Description	Average Daily Traffic Volume[1]	Average Annual No. Accidents[2]	Segment Length	Accident Rate/ Mile-Year
1	From Hilo Harbor to Junction of Hwy 19 and Hwy 11	15,350	20	1.1	3.57E-06 (3.57 in 1,000,000)
2	Junction of Hwy 19 and Hwy 11	23,300	21	0.2	1.23E-05 (1.23 in 100,000)
3, 4, and 5	From Junction of Hwy 19 and Hwy 11 to Keaau	23,200	103	9	1.35E-06 (1.35 in 1,000,000)
6 and 7	From Keaau to National Park Gate	7,050	57	21	1.05E-06 (1.05 in 1,000,000)
8	From National Park Gate to Pahala	1,835	38	23.1	2.46E-06 (2.46 in 1,000,000)

Source: Acta, Inc., DEIS Appendix VI-A

Notes:

(1) Data source based on 1990 traffic volume report
(2) Data source based on 1988 and 1989 accident report

E. TOXIC SPILLS HAZARD ANALYSIS

1.0 Overview of Spills Analysis

Typically, only a single chemical is involved in an accidental spill thereby minimizing the likelihood of an explosive reaction. Under these conditions the spill is characterized as an evaporating liquid, or as a gaseous cloud that is generally neutrally buoyant, or heavier than air. A class of dispersion models, commonly known as cold spill models, were developed to model the dispersion of neutrally buoyant or denser-than-air gases produced from liquid spills. The Air Force Toxic Program (AFTOX) was used to model these types of releases and provide an estimate of downwind concentrations. Only the worst case spill, incidents considered to be possible, were selected for analysis.

Only cold spills were evaluated because, in general, spills involving unreacted hypergolic propellants pose the greatest hazard to human and ecological populations. This is because the minimum vapor concentrations with toxic impacts are much below those required to sustain flame. Consequently the size of a toxic cloud is much bigger than that of a flammable cloud. For equal amounts of propellants, therefore, the potential for toxic impacts from cold spills is much greater than for fire.

Preliminary hazard analyses, such as those evaluated in this Section of the EIS, are usually applied at very early stages of project development to guide progress of safeguards for controlling the potentially most hazardous conditions. If a clearly defined Hawaii commercial satellite launch project emerges, a probabilistic risk assessment should be performed to more accurately define the associated risk levels.

2.0 Assumptions

The analysis of transportation spills of liquid propellants is based on the following assumptions:

Meteorology. Typical day and night meteorological conditions at each representative accident location were provided by Dr. Thomas Schroeder of the University of Hawaii. Day and night weather conditions specific to each location are shown on Table 5.2.1. Wind conditions are perhaps the single most important consideration in predicting the severity of impact to population centers near the accident location. Typically, the highest downwind concentrations are expected to occur under calm wind conditions with a low level of nocturnal drainage inversion. This pattern can vary somewhat due to the effect of the wind speed on evaporation rate and the transport time to carry the chemical downwind. In order to identify what was deemed to be reasonable worst case conditions, spills were simulated over a range of wind conditions.

Spill Quantities. There is currently insufficient accident data pertaining to small containers like drums and cylinders that would enable the computation of leakage or rupture rates per transportation accident. To estimate the type and magnitude of impacts, therefore, catastrophic (and unlikely) events of instantaneous (15 seconds or less) spills of an entire tank, drum or cylinder were analyzed to evaluate the magnitude of the consequences and to consider possible risk management.

Pool Depth and Blanketing Time. For the purpose of modeling each spill was based on a pool depth of 0.5 mm. A blanketing time (time to cover or remove the spill) of 30 minutes was used throughout the analysis for all container spills. This blanketing time was considered conservative.

Spills of two chemicals, a 55-gallon drum of hydrazine and a 300-gallon cylinder of nitrogen tetroxide, were modeled using both 30-minute and 15-minute blanketing times. The 15-minute blanketing time was modeled to simulate the concentration level that would occur if the accidental spill is remediated within that time period by a hazardous material (HAZMAT) emergency response team that would accompany trucks transporting toxic propellants.

Toxic Exposure Criteria. Toxic exposure criteria used to model the transportation scenarios are based on recommendations made by Risk Science Associates (DEIS Appendices VIIIA and VIIIB) and others. These short-term emergency guidance levels (SPEGLs) are based on the National Research Council's 1985 SPEGLs, except where noted. The NRC's 1985 SPEGLs for some of the toxic propellants are more stringent than current standards, however, the more conservative 1985 values are considered to be reasonable for this assessment. These recommended exposure limits are listed in Table 5.2.4.

3.0 Short-term Public Emergency Guidance Levels (SPEGLs)

The modeling results for 1-Hour SPEGLs are presented as contour plots for each chemical overlaid on the map of each representative potential accident location. The contours reflect areas where mild effects could occur to the most sensitive groups. These effects are described in Table 5.2.4.

Instantaneous spills of an entire container of nitrogen tetroxide, hydrazine, UDMH, MMH, and Aerozine-50 were analyzed for each location. The 1-Hour SPEGL contours extend from 1,000 feet to as far as 6,000 feet from the source, depending on wind conditions and evaporation properties. The predicted concentrations for the daytime meteorological case is more severe than the nighttime case.

Liquid oxygen, hydrogen, and nitrogen are shipped via 4,000-gallon cryogenic tanks. These cryogenic liquids boil vigorously if spilled and convert very quickly to cold gaseous clouds. These materials are flammable and induce asphyxiation, rather than being toxic. Consequently the concentrations of concern are much higher for the cryogenics than for the toxics and are confined to within a 50- to 400-foot radius.

Chlorine is designated as a non-flammable gas, poison, and oxidizer substance by USDOT, it is used regularly on the island of Hawaii. It is non-carcinogenic however exposure at concentrations equal to or exceeding 3 ppm (SPEGL) could result in eye and skin irritation and corrosion of teeth. Although chlorine is not a rocket propellant, contours were calculated as a point of comparison. The calculations were based on the rupture of a 150 pound cylinder at the corner of Kalanianaole Highway and Highway 11 in Hilo for both day and nighttime weather conditions. The resultant chlorine SPEGL contours are approximately 600 to 1000 feet from the accident source (Figure V-2.3).

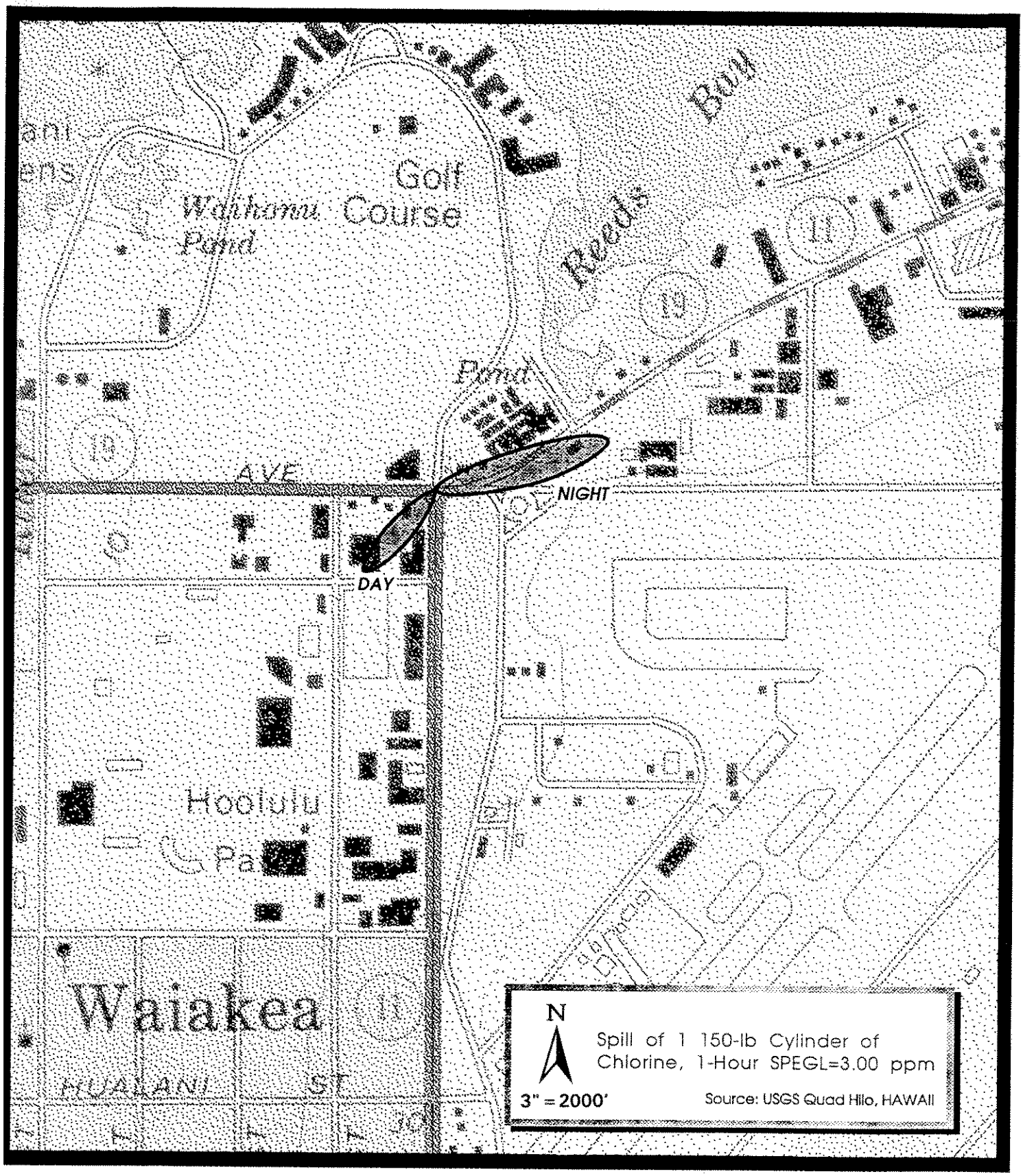
Figures V-2.4 through V-2.28 showing SPEGL contours for hydrazine and nitrogen tetroxide are at each accident location are presented on pages 5-56 through 5-79 at the end of this Section. Figures V-2.4 through V-2.15 show 1-Hour SPEGL isopleths from a 55-gallon hydrazine spill at each accident location for both 30-minute and 15-minute blanketing times. Figures V-2.16 through V-2.28 show isopleths for a 300-gallon nitrogen tetroxide spill for the same locations and conditions.

Table 5.2.4 **RECOMMENDED EXPOSURE LIMITS FOR TOXIC PROPELLANTS**

Chemical	1-Hr. SPEGL*	Effects**
Hydrazine (N_2H_4)	0.12 PPM	• Irritating to eyes, upper respiratory tract and skin. May cause dizziness and nausea. Suspected carcinogen.
Unsymmetrical dimethylhydrazine (UDMH)	0.24 PPM	• Eye and skin irritation, choking, chest pain, nausea, anoxia. Strong convulsive agent. Suspected carcinogen.
Nitrogen Tetroxide (N_2O_4)	1 PPM	• Airway resistance. Mild reversible to irreversible pulmonary function effects.
Aerozine-50 (A-50)	0.12 PPM	• Irritating to eyes, upper respiratory tract and skin. May cause tremors. Suspected carcinogen.
Monomethylhydrazine (MMH)	0.24 PPM	• Eye irritation, vomiting, diarrhea, respiratory irritation, tremors, ataxia, anoxia. Suspected carcinogen.

Source: Acta, Inc., DEIS Appendix VI-A.

* Based on National Research Council 1985 levels.
** See Chapter 5, Section I for more detailed description of effects.



Source: ACTA, Inc.
DEIS Appendix VI-A

Figure V-2.3

1 HR SPEGL ISOPLETHS FROM AN ACCIDENTAL SPILL OF A CHLORINE CYLINDER

F. HUMAN HEALTH RISKS FROM TOXIC SPILLS

1.0 Inhalation Exposure Assessment

Procedures and Assumptions. Potential health effects from transportation spills were evaluated at the eight representative accident locations along the Hilo-Palima Point transportation route shown on Figure V-2.1. Peak 60-minute average ground level concentrations (GLCS) that could result from an accidental spill of a 55-gallon drum of hydrazine or 300-gallon cylinder of nitrogen tetroxide near the eight locations were assessed.

All analyses assume a 15-minute blanketing time for spill remediation. It is assumed that within this 15-minute blanketing time, the HAZMAT team following the transportation truck will be able to cordon off the spill area, contain the spilled product, and either cover the spill with foam, plastic, etc., or remove it. The analysis therefore addresses the impact of a transportation accident where blanketing is 15 minutes. An emergency response time of less than 15 minutes would result in lower ground level concentrations and correspondingly lower risks; a longer response time would result in higher ground level concentrations and higher risks.

Worst Case Scenario. The highest concentrations of hydrazine and nitrogen tetroxide are predicted to occur under daytime conditions at a range of 20 m (66 feet, the closest distance modeled) from the source as a result of a transportation accident at Location 1 (Hilo Harbor between ship and truck). Table 5.2.5 lists these values at Location 1 for distances ranging from 20 m to 1,000 m (66 to 3,300 feet); see RSA, DEIS Appendix VIIIA for similar information at all other accident locations.

Predicted GLCs. The highest concentration of hydrazine predicted to occur at a distance of 20 m (66 feet) from the Location 1 spill site would be 42 ppm during daytime conditions and 8.2 ppm during nighttime conditions. The highest concentration of nitrogen tetroxide predicted to occur at a distance of 20 m from the Location 1 spill site would be 748 ppm during daytime conditions and 300 ppm during nighttime conditions.

2.0 Cancer Risk

Analysis. A short-term cancer risk analysis was conducted for the transportation spill scenario in which spills are assumed to occur at a rate of one per lifetime (one per 70 years) assuming a 15-minute blanketing time. The maximum cancer risk due to hydrazine under daytime conditions and a 15-minute blanketing time occurs at Location 1 and is equivalent to 1.1 in 10,000. Under nighttime conditions the maximum cancer risk is 2.2 in 100,000. Risks due to more than one transportation accident involving hydrazine per lifetime are directly proportional to the values determined in this cancer risk analysis (Table 5.2.6).

Significance. The risk of cancer in the population from transportation spills that are not immediately remediated (less than 15 minutes) of 1.1 in 10,000 would be significant as defined by the US EPA. This result underscores the need for an emergency response team to accompany transportation vehicles.

3.0 Noncancer Hazard Analysis

Acute Hazard Index. The 1-Hour SPEGLs for hydrazine and nitrogen tetroxide (0.12 ppm for hydrazine and 1.0 ppm for N_2O_4) were used in the calculation of the acute hazard index for exposure to a receptor via inhalation of airborne emissions released during a transportation spill. The use of a 1-Hour SPEGL may overestimate the potential hazards to humans

Table 5.2.5 **PREDICTED PEAK 60-MINUTE TIME MEAN (1 HOUR AVERAGE) CONCENTRATIONS AT LOCATION 1, 15-MINUTE BLANKETING TIME**
(IN PPM)

Range (meters)	Hydrazine Day	Hydrazine Night	Nitrogen Tetroxide Day	Nitrogen Tetroxide Night
20	42.05	8.24	747.68	300.28
40	14.79	3.20	288.92	121.75
60	7.87	1.75	157.01	68.77
80	4.91	1.11	99.63	44.86
100	3.39	0.78	69.52	31.96
120	2.50	0.58	51.64	24.09
140	1.92	0.46	40.05	18.91
160	1.53	0.37	32.06	15.28
180	1.25	0.30	26.29	12.63
200	1.04	0.25	21.97	10.62
300	0.52	0.13	11.04	5.51
400	0.31	0.08	6.72	3.41
500	0.22	0.05	4.60	2.37
600	0.16	0.04	3.36	1.74
700	0.12	0.03	2.58	1.36
800	0.10	0.03	2.06	1.08
900	0.08	0.02	1.68	0.89
1000	0.07	0.02	1.40	0.75

Source: Risk Science Associates, DEIS Appendix VIII-A.

Table 5.2.6 **CANCER RISK DUE TO RELEASE OF HYDRAZINE AT LOCATION 1, 15-MINUTE BLANKETING TIME (Inhalation Unit Risk for Hydrazine = .0049 $(\mu g/m^3)^{-1}$)**

Range (meters)	Hydrazine Day	Hydrazine Night
20	1.1E-04 (.00011)	2.2E-05 (.000022)
40	3.9E-05 (.000039)	8.4E-06 (.0000084)
60	2.1E-05 (.000021)	4.6E-06 (.0000046)
80	1.3E-05 (.000013)	2.9E-06 (.0000029)
100	8.9E-06 (.0000089)	2.0E-06 (.0000020)
120	6.5E-06 (.0000065)	1.5E-06 (.0000015)
140	5.0E-06 (.000005)	1.2E-06 (.0000012)
160	4.0E-06 (.000004)	9.7E-07* (.00000097)
180	3.3E-06 (.0000033)	7.8E-07* (.00000078)
200	2.7E-06 (.0000027)	6.5E-07* (.00000065)
300	1.4E-06 (.0000014)	3.4E-07* (.00000034)
400	8.1E-07* (.00000081)	2.1E-07* (.00000021)
500	5.7E-07* (.00000057)	1.3E-07* (.00000013)
600	4.2E-07* (.00000042)	1.0E-07* (.0000001)
700	3.1E-07* (.00000031)	7.8E-08* (.000000078)
800	2.6E-07* (.00000026)	7.8E-08* (.000000078)
900	2.1E-07* (.00000021)	5.2E-08* (.000000052)
1000	1.8E-07* (.00000018)	5.2E-08* (.000000052)

Source: Risk Science Associates. DEIS Appendix VIII-A.

* Less than 1 in a million

exposed for periods of less than one hour. The absence of toxicological data for shorter exposure periods and the uncertainty that the toxic vapor cloud created by the spill would disperse in less than one hour, however, dictate that the Acute Hazard Index be developed using the most health-protective, scientifically-based standard available.

Analysis of Results. The maximum hazard index projected to occur due to a transportation spill of hydrazine, 340, occurs at Location 1 during daytime conditions. During nighttime conditions the maximum hazard index at Location 1 is 67. The maximum acute hazard index due to a transportation spill of nitrogen tetroxide, 510, occurs at Location 1 during daytime conditions. During nighttime conditions the maximum hazard index at that location is 210.

Generally, at all locations, the airborne concentrations of hydrazine would fall below 0.12 ppm at 600 to 700 m (1,980 to 2,310 feet) from the spill. The concentrations of nitrogen tetroxide would only fall below 1.0 ppm at distances greater than 1000 m (3,300 feet). It should also be noted that the "Immediately Dangerous to Life and Health" (IDLH) level of 50 ppm for nitrogen tetroxide would be exceeded at distances up to 100 to 120 m (330 to 396 feet) from the spill site. Table 5.2.7 gives day and night acute hazard index values for hydrazine and nitrogen tetroxide at distances from 20 m to 1,000 m from the spill source.

The results of the analysis indicate that persons within 20 m (66 feet) of a spill of hydrazine or nitrogen tetroxide under unfavorable weather conditions could suffer severe adverse health effects, even if the toxic hazard spill emergency response team following the transportation truck is able to cordon off the spill area, contain the spilled product, and either cover the spill with foam, plastic, etc., or remove it.

Significance of Results. A hazard index of less than one is considered to be a nonsignificant risk. Because of the short-term, transitory, and infrequent nature of exposure, a hazard index of greater than 1.0 indicates that some members of the population may experience adverse effects, however brief or minor. These effects could range from mild respiratory irritation to an exacerbation of a preexisting condition (e.g., asthma or emphysema). At exposures where the hazard index exceeds 100, more severe effects such as pulmonary edema could possible occur in the exposed population.

G. ECOLOGICAL RISK FROM TOXIC SPILLS

1.0 Basic Assumptions

The sensitive species and habitats that have been identified within 1 km of Highway 11 are listed in Table 5.2.2, and illustrated in Figure V-2.2. An especially sensitive area along the transportation route is located within Hawaii Volcanoes National Park.

As noted in Section I of this Chapter, the only exposure pathway deemed complete in animals is exposure through inhalation, and for plants, dermal exposure and uptake through the surfaces of the leaf. After review of the available toxicological data, the most appropriate toxicity value was chosen (NOEL or LOEL values in species taxonomically related to the sensitive ecological receptors found in the transportation route). These selected values were then used to characterize risk by being compared to the estimated exposure point concentrations.

Of the eight different representative accident locations, those at 6 (near Kilauea Military Camp) and 7 (Volcanoes National Park Gate) have the greatest densities of identified and reported special status species of all the locations modeled. For this reason, only these locations are

Table 5.2.7 **ACUTE HAZARD INDEX - LOCATION 1, 15-MINUTE BLANKETING TIME**
(Acute inhalation AEL for Hydrazine = 160 μg/m³)
(Acute inhalation AEL for N_2O_4 = 1900 μg/m³)

Range (meters)	Hydrazine Day	Hydrazine Night	Nitrogen Tetroxide Day	Nitrogen Tetroxide Night
20	3.4E+02 (340)	6.7E+01 (67)	5.1E+02 (510)	2.1E+02 (210)
40	1.2E+02 (120)	2.6E+01 (26)	2.0E+02 (200)	8.4E+01 (84)
60	6.4E+01 (64)	1.4E+01 (14)	1.1E+02 (110)	4.7E+01 (47)
80	4.0E+01 (40)	9.1E+00 (9.1)	6.9E+01 (69)	3.1E+01 (31)
100	2.8E+01 (28)	6.4E+00 (6.4)	4.8E+01 (48)	2.2E+01 (22)
120	2.0E+01 (20)	4.7E+00 (4.7)	3.6E+01 (36)	1.7E+01 (17)
140	1.6E+01 (16)	3.8E+00 (3.8)	2.8E+01 (28)	1.3E+01 (13)
160	1.3E+01 (13)	3.0E+00 (3)	2.2E+01 (22)	1.1E+01 (11)
180	1.0E+01 (10)	2.5E+00 (2.5)	1.8E+01 (18)	8.7E+00 (8.7)
200	8.5E+00 (8.5)	2.0E+00 (2)	1.5E+01 (15)	7.3E+00 (7.3)
300	4.3E+00 (4.3)	1.1E+00 (1.1)	7.6E+00 (7.6)	3.8E+00 (3.8)
400	2.5E+00 (2.5)	6.5E-01 (0.65)	4.6E+00 (4.6)	2.3E+00 (2.3)
500	1.8E+00 (1.8)	4.1E-01 (0.41)	3.2E+00 (3.2)	1.6E+00 (1.6)
600	1.3E+00 (1.3)	3.3E-01 (0.33)	2.3E+00 (2.3)	1.2E+00 (1.2)
700	9.8E-01 (0.98)	2.5E-01 (0.25)	1.8E+00 (1.8)	9.4E-01 (0.94)
800	8.2E-01 (0.82)	2.5E-01 (0.25)	1.4E+00 (1.4)	7.4E-01 (0.74)
900	6.5E-01 (0.65)	1.6E-01 (0.16)	1.2E+00 (1.2)	6.1E-01 (0.61)
1000	5.7E-01 (0.57)	1.6E-01 (0.16)	9.6E-01 (0.96)	5.2E-01 (0.52)

Source: Risk Science Associates, DEIS Appendix VIII-A.

used in the toxicity assessment for a transportation accident. The 1-Hour predicted average concentrations for spill locations 6 and 7 are assessed for impacts on sensitive ecological receptors. For the purpose of the ecological risk assessment, it was assumed that only a single chemical was involved in a spill at any one time and that the spill would be blanketed within 30 minutes.

2.0 Analysis of Effects

Table 5.2.8 lists toxicological endpoint concentrations (TECs), uncertainty factors (UF) and centerline one hour average concentrations (EC) for hydrazine, UDMH and nitrogen tetroxide at locations 6 and 7. Table 5.2.9 gives predicted concentrations of these chemicals with both 30-minute and 15-minute blanketing times for distances of 20 m to 1,000 m from the source. See Section I of this Chapter for a summary description of the methodology used and RSA, DEIS Appendix VIIIB for data tables and a detailed description of the evaluation process. The effects of toxic spills on ecological receptors is described below for each chemical of concern.

Hydrazine. An accidental spill of a 55-gallon drum of hydrazine during daytime conditions (30-minute blanketing time) produces a 1-Hour average centerline concentration of 47.48 ppm at 20 m from the spill. Small but measurable quantities are predicted beyond 1.0 km from the spill. Exposure to hydrazine could potentially produce adverse effects in sensitive ecological receptors located in proximity to the spill, but would be unlikely to produce adverse effects at distances of 1.0 km (0.62 miles) or greater.

Nitrogen Tetroxide. The highest concentration from a spill of a 300-gallon cylinder of N_2O_4 would be found 20 m (66 feet) from source and would produce an EC of 1047.37 ppm. Small quantities of nitrogen tetroxide would be measured beyond 1.0 km from the spill. A comparison of the ECs with the adjusted TECs shows that there is the potential for adverse effects to occur to ecological receptors located up to 1.0 km from the spill. Predicted concentrations for N_2O_4 at distances ranging from 20 to 1,000 m (66 to 3,300 feet) are listed in Table 5.2.8.

UDMH. An accidental spill of a 55 gal drum of UDMH is estimated to produce an EC of 154.89 ppm at a distance of 20 m from the spill. Small quantities of UDMH would be measured beyond 1.0 km from the spill. Exposure to this concentration of UDMH could potentially produce adverse effects in sensitive ecological receptors located in proximity to the spill, but would be unlikely to produce adverse effects at distances greater than 1.0 km.

3.0 Significance of Effects

For the worst case scenario assessed, the highest concentrations were estimated to be closest to the highway. Within 20 m of the highway, estimated concentrations of all three substances - hydrazine, UDMH and nitrogen tetroxide - were above levels that have been found to produce adverse effects. The concentrations of these compounds, however, decreased in distance from the site. Only N_2O_4/NO_2 was still unacceptably high at 1 km from the site.

While estimated concentrations of the three substances could potentially produce adverse effects to biota close to the highway (there have been reports of listed species within 1 km of the highway), the three most sensitive habitats within the park are located farther away from Highway 11 and would unlikely be affected by any spills.

Table 5.2.8 **TRANSPORTATION SPILL SCENARIO RISK CHARACTERIZATION**

Substance	Toxicological Endpoint Concentrations (TECs)	Uncertainty Factors (UF)	Centerline one hour time mean concentration (EC)	Risk Characterization Is EC<TEC(UF)*?	Potential Risk? Yes/No
Hydrazine	animals = 634 ppm (1 hr LC50) plants = no data	species = 0.01 LC50 to NOEL/LOEL = 0.1	20 m downwind = 47.48 ppm 1 km downwind = 0.07 ppm	20 m = 47.48 ppm > 634 (0.01*0.1) ppm 1 km = 0.07 ppm < 634 (0.01*0.1) ppm	20 m: Yes 1 km: No
Nitrogen Tetroxide/ Nitrogen Dioxide N_2O_4/NO_2	animals = 30 ppm (1 hr LC50) plants = 0.5 µl/l LOEL	animal species = 0.01 LC50 to NOEL/LOEL = 0.1 plant species = 0.1	20 m downwind = 1047.37 ppm 1 km downwind = 1.68 ppm	Animals: 20 m = 1047 ppm > 30 (0.01*0.10) ppm 1 km = 1.68 ppm > 30 (0.01*0.10) ppm Plants : 20 m = 1047.37 ppm > 0.5 (0.1) ppm 1 km = 0.22 > 0.5 (0.1) ppm	Animals: 20 m: Yes 1 km: Yes Plants: 20 m: Yes 1 km: Yes
Unsymmetrical dimethyl-hydrazine (UDMH), FDH	animals = 981 ppm (1 hr LC50) plants = no data	species = 0.01 LC50 to NOEL/LOEL = 0.1	20 m downwind = 154.89 ppm 1 km downwind = 0.22 ppm	20 m = 154.89 ppm > 981 (0.01*0.1) ppm 1 km = 0.22 ppm < 981 (0.01*0.1) ppm	20 m: Yes 1 km: No

Source: Risk Science Associates, DEIS Appendix VIII-B.

* Is one-hour average concentration less than toxicological endpoint concentration times uncertainty factor?

Table 5.2.9 **PREDICTED PEAK 60-MINUTE TIME MEAN (1 HOUR AVERAGE) CONCENTRATIONS AT LOCATIONS 6 & 7, 15 MINUTE AND 30 MINUTE BLANKETING TIMES**
(IN PPM)

Range	30 min blanketing time			15 min blanketing time	
	Hydrazine (55 gal.)	N2O4 (300 gal.)	UDMH (55 gal.)	Hydrazine (55 gal.)	N2O4 (300 gal.)
20	47.48	1047.37	154.89	24.89	549.40
40	15.86	370.67	51.74	8.77	208.40
60	8.14	195.04	26.57	4.57	110.98
80	5.04	122.25	16.43	2.84	69.88
100	3.46	84.64	11.28	1.95	48.56
120	2.59	63.91	8.45	1.43	35.93
140	2.0	49.47	6.52	1.10	27.78
160	1.59	39.55	5.2	0.88	27.17
180	1.3	32.43	4.25	0.72	18.12
200	1.09	27.14	3.55	0.60	15.14
300	0.54	13.56	1.77	0.29	7.54
400	0.33	8.19	1.06	0.18	4.62
500	0.22	5.53	0.72	0.12	3.16
600	0.16	4.05	0.52	0.09	2.30
700	0.12	3.12	0.4	0.07	1.77
800	0.1	2.48	0.32	0.05	1.41
900	0.08	2.02	0.26	0.04	1.15
1000	0.07	1.68	0.22	0.04	0.96

Source: Risk Science Associates, DEIS Appendix VIII-A.

H. POTENTIAL HAZARDS FROM SOLID PROPELLANT TRANSPORT ACCIDENTS

1.0 Description

A typical solid propellant (SRM) is comprised of a rubber like material surrounded by a case of heat treated steel, titanium or glass filament. The internal section of the motor usually consists of a ring of propellant around a star-shaped hollow area. The star configuration increases the available surface area allowing for easy ignition by the igniter ordnance. Hot gases exit the motor from the nozzle, which is located on the end of the aft enclosure.

Solid propellants burn at over 6,000^{o}F. The thin-walled case must be insulated from the heat. Initially, the unburned propellant contributes to this insulation. A layer of insulated material is used between the propellant and the case, to provide end-of-burn insulation.

Solid propellants are designated Class B (non mass-detonating, mass-fire hazard) by USDOT. If a solid propellant is ignited and burns, the consequences can include the release of hot toxic gases, local fires, or ignition of adjacent rocket motors. Its exhaust cloud may also be corrosive.

2.0 Transport and Handling

The transportation of Solid Rocket Motors (SRMs) is regulated by USDOT. Solid propellant motors are classified as a fire hazard and, once ignited, are difficult to extinguish until all the propellant is consumed. They are shipped in containers designed to prevent inadvertent ignition. Containers must be designed to meet USDOT requirements before the solid propellants can be shipped to the Palima site. SRM shipments would be approved by USDOT on a case-by-case basis.

The handling operations of solid propellants, from shipboard at Hilo Harbor to storage at the Palima Point launch facility, are described as follows:

- Transfer from shipboard at Hilo Harbor to truck using slings that are approved for the purpose. Transport to Palima Point via truck from Hilo Harbor.
- Unload SRM segments from truck, using special cranes and lifting ships, and place in the solid propellant storage and processing area at the launch facility.

SRMs are usually shipped without the motor igniter installed and without pressures being induced to the casing. Inadvertent ignition of a solid propellant is not possible as a result of a transportation accident when standard safety practices are used (ACTA Inc., DEIS Appendix VIA).

3.0 Potential Hazards and Effects

The primary hazard from solid rocket motor propellants is their flammability. The propellant is commonly referred to as HTPB (Hydroxy Terminated Polybutadiene). HTPB is classified by the DoD as Class 2, Division 1.3 (non mass-detonating, mass-fire hazard). Items assigned to this classification will burn vigorously; the associated fires are difficult to extinguish. The material itself is not explosive, however, a solid propellant produces large volumes of gas upon burning, which can lead to rupture and/or explosion. Explosions are usually pressure ruptures of containers, which may produce fragments. Accidents which may result in fire or explosion of solid propellants are:

Inadvertent Ignition. Inadvertent ignition can be caused by: stray or induced currents activating the igniter, electrostatic discharge causing a spark or an arc, fires causing excessive heating of motor exterior--which can raise the propellant temperature above the ignition point of 300°-500°F, impact (bullet penetration or dropping motors onto a hard surface), and energy absorption from mechanical vibration that causes the propellant to overheat. If a rocket motor is ignited and burns, the consequences can include the release of hot toxic gases, local fires, or ignition of adjacent rocket motors. Its exhaust cloud may also be corrosive.

Impacts From Dropping. The issue of shipping dock hazards of SRM transportation cannot be answered until more is known about the shipping container design and port landing crane configurations. How high a cargo container would have to be lifted also depends on the size and design of the ship. All of these are unknowns at this time. Solid motors could ignite or explode if dropped from a sufficient height.

Vehicle Accident. The threat of a vehicle collision exists while the SRMs are being trucked to Palima Point. Whether or not a solid propellant will ignite or "explode" as the result of an impact depends on the plastic properties and shock wave propagation through the propellant.

The scenario of a spilled pool of burning gasoline causing ignition of the SRM would require further definition of the proximity of the propellant to the fire, the heat transfer rate to the propellant, and the duration of the fire. Direct exposure of HTPB propellant to the flame temperature of a gasoline fire (>3000 F) for more than a few seconds would ignite the propellant since the flame temperature is well above the range of possible ignition temperatures. The probability of direct exposure of the propellant to a gasoline fire is considered low.

Although ignition of an SRM as a result of a transportation accident is considered to be unlikely, further analysis will be required when the actual project is defined.

I. MITIGATING MEASURES

The use of a roadway for transporting propellants will require special permits from the State of Hawaii; speed limits along designated routes will be specified in such special permits.

If an accident involving a hazardous propellant occurs, a safety zone would be established to protect the public from danger. The extent of this zone would vary by type of accident and release. The duration would also vary, therefore, certain highway segments could be closed for hours, which is significant because there are no alternate roads for Highway 11. This type of closure is expected to be very infrequent.

Under USDOT performance standards, the design of a container must be tested and officially certified. The strength and integrity of the drum or cylinder is established by a series of performance tests, which the container must pass before it can be used to carry hazardous materials. The tests are a 6-foot-drop test, a stacking test, a leak test, and a hydrostatic pressure test. Based on the required slow speed of the trucks, and the container performance tests, the potential for container rupture in an accident is low. As regulated in Title 49 of the Code of Federal Regulations, containers must be secured against movement in transit with the use of proper bracing.

A SRM container meeting USDOT requirements is designed to prevent ignition in the event of

a highway or railway accident on the ground. Each motor shipped in a specific container or shipping arrangement is approved on a case-by-case basis.

In general, the most important mitigating measures involve reducing or eliminating accidents. To prevent problems and avoid accidents, extensive work force training, certification, and mandatory drug testing programs; comprehensive operations plans; safety and quality control inspections; and contingency plans should be implemented during all phases of hazardous materials transportation.

The transportation equipment and containers should be inspected regularly for safety compliance. Hazardous materials emergency response personnel and equipment should be available for immediate response. (See Appendix A for a description of typical emergency response procedures for transporting and handling toxic liquid propellants). Figures V-2.4 through V-2.13 and Figures V-2.14 through V-2.27 illustrate the reduced impact of an instantaneous spills involving 55 gallons of hydrazine and/or 300 gallons of nitrogen tetroxide when blanketed within 15 minutes. Reducing the spill blanketing time from 30 minutes to 15 minutes reduces the extent of the toxic contours by about one-third. It is recommended that the State of Hawaii enact legislation requiring that a HAZMAT response team accompany all shipments of hypergolic propellants to the Palima Point launch site.

Operations should be scheduled during the most favorable weather conditions. In the event of a spill, toxic vapors should be monitored to predict concentration levels; and, if necessary, facilitate evacuation of potentially affected areas. Emergency and contingency procedures must be developed in coordination with the State of Hawaii Civil Defense Division, Hawaii County Civil Defense and other interested agencies.

J. EVACUATION OF AFFECTED AREAS

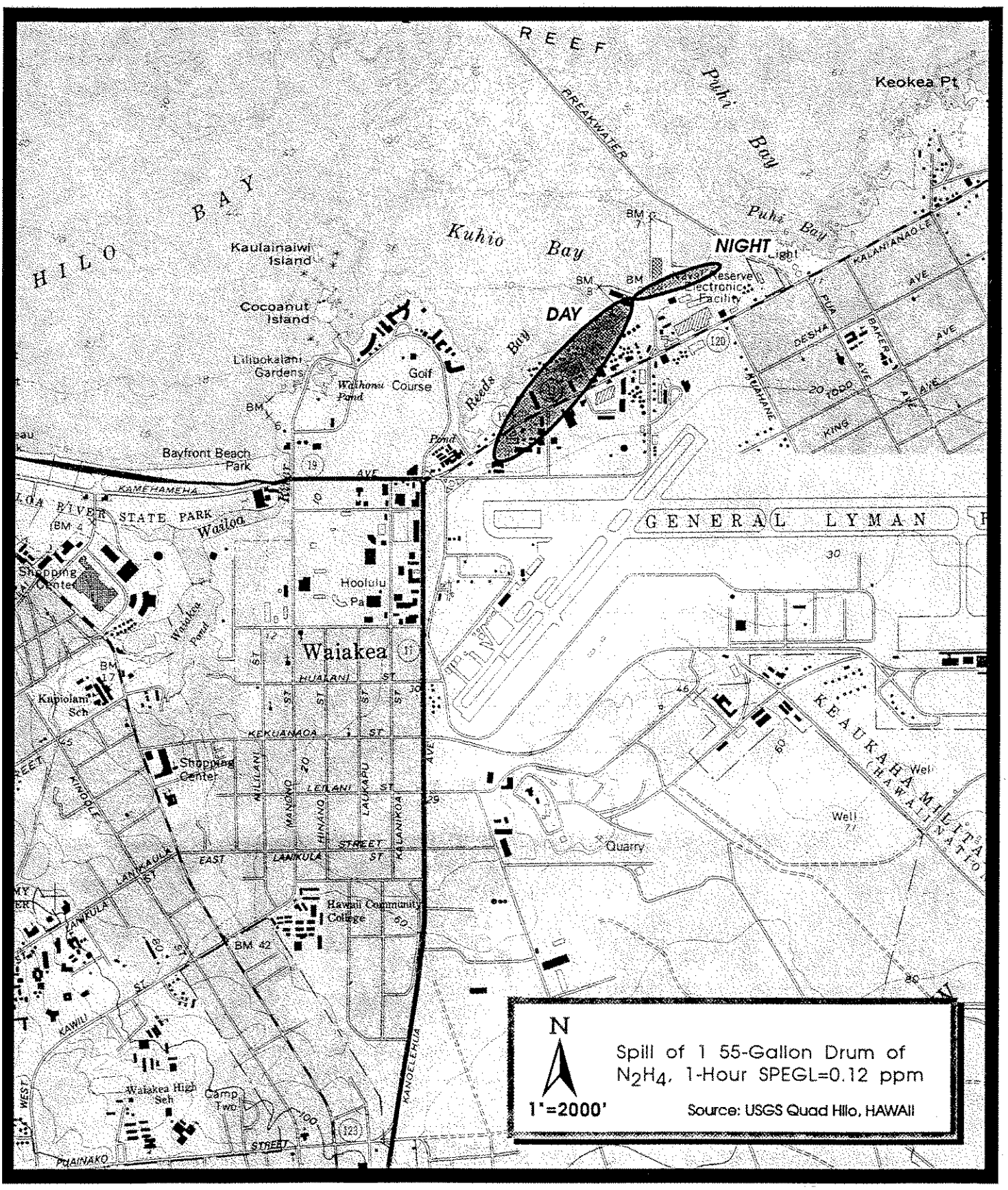
Evacuation of areas along the transport route between Hilo and Palima Point may also be necessary in the event of a transportation accident that results in toxic spills or fire. Since there is only a single roadway, diversion of traffic to an alternate route is not possible, except for the areas immediately adjacent to Hilo.

In the event of a serious accident, the only viable evacuation option is to move persons to a safe distance away from the accident site. The safe distance will be determined as part of a safety plan which must be submitted with a DOT application to transport hazardous materials. The following guidelines should be incorporated into an evacuation plan:

- A warning program (which should include a siren/alerting system or mobile units with public address capability to notify people to evacuate) should be developed in coordination with Hawaii Volcanoes National Park, the State of Hawaii Department of Transportation (HDOT), the State of Hawaii Civil Defense Division and the following County of Hawaii agencies: Civil Defense, Fire Department and Police Department.

- Public educational programs about evacuation procedures.

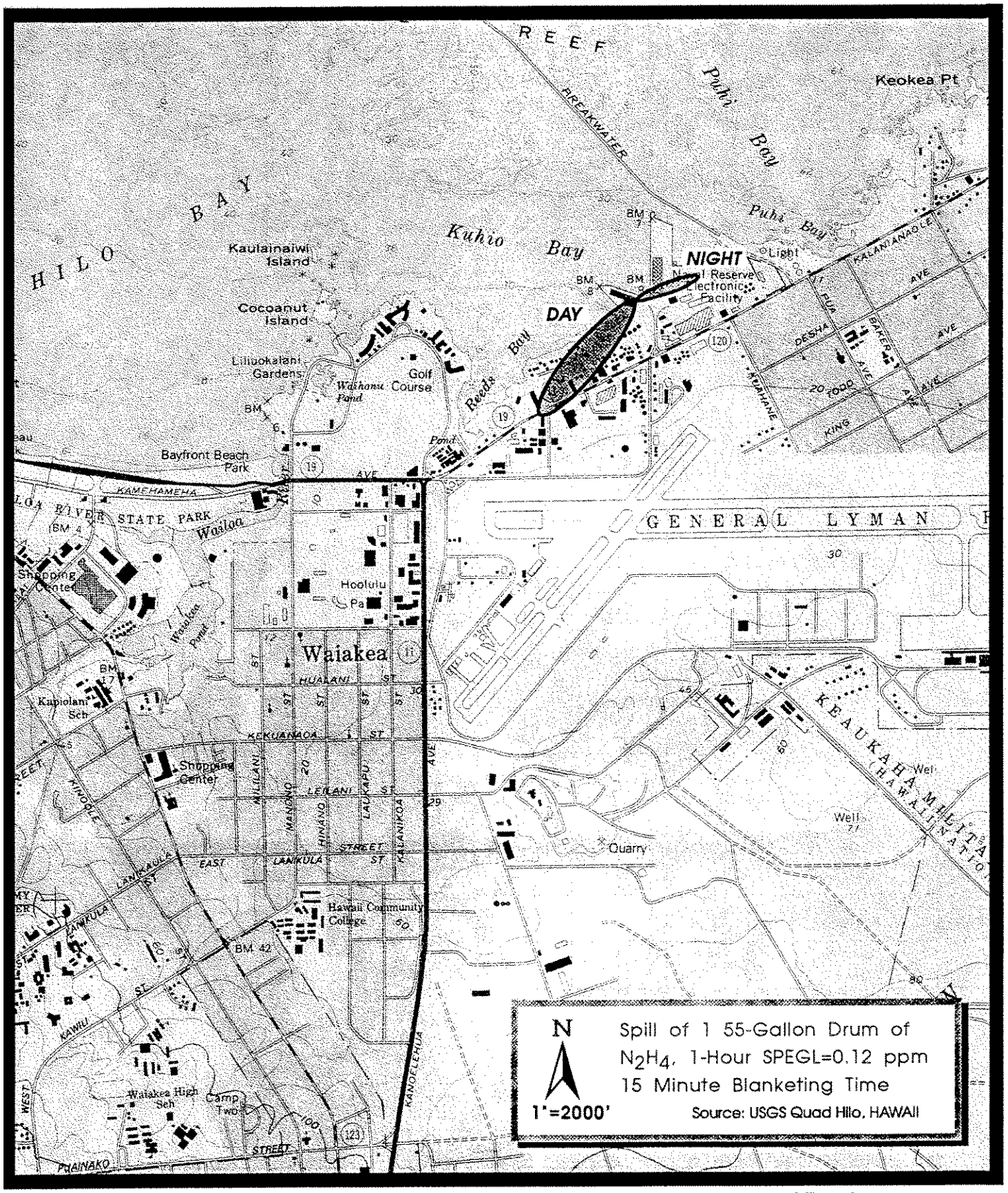
- Transport of hazardous materials should be restricted to non-peak daylight hours (between 9:00 am and 3:00 pm) and should be subject to an advisory permitting process so that coordinating agencies would be available (or on stand-by) in the event of an emergency. Transport during these hours would avoid peak traffic periods. It would also be at a time when National Park Service (NPS) and HDOT personnel would be on duty to assist.



Source: ACTA, Inc.
DEIS Appendix VI-A

Figure V-2.4

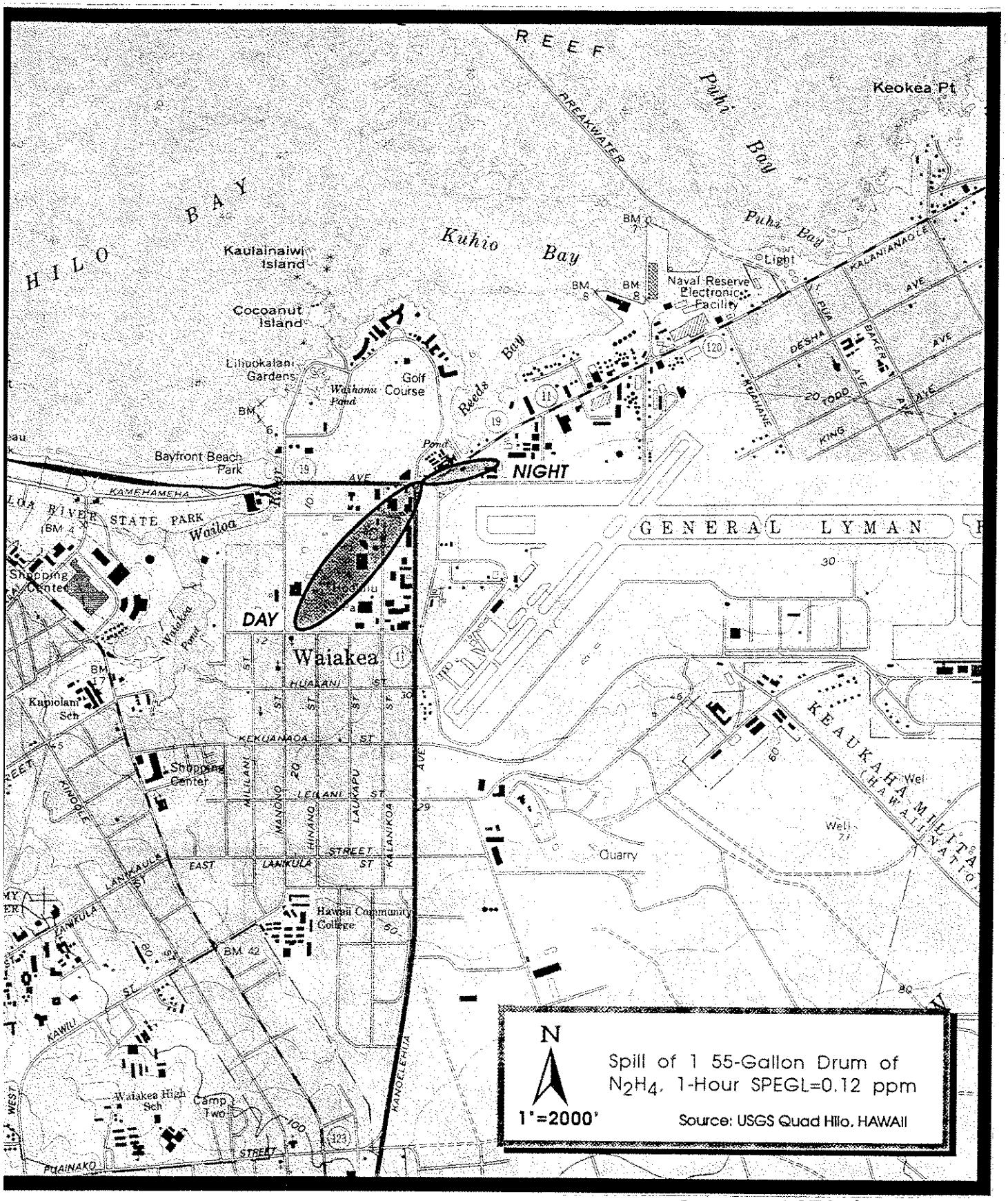
1 HR SPEGL ISOPLETHS FROM ACCIDENTAL SPILL OF N2H4 AT LOCATION 1 WITH 30 MINUTE BLANKETING TIME



Source: ACTA, Inc.
DEIS Appendix VI-A

Figure V.2.5

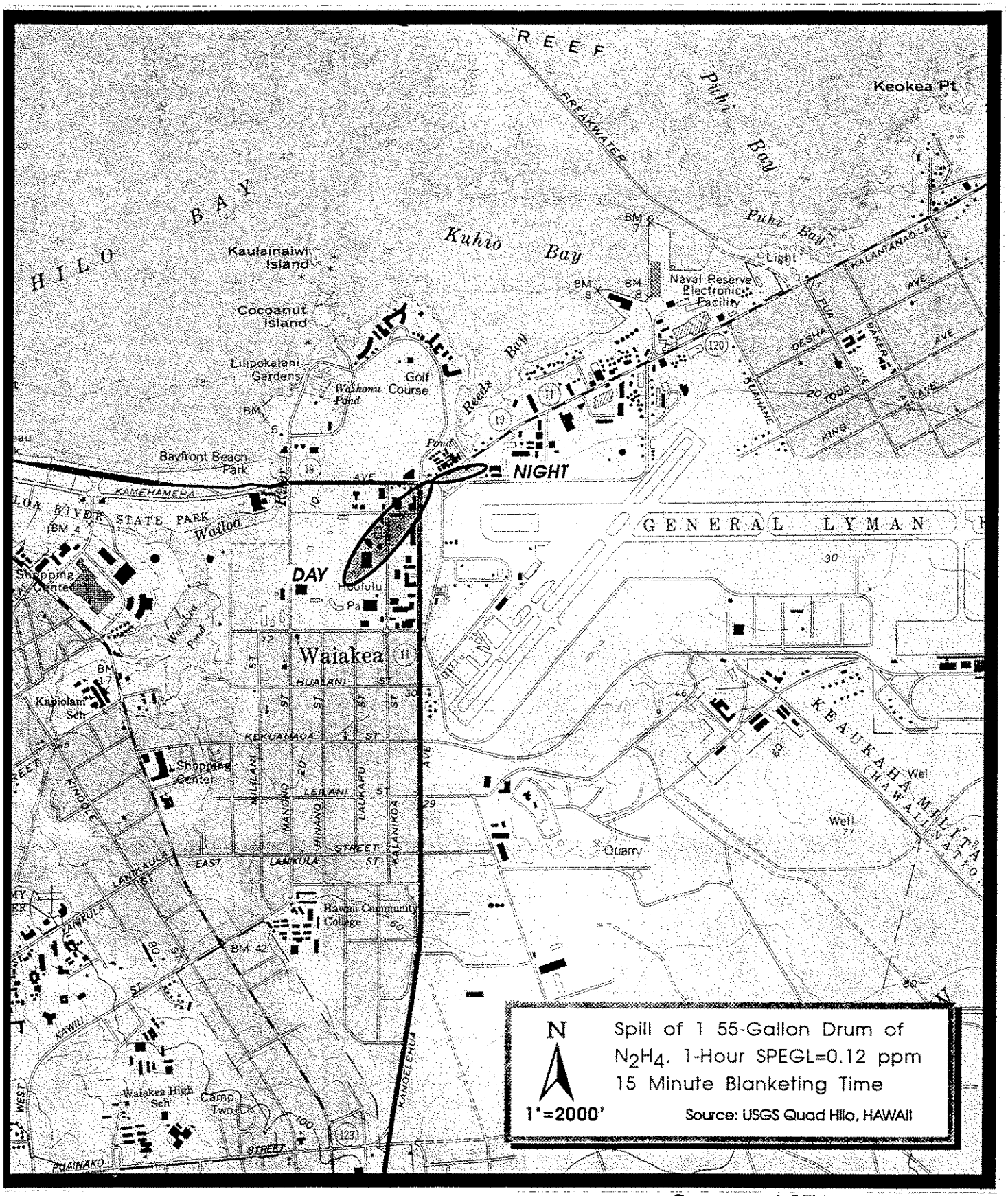
1 HR SPEGL ISOPLETHS FROM ACCIDENTAL SPILL OF N2H4 AT LOCATION 1 WITH 15 MINUTE BLANKETING TIME



Source: ACTA, Inc.
DEIS Appendix VI-A

Figure V-2.6

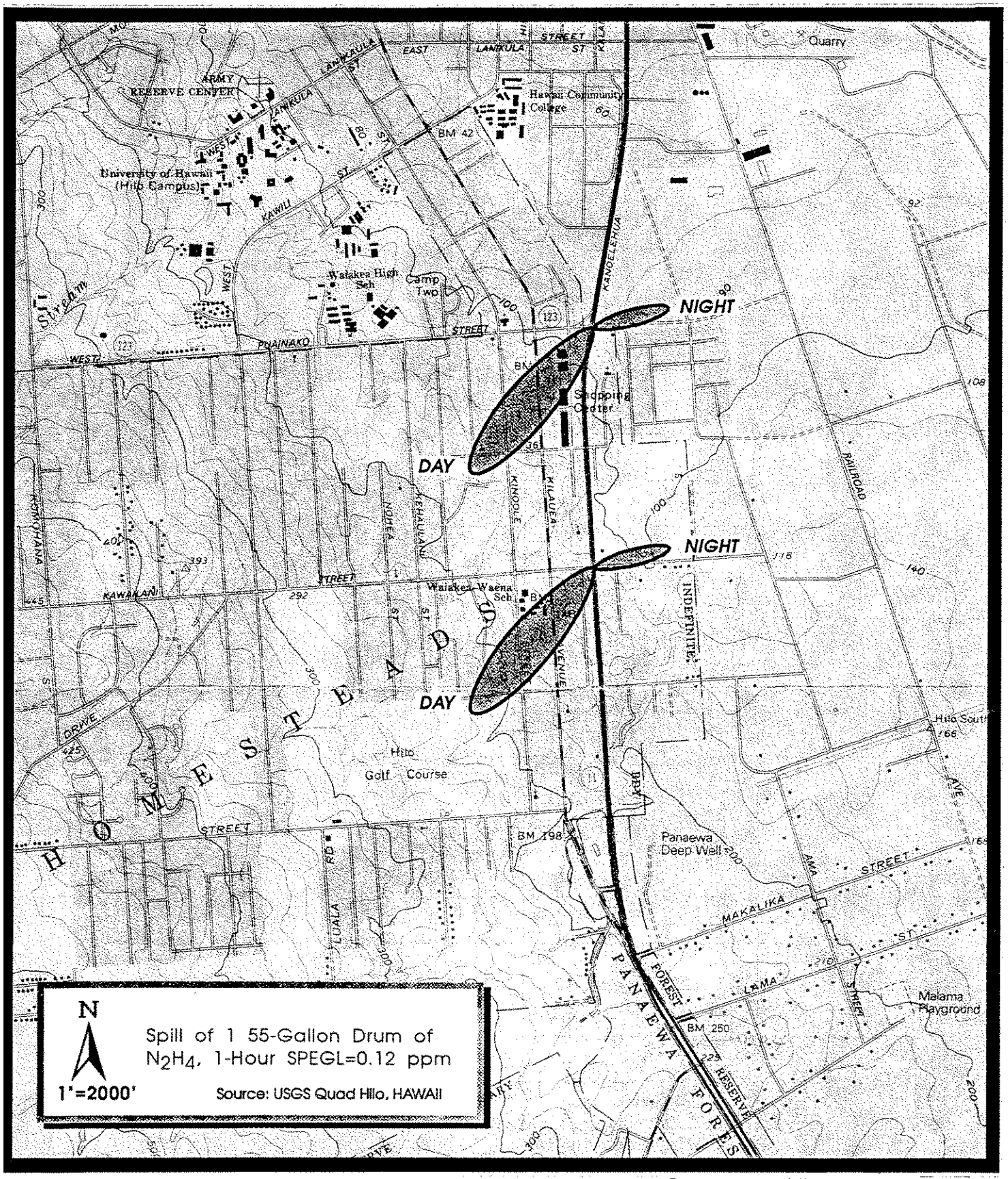
1 HR SPEGL ISOPLETHS FROM ACCIDENTAL SPILL OF N2H4 AT LOCATION 2 WITH 30 MINUTE BLANKETING TIME



Source: ACTA, Inc.
DEIS Appendix VI-A

Figure V-2.7

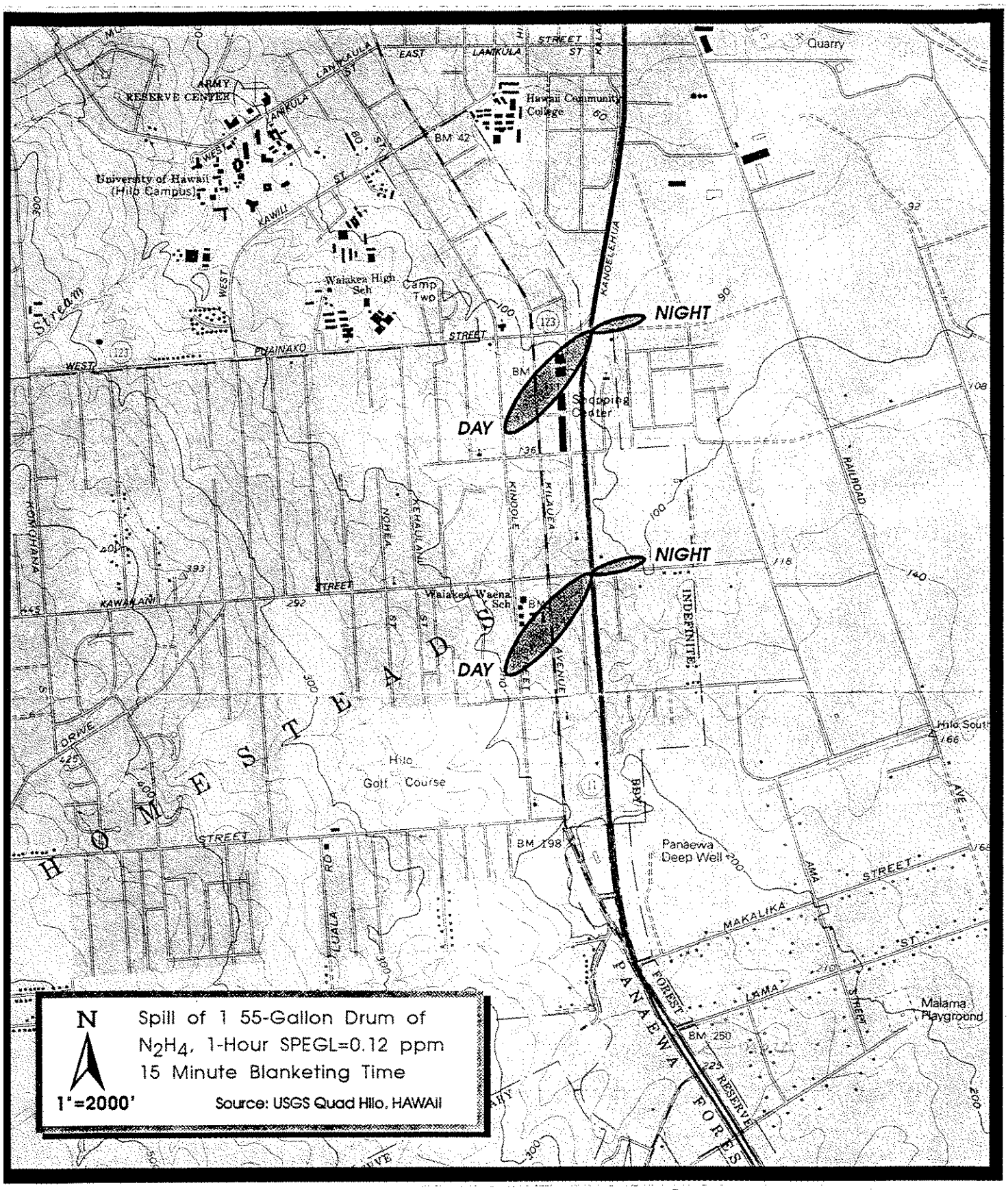
1 HR SPEGL ISOPLETHS FROM ACCIDENTAL SPILL OF N2H4 AT LOCATION 2 WITH 15 MINUTE BLANKETING TIME



Source: ACTA, Inc.
DEIS Appendix VI-A

Figure V-2.8

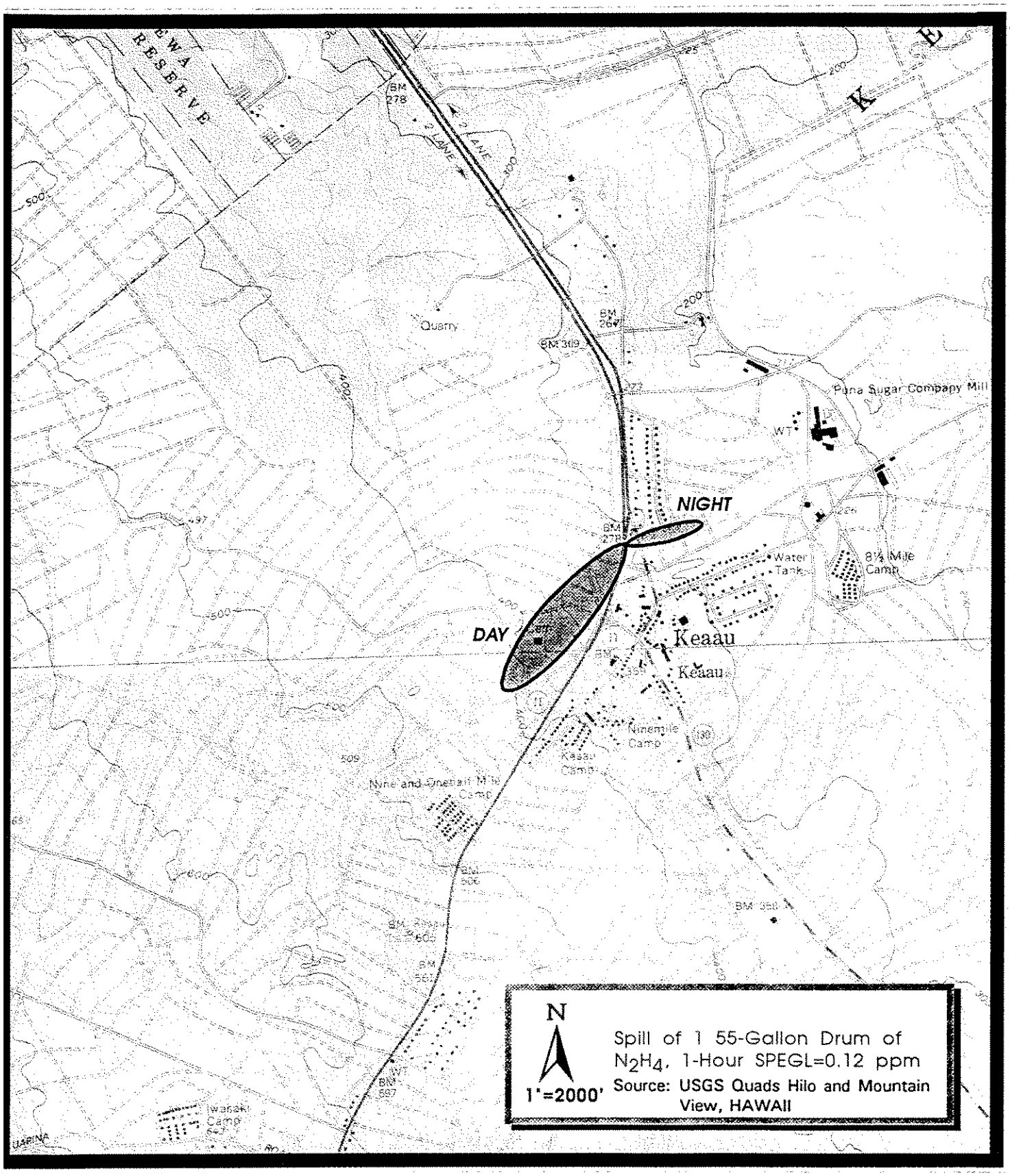
1 HR SPEGL ISOPLETHS FROM ACCIDENTAL SPILL OF N2H4 AT LOCATIONS 3 AND 4 WITH 30 MINUTE BLANKETING TIME



Source: ACTA, Inc.
DEIS Appendix VI-A

Figure V.2.9

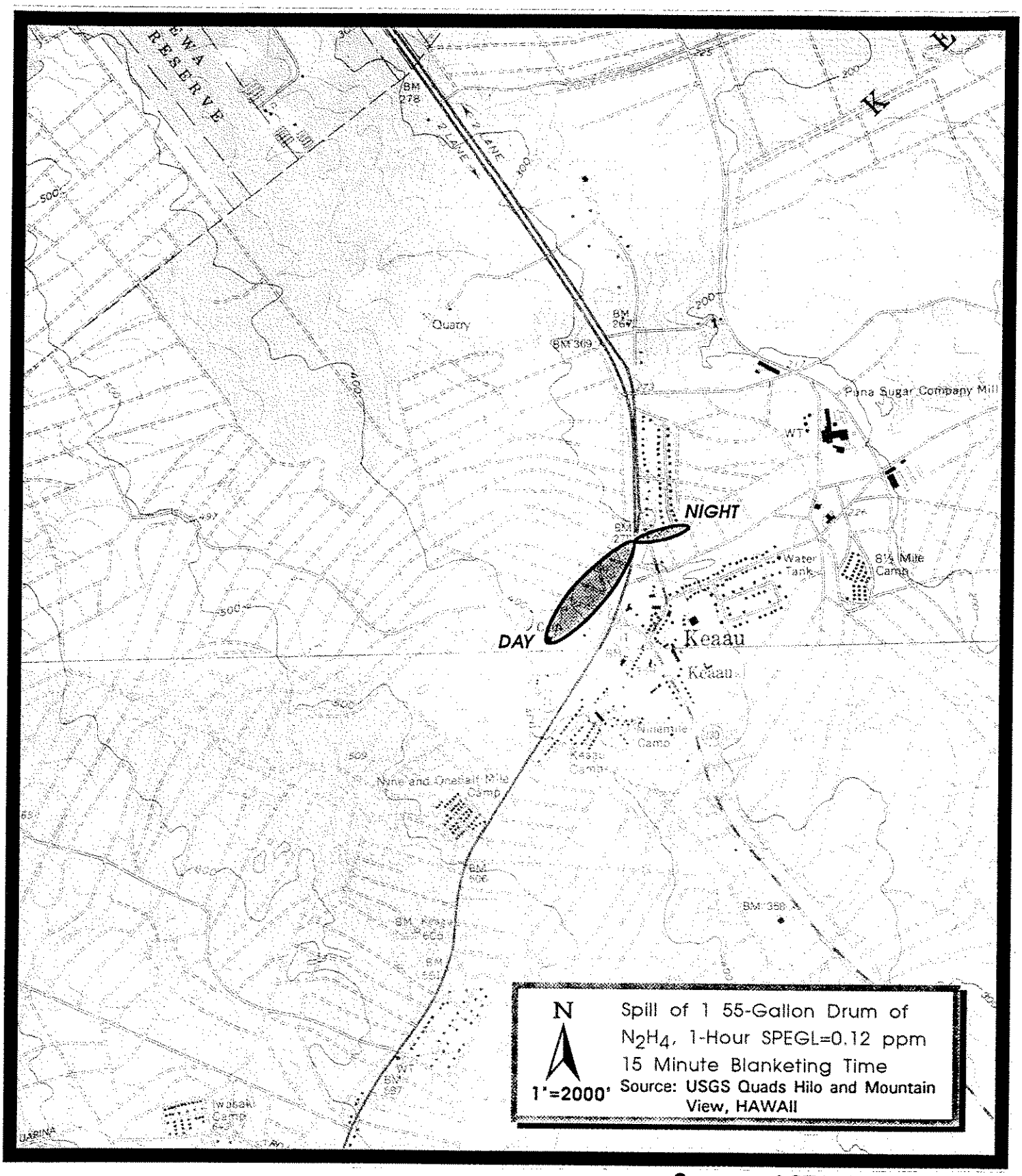
1 HR SPEGL ISOPLETHS FROM ACCIDENTAL SPILL OF N2H4 AT LOCATIONS 3 AND 4 WITH 15 MINUTE BLANKETING TIME



Source: ACTA, Inc.
DEIS Appendix VI-A

Figure V-2.10

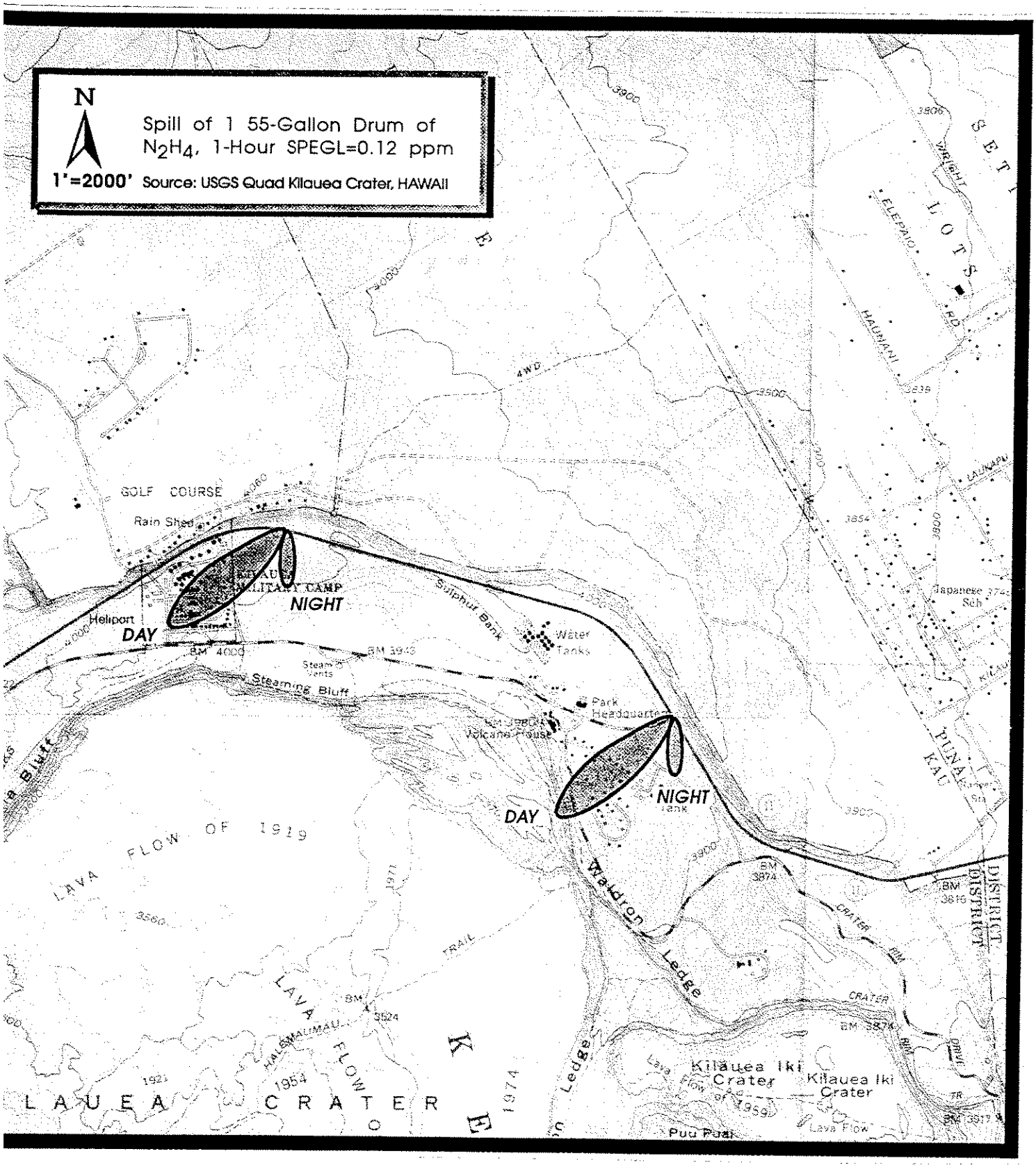
1 HR SPEGL ISOPLETHS FROM ACCIDENTAL SPILL OF N2H4 AT LOCATION 5 WITH 30 MINUTE BLANKETING TIME



Source: ACTA, Inc.
DEIS Appendix VI-A

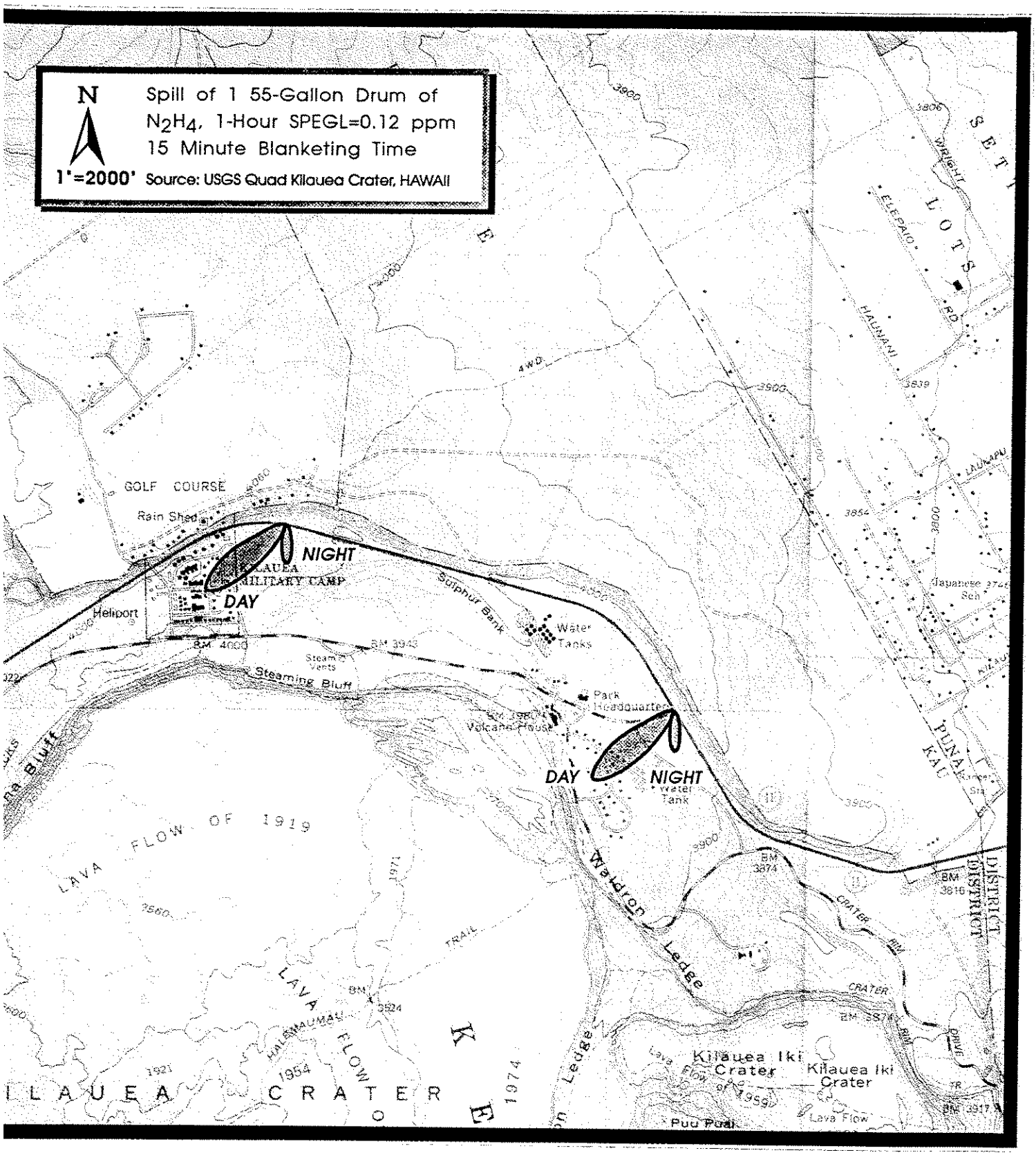
Figure V-2.11

1 HR SPEGL ISOPLETHS FROM ACCIDENTAL SPILL OF N2H4 AT LOCATION 5 WITH 15 MINUTE BLANKETING TIME



Source: ACTA, Inc.
DEIS Appendix VI-A

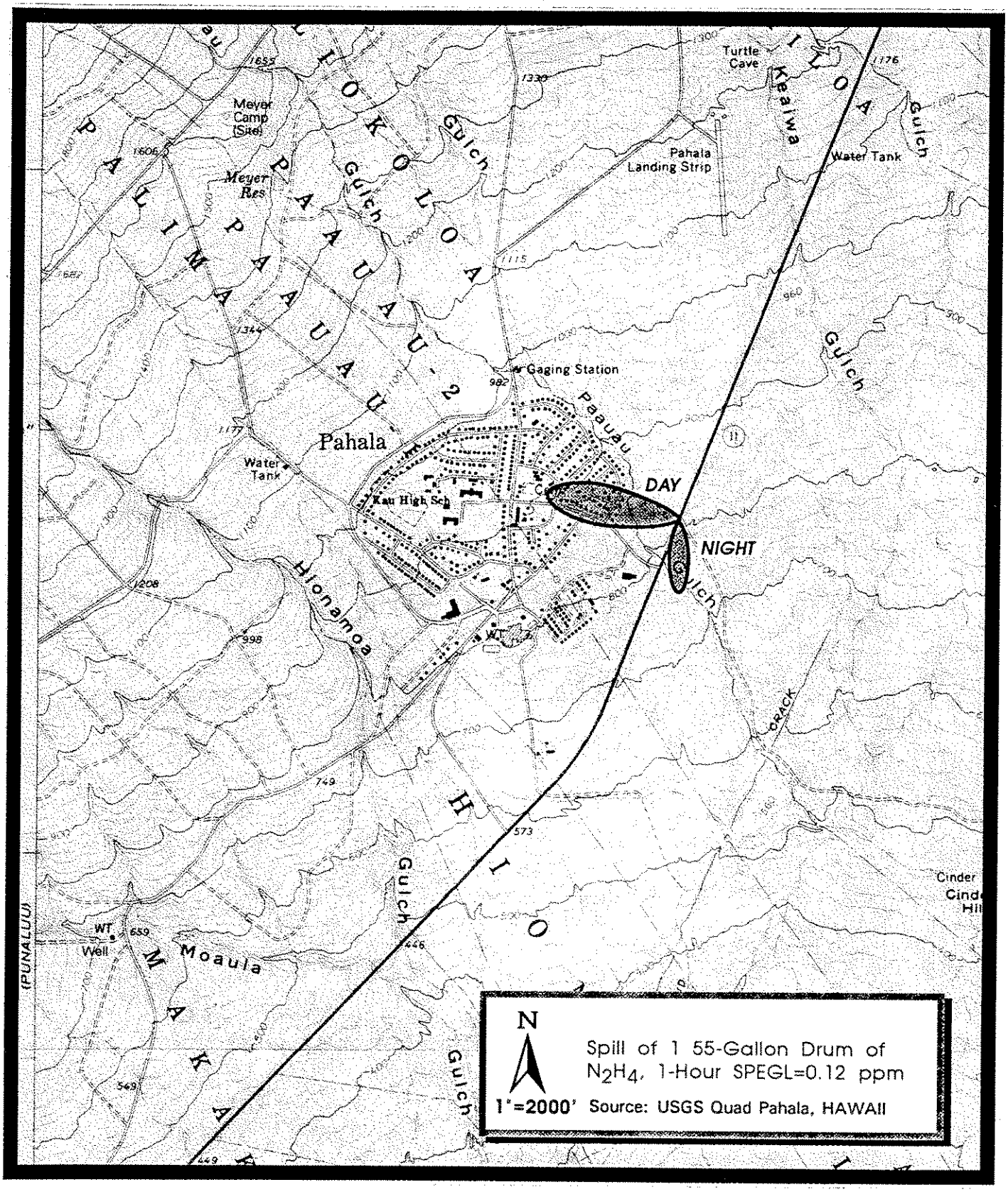
Figure V-2.12
1 HR SPEGL ISOPLETHS FROM ACCIDENTAL SPILL OF N2H4 AT LOCATIONS 6 AND 7 WITH 30 MINUTE BLANKETING TIME



Source: ACTA, Inc.
DEIS Appendix VI-A

Figure V-2.13

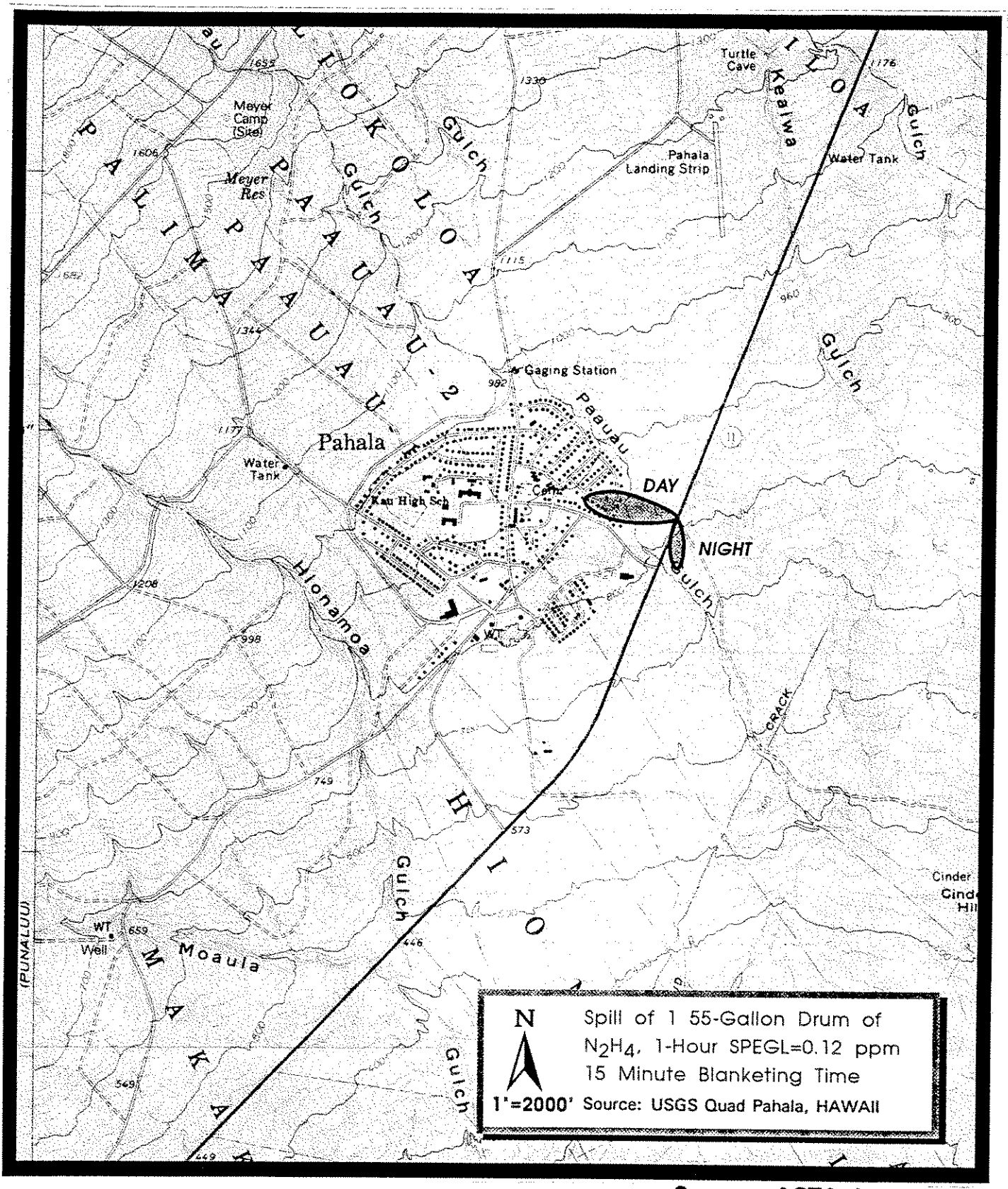
1 HR SPEGL ISOPLETHS FROM ACCIDENTAL SPILL OF N2H4 AT LOCATIONS 6 AND 7 WITH 15 MINUTE BLANKETING TIME



Source: ACTA, Inc.
DEIS Appendix VI-A

Figure V-2.14

1 HR SPEGL ISOPLETHS FROM ACCIDENTAL SPILL OF N2H4 AT LOCATION 8 WITH 30 MINUTE BLANKETING TIME



Source: ACTA, Inc.
DEIS Appendix VI-A

Figure V.2.15

1 HR SPEGL ISOPLETHS FROM ACCIDENTAL SPILL OF N2H4 AT LOCATION 8 WITH 15 MINUTE BLANKETING TIME

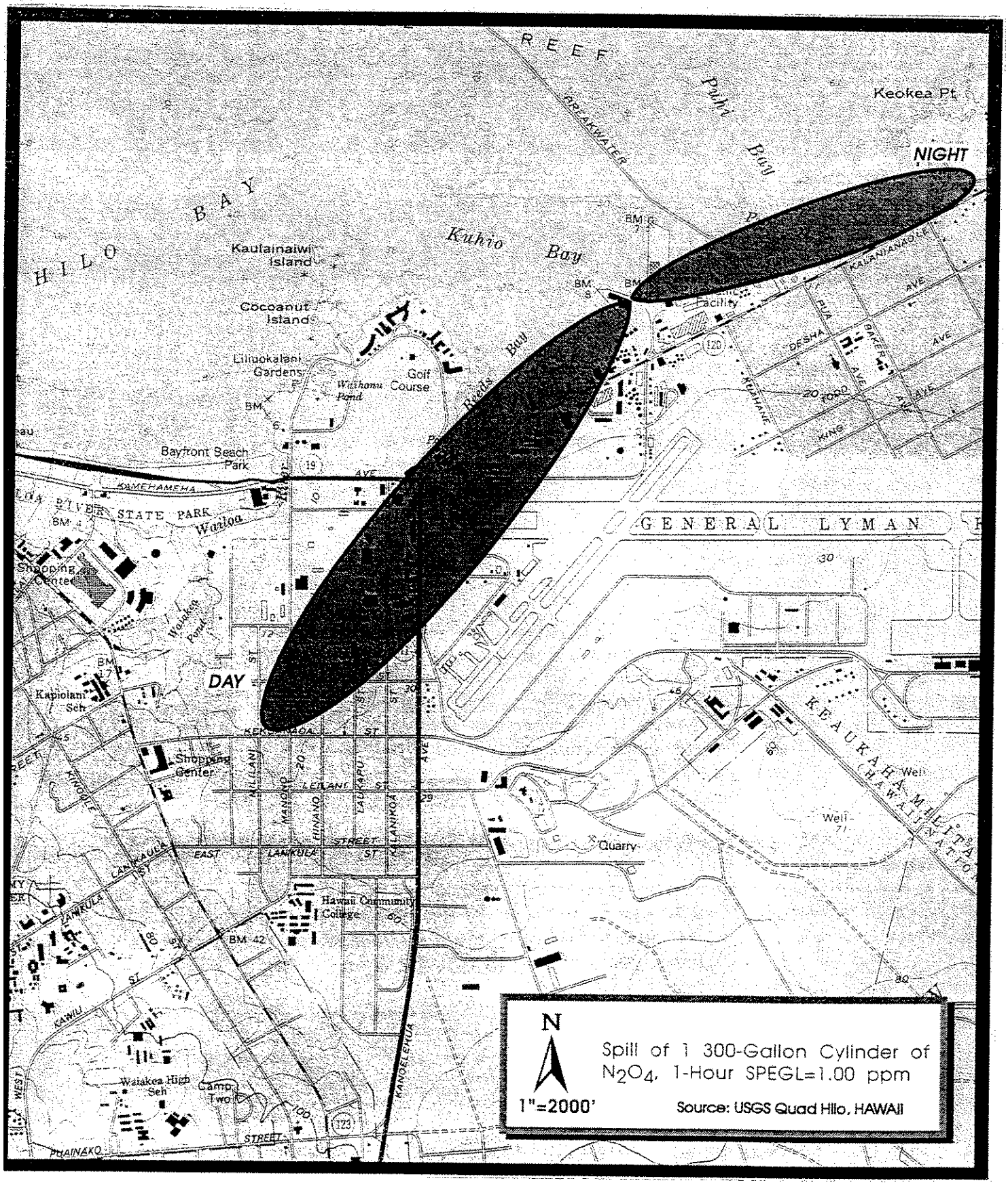


Figure V-2.16

1 HR SPEGL ISOPLETHS FROM ACCIDENTAL SPILL OF N2O4 AT LOCATION 1 WITH 30 MINUTE BLANKETING TIME

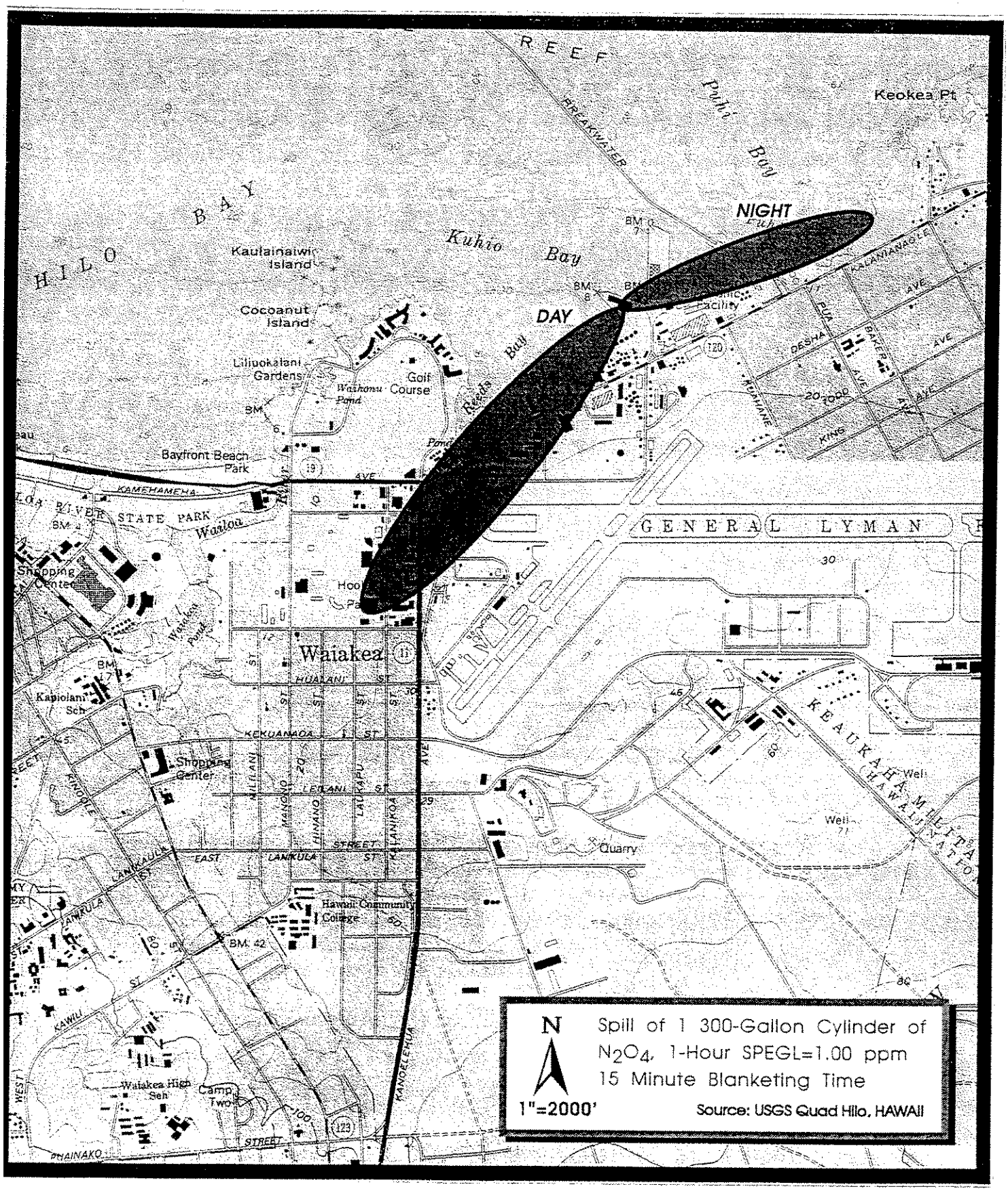


Figure V-2.17

1 HR SPEGL ISOPLETHS FROM ACCIDENTAL SPILL OF N2O4 AT LOCATION 1 WITH 15 MINUTE BLANKETING TIME

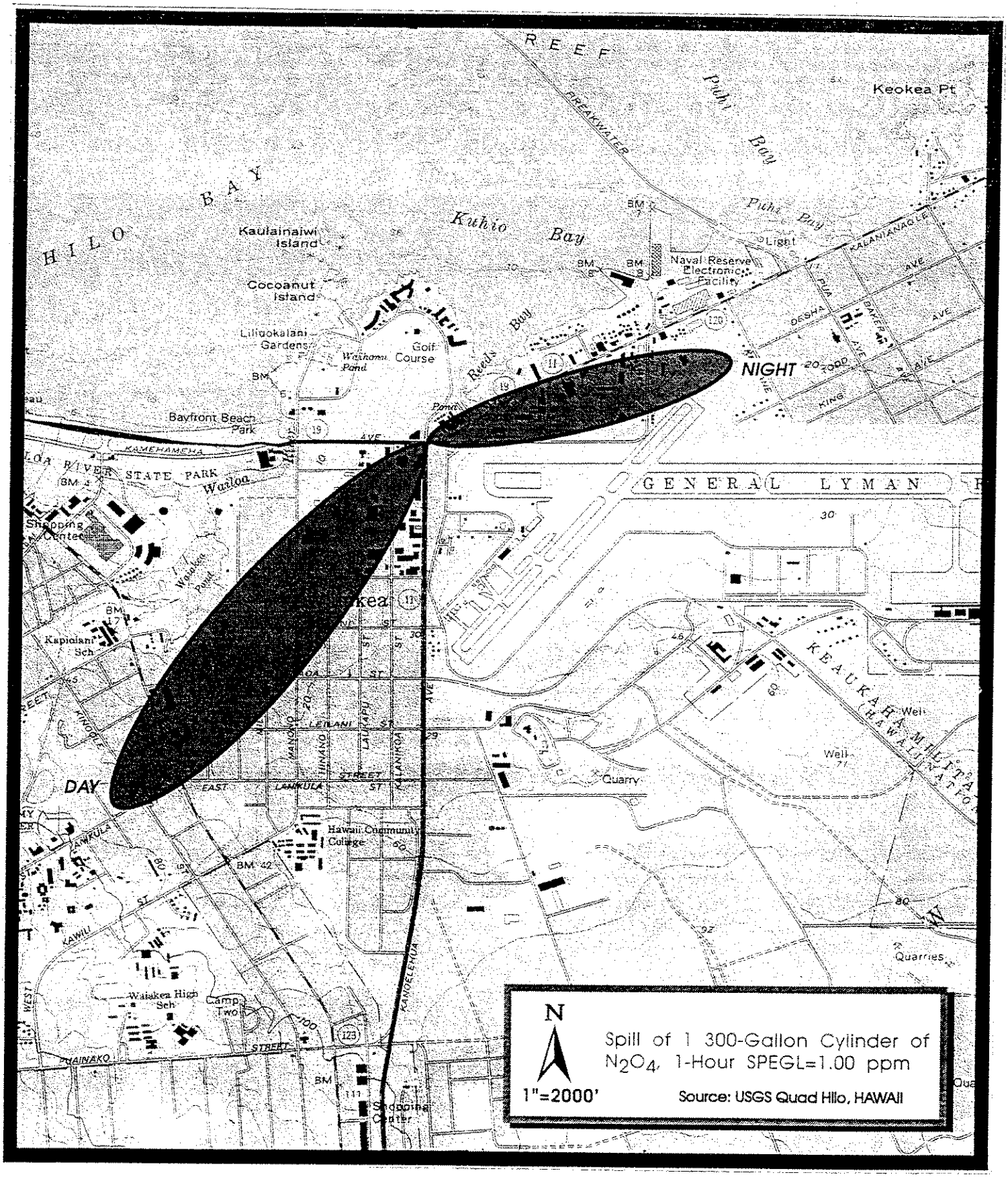


Figure V-2.18

1 HR SPEGL ISOPLETHS FROM ACCIDENTAL SPILL OF N2O4 AT LOCATION 2 WITH 30 MINUTE BLANKETING TIME

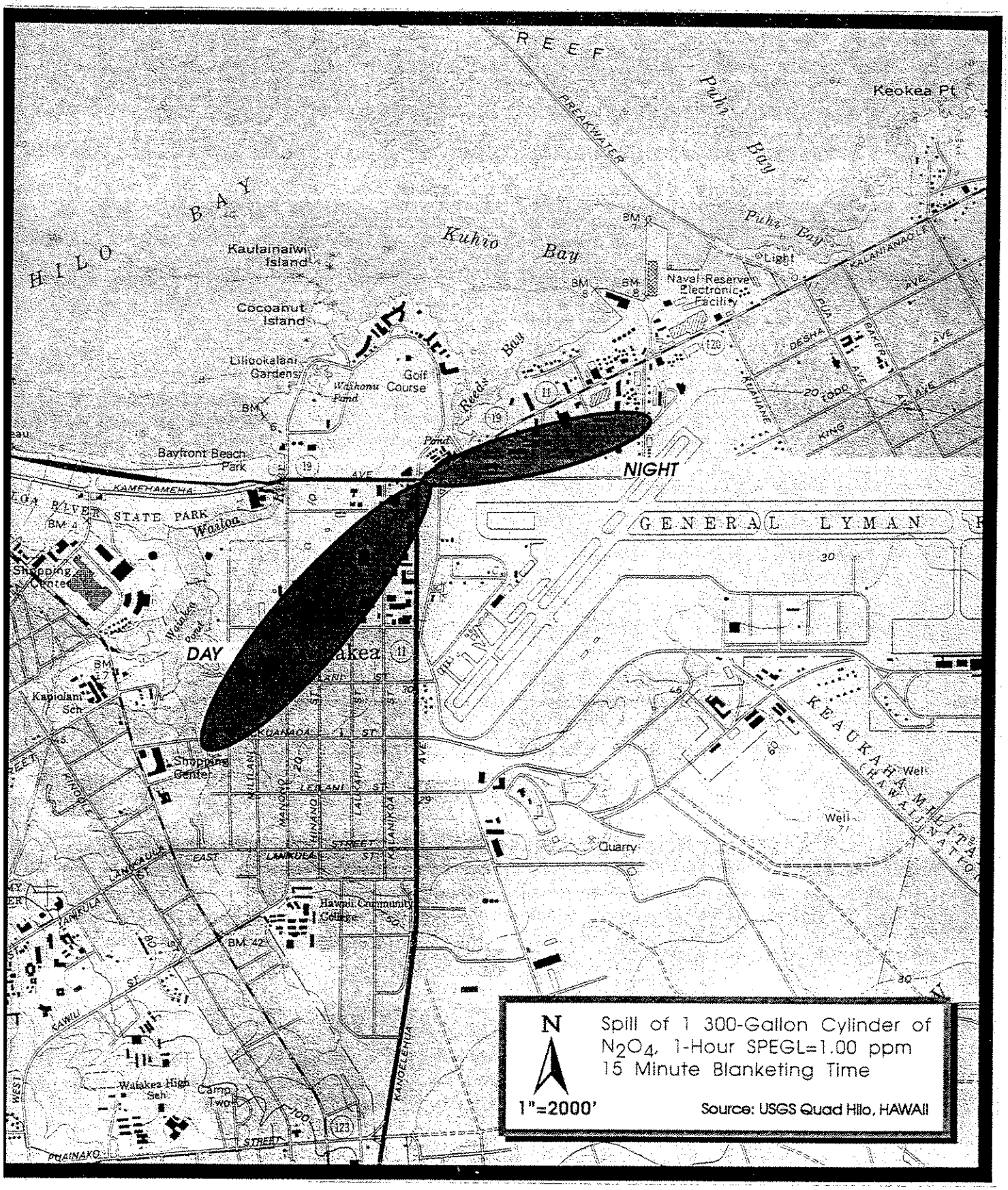


Figure V-2.19

1 HR SPEGL ISOPLETHS FROM ACCIDENTAL SPILL OF N2O4 AT LOCATION 2 WITH 15 MINUTE BLANKETING TIME

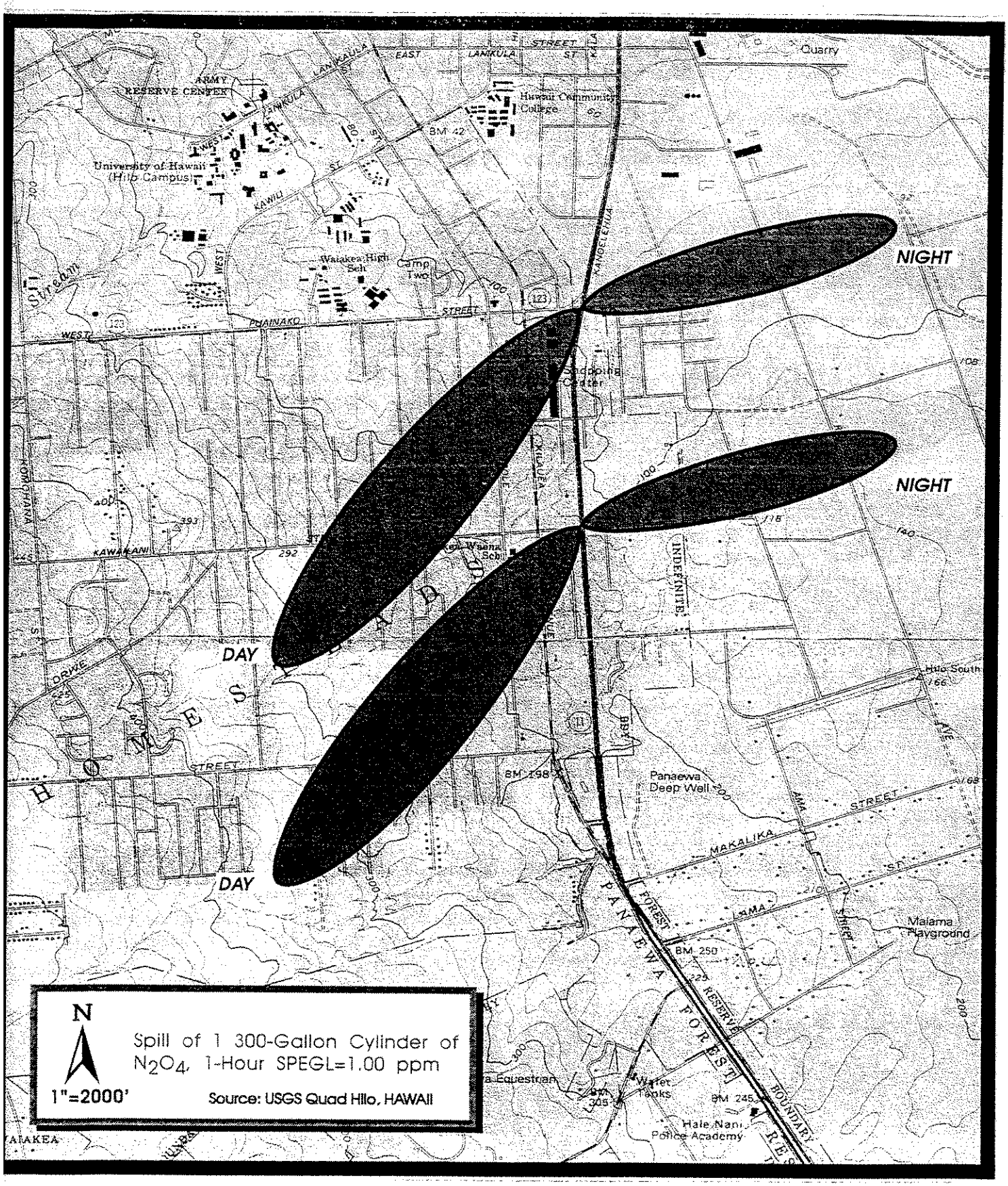


Figure V-2.20

1 HR SPEGL ISOPLETHS FROM ACCIDENTAL SPILL N2O4 AT LOCATIONS 3 AND 4 WITH 30 MINUTE BLANKETING TIME

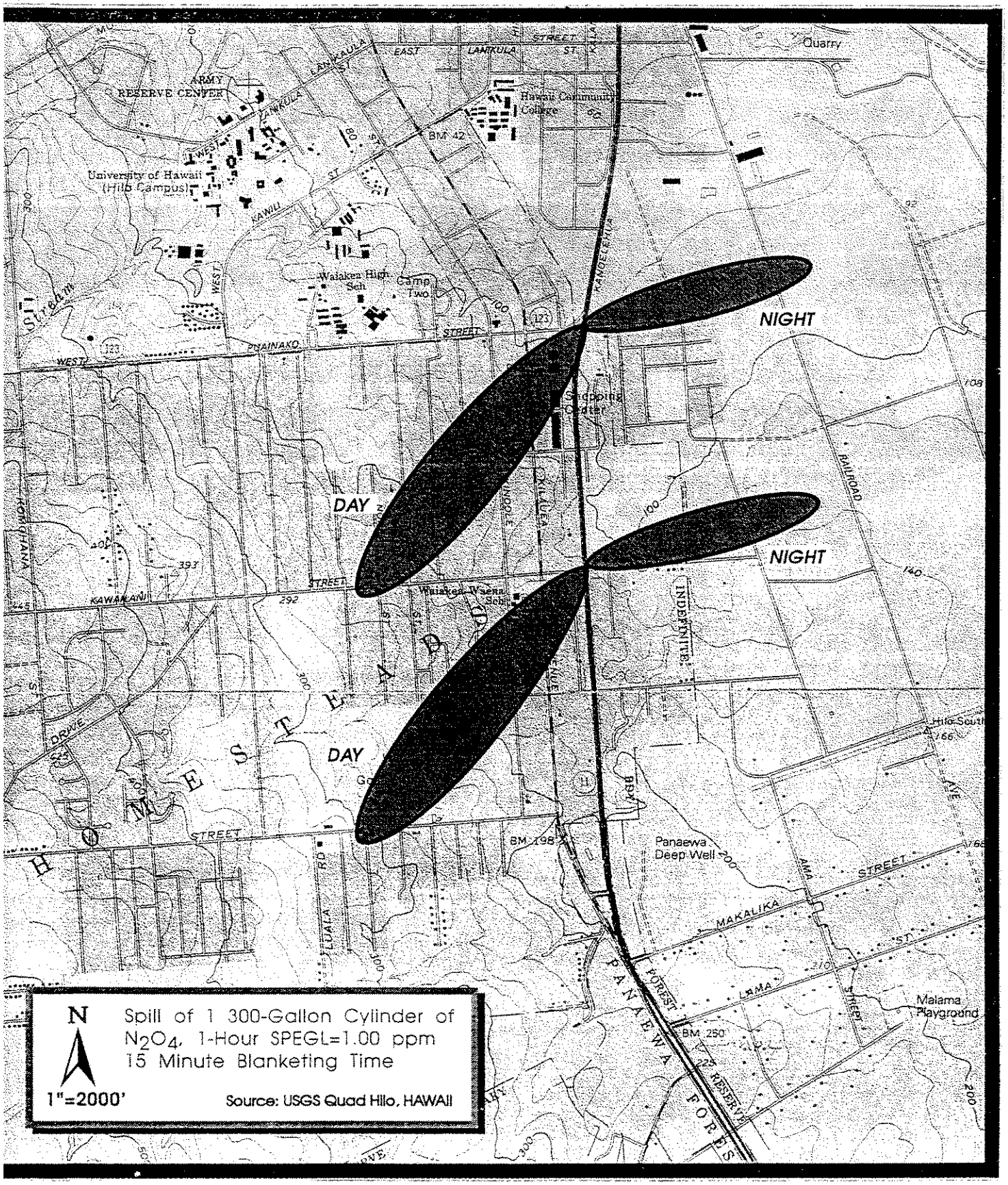


Figure V-2.21

1 HR SPEGL ISOPLETHS FROM ACCIDENTAL SPILL N2O4 AT LOCATIONS 3 AND 4 WITH 15 MINUTE BLANKETING TIME

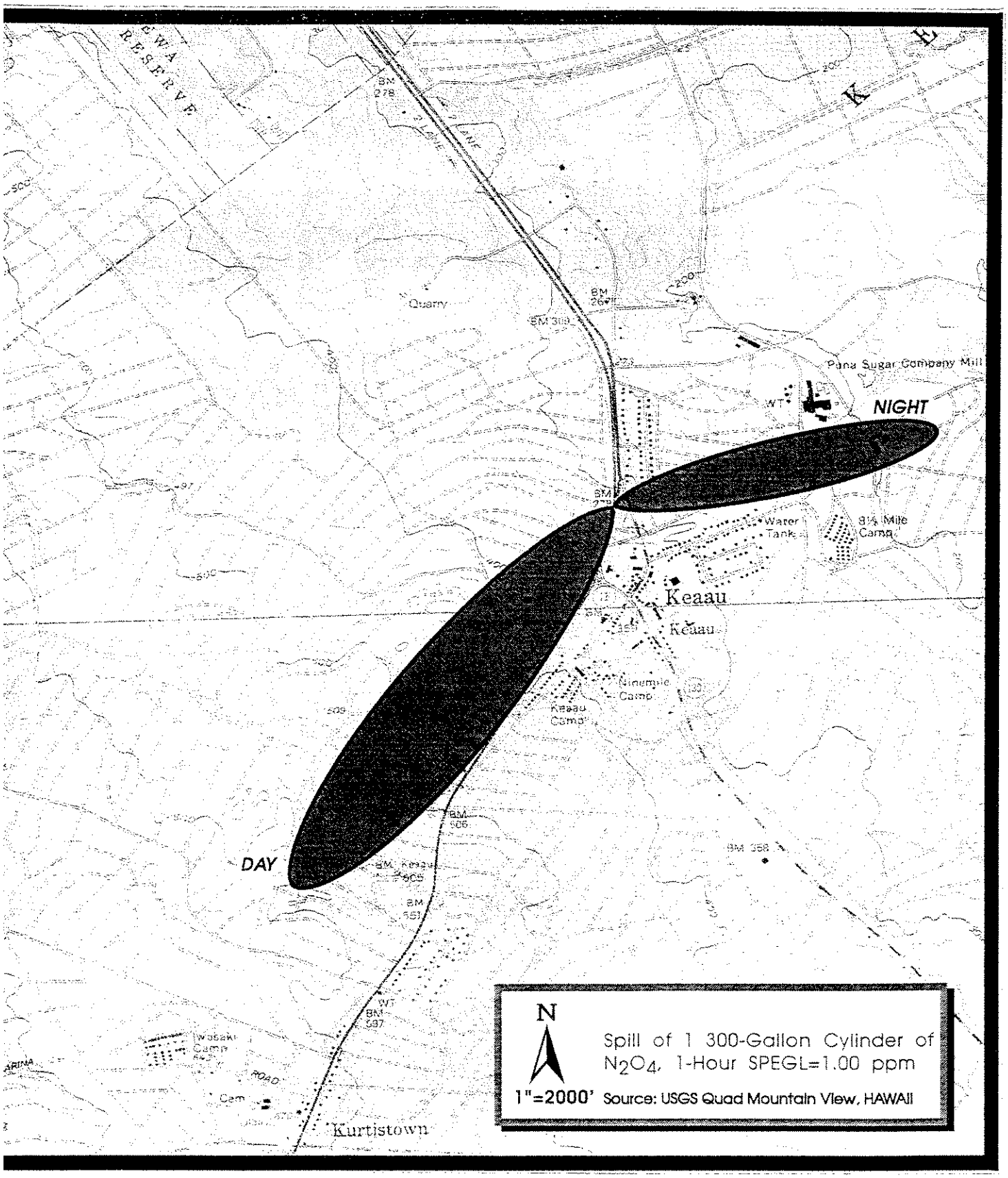


Figure V-2.22

1 HR SPEGL ISOPLETHS FROM ACCIDENTAL SPILL OF N2O4 AT LOCATION 5 WITH 30 MINUTE BLANKETING TIME

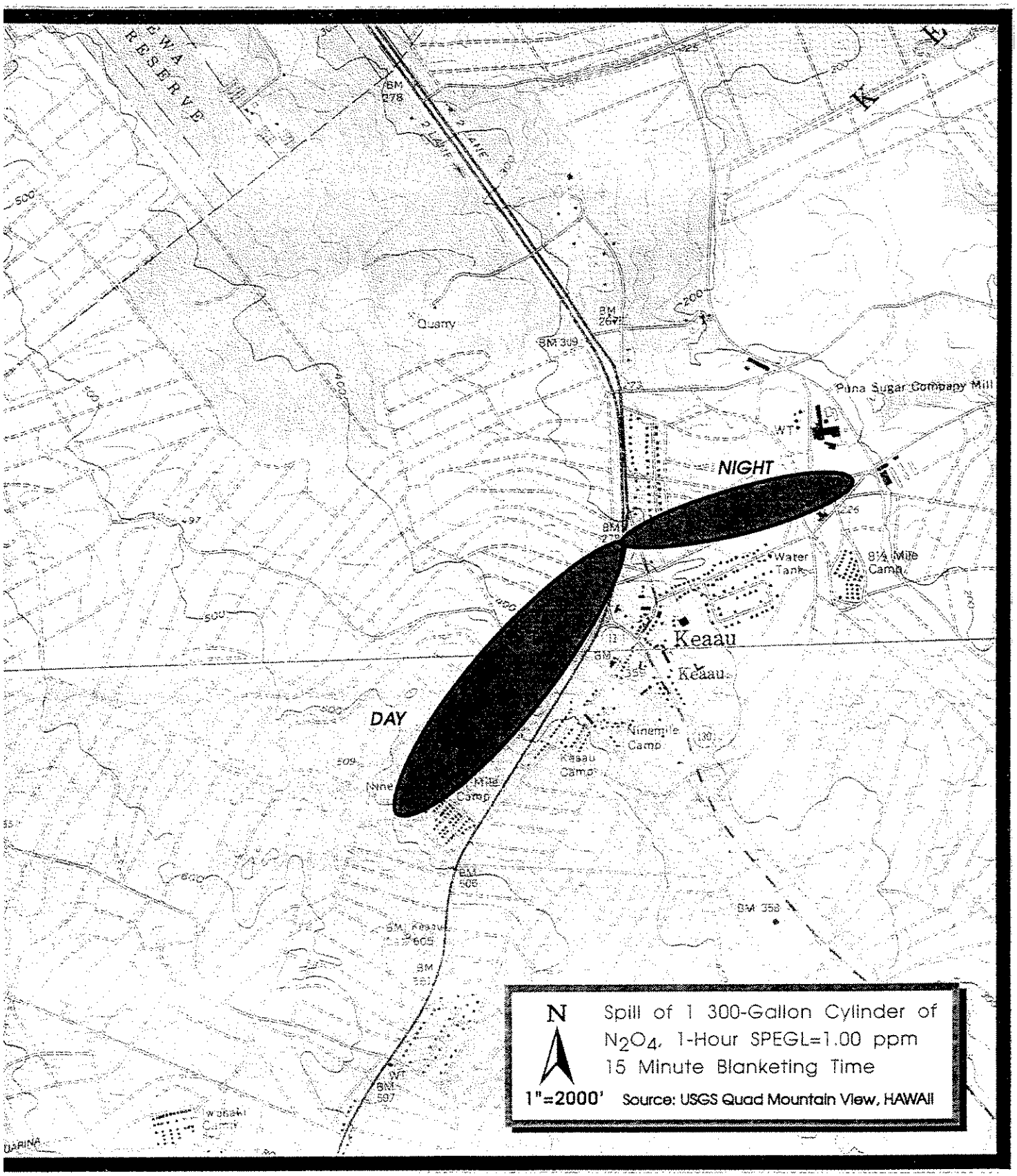


Figure V-2.23

1 HR SPEGL ISOPLETHS FROM ACCIDENTAL SPILL OF N2O4 AT LOCATION 5 WITH 15 MINUTE BLANKETING TIME

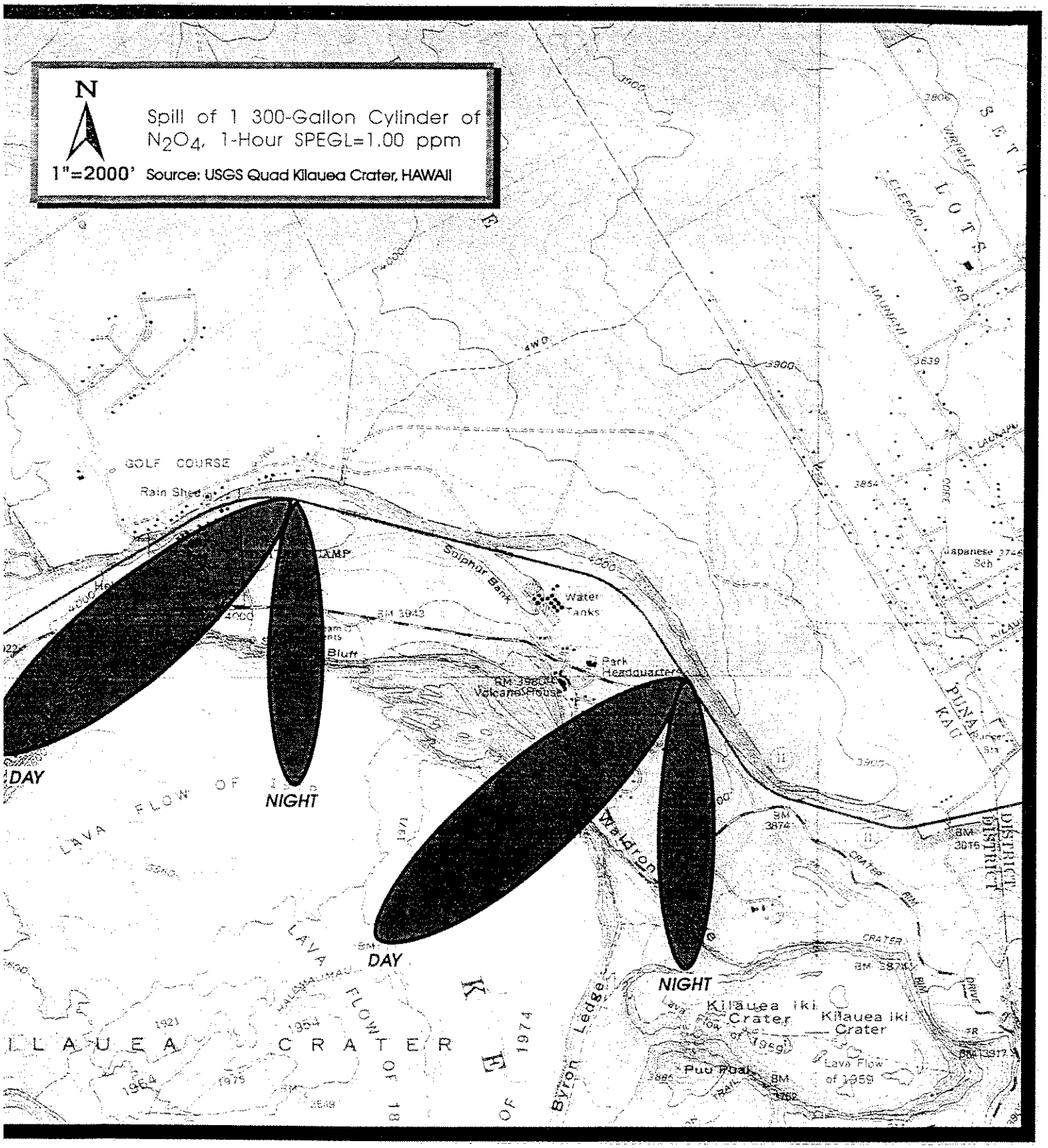


Figure V-2.24

1 HR SPEGL ISOPLETHS FROM ACCIDENTAL SPILL N2O4 AT LOCATIONS 6 AND 7 WITH 30 MINUTE BLANKETING TIME

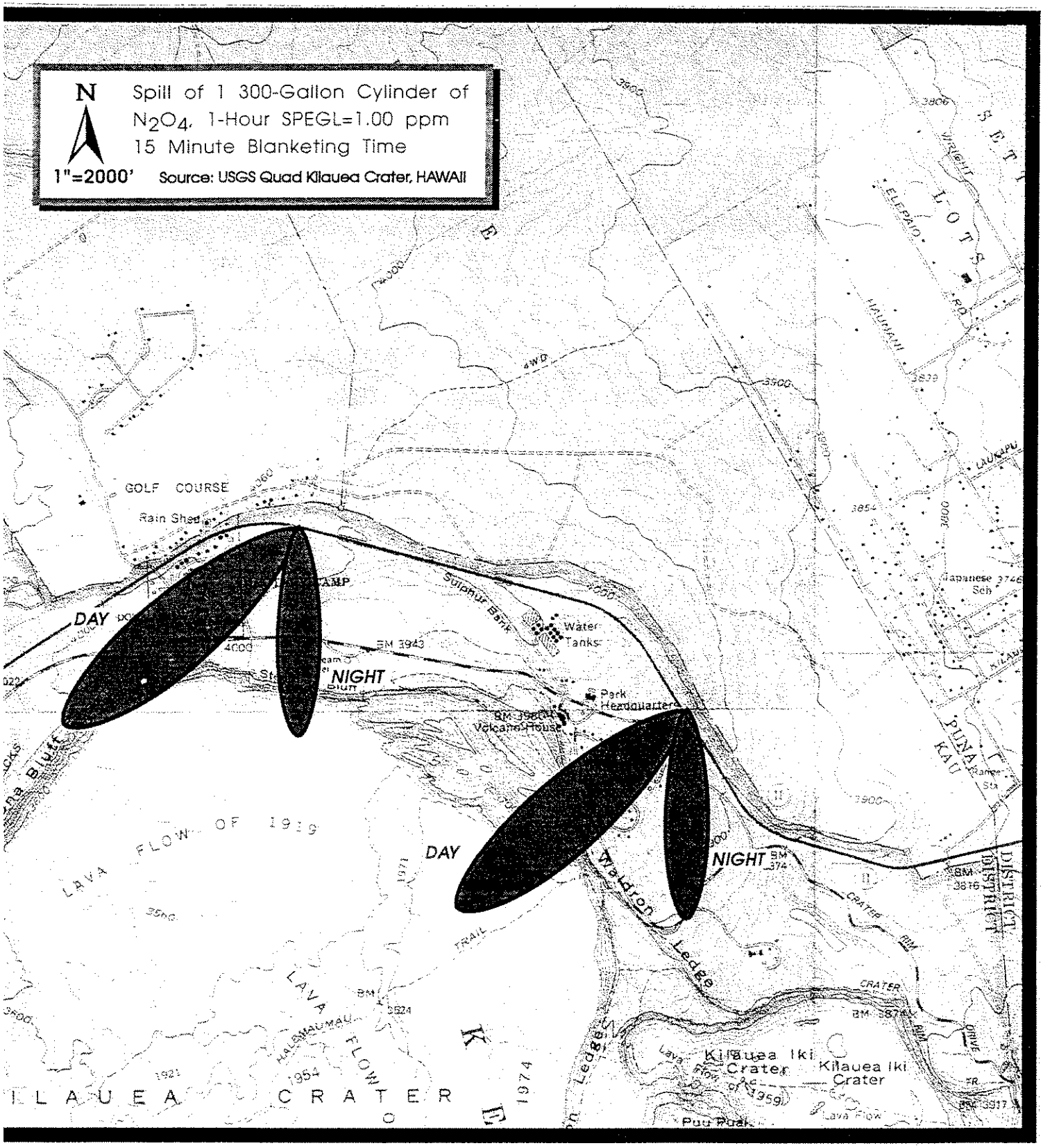


Figure V-2.25

1 HR SPEGL ISOPLETHS FROM ACCIDENTAL SPILL N2O4 AT LOCATIONS 6 AND 7 WITH 15 MINUTE BLANKETING TIME

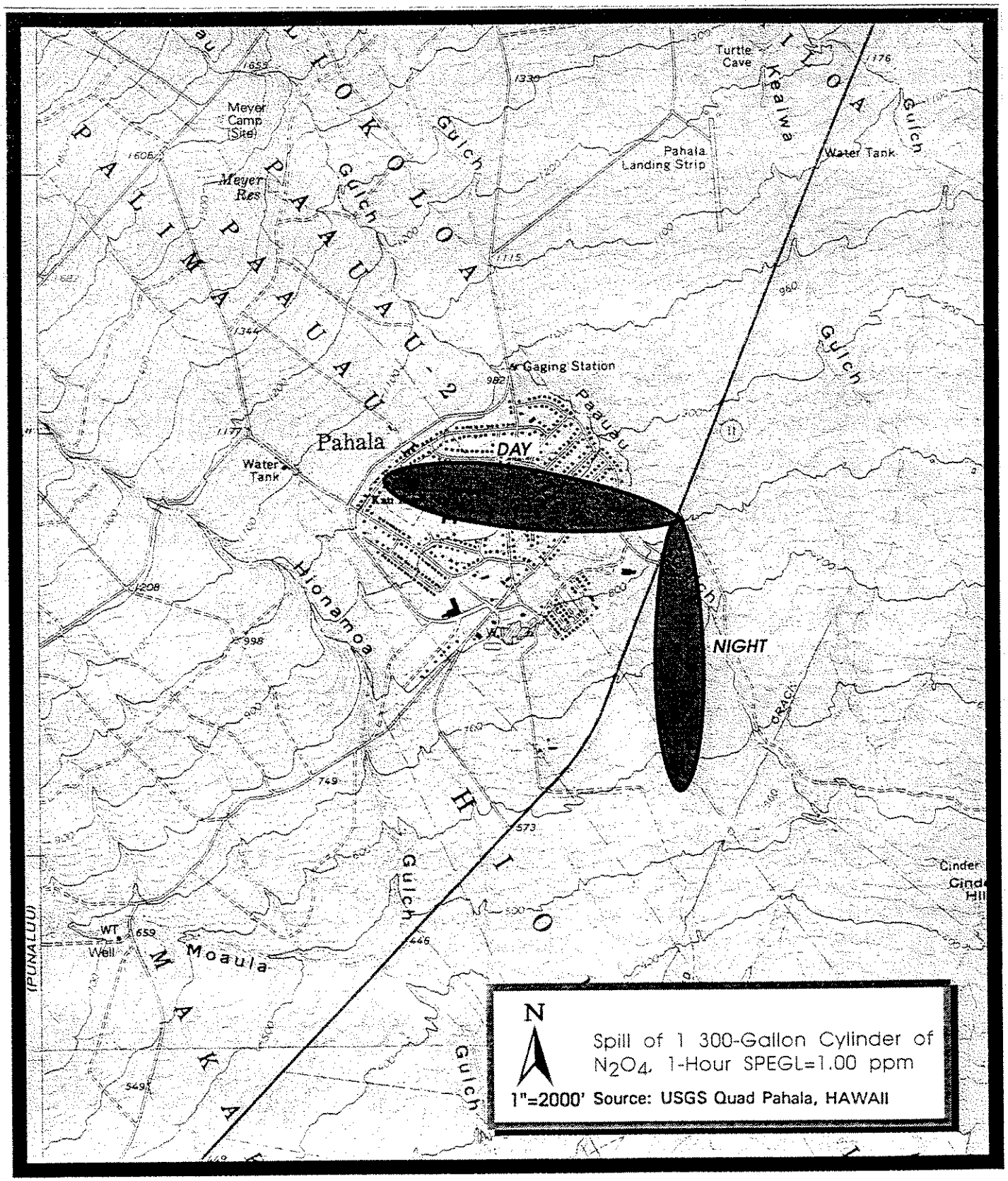


Figure V-2.26

1 HR SPEGL ISOPLETHS FROM ACCIDENTAL SPILL OF N2O4 AT LOCATION 8 WITH 30 MINUTE BLANKETING TIME

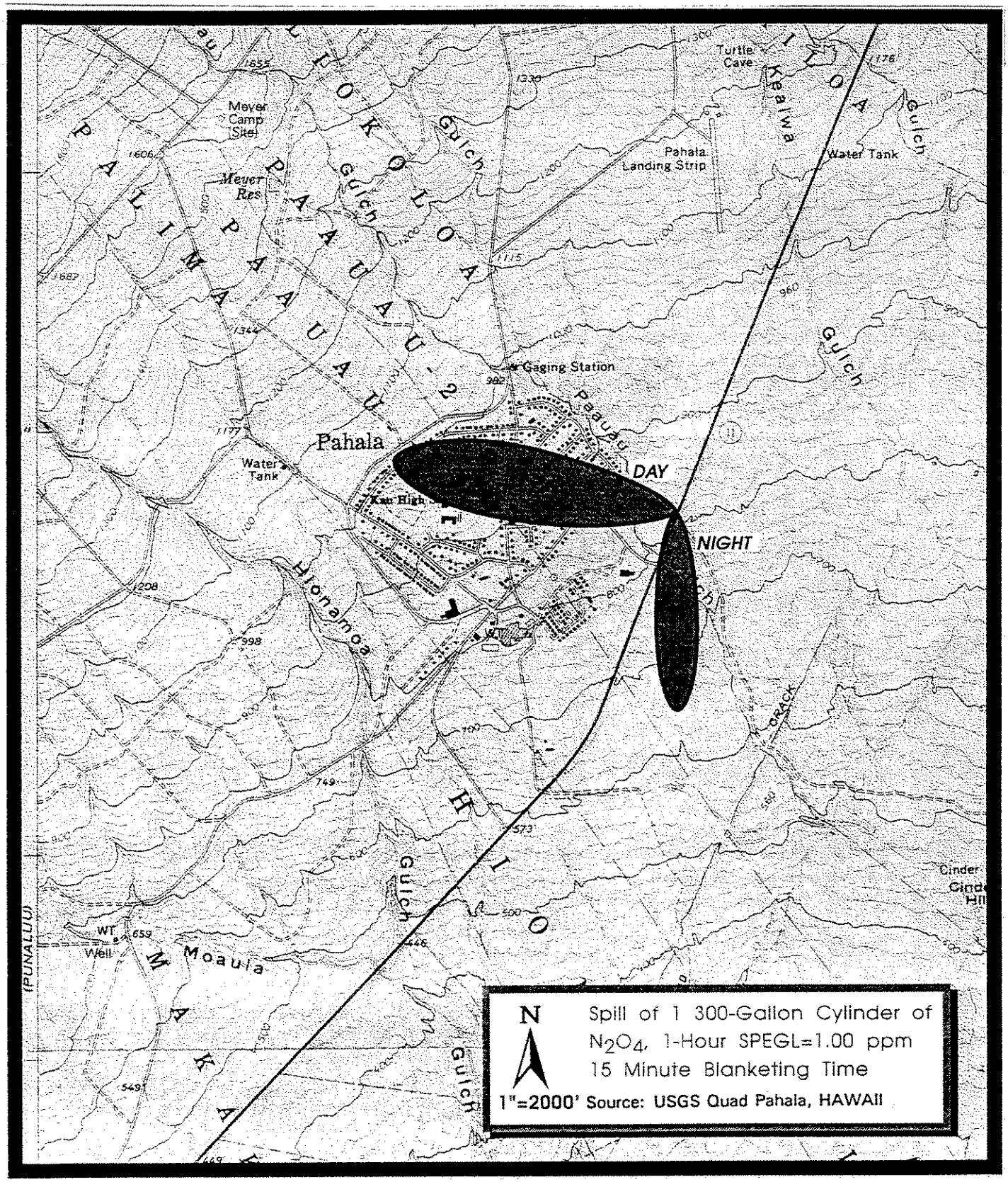


Figure V-2.27

1 HR SPEGL ISOPLETHS FROM ACCIDENTAL SPILL OF N2O4 AT LOCATION 8 WITH 15 MINUTE BLANKETING TIME

SECTION III: NORMAL LAUNCHES AND LAUNCH FAILURES

A. ACTIONS ASSESSED

1.0 Overview

The prime objective of the launch phase is to boost the vehicle to overcome Earth's gravity, rise through the atmosphere and overcome friction. Launch vehicles must be controlled continuously because they are aerodynamically unstable. A slight increase in the angle of attack will cause aerodynamic forces to attempt to increase the angle of attack even further.

A launch vehicle can malfunction and stray off its planned course. If this occurs, the termination system is activated and the vehicle is destroyed by radio command. Range safety systems are designed to protect people and property from errant vehicles and debris.

Most launch vehicles contain several stages. Thrust is initially provided by the lowest and largest boost stage. When the fuel for this first stage is consumed, the spent fuel casing is jettisoned to Earth, and the next stage is fired and the remainder of the vehicle continues its flight. Part of the preparation for any mission is the planning of the impact location of the spent stages in order to minimize risk to people and property.

2.0 Launch Vehicle Scenarios

Normal Launch. A normal launch, as the name implies, indicates a successful launch. The rocket ascends along a nominal trajectory functioning within design parameters.

Conflagration. This represents a vehicle failure where the vehicle solid rocket booster(s) are assumed to explode resulting in scattered burning solid propellant fragments. A conflagration can occur either on the launch pad or during ascent. Each scenario has different effects. The conflagration scenario does not apply to vehicles that do not utilize solid propellants.

Deflagration. This represents a vehicle failure where the liquid hypergolic fuels react in a fireball explosion. The exhaust cloud resulting from the fireball is comprised of vaporized hypergols and combustion by-products.

Command Destruct. The destruction of an errant rocket by the range safety officer during launch produces a breakup and falling debris, which have the potential to cause injury or damage.

3.0 Major Effects

The major effects associated with rocket launches and launch failures are assessed in this Section. A description of the methodology used in evaluating these effects is presented in Section I of this Chapter. The major effects of concern are:

Toxic Exhaust and Vapor Clouds. Rocket exhaust products are characterized as a ground cloud plus the plume trailing behind the ascending launch vehicle. Volatile and particulate

substances that could be harmful to people, animals and vegetation released during a successful launch and during launch failures when solid fuel explodes and burns (conflagrations), include HCl and Al_2O_3. During launch failures when liquid fuel is involved (deflagration), potential emitted substances include hydrazine, UDMH, nitrogen tetroxide, FDH and DMNA. These propellants and are toxic and/or corrosive. If released in an accident, unreacted vapors and aerosols may be transported by prevailing winds in the form of clouds. Such clouds may pose a health hazard to people and are potentially harmful to animals and vegetation.

Explosions. Uncontrolled combustion of the propellants at a very fast rate such that part of the chemical energy is converted to mechanical energy and part to heat. The mechanical energy is produced in the form of a blast wave with the potential for damage by crushing forces and winds.

Debris. Vehicle fragments that may land upon structures or populated areas. Fragments may include burning propellants which could explode or burn upon landing thus posing additional hazards such as fires and explosions.

Launch-Generated Noise and Vibration. With each rocket launch, there will be intense noise for one or two minutes within several miles of the launch site. Because the Atlas II AS and the Delta II booster systems are expected to generate essentially the same noise levels, they are treated as one and the same in the analysis.

Sonic Boom. A sonic boom can result from the acoustical energy generated when a rocket exceeds the speed of sound. The shape and footprint of the sonic boom from any particular launch will be affected by the launch trajectory and meteorological conditions. Meteorological conditions can alter the peak overpressures, shift the focal region up or down range, and distort the shape of the footprint. Sonic boom effects from successful launches are evaluated for both the Atlas IIAS and the Delta II.

B. BASIC ASSUMPTIONS

1.0 Weather

The severity of toxic diffusion, debris dispersion and noise propagation effects from successful launches and launch failures is dependent upon weather conditions at launch time. The Eight meteorological scenarios were used in the launch studies to simulate representative and worst case meteorological conditions. The first seven were developed from rawinsonde soundings, primarily from the project site; the eighth is a hypothetical worst case condition developed to compensate for the lack of a one-year meteorological monitoring program. Each scenario is described in terms of wind speed, direction, and temperature, both above the launch facility and on the surface. The meteorological scenarios used in the assessment and evaluation of launch events are:

- **Tradewind 1.** A September 1991 evening sounding. This scenario is representative of moderate evening tradewind conditions with 6 to 16 knot winds from the northeast.

- **Tradewind 2.** A May 1989 afternoon sounding. This represents relatively strong afternoon tradewind conditions with 8 to 19 knot winds from the east to northeast direction.

- **Weak Tradewinds.** A September 1991 afternoon sounding. This scenario represents weak to moderate tradewind conditions with 2 to 12 knot winds from the east to northeast.

- **Kona.** A September nighttime sounding from Hilo. This scenario represents a tradewind decline (Kona weather) with 4 to 14 knot winds from the southeast.

- **Nocturnal Drainage.** A September 1991 pre-dawn sounding. This scenario represents a shallow surface layer offshore nocturnal drainage flow from the surrounding mountains.

- **Transition 1.** A September 1991 early morning sounding. This scenario represents early morning transitional conditions with surface winds shifting from nocturnal drainage flow to a tradewind condition.

- **Transition 2.** A September 1991 morning sounding. This condition represents continuing transition from nocturnal drainage flow to a tradewind condition.

- **Hypothetical Worst Case.** This is a hypothetical weather scenario based on the Kona weather condition. All wind speeds at different altitudes are set to the same bearing and the base of the thermal inversion is set to the lower limit of the tradewind inversion mixing region. This hypothetical worst case does not represent expected weather conditions but simply serves as a mechanism to determine what the effects would be if the winds at all altitudes were directed toward various receptor sites.

  The hypothetical scenario combines the worst aspects of vertical wind velocity profiles and inversion layer conditions. The result is to predict the highest downwind ground level concentrations of pollutants. Assessment results which show that there would be no adverse effects even under the Hypothetical Worst Case conditions generally indicate that they would not be expected under any other condition.

Launches must be held if meteorological data show that unacceptable consequences are possible. An on-site meteorological monitoring program--of at least one year duration--will be conducted to measure the actual meteorological range and to identify any other conditions that might result in adverse effects on off-site populations and ecosystems. In addition, safe launch operations require continuous meteorological monitoring prior to any launch. Models are run and effects are predicted in real-time. If conditions are not favorable the launch will be held until they are acceptable from a safety perspective. (Appendix B of the FEIS describes the major elements of meteorological monitoring to support space launch operations).

2.0 Affected Environment

Human Populations. Based upon predominant wind direction and meteorological conditions in the Palima Point area, residents to the north and southwest of the facility site, and the Kona coast north to Kailua, may potentially be affected by launch operations. Sixty-six sensitive receptor locations from Pahala to Kailua-Kona were identified. These locations were modeled for ground level pollutant concentrations. In addition, calculations were made of the potential impact of airborne pollutants on rainwater roof catchment systems in the same areas.

Sensitive receptors are those individuals who might be particularly sensitive to increased exposure to pollutants. They include individuals with respiratory problems, infants, the elderly and the infirm. Sensitive receptor locations generally include hospitals, convalescent homes, schools, day care centers, and water supply sources. The 66 receptors are listed in RSA, DEIS Appendix VIIIA, and include, among others, individuals residing in Pahala, Na`alehu, and Punalu`u.

Ecological Populations and Habitats. Because the estimated concentrations of toxic chemicals released through on-site launch activities are highest for areas outside of the PCZ

(ACTA Inc., DEIS Appendix VID), a 15 km (9 mile) zone of ecological concern was delineated and characterized. The 15 km zone encompasses the following 7.5' USGS quadrants: Keaiwa Reservoir, Na`alehu, Pahala, Punalu`u, and Wood Valley. Of particular concern is the Ka`u Forest Reserve, which has been identified as an important refuge for plants and animals on the Island of Hawaii (Scott et al. 1986).

Baseline studies of the ecological environment within the boundaries of the PCZ were taken, however, no comparable surveys were conducted outside the zone. Federally listed species and sensitive habitat types outside of the project site were identified by consulting the USFWS, the U.S. National Park Service and the Hawaii Heritage Program of the Nature Conservancy. Vegetation maps produced by Jacobi (1989) were also used to describe the vegetational communities located in the Ka`u Forest Reserve.

Two listed terrestrial vertebrate species were found within the PCZ: the Hawaiian hawk (*Buteo solitarius*) and the Hawaiian hoary bat (*Lasiurus cinereus semotus*) (DEIS Appendix IIID). The threatened Green Sea Turtle (*Chelonia mydas*) and the endangered Hawksbill turtle (*Eretomchelys imbricata*) are also reported within the vicinity of Palima Point. Nesting hawksbill turtles have been found at Kamehame Hill, Punalu`u Bay and Ninole Cove (DEIS Appendix IIIE). Sensitive species (plant and animal) have also been reported by the Hawaii Heritage Program within the zone of ecological concern. Table 5.3.1 gives listed species within a 15 km (9-mile) radius of Palima Point.

The uncultivated lands within the PCZ at Palima Point contain seven major plant communities (DEIS Appendix IIIC and Figure III-2.9). It is likely that the coastal area (east of the Mamalahoa Highway) contains the same habitat types as those described within the launch site. Agricultural areas (sugar cane, macadamia nuts, cattle) are located west of the Mamalahoa Highway. Approximately 6 km (4 miles) west of the Highway and at about the 900 m (2,970-foot) elevation, this agricultural zone merges into the Ka`u Forest Reserve, described by Scott (1986) as a relatively undisturbed, isolated montane rainforest of `ohi`a (*Metrosideros polymorphs*) and koa (*Acacia koa*).

Water Resources. Rainwater falling on the highly porous, geologically young lavas at Palima Point quickly soaks into the soil becoming groundwater rather than producing high surface water flows. Groundwater then reemerges at springs or discharges at the shoreline (DEIS Appendices IIIB and IIIE). Surface water can be found in the form of intermittent freshwater streams; one anchialine pool was found within the PCZ (DEIS Appendix IIIE). The coastal marine waters fronting Palima Point are typical of the open Hawaiian coast.

C. AIR QUALITY EFFECTS FROM ROCKET LAUNCHES

1.0 Emissions of Criteria Pollutants

Estimated emissions of the criteria pollutants carbon monoxide (CO), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), ozone (O_3), lead (Pb), and aluminum oxide (PM_{10}) emitted for each candidate vehicle are described below.

Atlas IIAS. The primary source of launch pollutants are the four SRMs, the two booster liquid rocket engines, and the one sustainer liquid rocket engine. The primary pollutant products of SRM fuel combustion are CO, aluminum oxide (Al_2O_3), and hydrogen chloride (HCl). Aluminum oxide is in the form of respirable particulate matter with an average diameter of two microns, therefore it is considered as PM_{10} (particulate matter smaller than 10

Table 5.3.1 **LISTED SPECIES WITHIN A 15 KM RADIUS OF PALIMA POINT**

Scientific Name	Common Name	Federal Status	Source
Plants			
Bobea timonioides	'Ahakea	C2	Nature Conservance 1992
Cyanea tritomantha	'Oha, haha,'oha wai	C2	Nature Conservance 1992
Melicope zahlbruckneri	Alani	C2	Nature Conservance 1992
Neraudia ovata	Ma'aloa, ma'oloa 'oloa	C2	Nature Conservance 1992
Ophioglossum concinnum	Pololei	C1	Nature Conservance 1992
Pleomele hawaiiensis	Halapepe	C2	Nature Conservance 1992
Pritchardia affinis	Loulu	C1	Nature Conservance 1992
Scaevola kilaueae	Naupaka	3C	Nature Conservance 1992
Animals			
Reptiles			
Chelonia mydas	Green Sea Turtle	FE	Brock & Kam 1990
Eretmochelys imbricata	Hawksbill Sea Turtle	FE	Nature Conservance 1992
Birds			
Anas wyvilliana	Hawaiian Duck	FE	Freed 1992
Buteo solitarius	'Io Hawaiian Hawk	FE	Nature Conservance 1992
Corvus hawaiiensis	'Alaia Hawaiian Crow	FE	Nature Conservance 1992
Hemignathus munroi	'Akiapola'au	FE	U.S. Fish & Wildlife 1982
Loxops coccineus coccineus	Hawaii 'Akepa	FE	Nature Conservance 1992
Nesochen sandvicensis	Nene Hawaiian Goose	FE	Nature Conservance 1992
Oreomystis mana	Hawaiian Creeper	FE	Nature Conservance 1992
Oceanodroma castro	Band-rumped Storm Petrel	SE	Freed 1992
Pterodroma phaeopygia	Hawaiian Dark-rumped Petrel	FE	Freed 1992
Puffinus auricularis newelli	Newell's Townsend's Shearwater	FT	Freed 1992
Mammals			
Lasiurus cinereus semotus	'Ope'ape'a Hawaiian Hoary Bat	FE	Nature Conservance 1992 Freed 1992

LISTING STATUS

FE: Species formally listed as endangered by the federal government.

FT: Species formally listed as threatened by the federal government

SE: Species formalisted as endangered by the State of Hawaii.

C1: Category 1 candidate. Species for which USFWA has substantial information on biological vulnerability to support a proposal to list them as endangered or threatened.

C2: Category 2 candidate. Species for which USFWA has information that they are possibly endangered or threatened. More data is needed.

3C: Species that are no longer being considered for listing as threatened or endangered.

Source: RSA, Appendix VIIIB

aluminum oxide (PM_{10}), 10.1 tons of CO and 7.9 tons of HCl.

The primary combustion pollutants for the booster and sustainer engines are CO and CO_2. Upon release to the atmosphere, nearly all of the CO oxidizes to CO_2. The liquid-fueled booster and sustainer engines operate throughout the booster phase. The booster phase ends at an approximate altitude of 275,000 feet. The estimated total emission of CO from the liquid-fueled engines during the booster phase is 45.7 tons. The emissions which impact ground level air quality are principally those released below 5,000 feet.

The first pair of SRMs burn out at an elevation of 20,000 feet. Assuming constant acceleration during the first 20,000 feet, it is calculated that the Atlas IIAS will reach 5,000 feet in 27.0 seconds. This time interval was used to scale the emissions from the two SRMs and the liquid-fueled engines. Assuming a maximum launch rate of five per year, the Atlas IIAS emissions occurring below 5,000 feet are:

Aluminum Oxide (PM_{10}):	4.0 tons/launch; 20.0 tons/year
CO:	9.9 tons/launch; 49.5 tons/year

Some Atlas IIAS missions require N_2O_4 and hydrazine to be carried on the payload for use as propellants in orbit. These propellants, however, are burned by the satellite only after it reaches orbital altitudes, resulting in no emissions in the lower atmosphere.

The most significant emission is HCl from a conflagration failure. The quantity of HCl that would be generated is uncertain. In-flight vehicle destruction most likely would occur at some vertical distance, therefore, dilution would occur prior to detection at ground level.

Delta II. The combustion of the fuel and oxidizer used on the Delta II results in the production of CO and aluminum oxide (PM_{10}). Exhaust carbon monoxide is not detectable in significant quantities because of effects of afterburning on conversion of carbon monoxide to carbon dioxide. The booster does not emit nitrogen oxides. The estimated emissions are assumed to be released below the 5,000-ft altitude. Delta II launch vehicle emissions are given below on a per-launch basis and a per-year basis assuming a maximum of five launches per year.

Aluminum Oxide (PM_{10}):	8.8 tons/launch; 44.0 tons/year
CO:	6.2 tons/launch; 31.0 tons/year

In a normal launch, the exhaust products are not released at a single point, but are distributed along the vehicle trajectory. Due to the acceleration of the vehicle and the staging process, the quantities emitted per unit length of trajectory are greatest at ground level and decrease continuously. In the event of a vehicle failure in flight, the vehicle destruct system typically ruptures the propellant tanks and releases all remaining propellants. These propellants will normally ignite and burn; however, only limited information is available concerning the products formed or the extent to which the propellants are consumed.

Taurus. For the Taurus launch, only a portion of the Stage 0 SRM is combusted at a level below 5,000 feet. The launch vehicle reaches 5,000 feet within 9.3 seconds of ignition. At a burn rate of 1,750 lbs/sec of solid propellant, the amount of solid propellant burned is 16,275 lbs at 5,000 ft. The equivalent emissions are listed below. The annual emissions are based on a maximum of 12 Taurus launches per year.

Aluminum Oxide (PM_{10}):	3.0 tons/launch; 35.6 tons/year.
CO:	1.7 tons/launch; 20.8 tons/year.
Nitrogen Oxides (NO_x):	0.7 tons/launch; 8.0 tons/year.

There are other unstable chemical species associated with propellant combustion, including a small amount of iron oxide (Fe_2O_3), which is a catalyst. Those listed above are the most likely to be detected, however. CO is expected to be converted rapidly to CO_2 due to the high initial combustion temperature and the abundance of oxygen in the surrounding atmosphere.

Another factor that could contribute to launch emissions would be a vehicle failure on or near the launch pad. The Flight Termination System, however, is designed such that it fragments the booster case and grain in such a way that no detonation is possible, and in fact most of the propellant would not even burn. Hence, emissions would be less than for a normal launch (Engineering-Science, DEIS Appendix VB).

2.0 Impacts on Air Quality

All exhaust emissions would be intermittent and of short duration, therefore, impacts to air quality are not expected to be significant. Estimated annual launch exhaust emissions (tons/year) that would be generated from launch operations at the Hawaii Spaceport are as follows:

Aluminum Oxide (PM_{10}):	± 100.0 tons/year.
CO:	± 101.0 tons/year.
NO_x:	± 8.0 tons/year.

Overall, the nitrogen oxides (NO_x), aluminum oxides (PM_{10}), and CO emissions are not expected to exceed the prevention of significant deterioration (PSD) limit of 250 tons/year. Cumulative impacts on air quality from launch operations are not anticipated to be significant because of the intermittent nature of the vehicle launches.

Potential effects of the exhaust ground cloud are governed by the speed and direction of its movement, which are dictated by the local meteorological conditions, and concentration of the chemical constituents in the ground cloud. Hence, to avoid impacting population centers with the ground cloud, operational constraints will be imposed to limit launches to times when meteorological conditions are favorable.

D. EFFECTS OF TOXIC RELEASES FROM NORMAL (SUCCESSFUL) LAUNCHES

1.0 Vehicle Scenario

The Delta II 7925 vehicle contains the largest fuel loading of solid propellants and hydrazine class hypergols and therefore represents the worst case vehicle from the standpoint of possible releases of hazardous combustion products. Analysis of the Delta II exhaust cloud dispersion was done for normal launch conditions across the eight identified meteorological regimes characterizing the Palima site.

The combustion by-products of concern resulting from a normal launch are hydrogen chloride (HCl) gas and aluminum oxide (Al_2O_3) particles. A ground cloud containing exhaust products is produced during the first few seconds of a normal launch, up to the point when the vehicle climbs about 200 m (660 feet) above the launch pad. As the rocket ascends it gains speed; the exhaust then forms a plume which trails behind the rocket until all of the propellant is consumed. The mass of exhaust products present in the ground cloud and plume represent the total amount of material available for subsequent dispersion into the lower atmosphere. It is

assumed that total dispersion of emitted substances occurs within one hour.

Acidic releases occur during a launch as the water vapor formed in the ground cloud condenses around the aluminum oxide particles to form droplets. Once condensed, the droplets readily absorb hydrogen chloride from the cloud before they fall to earth. In the event a rainstorm occurs immediately (within one hour) after a normal launch, it is possible that the rain will remove some atmospheric contaminants. The pH of these droplets from the candidate launch vehicles is unknown, however, measurements taken from Space Shuttle launches range between 0.1 and 1.0 which is highly acid.

2.0 Effects on Human Health

Assumptions and Methodology. Peak 30-minute average ground level concentrations (GLCs) for HCl and Al_2O_3 were predicted for each weather scenario (including the Hypothetical Worst Case condition) for the 66 previously described sensitive receptor sites. The estimates assume that the wind follows a straight path from the launch site to the receptor. This is not entirely realistic because the presence of Mauna Loa would deflect the wind and influence its path.

Predictions of aluminum oxide (Al_2O_3) concentrations at receptor locations are based on worst case weather conditions and an internal REEDM gravitational settling model that accounts for loss of material as the cloud is transported downwind. Particulate settling velocities were derived for solid rocket boosters using a minimal amount of deluge water, which is reasonable when applied to the Delta II and Atlas vehicles. Specific data on aluminum oxide particulate size distributions and settling velocities was not available for the Delta vehicle, therefore REEDM default values were used for the ACTA analysis.

In order to estimate concentrations at other receptor sites not included in the list of 66 sensitive receptors, centerline 30-minute average concentrations downwind from the launch pad under the Hypothetical Worst Case meteorological condition were estimated. Please refer to Figures V-1.1 and V-1.2 in Section I of this Chapter for a graphic illustrations of the two methods (peak 30-minute average and centerline) of computing average concentrations.

Although on-site concentrations for facility employees were not specifically modeled, centerline concentrations at a downwind distance of 6 km (about 4 miles) from the launch pad (the closest distance modeled) were used in the assessment of worker health effects. The evaluation of facility workers is extremely conservative in that it assumes that during a rocket launch, indoor workers are exposed to levels of contaminants present in outdoor air and that all workers within the population control zone are exposed to the maximum centerline ground level concentration that would occur within the PCZ.

Exposure Concentrations. Hydrogen chloride gas (HCl) is the exhaust product of greatest concern to human health because of the potential for lung irritation. The highest peak 30-minute average concentration for HCl predicted for an off-site receptor location was 0.23 ppm for Pahala under the Nocturnal Drainage meteorological scenario with winds blowing in the direction of Pahala.

The maximum centerline average concentration for HCl is predicted to be 0.18 ppm at a distance of 15 km (about 9 miles) from the launch site under the Hypothetical Worst Case meteorological scenario; centerline HCl concentrations under the same weather scenario are predicted to be less than 0.05 ppm in the Kailua-Kona area. The centerline 30-minute average concentration of HCl for facility workers is 0.048 ppm at a downwind distance of 6 km (about 4 miles) the closest distance modeled.

Concentrations for aluminum oxide are expressed in terms of milligrams per cubic meter (mg/m^3) as an average value over the worst 30 minutes of exposure. The highest Al_2O_3 peak 30-minute average concentration of approximately 2 mg/m^3 is predicted to occur at Pahala and Punalu`u under the Hypothetical Worst Case weather condition. The maximum centerline concentration is predicted to be less than 2.1 mg/m^3 at a range of 9,000 m (about 6 miles) from the launch site under the same Hypothetical Worst Case weather condition. At a downwind distance of 3 km (about 2 miles), centerline ground level concentrations (GLCs) of Al_2O_3 released during a normal launch are 0.428 mg/m^3. At a downwind distance of 6 km (about 4 miles) the GLC is 1.92 mg/m^3.

Cancer Risk Analysis. A cancer risk analysis was not conducted because carcinogenic substances such as hydrazine and UDMH are not released in rocket exhaust emissions from a successful launch. During a normal launch, the liquid fuel and oxidizer undergo complete combustion to products that do not contain vaporized fuel (ACTA Inc., DEIS Appendix VID).

Noncancer Hazard Index Analysis. Results of the chronic hazard index calculations for exposure to a receptor via inhalation of HCl and via inhalation, soil ingestion, and dermal absorption of Al_2O_3 released during a successful launch are given in DEIS Appendix VIIIA. Noncancer risk due to ingestion of drinking water to which HCl has been deposited following a successful launch was also determined.

The maximum chronic hazard index projected to occur from a normal launch, 0.54, occurs at Punalu`u under the Hypothetical Worst Case weather condition. At Pahala, the maximum hazard index is 0.50 under the Hypothetical Worst Case weather scenario.

The maximum overall acute hazard index for a normal launch is 0.16 at Punalu`u under the Hypothetical Worst Case weather scenario. At Pahala, the maximum overall acute hazard index (Nocturnal Drainage and Hypothetical Worst Case weather conditions) is 0.15. The hazard index for a worker exposed to HCl and Al_2O_3 at a distance of 6 km from the launch pad is equivalent to 0.20.

Rain catchment systems may be impacted by wet deposition of hydrogen chloride as a result of the emissions from a normal launch. The average concentration of pollutants projected to occur in a rain catchment system is a function of direct wet deposition on the roof of a house.

Noncancer risk due to ingestion of drinking water to which HCl has been deposited following a successful rocket launch was calculated (Ibid.). A comparison was made between the projected HCl concentration due to wet deposition (0.12 mg/l) and the chlorine concentration recommended by the County of Hawaii in their "Guidelines for Owners of Rain Catchment Systems." In this document, it is recommended that water in a rain catchment system be chemically treated by residents on a monthly basis to control the growth of bacteria and algae.

The use of household bleach for this treatment is recommended at a dosage of 3 ounces per 1,000 gallons of water in the storage tank. Dilution of the bleach at the rate recommended results in a chlorine concentration in water of 2.6 mg/l. The concentrations of HCl would be less than 5 percent of the amount used in regular treatment of rain catchment systems. The resulting hazard index is 0.

Significance of Results. In all cases modeled, the predicted HCl concentrations for normal launches are well below the recommended 3 ppm SPEGL. The Al_2O_3 values are all well below the recommended limit of 15 mg/m^3. Noncancer Hazard Indices for exposure to a receptor via inhalation of HCl and via inhalation, soil ingestion, and dermal absorption of aluminum oxide released during a successful launch were all less than 1.0. A hazard index of

less than one is considered to be a nonsignificant risk.

The noncancer hazard index for concentrations of HCl in rain catchment systems was equal to 0, therefore, wet deposition of exhaust products from normal launches will not adversely effect the safety of drinking water from off-site individual rainwater collection systems.

Relationship Between Aluminum and Alzheimer's Disease. The release of aluminum oxide particles in the rocket exhaust has caused some concern because of published reports that indicate a relationship between aluminum and Alzheimer's disease. Research in the early 1970s found high levels of aluminum in the brain tissue of deceased Alzheimer's patients. A number of studies have been undertaken to determine whether the aluminum causes the illness or whether the lesions in the brain are caused by a defect in the cells which allows the aluminum to accumulate.

The controversy over the cause and effect relationship of aluminum and brain deterioration is complicated by the fact that aluminum is a ubiquitous element and is the third most common element in the earth's crust, after oxygen and silicone. It is found in everything from antiperspirants, antacids, and aspirin to food, everyone is exposed to it. In healthy bodies very little is absorbed and most is excreted by the kidneys.

Adult humans consume an average of 1-15 milligrams of aluminum per day from food, water and food additives. Only trace amounts accumulate in the body, with a normal person having no more than 30-45 milligrams (Anderson 1991). Other sources indicate that normal ingestion is as high as 30-50 milligrams per day, with an average human body burden of 100 milligrams per day (Ibid.).

Both the U.S. Food and Drug Administration and the EPA have issued statements that they have found no risk associated with aluminum in food, drugs or the environment generally. The Alzheimer's Association also does not find evidence to support the hypothetical cause and effect relationship between aluminum and Alzheimer's disease and are focusing their research efforts to determine the cause of the disease in other areas (Anderson, 1991).

3.0 Effects On Sensitive Ecological Species

Assumptions and Methodology. The ground level concentrations of HCl and aluminum oxide in the atmosphere were modeled for the eight different meteorological cases described in Part B of this Section. The peak centerline average concentrations were computed by defining the peak instantaneous concentrations in the downwind direction of the exhaust plume.

The centerline concentrations in the downwind direction represent the maximum ground level concentration that occurs at a given distance from the launch site; by this method, the 30-minute average concentration and predicted centerline peak instantaneous concentration can be estimated at varying distances from the launch site. Because the sensitive ecological receptors of concern are distributed in different geographic areas from the sensitive human receptors, the most appropriate ecological exposure point concentrations are the peak centerline average and predicted centerline peak instantaneous concentrations.

Exposure Point Concentrations. The maximum centerline time mean HCl concentration predicted for a normal Delta II 7925 launch under the Hypothetical Worst Case scenario, was 0.18 ppm at a distance of 15 km from the launch pad and the value for Al_2O_3 was predicted to be 2 mg/m^3 at a distance of 9 km from the pad.

The highest centerline peak instantaneous and 30-minute HCl concentrations of 4.4 ppm and of 0.23 ppm, respectively, occurred at 6 km from the launch site under the Nocturnal Drainage weather scenario. Equivalent concentration were not computed for Al_2O_3.

Effects on Vegetation. High levels of gaseous HCl in air have been shown to adversely affect plants, with broadleaf plants being generally more sensitive than conifers. Symptoms include discoloration of leaf edges and spotting. The degree of damage due to HCl exposure is related to the concentration of the gas in the air and the relative humidity. Exposure to concentrations of less than 3 ppm for 2 hours produces no adverse effects.

Aluminum is the third most abundant element on earth and its presence in soil, air and water makes exposure to this substance virtually universal. While low levels of aluminum can increase plant growth, aluminum phytotoxicity causes overall stunting of a plant, dark green leaves, purpling of stems, death of leaf tips, and damaged root systems. An accurate assessment of the amount of Al_2O_3 deposition from the ground cloud is not possible with current hot plume models.

Effects on Terrestrial Fauna. HCl acts as a strong irritant to exposed animals. Due to its corrosive action, it is highly toxic via ingestion, inhalation or dermal exposure, however, there is a large variance in sensitivities between species. Because there are no specific eco-toxicity data available for the selected ecological receptors, data from other species are used as surrogates. These include: rodent data for the Hawaiian hoary bat, pigeon data for Hawaiian birds, and temperate plant species data for local plants. There are no toxicity data for reptiles.

The Lowest Observed Effect Level (LOEL) for inhalation of HCl in mammals and birds is 150 mg/m^3 in rodents and pigeons. In comparison, the highest peak centerline 30-minute average HCl concentration computed within the zone of ecological concern - under the Nocturnal Drainage meteorological scenario - is 0.23 ppm (0.342 mg/m^3). Instantaneous peak concentrations of HCl are estimated to reach 2.25 ppm (0.348 mg/m^3). The estimated concentrations are an order of magnitude lower than the selected toxicity values.

The highest centerline average concentration for aluminum oxide, 2 mg/m^3 under the Hypothetical Worst Case meteorological condition, was higher than the NOEL value of 0.478 mg/m^3 in rodents for a 1-hour exposure and lower than the human EEGLs of 15 mg/m^3. (The data for rodents might be extrapolated to apply to the Hawaiian hoary bat but is difficult to apply to birds or turtles). The lack of appropriate response data therefore makes it impossible to calculate the risks associated with exposure at higher concentrations.

Significance of Effects. Estimated exposure point concentrations for HCl were lower than those that produce adverse effects in flora and fauna; therefore, it is highly unlikely that exposure to HCl from a normal launch would be detrimental to sensitive ecological receptors (RSA, DEIS Appendix VIIIB).

In contrast, the estimated concentration of Al_2O_3 was higher than the toxicological endpoint concentration (TEC) for biota but lower than human EEGLs (Emergency Exposure Guidance Levels). Because the TEC is a conservative value based upon a No Observed Effect Level (NOEL) and the toxicological database is lacking in short-term dose response information, it is reasonable to assume--at least for short-term exposures of approximately 1-hour duration--that mammalian and avian species are not significantly more sensitive than humans to Al_2O_3. It is unlikely that exposures to concentrations of Al_2O_3 less than the human EEGL will result in measurable adverse effects to biota (Ibid.).

E. EFFECTS OF TOXIC RELEASES FROM AN ON-PAD CONFLAGRATION

1.0 Vehicle Scenario

The Delta II 7925 vehicle uses nine strap-on solid rocket motors. Six of the solid rocket boosters (SRBs) are ignited when the vehicle is still on the launch pad and three are ignited 63 seconds into flight. In an on-pad conflagration, a number of scenarios involving varying numbers (one to nine) of solid rocket boosters is possible. The combustion by-products of concern are hydrogen chloride (HCl) gas and aluminum oxide (Al_2O_3) particles, as is the case for the normal launch.

It is probable that an on-pad explosion will result in the destruction and burning of all nine SRBs. In order to assess the worst case conditions for downwind surface concentrations of exhaust gases, however, it is necessary to analyze conflagration scenarios involving from 1 to 9 solid rocket motors. The amount of solid fuel, fuel fragment sizes, burn rates as a function of pressure, solid fuel heat content (as affected by the presence or absence of atmospheric oxygen) and buoyancy of the exhaust cloud must be considered when analyzing the behavior of the solid fuel exhaust cloud following an explosion.

2.0 Effects on Human Health

Assumptions and Methodology. It is assumed that one conflagration event occurs per 70-year lifetime and that total dispersion of emitted substances occurs within one hour. Potential exposure levels from a conflagration on the pad involving 1 to 9 solid rocket boosters were assessed for the 66 sensitive receptor sites. Peak 30-minute average concentrations of HCl and Al_2O_3 under both the Kona and the Hypothetical Worst Case meteorological scenarios were used in the toxicity assessment. An analysis of concentrations at each of these receptors is presented in RSA, DEIS Appendix VIIIA.

Centerline 30-minute average concentrations downwind from the launch pad under the Hypothetical Worst Case meteorological conditions were determined in order to estimate concentrations at other receptor sites (not included in the list of sensitive receptors). These results, which are summarized below, are also presented in Appendix VIIIA.

Exposure Concentrations. The highest predicted peak 30-minute average concentration of HCl during a under the Kona meteorological condition from an on-pad conflagration on the pad involving <u>9 SRBs</u> is estimated to be 0.11 ppm at Honaunau and Captain Cook in the South Kona District of Hawaii. At Pahala and Punalu'u the comparable values from a conflagration that involves <u>1 SRB</u> are predicted to be 0.005 ppm and 0.009 ppm, respectively.

The highest peak 30-minute average concentration for Al_2O_3 from an on-pad conflagration in which 9 SRBs are involved, for the Hypothetical Worst Case weather condition, is predicted to be 0.76 mg/m^3 at Oceanview Estates in the Ka`u District.

The maximum centerline HCl concentration under the Hypothetical Worst Case meteorological condition was 0.11 ppm at a distance of 48 km from the launch pad. The comparable value for Al_2O_3 is predicted to be 0.78 mg/m^3 at a distance of 30 km (about 19 miles) from the launch site. The centerline 30-minute concentration of HCl at a downwind distance of 6 km (about 4 miles) from the launch pad would be 0.002 ppm at ground level. Centerline 30-minute concentrations of Al_2O_3 at a downwind distance of 6 km (about 4 miles) from the launch pad at ground level would be 0.012 ppm.

Cancer Risk Analysis. Carcinogenic substances such as hydrazine and UDMH are not released as part of a rocket conflagration. A cancer risk analysis was not conducted for the conflagration launch scenario.

Noncancer Hazard Index Analysis. The maximum overall chronic hazard index for exposure to a receptor via inhalation of HCl and via inhalation, soil ingestion and dermal absorption of Al_2O_3, 0.00016, occurs at Oceanview Estates under the Hypothetical Worst Case weather condition. At Pahala, the maximum overall chronic hazard index is 0.00005 and at Punalu`u it is 0.000016.

The maximum acute hazard index occurs at Oceanview Estates under Hypothetical Worst Case weather conditions and is equivalent to 0.072. At Pahala, the maximum overall acute hazard index is 0.0042 and at Punalu`u it is 0.0065.

The hazard index for on-site workers located within 6 km of the launch pad during an on-pad rocket conflagration episode is 0.0052.

The noncancer hazard index for ingestion of HCl-affected drinking water is 0.82. This calculation is based on a comparison between the projected HCl concentration due to wet deposition (0.57 mg/l) and the chlorine concentration of drinking water recommended by the County of Hawaii (2.6 mg/l).

Significance of Effects. Noncancer chronic hazard indices for exposure to a receptor via inhalation of HCl and via inhalation, soil ingestion, and dermal absorption of released during a successful launch were all less than 1.0. A hazard index of less than one is considered to be a nonsignificant risk. Addition of the chronic hazard index due to ingestion of drinking water from a rain catchment system where HCl has been deposited following conflagration (0.82) results in an overall chronic hazard index of 0.82, a level which is not considered to represent a significant hazard. Results of the analysis of acute noncancer hazard indices indicate that adverse acute noncancer health effects are not expected to occur as a result of an on-pad vehicle conflagration.

3.0 Effects on Sensitive Ecological Receptors

Assumptions and Methodology. The worst case scenario for an on-pad conflagration event consisted of an explosion of all nine solid rocket boosters modeled for a Hypothetical Worst Case weather condition. The results were assessed for potential sensitive receptors within the zone of ecological concern--within 15 km from the launch pad. In the assessment it is assumed that one conflagration event occurs within the lifetime of the ecological receptor in question and that total dispersion of emitted substances occurs within one hour.

Exposure Concentrations. Peak 30-minute concentrations of HCl and Al_2O_3 are presented in DEIS Appendix VIIIB. The peak 30-minute average concentration of HCl within the zone of ecological concern is estimated to be 0.012 ppm. The peak concentration for Al_2O_3 within the ecological zone of concern - under the worst case meteorological conditions - is estimated to be 0.33 mg/m^3.

Analysis of Effects. When the highest estimated concentration (EC) of HCl (0.012 ppm) is compared to the selected toxicological endpoint concentration (TEC) and the appropriate uncertainty factors (UFs) applied, the EC is consistently less than the TEC for bats, birds and plants. It is unlikely therefore that adverse effects will occur from exposure to HCl during an on-pad conflagration. Instantaneous peak concentrations of HCl are estimated to reach 8.41 ppm; this is above the selected TEC. It is difficult to draw conclusions based on a direct comparison

of these numbers because the TEC value is based on toxicity tests with longer exposures.

A comparison of the 0.33 mg/m^3 EC with the TEC for Al_2O_3 (Appendix VIIIB) shows that the potential exists for adverse effects to animal species. The TEC for Al_2O_3 is based on a very conservative NOEL value; the lack of appropriate dose-response data (e.g., LOEL values) makes it impossible to calculate at what concentration adverse effects begin to manifest.

Significance of Effects. The risk to plants by exposure to HCl depends on the humidity of the atmosphere at the time of the exposure, however, a comparison of the adjusted TEC values with the estimated EC concludes that it would be highly unlikely that exposure to HCl released in an on-pad conflagration event would be phytotoxic to plants within the zone of ecological concern (RSA, DEIS Appendix VIIIB).

Due to the high density of endangered species reported around Palima Point and the proximity of the site to the Ka`u Forest Reserve (an important refuge for endangered forest birds) a conservative risk characterization was undertaken. The evaluation concluded that HCl and Al_2O_3 produced during a conflagration on the launch pad are unlikely to produce an adverse effect in biota (Ibid.).

F. EFFECTS OF TOXIC RELEASES FROM A CONFLAGRATION DURING ASCENT

1.0 Vehicle Scenarios

A conflagration occurring during vehicle ascent results in debris scattered over a wider area than if the vehicle were destroyed on the pad. The exhaust cloud is more diffuse and not as thermally buoyant as that produced in an explosion on the pad. This results in higher ground level concentrations of HCl and Al_2O_3 than the on-pad conflagration exhaust cloud because it does not rise as high into the atmosphere.

The Launch Area Risk Analysis (LARA) program was used to predict the impact location and scatter of solid propellant fragments generated by destruct of a Delta 7925 at various times during ascent resulting in scattered burning solid propellant fragments and an exhaust cloud containing exhaust from the residual solid propellant. At some point during flight, however, the vehicle will have achieved sufficient altitude and velocity so that fuel fragments from a break-up will either burn up during descent or land in the ocean well downrange from the launch pad.

2.0 Effects on Human Health

Assumptions and Methodology. Impact locations of solid propellant fragments resulting from destruct of a Delta vehicle at various times during the first 20 seconds of flight were predicted. The modeling results indicate that the highest HCl and Al_2O_3 concentrations occur about ten seconds into flight. In order to assess differences in effects, concentrations of HCl and aluminum oxide were predicted for aborts at both 5 and 10 seconds after lift-off. The results are based on Hypothetical Worst Case weather and presume that fuel fragments from all nine SRMs contribute to the conflagration exhaust cloud.

Peak 30-minute average concentrations of HCl and aluminum oxide were predicted at the 66 sensitive receptor sites under Hypothetical Worst Case weather scenario. In order to estimate concentrations at other receptor sites (not included in the list of 66 sensitive receptors),

centerline 30-minute average concentrations downwind from the launch pad were estimated. These levels are calculated at both 5 and 10 seconds after lift-off.

Exposure Concentrations. The maximum peak 30-minute average concentration for HCl (2.5 ppm) and for Al_2O_3 (5.7 mg/m^3) occurs at 10 seconds after lift-off at Pahala. The predicted worst case 30-minute average Al_2O_3 concentration at the PCZ boundary is estimated to be 12.6 mg/m^3.

The maximum centerline average HCl concentrations predicted for a conflagration 5 and 10 seconds after lift-off were 1.0 ppm (at a distance of 15 km from the launch pad) and 2.6 ppm (at a distance of 6 km), respectively. The values for Al_2O_3 at 5 and 10 seconds are predicted to be 11.8 mg/m^3 (at a distance of 6 km) and 20 mg/m^3 (at a distance of 3 km, which occurs within the population control zone boundary).

Cancer Risk Analysis. Carcinogenic substances such as hydrazine and UDMH are not released as part of a rocket conflagration. A cancer risk analysis was not conducted for the conflagration launch scenario.

Noncancer Hazard Index Analysis. Results of the chronic hazard index calculations for exposure to a receptor via inhalation of HCl and via inhalation, soil ingestion, and dermal contact of Al_2O_3 released during a conflagration episode which occurs during vehicle ascent are presented in DEIS Appendix VIIIA for 5 and 10 seconds after lift-off. The maximum hazard index projected, 0.0019, occurs at Pahala at 10 seconds after lift-off.

The acute hazard indices due to hydrogen chloride and aluminum oxide releases from a conflagration at 5 and 10 seconds after lift-off are also included in DEIS Appendix VIIIA. The maximum value, 1.1, occurs at Pahala at 10 seconds after lift-off.

At a downwind distance of 6 km from the launch pad (the closest distance modeled) the hazard index for a worker exposed to HCl and Al_2O_3 released during an in-flight conflagration ranges from 1.2 to 2.5 depending on the exact circumstances of the conflagration event.

Noncancer risk from drinking water where HCl has been deposited is determined by comparing the projected HCl concentration due to wet deposition (0.57 mg/l) with the chlorine concentration of drinking water recommended by the County of Hawaii (2.6 mg/l). The resulting hazard index is 0.82.

Significance of Effects. Noncancer chronic hazard indices for exposure to a receptor via inhalation of HCl and via inhalation, soil ingestion, and dermal absorption of released during a conflagration were all less than 1.0. A hazard index of less than one is considered to be a nonsignificant risk. Addition of the chronic hazard index due to ingestion of drinking water from a rain catchment system where HCl has been deposited results in an overall chronic hazard index of 0.82, a level which is not considered to be a significant hazard.

The maximum acute hazard index that occurs at Pahala under the Hypothetical Worst Case meteorological scenario is greater than 1.0, indicating that acute noncancer adverse health effects may occur to sensitive individuals in Pahala in the event of a vehicle conflagration occurring 10 seconds after lift-off.

The hazard indices for a worker exposed to HCl and Al_2O_3--1.2 to 2.5--are considered significant. They indicate that potential health effects can occur to workers exposed to emissions resulting from an in-flight vehicle conflagration at both 5 and 10 seconds after

lift-off. These evaluations are extremely conservative in that it is assumed that indoor workers are exposed to levels of contaminants present in outdoor air and that all workers within the population control zone are exposed to the maximum centerline ground level concentration that would occur within the PCZ. Additionally, the ability of a HAZMAT team to respond to a launch accident and reduce ground level concentrations is not considered.

3.0 Effects on Sensitive Ecological Species

Assumptions and Methodology. The concentration of chemicals of concern (COCs) produced by conflagration during vehicle ascent depends on the height of the vehicle above the ground when the explosion occurs. Two scenarios were modeled for the ERA: 5 seconds after lift-off and 10 seconds after lift-off.

Exposure Concentrations. Peak 30-minute average concentrations of HCL and Al_2O_3 produced in a conflagration 5 seconds after lift-off during Hypothetical Worst Case weather conditions are presented in DEIS Appendix VIIIB. The highest peak 30-minute average concentration of HCl produced by such an event is estimated to be 1.027 ppm at 15 km (about 9 miles) from the launch site; the highest peak average concentration of Al_2O_3 is estimated to be 11.84 mg/m^3 at 6 km (about 4 miles) downwind from the site.

Peak 30-minute average concentrations of HCl and Al_2O_3 produced in a conflagration 10 seconds after lift-off under the same Hypothetical Worst Case weather scenario are estimated to be 2.6 ppm at 6 km from the launch site and 20 mg/m^3 at 3 km downwind from the site, respectively.

Analysis of Effects At 5 Seconds After Lift-off When the EC for HCl of 1.027 ppm is compared to the selected TECs and the appropriate UFs are applied, the EC is consistently less than the TEC for bats, for birds it is the same, and for plants it is higher.

The 11.81 mg/m^3 maximum 30-minute average concentration for Al_2O_3 at 6 km from the launch site is much higher than the TEC, although it is still lower than the human EEGLs.

Analysis of Effects At 10 Seconds After Lift-off The EC for HCl of 2.6 ppm, 6 km from the launch site is greater than the adjusted TEC values; thus exposure to HCl could potentially produce adverse effects in bats, birds and plants.

The 20 mg/m^3 maximum 30-minute average concentration for Al_2O_3 that occurs 3 km from the launch site is much higher than the TEC and higher than the human EEGL (DEIS Appendix VIIIB).

Significance of Effects. Based on the analysis of ECs and TECs for HCl it is unlikely that an adverse effect will occur to bats from exposure to HCl during a conflagration 5 seconds after lift-off. There is a possibility that adverse effects could occur to exposed birds and plants. Although the risk to plants from exposure to HCl depends on the humidity of the atmosphere at the time of the exposure, it is likely that exposure to HCl produced by a conflagration event 5 seconds after lift off could be potentially toxic to plants within the zone of ecological concern.

The potential also exists for adverse effects in vertebrate receptors exposed to the predicted concentrations of aluminum oxide particles if a conflagration occurs 5 seconds after lift-off.

The analysis of peak 30-minute average concentrations for HCl for a conflagration 10 seconds after lift-off indicates that exposure to HCl could potentially produce adverse effects in bats, birds and plants. In this scenario, the potential also exists for adverse effects to occur in species that are exposed to elevated concentrations of aluminum oxide.

In summary, due to the high density of endangered species reported around Palima Point and the proximity of the site to the Ka`u Forest Reserve (an important refuge for endangered forest birds) a conservative risk characterization was undertaken. The evaluation concluded that HCl produced during conflagration events occurring 5 and 10 seconds after lift-off could potentially produce adverse effects in sensitive receptors. Aluminum oxide particles released during a conflagration event 10 seconds after lift-off could also adversely affect biota (RSA, DEIS Appendix VIIIB).

G. EFFECTS OF TOXIC RELEASES FROM A LIQUID FUEL DEFLAGRATION

1.0 Vehicle Scenario

Deflagration is a vehicle failure where liquid hypergolic fuels react in a fireball explosion. The exhaust cloud resulting from the fireball is comprised of vaporized hypergols and combustion by-products. The hazardous chemicals in the fireball are: hydrazine, unsymmetrical dimethylhydrazine (UDMH), nitrogen tetroxide, formaldehyde dimethylhydrazone (FDH) and dimethylnitrosamine (DMNA). These vaporized hypergols present a toxic hazard to downwind populations. The Delta II 7925 is the only candidate vehicle that uses hypergolic fuels in any significant quantity.

Deflagration can represent either an explosion on the launch pad or an explosion of the vehicle during ascent. REEDM models the explosive reaction that occurs when nitrogen tetroxide oxidizer and Aerozine-50 liquid propellant mix following a vehicle failure. The deflagration model assumes that the reaction by-products, decomposed chemicals, and vaporized liquids form a single spherical cloud that is hot and buoyant. During a normal launch the liquid fuel and oxidizer are combusted, therefore, it is only in the event of a vehicle destruct, explosion, or accidental spill that toxic hazards due to hypergols are present.

Palima Point is located in a hazardous geologic area. Because of the frequency of earthquakes on the Big Island there is a potential for an earthquake to occur while a fully fueled rocket is on the launch pad. The possibility exists for the vehicle to topple over during a very strong earthquake. If this happens the liquid propellants will most likely ignite and the rocket will be consumed. The effects will be similar to the on-pad launch failure assessed in this scenario.

2.0 Effects on Human Health

Assumptions and Methodology. The same receptors, assumptions and exposure pathways used for the conflagration scenario are also used in the deflagration analysis. It is assumed that one deflagration event occurs per 70-year lifetime and that total dispersion of emitted substances occurs within one hour. Calculations were made for hydrazine, UDMH, FDH, and DMNA, respectively. According to ACTA (DEIS Appendix VID), deflagration of the vehicle on the pad yields the highest predictions of hydrazine, UDMH and N_2O_4 concentrations.

FDH is a decay product of UDMH decomposition for which exposure standards have not been established. In the absence of toxicological information specific to FDH, it is assumed that the

toxicological properties and acceptable exposure levels of FDH are equivalent to its parent compound, UDMH. Both nitrogen tetroxide (N_2O_4) and nitrogen dioxide (NO_2) are used as oxidizing agents in rocket fuel. They are combined under pressure. At very low temperatures the mixture is predominantly N_2O_4; at high temperatures the gas is predominantly NO_2. Exposures are essentially the same for both.

Evaluation of potential exposures to the 66 sensitive receptor sites involved determination of ground level pollutant concentrations under eight different weather scenarios, including the Hypothetical Worst Case condition. Peak 60-minute average concentrations of hydrazine, unsymmetrical dimethylhydrazine (UDMH), nitrogen tetroxide, formaldehyde dimethylhydrazone (FDH), and dimethylnitrosamine (DMNA) for a Delta II 7925 explosion on the pad at the sensitive receptor sites under the eight meteorological cases are presented in DEIS Appendix VIIIA. Worst case ground level concentrations under each meteorological condition assumed that the wind direction follows a straight path from the launch pad to the receptor. This is a worst case approach in that it neglects predominant wind directions and the presence and effects of the mountainous terrain of Hawaii.

A Nocturnal Drainage flow, if it were directed toward Punalu`u, Pahala, and Na`alehu, would produce higher concentrations than the Hypothetical Worst Case weather condition. Although it is unrealistic to expect the Nocturnal Drainage flow to move from the launch site inland, concentrations were computed assuming this condition could occur. In that sense, the analysis is very conservative and is biased toward overestimating the concentrations at receptor locations.

Centerline 1-hour average concentrations downwind from the launch pad under the Hypothetical Worst Case meteorological condition were determined in order to estimate concentrations at other receptor sites not included in the list of sensitive receptors.

It is also assumed that drinking water from residential rain catchment systems will be impacted by wet deposition of hydrazine as a result of emissions from a vehicle deflagration. The average concentration of pollutants projected to occur in a rain catchment system is a function of direct wet deposition onto the roof of a house. In this assessment it is assumed that dilution of the hydrazine in catchment water will occur at a rate of 50 percent per month for a period of one year after the deflagration event, at which time the concentration is assumed to be zero.

Exposure Concentrations. As shown in DEIS Appendix VIIIA, the highest peak 60-minute average concentrations of hydrazine, UDMH, and N_2O_4 are predicted to occur at Pahala and Punalu`u under the Nocturnal Drainage weather scenario. At Pahala the levels are: 0.038 ppm hydrazine, 0.019 ppm UDMH, and 0.47 ppm $N_2O_4$. At Punalu`u the levels are: 0.035 ppm hydrazine, 0.017 ppm UDMH, and 0.43 ppm N_2O_4. The highest level of FDH, ranging from 0.098 to 0.127 ppb, occurs under the Nocturnal Drainage weather scenario for all receptors. DMNA ground level concentrations are lower than the recording capability of the REEDM model used by ACTA (0.001 ppb). In the absence of more precise information, all receptors under all weather conditions are assumed to be exposed to 0.001 ppb DMNA.

Centerline 60-minute average concentrations downwind from the launch pad under Hypothetical Worst Case meteorological conditions are also presented in DEIS Appendix VIIIA. The maximum centerline average concentrations of hydrazine, UDMH, and N_2O_4 predicted are 0.023 ppm, 0.012 ppm, and 0.289 ppm, respectively, occur at a distance of 9 km from the pad. The maximum centerline concentration for FDH occurs at a distance of 15 km and is equivalent to 0.089 ppb.

Centerline 60-minute average concentrations of hydrazine, UDMH, nitrogen tetroxide, and FDH

released as a result of deflagration of a Delta II 7925 vehicle under the Hypothetical Worst Case meteorological condition at a downwind distance of 6 km from the launch pad (the closest distance modeled) are: hydrazine, 0.019 ppm; UDMH, 0.009 ppm; N_2O_4, 0.231 ppm; and FDH, 0.037 ppm.

Based on an average concentration over a one-year period, the projected dose of hydrazine ingested from drinking water obtained from a residential rain catchment system is 0.0008 (8.1×10^{-4}) mg/kg/day. Algorithms and assumptions used in the evaluation of the drinking water exposure pathway are described in DEIS Appendix VIIIA.

Cancer Risk. Results of the cancer risk calculations for exposure to a receptor via inhalation of airborne vapors released during a launch deflagration episode are given in DEIS Appendix VIIIA. The maximum projected cancer risk, 4.35 in 10,000,000, occurs at Pahala under the Nocturnal Drainage weather condition. At Punalu`u, a maximum cancer risk of 4.0 in 10,000,000 is predicted under the same weather scenario. Ninety-one percent of the overall cancer risk at Pahala is due to hydrazine; 9 percent is from UDMH, FDH and DMNA.

Cancer risk from drinking water in which hydrazine has been deposited following a deflagration episode, based on an average hydrazine water concentration of .0047 mg/l, a corresponding daily dose of .0001 mg/kg, the estimated lifetime cancer risk if a person drinks this water for one year is 5.8 in a million.

Cancer Burden. Excess population cancer burden is the predicted number of cancer cases added to the community or study area due to rocket exhaust emissions of carcinogenic substances. In this health risk assessment, the added cancer cases are calculated by multiplying the individual cancer risk determined for Pahala (worst case estimate) by the number of people living and working in the Ka`u District. The total community excess cancer burden per 70-year lifetime is 0.0016 estimated excess cancers due to rocket exhaust emissions based on 1990 population estimates (DBED 1990) and 0.0018 based on 2000 population projections (DEIS Appendix VIIIA).

Noncancer Hazard Index Analysis. The maximum chronic hazard index due to inhalation of hydrazine, UDMH, N_2O_4, FDH, and DMNA, 0.44, occurs at Pahala under the Nocturnal Drainage weather condition. At Punalu`u, under the same weather condition, the maximum hazard index is 0.40.

The maximum acute hazard index, 0.86, occurs at Pahala under the Nocturnal Drainage weather condition. At Punalu`u, under the same weather scenario, the maximum acute hazard index is 0.79. Thirty-six percent of the overall acute hazard index at Pahala is from hydrazine, 54 percent is from N_2O_4 and 9 percent is from UDMH.

The hazard index for a worker exposed to substances resulting from a deflagration, based on ACGIH TLVs, is equivalent to 6.6.

Noncancer risk due to drinking water in which hydrazine has been deposited following deflagration of an ascending vehicle is based upon an average hydrazine water concentration of .0047 mg/l. The corresponding daily dose was determined to be .0001 mg/kg. The chronic oral acceptable exposure level for hydrazine based on the inhalation AEL is .007. The resulting noncancer hazard index due to this exposure pathway is calculated to be 2.0.

Significance of Effects. Carcinogenic substances released during deflagration include hydrazine, UDMH, FDH, and DMNA. The maximum cancer risk occurs at Pahala under the Nocturnal Drainage weather condition. This risk is equivalent to 4.35 in 10,000,000. Lifetime cancer risk

due to ingestion for a one year period of drinking water to which hydrazine has been deposited following a deflagration episode is 5.8 per 1,000,000. Cumulative cancer risk via all exposure pathways is 6.2 per 1,000,000.

Under more likely weather conditions, the cancer risk due to vehicle deflagration to the population would be lower than the results listed above. Under tradewind conditions, the cancer risk at Pahala would be 6.7×10^{-11}.

These results indicate that if individuals were to be in the general area of the Spaceport (Pahala, Na`alehu, etc.) during a launch failure one time during their lives, and if the weather conditions were Nocturnal Drainage - an unusual weather condition which is doubtful to occur - the risk of cancer would be within the range of levels termed negligible by the EPA. As a point of comparison, the national cancer rate is estimated at 25 percent or 250,000 per 1,000,000. Even if a person were to experience 10 launch failures in a lifetime, the cancer risk would still be negligible. In the unlikely event that a launch failure was immediately followed by rain, the risk of cancer due to possible contamination of individual roof-catchment drinking water systems would also be negligible (RSA, DEIS Appendix VIIIA).

The maximum chronic hazard index of 0.44 at Pahala, under the Nocturnal Drainage weather condition, added to the chronic hazard index due to drinking water from a rain catchment system to which hydrazine has been deposited following deflagration (2.0) results in an overall chronic hazard index at Pahala of 2.4. Because the index is greater than 1.0, it indicates that chronic adverse health effects are possible due to a deflagration launch accident at the proposed Palima Point facility (Ibid.).

The maximum overall acute hazard indices at Pahala and Punalu'u are both less than 1.0 under the Nocturnal Drainage weather condition. This is considered insignificant and indicates that acute adverse health effects due to deflagration are not expected to occur.

At a downwind distance of 6 km from the launch pad (the closest distance modeled), the hazard index for a worker exposed to substances resulting from a deflagration episode based on occupational exposure limits is 6.6. It is evident from this analysis that potential health effects can occur to workers exposed to emissions resulting from a vehicle deflagration under the Hypothetical Worst Case scenario.

This evaluation is extremely conservative in that it assumes that during a rocket launch, indoor workers are exposed to levels of contaminants present in outdoor air. The assumption that workers within the population control zone are exposed to the maximum centerline ground level concentration that would occur within the population control zone also renders this a conservative health assessment. Additionally, the ability of a HAZMAT team to respond to a launch accident and reduce ground level concentrations is not considered.

3.0 Effects on Sensitive Ecological Species

Assumptions and Methodology. It is assumed that one deflagration event occurs within the lifetime of an ecological receptor and that total dispersion of emitted substances occurs within one hour. Because the ecological receptors of concern are distributed in different geographic areas from the sensitive human receptors, the most appropriate ecological exposure point concentrations are the peak centerline time mean and predicted centerline peak instantaneous concentrations.

Exposure Concentrations and Analysis of Effects. Each chemical of concern has different effects, therefore, the discussion of exposure concentrations and effects which follows is by

Hydrazine. The estimated centerline 1-hour average concentration of hydrazine produced during a Nocturnal Drainage weather condition is 0.038 ppm at 9 km from the launch site. This EC is less than the adjusted TEC value, therefore, it is unlikely that an adverse effect would occur. The predicted instantaneous peak concentration of hydrazine is estimated to reach 10.40 ppm at 1.0 km from the launch pad. When this EC is compared to the adjusted TEC it is higher. It is difficult to draw conclusions based on a direct comparison of these numbers, however, because the TEC value is based on toxicity tests with longer exposures.

UDMH/FDH. The estimated centerline 1-hour average concentration of UDMH produced under a Nocturnal Drainage weather condition is 0.019 ppm at 9 km from the launch site; the comparable concentration for FDH is 0.089 ppm at 15 km from the launch. Since toxicological data are unavailable for FDH and it is similar to UDMH, it is treated as if it were UDMH. A conservative estimate of the amount of UDMH and FDH that a receptor could be exposed to is then the sum of these two concentrations, or 0.101 ppm. When the EC of 0.101 is compared to the adjusted TEC it is higher, therefore, there is a potential for adverse effects to occur to sensitive receptors exposed to these levels of UDMH/FDH.

The predicted instantaneous peak concentration of UDMH is 4.9 ppm at 1 km from the launch pad. When this EC is adjusted using the appropriate UFs it is also higher than the TEC. It is difficult to draw conclusions based on a direct comparison of these numbers because the TEC value is based on toxicity tests with longer exposures.

Nitrogen Tetroxide. The estimated centerline 1-hour concentration of N_2O_4 produced during the Hypothetical Worst Case weather condition is 0.47 ppm at 9 km from the launch site. This is an EC of about 0.94 ppm of NO_2. An LC_{50} of 30 ppm of NO_2 was selected as the TEC. When the EC is compared to the adjusted TEC it is higher. This suggests that N_2O_4/NO_2 exposure could produce adverse effects in sensitive ecological receptors (DEIS Appendix VIIIB). The predicted peak instantaneous concentration of 122.9 ppm at 1.0 km from the launch pad is also higher than the TEC, again suggesting that adverse effects could occur.

DMNA. The estimated centerline 1-hour average concentration for DMNA is estimated to be 0.005 ppb. Because the EC for DMNA is less than the adjusted TEC, it suggests that there is a low probability that adverse effects will occur to sensitive ecological receptors exposed to DMNA.

Significance of Effects. A liquid fuel deflagration could release carcinogenic substances such as hydrazine, UDMH, FDH and DMNA as well as N_2O_4/NO_2. The estimated ECs of DMNA and N_2H_4 are lower than the selected TEC values suggesting that exposure to these compounds will be unlikely to produce adverse effects. In contrast, the estimated exposure point concentrations for N_2O_4/NO_2 and UDMH/FDH are above selected TECs. Exposures to these compounds have a higher probability of producing adverse effects in sensitive biotic receptors.

If the sensitive receptors within the ecological zone of concern have responses to N_2O_4/NO_2 similar to laboratory rodents, exposure to N_2O_4/NO_2 released in a deflagration could be detrimental to these species. One of the reported adverse effects of N_2O_4 is an increase in susceptibility to infection. If the affected receptors (especially the endangered bird species) respond in the same manner as rodents, this could have serious repercussions. Because the populations of many of the endangered bird species are declining due to introduced avian diseases (USFWS 1982), any decrease in their immunity could leave them more vulnerable to infection.

It is also unknown how simultaneous exposure to all of these carcinogens (as would be the case in a deflagration event) would effect ecological receptors. Multiple exposure could result in additive, synergistic or antagonistic toxicological effects.

H. EFFECTS OF TOXIC RELEASES FROM A LAUNCH ACCIDENT INVOLVING BOTH CONFLAGRATION AND DEFLAGRATION

1.0 Description

Because a launch accident may involve both conflagration and deflagration which can result in the release of HCl and aluminum oxide from a burning SRB and the release of unburned hydrazine, UDMH and nitrogen tetroxide from a ruptured second stage rocket, as well as the combustion by-products of a second stage fuel burning, FDH and DMNA, the cumulative health effects of such an event were evaluated. Cancer risk and noncancer hazard analyses for on-pad conflagration/deflagration and conflagration/deflagration on the pad and during vehicle ascent at 10 seconds after lift-off are both evaluated. Groundwater effects at the project site are also assessed.

2.0 Human Health Effects

Cumulative Cancer Risk. Results of the analysis of the cumulative cancer risk due to conflagration and deflagration are given in DEIS Appendix VIIIA. The analysis indicates that the cumulative cancer risk is due entirely to deflagration (carcinogenic substances are not released during conflagration). At Pahala the cumulative cancer risk is 4.3 in 10,000,000 while at Na`alehu and Captain Cook, the values are 1.5 in 10,000,000 and 2.5 in 100,000,000, respectively.

Cumulative Noncancer Hazard Indices. Cumulative chronic hazard indices for Pahala, Na`alehu, and Captain Cook are presented in DEIS Appendix VIIIA. Hazard indices due to on-pad conflagration and deflagration and due to conflagration during vehicle ascent and deflagration are equivalent (due entirely to deflagration): 0.44 for Pahala, 0.16 for Na`alehu and 0.03 for Captain Cook.

At Pahala the cumulative acute hazard index due to an on-pad conflagration and deflagration is 0.86; at Na`alehu and Captain Cook the values are 0.36 and 0.14, respectively. The cumulative acute hazard index due to conflagration during vehicle ascent (10 seconds after lift-off) and deflagration are: 2.0 at Pahala, 0.61 at Na`alehu 0.61 and 0.12 at Captain Cook.

The maximum cumulative overall chronic hazard index for conflagration and deflagration at Pahala is 1.19 (0.44 is due to inhalation, soil ingestion, and dermal absorption pathways and 0.75 is due to drinking water from rain catchment system to which wet deposition of HCl has occurred) while the maximum cumulative acute hazard index at Pahala is 2.0. For workers within a 6 km radius of the launch pad, the hazard index is 7.8 to 9.1. The results of the cumulative noncancer hazard analysis indicate that both chronic and acute noncancer adverse health effects may occur to residents and on-site workers as a result of launch failures under worst case weather conditions (RSA, DEIS Appendix VIIIA).

Under more likely weather conditions, the cumulative noncancer risks due to conflagration and deflagration to the population and workers would be lower than the results listed above. At Pahala, the chronic hazard index would be 0.0019 while the acute hazard index would be 1.1.

Significance of Results. The results of the cancer risk assessment for the deflagration

scenario indicate that if an individual were to be in the general area of the Spaceport (Pahala, Na`alehu, etc.) during a launch failure one time during their life, and if the weather conditions were Nocturnal Drainage - an unusual weather condition which is doubtful to occur - the risk of cancer would be termed negligible and no additional cancer would be expected in the population as a result of the accident. Even if a person were to experience 10 launch failures in a lifetime, the cancer risk would still be negligible (RSA, DEIS Appendix VIIIA).

In some accidents where a launch failure occurs on the pad, conflagration and deflagration will not result in off-site chronic hazards to the population. In others, adverse effects are possible and chronic (long-term) adverse health effects may occur in people living near the Spaceport if launch failures occur during certain unfavorable weather conditions and these failures involve the rupture and explosion of the second-stage rocket containing hydrazine. Acute (short-term) adverse health effects such as respiratory irritation might also occur during a launch failure. An off-site acute hazard index could be as high as 2.0 at Pahala if conflagration occurs during ascent at 10 seconds after lift-off. Because the chronic hazard index is only slightly above 1.0, there is only a small chance that chronic respiratory irritation would occur even in sensitive individuals in Pahala even after several failures.

Workers at the Spaceport have the greatest chance of adverse health effects due to a launch failure. The acute hazard index for a worker exposed to substances resulting from a deflagration episode based on occupational exposure limits is 6.6, indicating that proper protection must be provided to on-site workers during launch activities.

3.0 Effects on Groundwater

Assumptions and Methodology. The deposition effects of propellant releases to the atmosphere above the site from exploding vehicles was modeled. Two scenarios were analyzed: the release of 300 gallons of Aerozine-50 from Delta II and 7,800 gallons of RP-1 from an Atlas II. These assumptions are very conservative because there is little information on which to base an estimate of the amount of fuel that could be released during an explosion (DEIS Appendix IIIB).

For the purpose of numerical modeling, the subsurface was assumed to be fresh, layered basalt with a hydraulic conductivity of 3,000 feet per day, porosity of 0.1, longitudinal dispersivity of 328 feet and transverse dispersivity of 98 feet. Based on measurements of wells in the region, the hydraulic gradient in the aquifer is about four feet per mile towards the sea.

To model the effects of propellant releases to the atmosphere above the site from exploding vehicles, it is assumed that the released propellants would fall out on the ground surface in a roughly circular area--about 1,000 feet in diameter, covering 18 acres--at an elevation of 500 feet, about 3,000 feet from the Spaceport shoreline. A description of the numerical models used in the analysis is presented in Section I of this Chapter.

It is expected that propellants released over the ground surface will infiltrate, percolate downward through the unsaturated zone to the groundwater surface, and then migrate horizontally with the groundwater either as a solute (in the case Aeozine-50, a miscible liquid) or a floating separate-phase liquid (RP-1). Groundwater in the area of the proposed Spaceport generally flows seaward and discharges from the subsurface at the shore of the ocean as dispersed fresh or brackish springs.

In the event of vehicle explosion or destruct, unused propellants could be released in the atmosphere and fall to the ground. Because such fall-out would be widely scattered, it would not pond on the ground surface and would not likely percolate to the groundwater in the manner of spilled fuel. Assuming as a worst case, however, that the propellant would migrate in the

subsurface as if spilled, the effect would be more widely distributed and correspondingly less concentrated.

Effects on Groundwater Quality. It is estimated that Aerozine-50 could affect groundwater in an area of approximately 100 acres; peak concentrations of Aerozine-50 in groundwater at the shore, no greater than 0.5 mg/l, would occur about 20 days after the release. Kerosine (RP-1) would also be distributed by an explosive release over a large area and would migrate to the shore in a wider zone of lower concentration than from a spill. Peak discharge rates would probably by less than 50 pounds per day along 5,000 feet of shore.

The groundwater will be unsuitable for drinking water supplies without treatment until the contaminants have completely discharged into the ocean. Existing drinking water wells are landward of the proposed facility near the town of Pahala and along the highway to the south of the site. An explosive release could potentially could affect those resources if propellant fall-out reached areas near the wells.

The quality of water in anchialine ponds near the shore, if any exist downgradient from a spill, could be affected because the ponds are actually exposures of groundwater, and contaminants in the groundwater surrounding the ponds would be present in similar concentrations in pond waters.

The contaminants entering the ocean with migrating groundwater will be exposed to turbulent wave action and strong currents and would likely be difficult to detect.

Effects on Anchialine and Marine Biota. The assumption is made that any spilled materials would be toxic to biota both residing in the groundwater and the anchialine pool on the project site as well as to nearshore marine biota. Qualitatively there appears to be a large groundwater input along much of the shoreline in the vicinity of the launch pads suggesting that spilled materials would quickly be delivered to the sea. Toxicity is a function of concentration. When any material reaches groundwater, concentration declines. Once in the ocean the mixing processes are enhanced suggesting that a potentially harmful spill may not have an adverse impact (Brock, DEIS Appendix IIIE).

The extent of impacts on marine biota are difficult to assess because of the unknown nature of the materials involved; their initial distribution on and in the sea; the dilution and advection rates; and the toxicity of these materials to organisms. In sea turtles, changes in water quality from the addition of anthropogenic chemicals may all adversely effect their reproductive success, however the concentrations at which these impacts may be manifested are unknown (Ibid.). The same statement may be made of all of the anchialine and marine organisms residing in the waters fronting the Palima Point Site.

I. MITIGATING MEASURES FOR TOXIC RELEASES FROM SUCCESSFUL LAUNCHES AND LAUNCH FAILURES

The most significant mitigating measure would be to use propellants that don't pose a toxic hazard to human and ecological populations. Until these types of propellants are in common use, conservative launch parameters that do not allow launches when meteorological conditions indicate that adverse effects on off-site populations and ecosystems are possible must be instituted. Safe launch operations, as currently practiced at the national ranges, require continuous meteorological monitoring prior to any launch (See Appendix B of the FEIS). This allows models to be run and effects predicted in real-time. If conditions are not favorable the launch will be

held until they are acceptable from a safety perspective.

Proper safety precautions for facility workers and the presence of a HAZMAT team at the launch pad will both serve to mitigate adverse effect on Spaceport employees.

J. EXPLOSIVE OVERPRESSURE EFFECTS FROM AN ON-PAD CONFLAGRATION OR DEFLAGRATION

1.0 Description of the Event

Under some circumstances, an accident on the pad or the fall back of a rocket shortly after lift-off could produce a high yield explosion. This explosion could generate a shock wave that would propagate through the atmosphere and affect areas that may be a significant distance away from the launch pad. Although these shock waves attenuate with distance from the source, certain atmospheric conditions would either decrease the rate of attenuation or cause amplification because of the convergence of the acoustic ray paths.

These highly explosive events would most likely occur at the ground. A downward portion of a burst at the surface is reflected upward and, consequently, gives the effect of twice the yield of an explosion aloft. Events such as fall back are not common. Although energetic and potentially very hazardous, they have an occurrence probability of less than one in ten of the normal failure probability. The analysis assumed that the probability of an accident at the pad having a high order explosion is no more than one in one thousand.

2.0 Analysis of Effects

The methodology used in the analysis is described in detail in ACTA Inc., DEIS Appendix VIIF and Section I of this Chapter. An alternative methodology is presented in OSI, DEIS Appendix VIIG.

Assumptions and Methodology. A TNT equivalent of 95,000 pounds was assumed for the most energetic rocket, the Atlas II AS. Following lift-off, the TNT equivalent yield for a launch vehicle decreases due to consumption of propellants. If impact velocities are involved, such as if a vehicle were to fall from some distance and hit the ground, the TNT equivalent yield is expected to increase because of the additional pressure involved.

The meteorological scenarios described previously were used to develop the overpressure scenarios. These meteorological profiles provide coverage of the range of meteorological conditions to be expected and account for both the tradewind subsidence inversion and low level nighttime drainage flow inversion.

The BLAST model utilized to assess overpressure hazards includes topography and meteorological profiles. It does not include the effects of attenuation due to terrain, foliage, and blockage by buildings, which could reduce the overpressure effects. The Air Force Regulations Manual (AFR 127-100) presents a procedure for calculating overpressure at some distance from the blast assuming a flat terrain and uniform atmosphere. In comparison, the BLAST gradient model computed overpressure estimates approximately 30 percent higher than AFR 127-100.

Seven noise sensitive areas were evaluated and maximum expected overpressures computed using the BLAST program for each of the seven given wind conditions. These areas, and their approximate distances from the launch pads, are:

- Pahala	3.56 miles	- Punalu`u	3.63 miles
- Na`alehu	11.00 miles	- Bird Habitat	8.75 miles
- HVNP	22.40 miles	- Hilo	52.00 miles
- Mauna Kea	46.00 miles		

Predicted Overpressures. The maximum expected overpressures (PSI) based on 95,000 pounds TNT blast at the center launch pad, for typical wind conditions or slight variations thereof, are:

- Pahala	0.178	- Punalu`u	0.174
- Na`alehu	0.046	- Bird Habitat	0.028
- HVNP	0.014	- Hilo	0.007
- Mauna Kea	0.005		

According to ACTA Inc. (DEIS Appendix VIIF), overpressures higher than 0.05 psi indicate a relatively high probability of window breakage. This assumption is somewhat more conservative than the threshold level of 0.2 psi that the Office of Commercial Space Transportation (OCST) currently uses. The procedure used by OCST places the threshold value for window breakage at between 0.1 and 0.2 psi.

Effects on People and Property. Impacts from high-order detonations that may be expected in the vicinity of the Palima Point Spaceport include broken windows and possible injuries resulting from flying glass fragments. The population centers at risk are Punalu`u and Pahala; Na`alehu is just below the threshold. No window breakage is expected at Hilo due to its greater distance from the site.

If an explosion of the magnitude capable of an Atlas IIAS or a Delta II occurs, there is a high probability of window breakage at Pahala and Punalu`u. The breakage probabilities would be reduced if the explosion involved a lower TNT yield. Since yield effects scale by the cube root, a factor of eight reduction in yield only reduces the overpressure by approximately one half. Smaller ELVs like the Taurus are expected to produce fewer adverse effects.

Prior analysis has concentrated on windows supported along all four edges by a rigid frame. Jalousie windows, which are widely used in Hawaii, can flex and seldom close into an airtight surface. These properties were considered for modeling purposes, however, there is still some uncertainty what the average jalousie window threshold value is.

Effects on Sensitive Ecological Species. Close to the launch pad, the overpressure due to the shock would exceed 1 psi. This could have significant effects on nearby fauna, however, there is no clinical data supporting this.

3.0 Potential Mitigating Measures

The following measures should be undertaken to reduce adverse overpressure effect:

- Design range safety procedures that reduce the chance of a complete vehicle fall-back and impact by destroying the vehicle before it can land intact. A vehicle broken up by a destruct system produces a much lower yield at impact because of the reduced confinement; and,

- Restrict the types of vehicles launched from Hawaii to those with an acceptably low TNT equivalency.

The establishment of launch windows due to weather could be of some help, however, a major factor in overpressure hazards is the close proximity of Pahala and Punalu`u to the launch site.

If overpressures sufficient to break glass do occur, injuries would be minimized if people do not stand next to windows at the time of launch. Leaving windows open also reduces the potential for injury because the room behind the windows ventilates and pressurizes.

Windows that do break as a result of a launch explosion should be replaced with windows that are more resistant to breakage, thus reducing the potential for reoccurrence.

K. DEBRIS EFFECTS FROM DESTROYED ROCKETS

1.0 Description of the Event

The primary source of risk during most rocket launches is from errant rockets or from the debris from a destroyed rocket. The destruction of a rocket during launch produces a breakup either due to explosive charges or by aerodynamic and inertial forces. Range safety systems are designed to contain rockets or debris from destroyed rockets within boundaries so that people and property are protected. Zones, such as the population control zone at the proposed Palima Point launch site, are established around the launch area that exclude the public and all but essential personnel. Specially reinforced structures are used to protect those who must be closer to the immediate launch area.

The debris pattern is dynamic, that is, it changes progressively during the flight. Very early in the flight, because of the low altitude, the spread of debris is limited. As the vehicle rises, the debris can spread over a larger area. The wind becomes a bigger contributor to drift as the altitude increases.

During launch operations real-time meteorological data is obtained and computer simulations are conducted to set the boundaries of the flight safety corridor within which the launch vehicle must fly. Impact Limit Lines (ILL), which define the boundary beyond which no rocket debris will be allowed to fall, are plotted on a map. If the rocket deviates from its planned trajectory and heads toward the ILL then it may be deliberately blown up by ground command. The intent is to destroy the rocket early enough to contain all debris within the ILL.

2.0 Analysis of Effects

Assumptions and Methodology. Impact dispersion patterns were analyzed for debris from destruct breakup of a Delta II intermediate launch vehicle at 20, 40 and 60 seconds after lift-off along two launch azimuths (east and north) under seven different weather conditions. Debris patterns produced by using Delta data with an Atlas trajectory were also evaluated.

A probabilistic debris pattern was computed for a range of ballistic coefficients; the boundaries of the pattern express a probability of non-exceedance of impacts of debris. The uncertainties leading to the impact dispersions include vehicle malfunction turn, wind, velocity due to explosion, and lift effects.

The ellipses representing the impact dispersions are probabilistic with the boundary representing a probability of 90 percent of no more than one fragment landing outside of the boundary in that particular direction. (Depending on the number of fragments in a particular category these bounds range from 2.7 to 4.6 sigma).

The results of the analyses indicate that a the potential for debris to impact lands outside of the PCZ occurs only under Kona wind conditions from an easterly launch. Figures V-3.1 through V-3.8 illustrate the debris patterns calculated under tradewind and Kona conditions; debris footprints for all meteorological conditions are presented in DEIS Appendix VIIA.

Effects on Human Populations. Launch holds during Kona weather will prevent debris from falling on land outside of the immediate vicinity of the launch pads. It is anticipated that Spaceport employees will be appropriately protected during launch. During a launch, the PCZ and the offshore area downrange will be closed to unauthorized persons.

Effects on Ecological Species Debris from an abort could result in the loss of flora in the launch area. This is not expected to result in significant impacts to on-site vegetation because the flora in the launch pad area consists primarily of introduced species (Char, DEIS Appendix IIIC).

Fauna near the launch pad will be affected. None of the calculated debris footprints however indicate an effect on the Kamehame Hill area, an area frequented by the Green and Hawksbill sea turtles. It should be noted, however, that the debris patterns were computed assuming the launch was from the center pad. There is a possibility that debris from rockets launched from the southern pad could impact the turtle nesting area. If calculations of debris pattern show that the Kamehame Hill and beach area could be affected, mitigating measures will have to be developed in cooperation with the USFWS and the NMFS.

3.0 Mitigating Measures

As shown on Figure II-2.1, the ILL is well within the PCZ boundary in order to ensure that the public is protected from a failure either on the pad or in flight. In addition to the ILL, destruct lines are defined for each flight. These are the lines which actually define the boundary of the vehicle flight corridor. The destruct lines are located so that if the vehicle is destroyed before crossing these lines, the debris will be contained within the ILL.

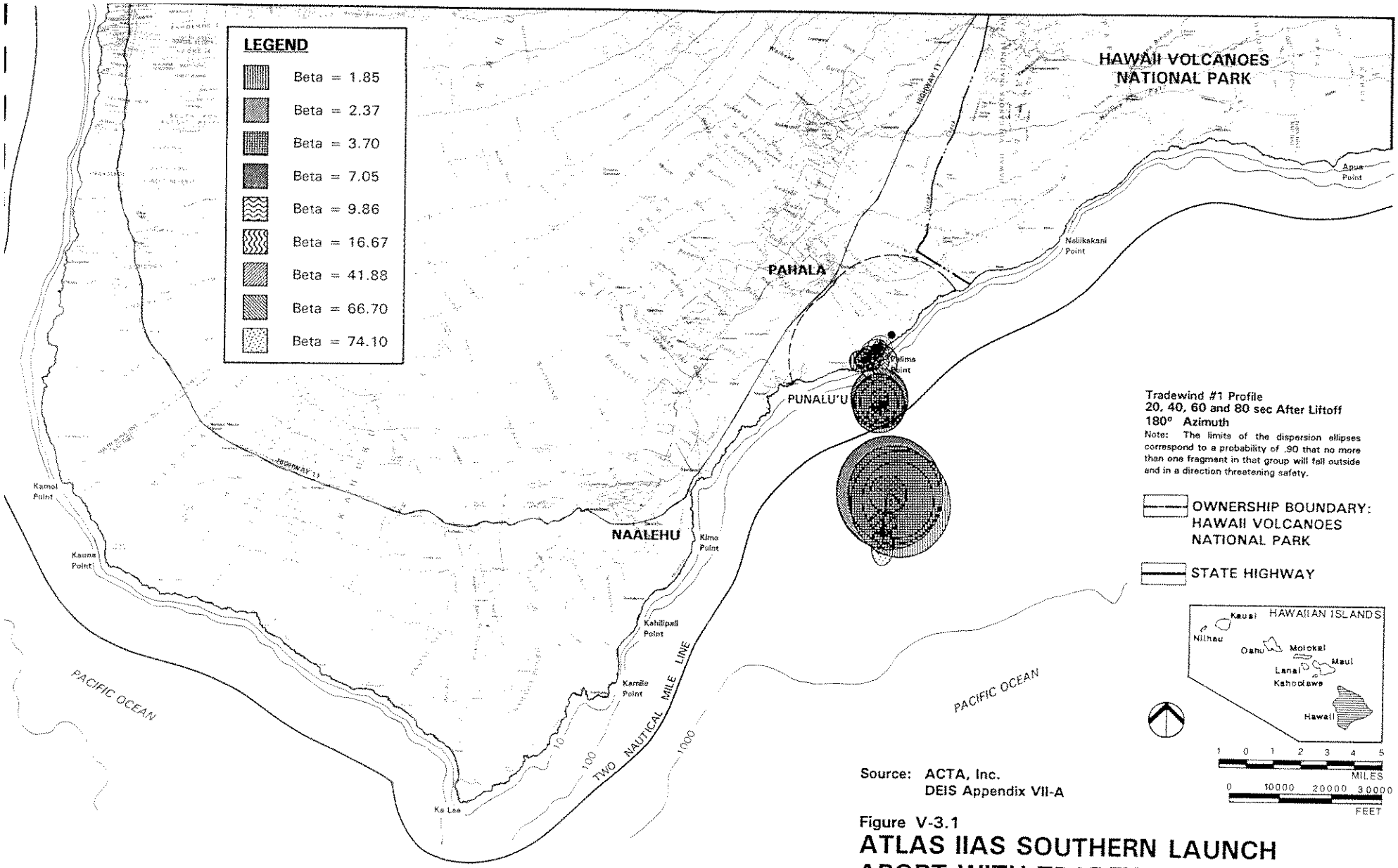
During unfavorable meteorological conditions, such as Kona, the launch will be held until the Range Safety Officer is assured that all debris would be contained within the ILL should an explosion or command-destruct event occur. The Range Safety Officer may also have to hold launches if endangered and/or threatened sea turtles are present in the area that could potentially be affected by debris.

L. NOISE AND VIBRATION EFFECTS FROM SUCCESSFUL LAUNCHES

1.0 Description

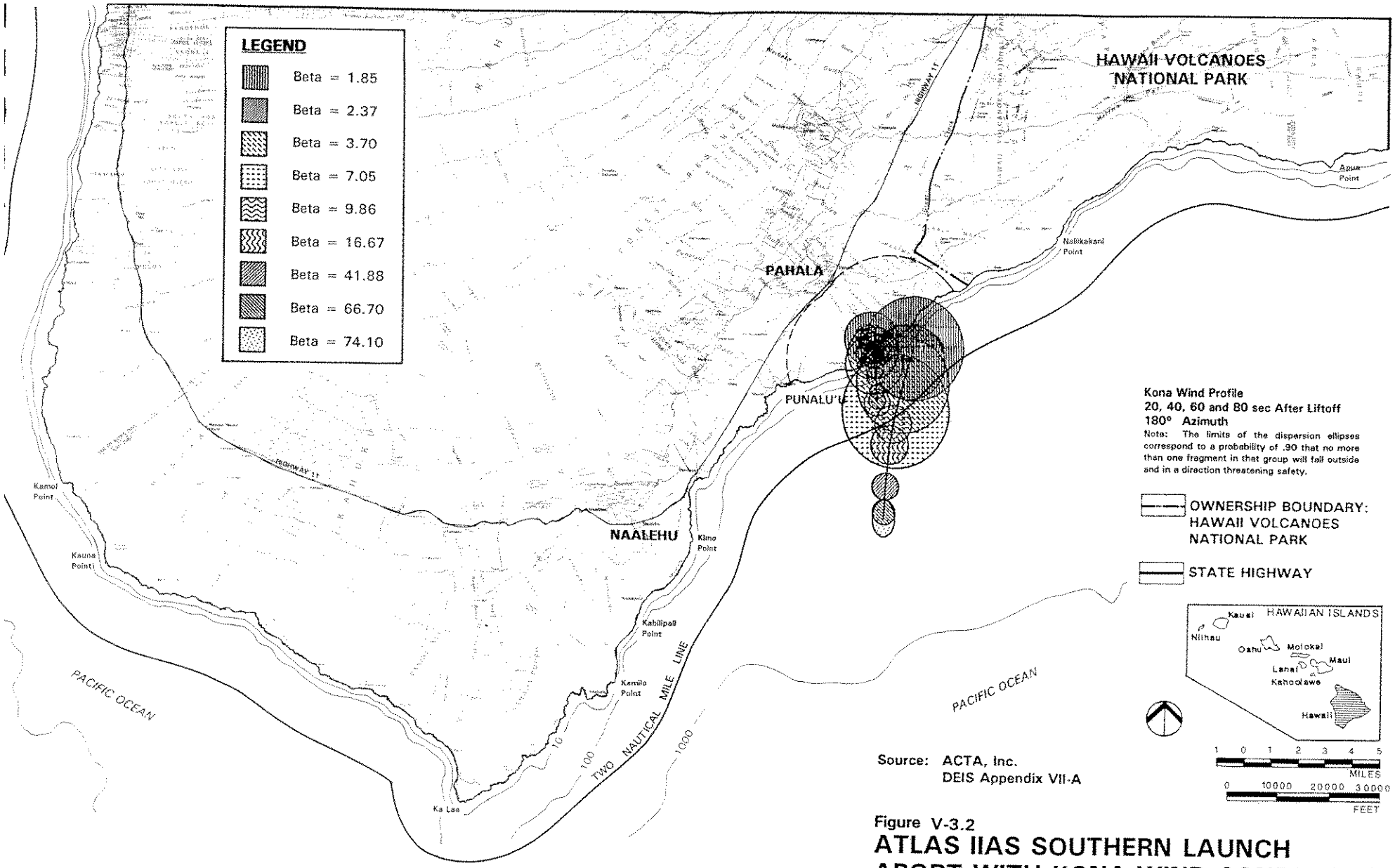
With each rocket launch, there will be intense noise for one or two minutes in locations within several miles of the launch site. Each of the candidate vehicles were evaluated to determine the "most energetic" acoustical effects. Based on analyses performed by ACTA Inc. (DEIS Appendix VIIC), the Atlas IIAS or the Delta II booster systems would be expected to generate essentially the same noise levels, therefore, they are treated as one and the same "most energetic" or worst case scenario.

Eastern and Southern launch trajectories were evaluated for sound propagation effects on seven receiver locations. The analysis also includes directivity of rocket noise, changes in source noise characteristics due to motion, atmospheric absorption of sound, and excess



Source: ACTA, Inc.
DEIS Appendix VII-A

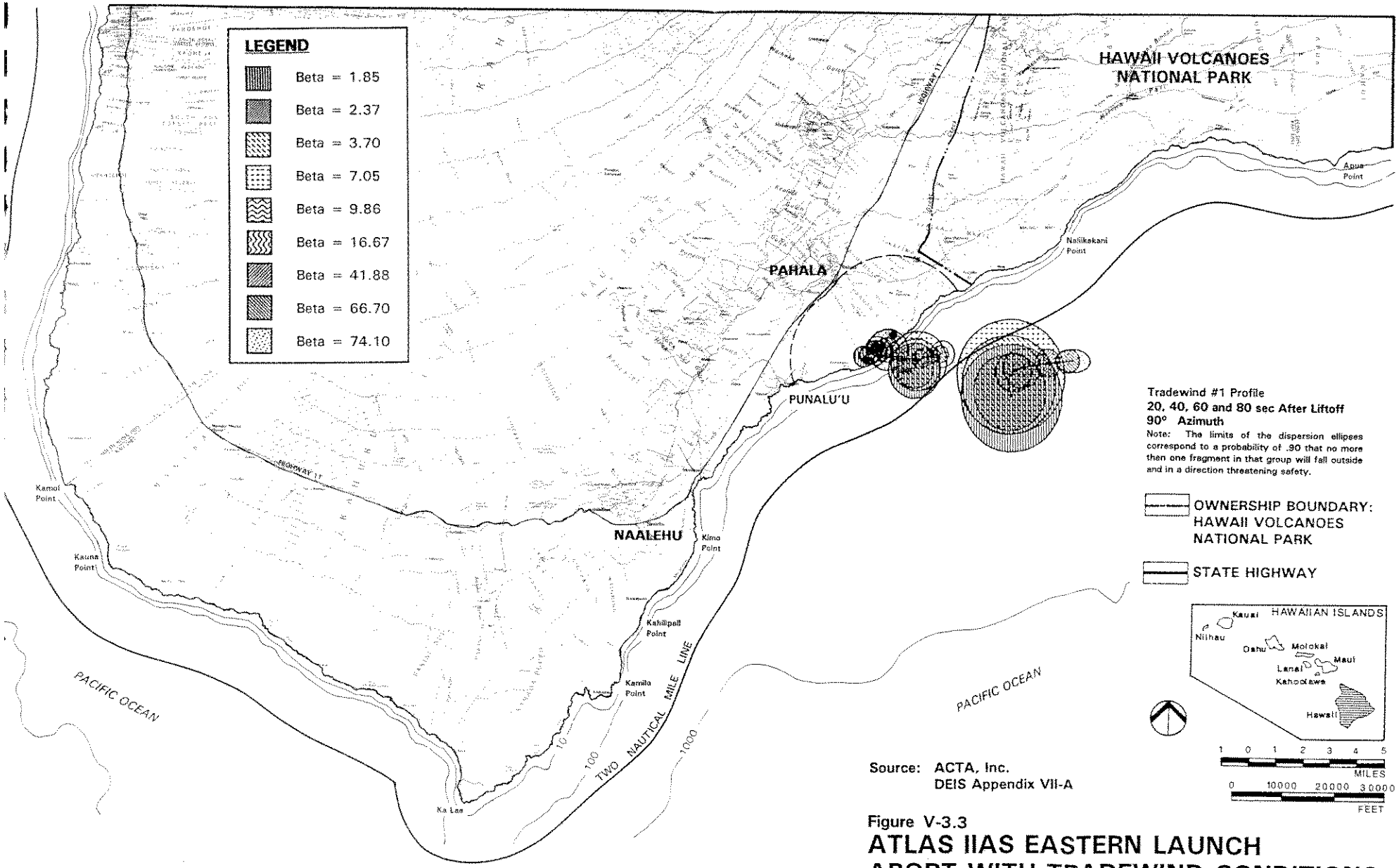
Figure V-3.1
ATLAS IIAS SOUTHERN LAUNCH ABORT WITH TRADEWIND CONDITIONS



Source: ACTA, Inc.
DEIS Appendix VII-A

Figure V-3.2

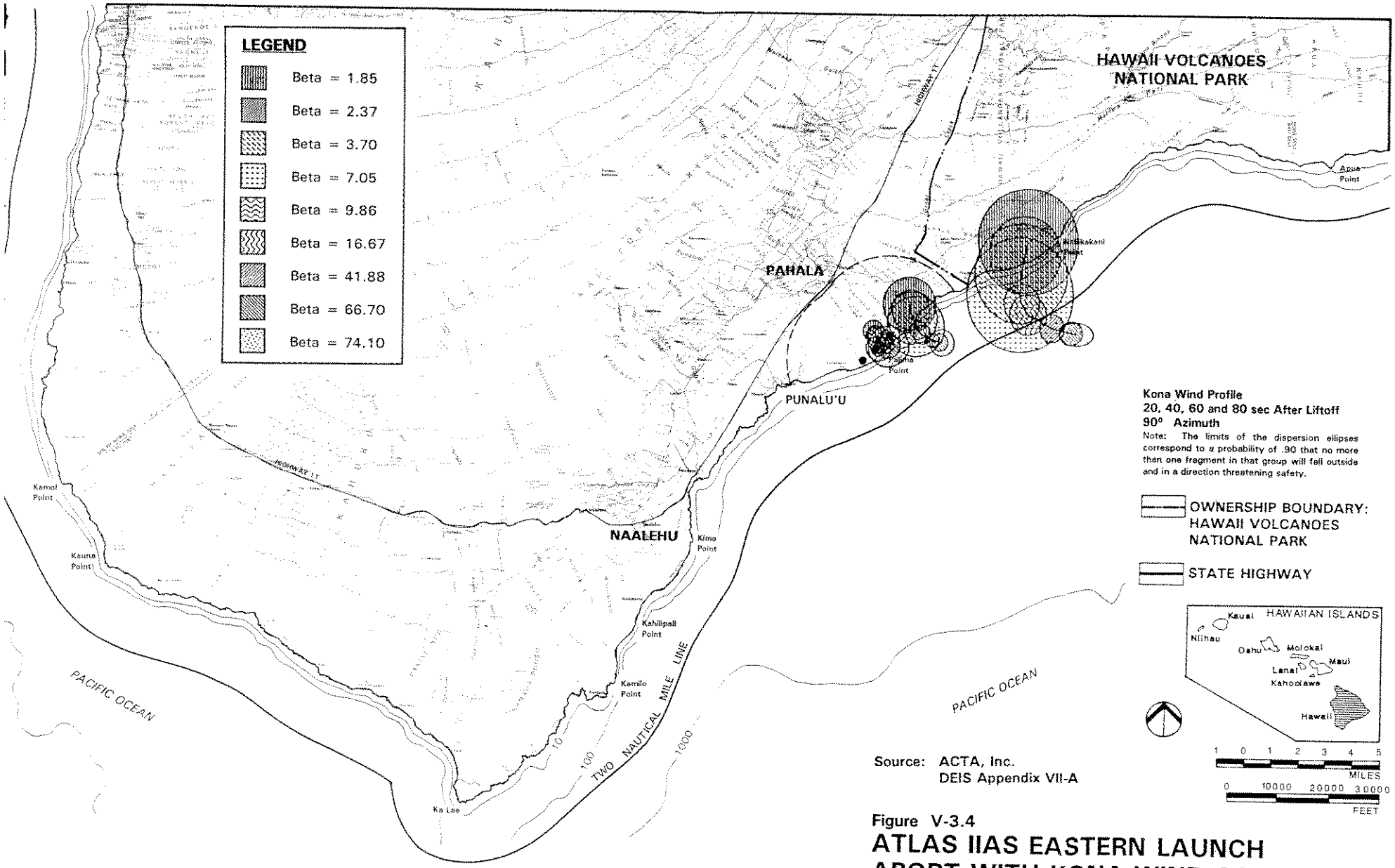
ATLAS IIAS SOUTHERN LAUNCH ABORT WITH KONA WIND CONDITIONS



Source: ACTA, Inc.
DEIS Appendix VII-A

Figure V-3.3

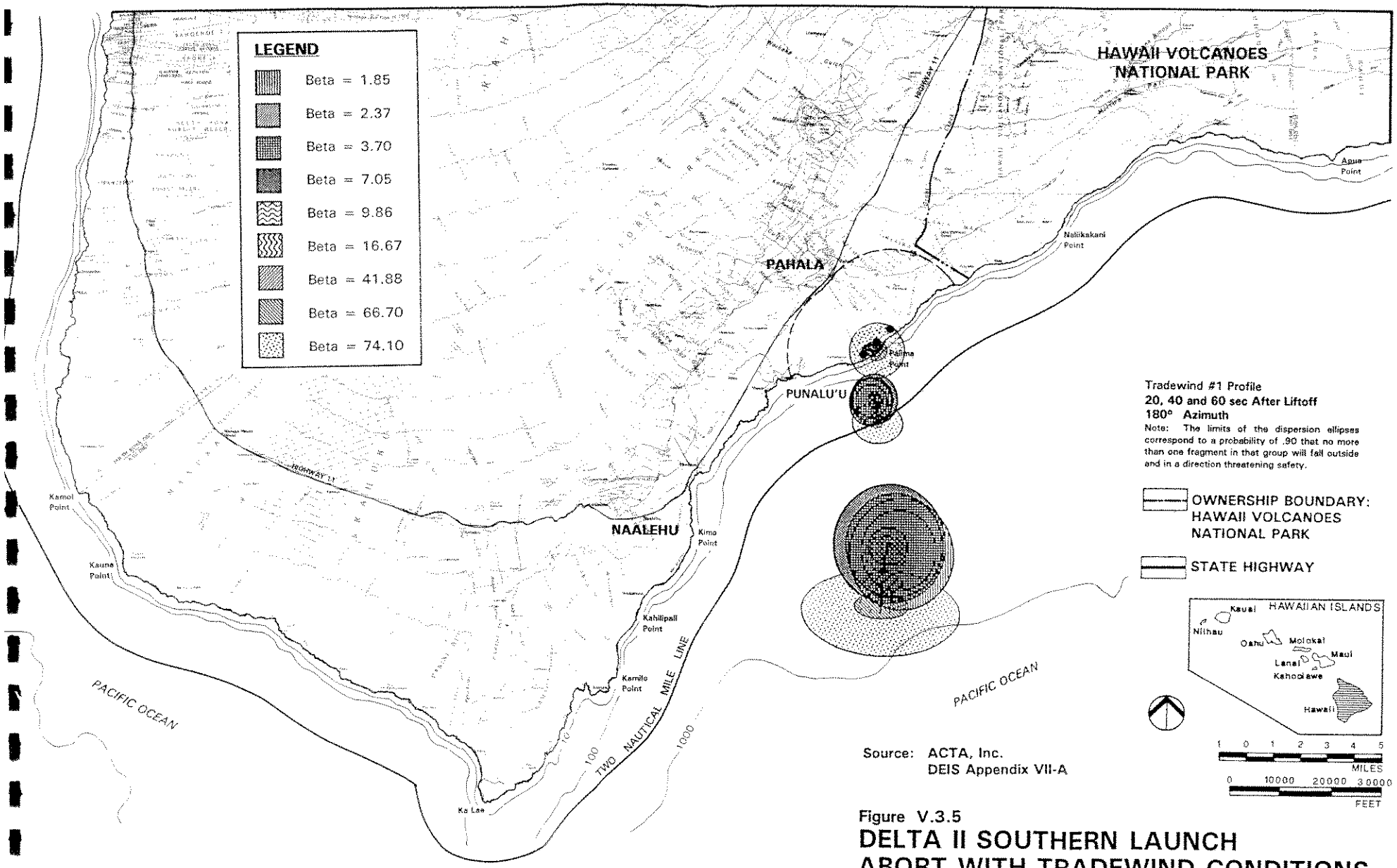
ATLAS IIAS EASTERN LAUNCH ABORT WITH TRADEWIND CONDITIONS



Source: ACTA, Inc.
DEIS Appendix VII-A

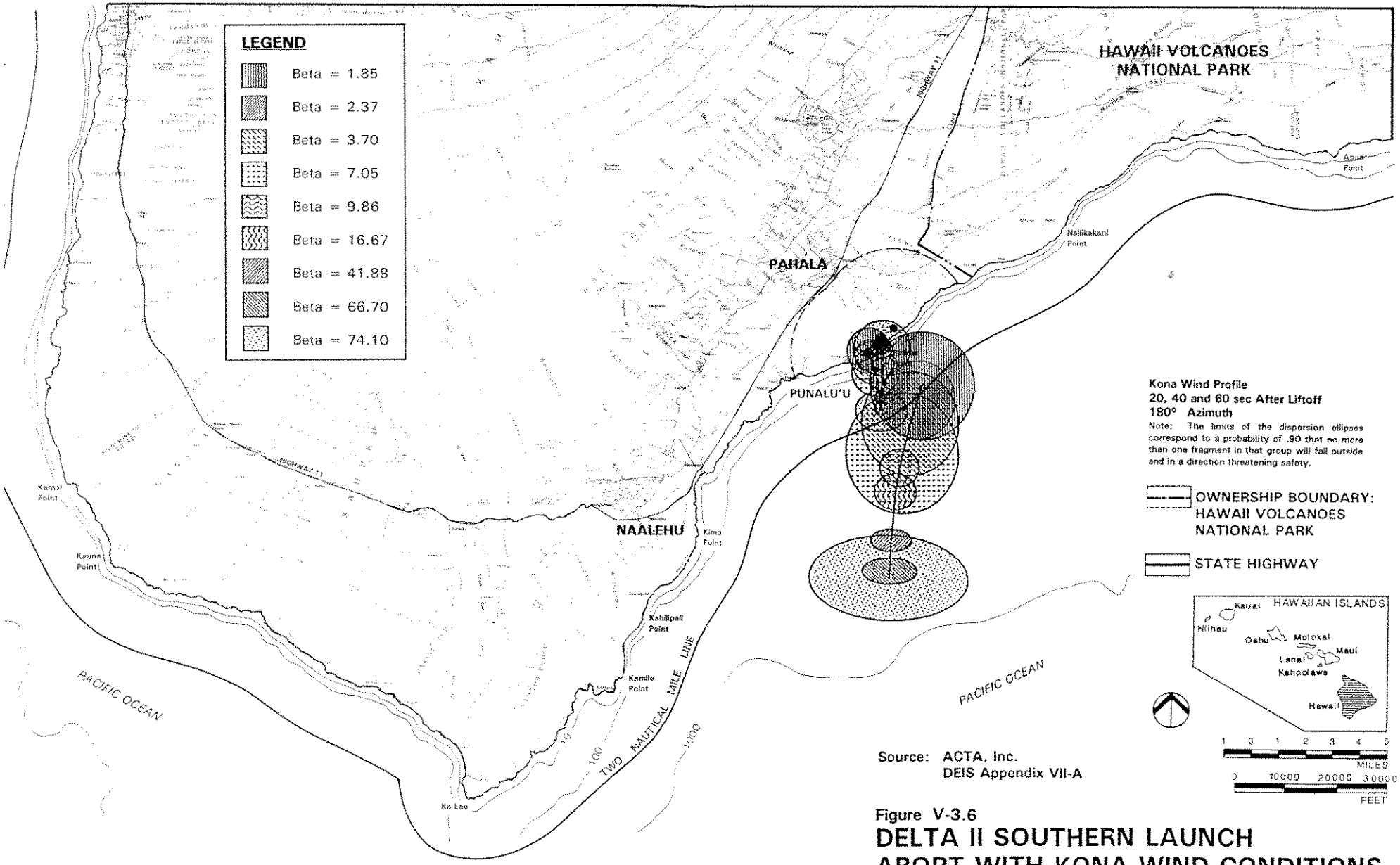
Figure V-3.4

ATLAS IIAS EASTERN LAUNCH ABORT WITH KONA WIND CONDITIONS



Source: ACTA, Inc.
DEIS Appendix VII-A

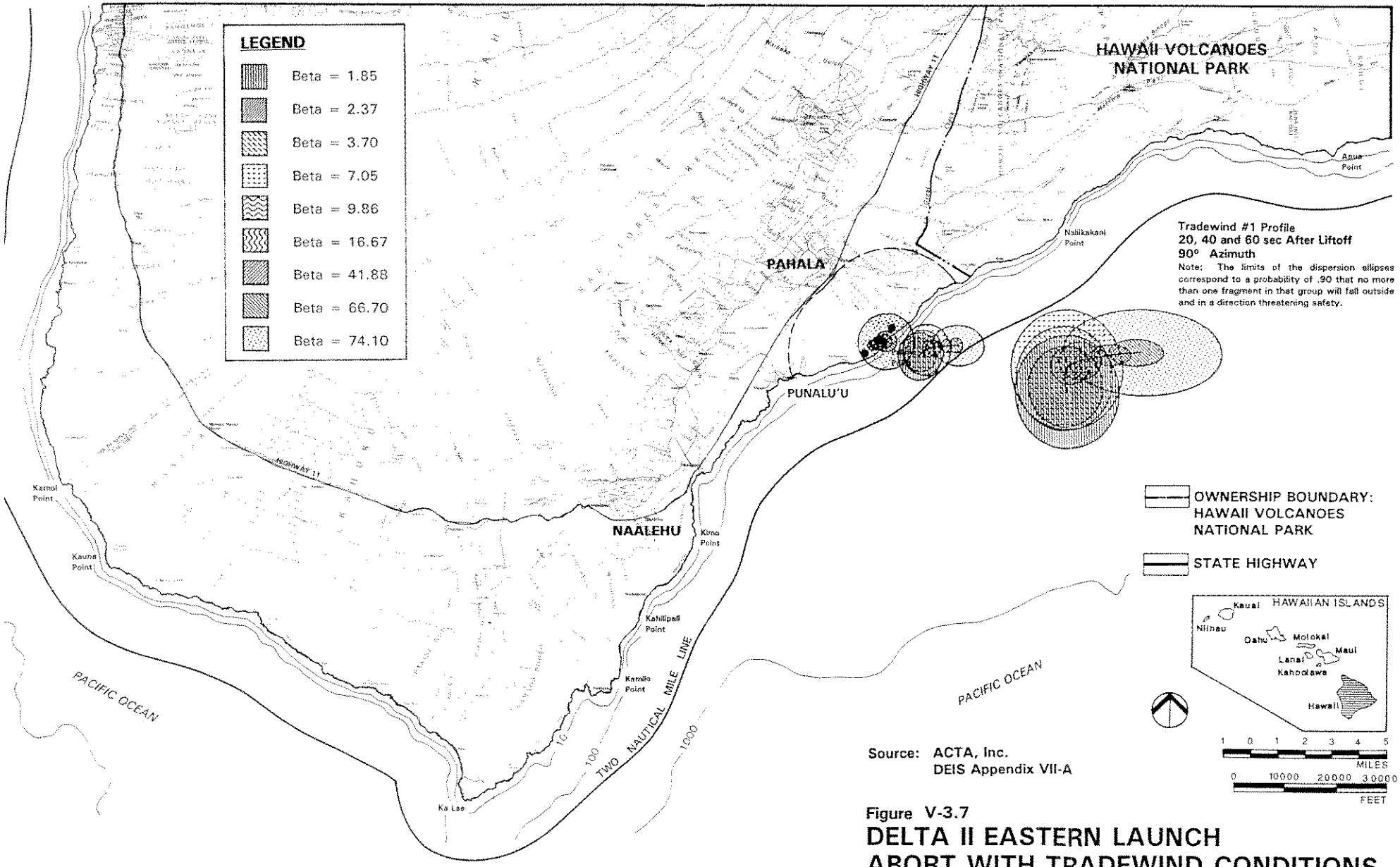
Figure V.3.5
DELTA II SOUTHERN LAUNCH ABORT WITH TRADEWIND CONDITIONS



Source: ACTA, Inc.
DEIS Appendix VII-A

Figure V-3.6

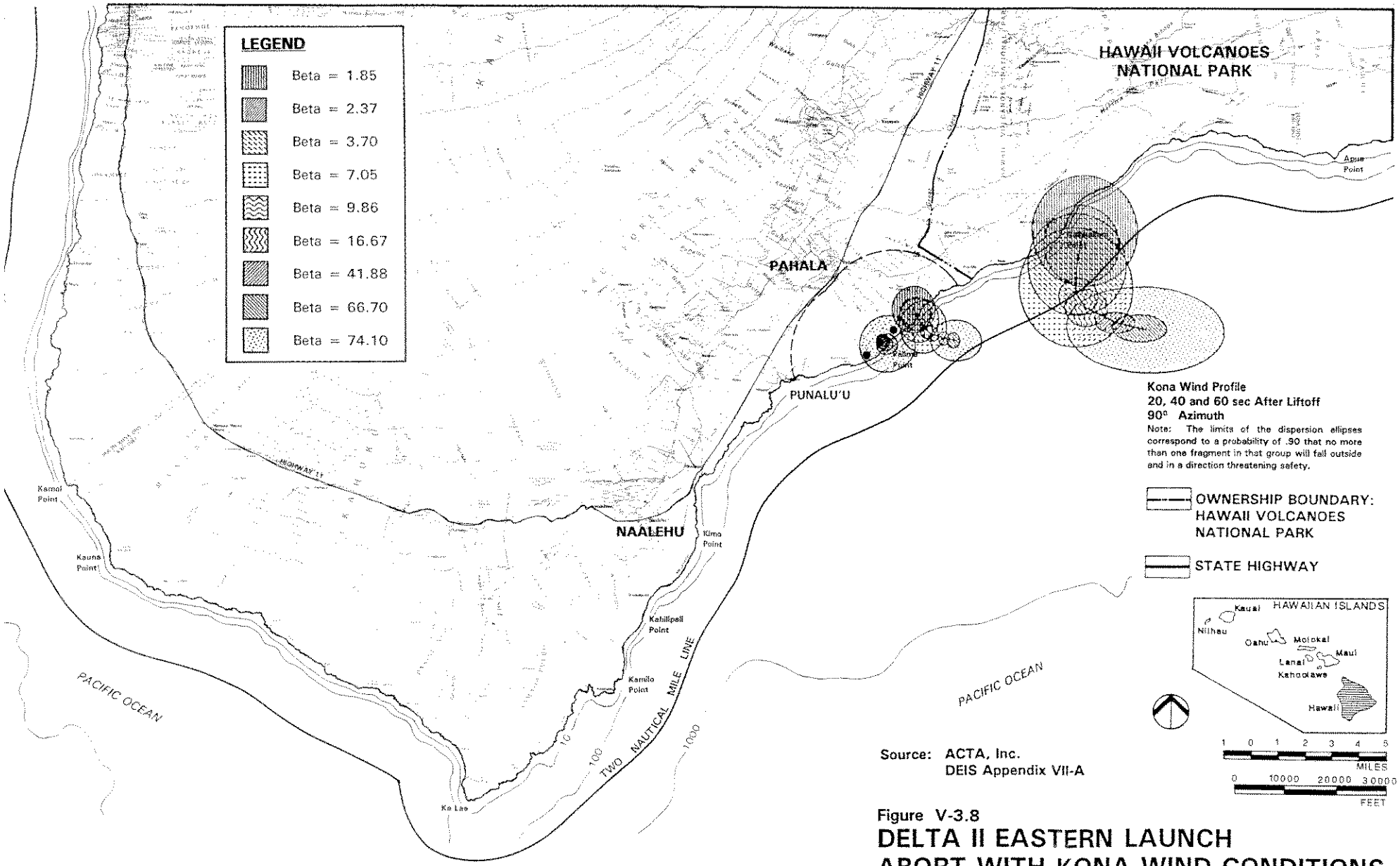
DELTA II SOUTHERN LAUNCH ABORT WITH KONA WIND CONDITIONS



Source: ACTA, Inc.
DEIS Appendix VII-A

Figure V-3.7

DELTA II EASTERN LAUNCH ABORT WITH TRADEWIND CONDITIONS



Source: ACTA, Inc.
DEIS Appendix VII-A

Figure V-3.8

DELTA II EASTERN LAUNCH
ABORT WITH KONA WIND CONDITIONS

attenuation due to ground effects. See Section I Chapter and DEIS Appendices VIIB, VIIC and VIID for a discussion of the analytic methods used in the assessment and descriptions of the conditions or combinations of factors that can affect the rate of attenuation of sound.

2.0 Analysis of Effects

Predicted Sound Pressure Levels. Tables 5.3.2 and 5.3.3 summarize the estimated maximum octave band sound pressure for Eastern and Southern launches from Palima Point. These sound levels do not include the effects of sound refraction and are essentially based on Condition 2 (standard) with selected ground attenuation effects when the rocket is at lower altitudes. Meteorological conditions, however, can cause a wide range in sound levels experienced by the observer, particularly at long distances from the noise source (positive refraction or focusing and negative refraction or defocusing).

Based on statistical analysis of focusing effects of actual rocket launches, the maximum C-weighted sound level during a launch under average conditions at the closest nearby communities of Pahala and\or Punalu`u is estimated to be 109 dBC. Under the most adverse (focusing) weather conditions, these maximum levels are not expected to exceed 115 dBC.

These estimates are based on average weather conditions and do not include potential moment-to-moment and daily variations in the exposure due to atmospheric turbulence and wind and/or temperature induced refraction effects. The latter are predictable by advance weather profiling. The former, random, short-term effects are not readily predictable.

Sound focusing due to meteorological conditions could increase the noise levels by 10 dB or more when the rocket is at low altitudes, but is believed to be probably limited to gains of 6 to 10 dB. It is recommended that sound focusing be measured prior to each launch and that the launch be held when adverse focusing conditions are present.

Effects on Human Populations. Due to the low pitch and short durations of rocket launch noise events, there is no danger of exceeding the noise exposure limits set by OSHA with respect to causing hearing damage outside of the PCZ. Rocket launch noise in Pahala and Punalu`u may be sufficiently loud to mask normal outdoor conversation speech for a half minute or so, but should not mask normal speech at more distant locations. Also, in the closer locations, the rocket noise may startle some persons or awaken them if they are sleeping.

Community response calculations, assuming a maximum number of launches per year, were made using techniques normally used for sonic booms, artillery or quarry blasts that tend to rattle (Darby, DEIS Appendix VIIB). The analysis indicates that about 18 percent of the population of Pahala may be highly annoyed if all launches are between 7 am and 10 pm; about 39 percent if one half of the launches are between 10 pm and 7 am. Rocket launches can arouse considerable interest, however, and it is not clear what sort of community reaction might be generated. It is expected that it will be minimal among those not already opposed to the launch facility and potentially substantial among those who are already opposed.

Effects on Sensitive Ecological Species. A temporary startle effect on terrestrial fauna could result from launches at Palima Point. Since exposure will be episodic and of an insufficiently high intensity, a hearing threshold shift, the correlated increase of hearing threshold level associated with partial or total hearing loss, is not expected in species which occur within the launch facility (EPA, 1980).

One area of uncertainty is the effect of low (but inaudible) frequency noise levels on reproductive behavior and development. Generally, faunal species (particularly birds) would be

Table 5.3.2 **SUMMARY OF ESTIMATED MAXIMUM OCTAVE BAND SOUND PRESSURE LEVELS FROM ATLAS AND DELTA LAUNCHES**

EAST LAUNCHES

SITE No.	1 Pahala	2 Punaluu	3 Naalehu	4 Mauna Loa Sanctuary	5 HVNP[1]	6 Mauna Kea Observatory	7 Hilo
Frequency Hz	OBL @ Lmax dB	OBL @ Lmax dB	OBL @ Lmax dB	OBL @ Lmax dB	OBL @ Lmax dB	OBL @ Lmax dB	OBL @ Lmax dB
8	100.0	99.3	91.3	90.6	85.1	78.4	80.9
16	103.9	103.1	94.6	94.1	88.0	79.8	83.0
32	105.9	105.1	95.3	95.1	88.0	77.4	81.8
63	105.0	104.1	92.1	90.4	83.8	68.7	76.4
125	101.5	100.4	84.6	79.2	74.0	49.8	59.2
250	94.9	93.3	70.9	59.4	56.8	15.1	44.8
500	82.5	81.6	44.2	22.6	29.6	<0	4.0
1000	67.1	64.6	<0	<0	<0	<0	<0
2000	47.4	37.9	<0	<0	<0	<0	<0
OA (flat)	111 dB	110 dB	100 dB	99 dB	93 dB	84 dB	87 dB
OA (C)	108 dBC	107 dBC	96 dBC	95 dBC	88 dBC	77 dBC	82 dBC
"A" Weight	90 dBA	89dBA	72 dBA	68 dBA	62 dBA	46 dBA	53 dBA

[1] Hawaii Volcanoes National Park

Source: Darby & Associates, Appendix VIIB (DEIS)

Table 5.3.3 **SUMMARY OF ESTIMATED MAXIMUM OCTAVE BAND SOUND PRESSURE LEVELS FROM ATLAS AND DELTA LAUNCHES**

SOUTH LAUNCHES

SITE No.	1 Pahala	2 Punaluu	3 Naalehu	4 Mauna Loa Sanctuary	5 HVNP[1]	6 Mauna Kea Observatory	7 Hilo
Frequency Hz	OBL @ Lmax dB	OBL @ Lmax dB	OBL @ Lmax dB	OBL @ Lmax dB	OBL @ Lmax dB	OBL @ Lmax dB	OBL @ Lmax dB
8	100.0	99.6	92.0	90.5	84.2	79.5	77.5
16	103.8	103.4	95.1	94.0	86.8	77.9	78.4
32	105.9	105.3	95.3	94.9	85.4	66.0	74.7
63	105.1	014.1	90.8	91.4	76.7	26.5	63.2
125	101.7	100.3	80.0	82.3	52.4	<0	37.9
250	94.9	93.5	60.2	65.6	4.3	<0	<0
500	84.4	82.5	28.9	33.8	<0	<0	<0
1000	69.0	64.9	<0	<0	<0	<0	<0
2000	44.4	24.2	<0	<0	<0	<0	<0
OA (flat)	111 dB	110 dB	100 dB	99 dB	91 dB	82 dB	82 dB
OA (C)	108 dBC	107 dBC	95 dBC	95 dBC	85 dBC	71 dBC	74 dBC
"A" Weight	90 dBA	89 dBA	69 dBA	70 dBA	54 dBA	30 dBA	41 dBA

[1]Hawaii Volcanoes National Park

Source: Darby & Associates, Appendix VIIB (DEIS)

most sensitive early in the breeding season during the nest site selection phase, when noise could cause the birds to abandon the site. Although there have been no reported adverse effects from rocket noise on fauna on or near Cape Canaveral, the species affected by the Palima facility may have different responses to low frequency noise.

Effects on Property. Calculations show that even if 10 dB of sound focusing occurred in Pahala and Punalu`u, there is no indication that window damage would be expected for windows in reasonable condition. Windows that are already cracked or damaged could possibly incur additional damage, but this is extremely unlikely for louvered windows or glass patio doors. Windows, pictures on walls, objects on shelves, and such, will probably rattle in Pahala and Punalu`u and/or locations further away and cause annoyance to some persons.

3.0 Mitigating Measures

There are no known mitigation measures to reduce rocket noise in the far-field. Much effort has been spent on reducing the acoustic load on the rocket by implementing deflectors and water injection at the pad during lift-off. These techniques, however, would not reduce the maximum noise levels received by the community if they occur at altitudes far above the pad.

Planting of dense foliage between the launch pad and noise sensitive areas could substantially reduce the acoustic energy that might otherwise be reflected and refracted to populated areas. Rocket noise mitigation involves suspending launches during weather conditions which could cause focusing of acoustic energy to the closest populated areas or any other sensitive location. A sound propagation monitoring system could be implemented which involves an artificial noise source and permanent noise monitoring stations in the closest communities. The monitoring system could provide measurements during actual rocket launches as well as a large statistical base of sound propagation data to be correlated with meteorological data for use in computer modeling to provide more accurate long-term prediction capabilities.

M. ANALYSIS OF SONIC BOOM EFFECTS

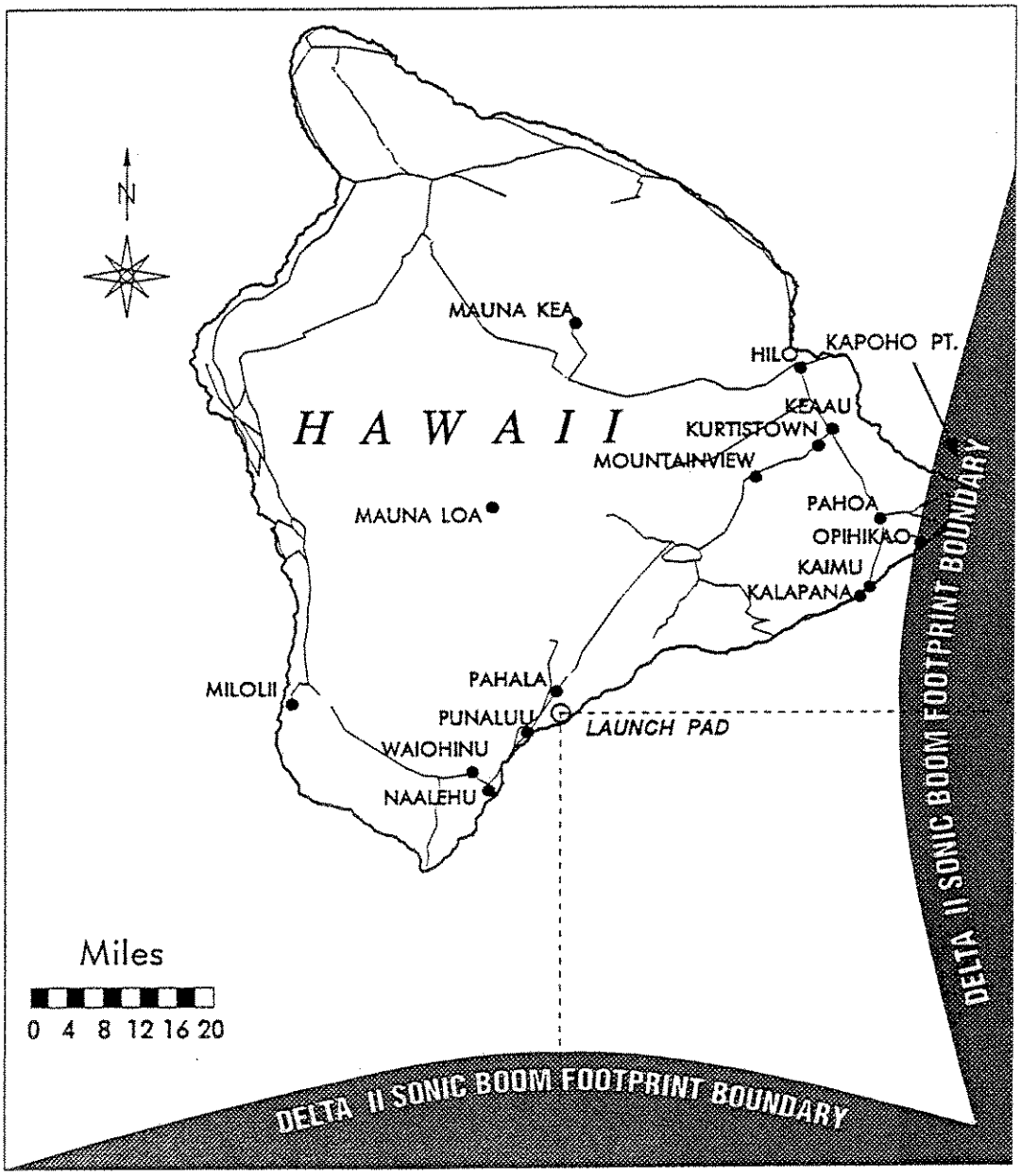
1.0 Description

A sonic boom effect results from acoustical energy that is generated when a rocket exceeds the speed of sound. The shape and footprint for any particular launch will be affected by the trajectory as well as meteorological conditions during the launch. Meteorological conditions may alter the peak overpressures, shift the focal region up or down range, and distort the shape of the footprint.

2.0 Analysis of Effects

Assumptions, Methodology and Findings. Sonic booms were analyzed by ACTA Inc. (DEIS Appendix VIIE) and Darby & Associates (DEIS Appendix VIIB). Sonic booms from Delta II and Atlas IIAS launches are expected to affect land areas only for equatorial or near-equatorial launches. Even for these launches, the affected area is confined to the vicinity of Kapoho Point in the Puna area (Figures V-3.9 and V-3.10). Under favorable meteorological conditions, Kapoho Point may not be subjected to any sonic boom.

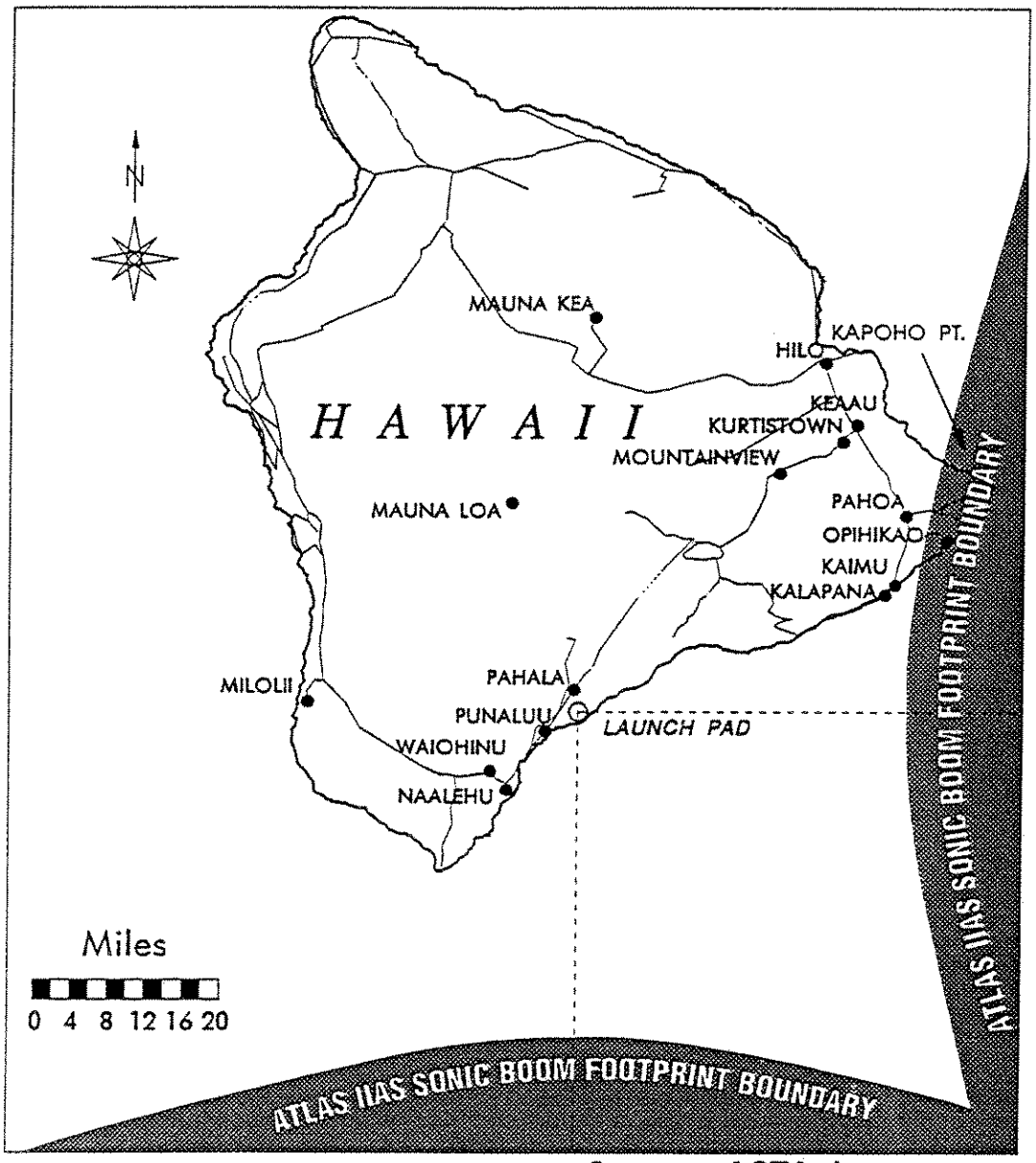
Estimated Delta II overpressures at Kapoho Point, when it is within the focal region, range from 0.016 to 0.049 psi, depending on meteorological conditions. Peak overpressures for the land area affected by Atlas IIAS launches are estimated to range from 0.017 to 0.052 psi.



Source: ACTA, Inc.
DEIS Appendix VII-E

Figure V.3.9

SONIC BOOM FOOTPRINTS FOR SOUTHERLY AND EASTERLY DELTA II LAUNCHES



Source: ACTA, Inc.
DEIS Appendix VII-E

Figure V-3.10

SONIC BOOM FOOTPRINTS FOR SOUTHERLY AND EASTERLY ATLAS IIAS LAUNCHES

Effects on People and Property. Sonic boom overpressures in the range of 0.016 to 0.052 psi will not cause any major structural damage nor any physiological impairment to humans. This level of sonic boom overpressure may be expected to annoy a significant number of the people in the exposed communities. At .016 psi, estimates of the proportion of the population who will be annoyed range from 30 percent to 90 percent.

There is a possibility of broken windows and plaster damage from sonic boom overpressures. Plaster damage is usually characterized by splaying of old cracks, hairline extensions of existing cracks and falling plaster. The probability of damage depends on both the sonic boom and the type and condition of exposed windows and walls.

3.0 Potential Mitigating Measures

Potentially adverse sonic boom effects can be eliminated by launch restrictions that make it impossible for a sonic boom to reach land. For Delta II launches, this may be accomplished by prohibiting launch azimuths too close to due east. The angular offset required must consider the most adverse meteorological conditions during which launches would be permitted. Alternatively, a combination of weather restrictions and azimuth restrictions could be developed to protect Kapoho Point. Sonic disturbances from Atlas IIAS launches can totally be avoided only by adopting strict exit azimuths.

Mitigation can also be accomplished by reshaping the trajectory using a dogleg maneuver to insure that the sonic boom footprint falls south of Kapoho Point and/or altering the pitch profile to shift the footprint downrange. While these strategies may be viable, the energy required for these maneuvers may make them unacceptable to potential range users.

SECTION IV: HAZARDOUS OPERATIONS AND ACCIDENTAL SPILLS

See ACTA Inc., DEIS Appendices VIB, VIC, and VID for more detailed analyses of spills and risk assessments of hazardous operations; RSA, DEIS Appendices VIIIA and VIIIB for health and ecological risk assessments of toxic spills; and HLA, DEIS Appendix IIIB for effects of spills on groundwater resources.

A. HAZARD ANALYSIS OF PAYLOAD PROCESSING OPERATIONS ON THE LAUNCH FACILITY SITE

1.0 Description of Payload Processing Operations

Payload processing operations are a set of activities performed on a spacecraft or satellite and assist motor(s), to ensure that the payload is flight ready prior to its mating with the launch vehicle. Variations in size, appearance, and function may mean that the sequence of operations differs somewhat for each payload processing operation. During payload preparation and pre-launch activities the primary events take place in three operational areas: (a) Non-hazardous Processing Facility; (b) Hazardous Processing Facility; and, (c) the Launch Complex.

Non-hazardous Processing. Non-hazardous check-out facilities are generally used for inspecting the spacecraft after it is received and checking to make sure no damage was incurred during shipment. The preparation and checkout performed in these areas usually requires a clean room environment and special test equipment. Activities classified as hazardous do not normally occur in this area. Non-hazardous activities generally include: final assembly or buildup of the spacecraft; leak tests and initial checkout of propellant systems before propellant loading; installation of solar panels, antennas, insulation and other equipment; payload function testing; inspection and cleaning; and, monitoring and checkout of payload electronic systems via hardlines and microwave communication.

Hazardous Processing. The hazardous processing facility is used for activities such as liquid propellant transfer operations, installation of ordnance for ignition and separation, spin balancing, and mating of the spacecraft with the upper stage motor(s). The procedures and operations considered potentially hazardous to personnel or to critical spacecraft equipment and/or systems generally include: transportation, short-term storage, sampling and loading of liquid propellants; installation of explosive devices used in space to ignite motors and to separate the payload from the vehicle; final assembly, lifting, and mating of solid rocket motors and liquid propellant motors with the payload; dynamic spin balancing of the assembled payload or the fueled parts of the payload; and, transportation of the fueled spacecraft to the launch complex.

Spacecraft Propellant Loading Late in the schedule, liquid propellants undergo thermal conditioning, after which they are loaded and the apogee kick motor (AKM) installed. The amounts of liquid propellants and oxidizer loaded onto a spacecraft is dependent on the spacecraft design and the functions it will perform. The typical payload generally requires between 1,000 and 1,500 pounds of liquid propellants (fuel and oxidizer combined), usually consisting of 350 to 500 pounds (40 to 60 gallons) of hydrazine and 650 to 1,000 pounds (55 to 85 gallons) of nitrogen tetroxide. Some payloads are monopropellant types and only use hydrazine.

Spin Testing. If the loaded satellite requires dynamic balancing, spin balancing is performed after the propellant is loaded into the spacecraft.

Transporting Fueled Spacecraft. After the satellite is mated to the motors, the entire assembly is either encapsulated in the launch vehicle fairing or placed in a special container to protect the payload during transport to the launch vehicle. Transporting the fueled spacecraft from the hazardous processing facility to the launch complex is a hazardous operation. Because the payload processing facility is within proximity of all the launch complexes there is no requirement to transport the fueled spacecraft on public roads.

2.0 Accident Scenarios

The following accident scenarios were identified as being capable of producing a fire, explosion, and possible venting of toxic vapors:

Explosion Resulting from Liquid Propellant Operations. The most likely cause of an uncontrolled leak is mechanical puncture of lines or tanks caused by dropped tools or other equipment. Hydrazine fuels are extremely flammable and a large spill or leak would likely result in a fire. The heat released by the burning of these fuels may overheat fluids/vapors remaining in payload tanks or fueling drums, thereby causing auto-ignition in the vessels.

Nitrogen tetroxide does not react to produce rapid heat release in the atmosphere. Combustion type reactions are possible only in the unlikely event that the released oxidizer comes into contact with a fuel source. The major result of a large oxidizer spill or leak is high concentrations of nitrogen dioxide in the area of the spill.

Explosion Resulting From a Dropped Payload. All payloads must be lifted at least once for transporting and are frequently lifted several times after fueling. If a fueled payload is dropped during lifting operations, fire and explosion would be likely. Major facility damage and possible release of unburned propellants could occur. Although payloads have been damaged in lifting operations, none has reportedly been damaged to the extent necessary to result in this type of event.

Explosion of a High Pressure Tank. In the unlikely event that a high pressure tank should burst as the result of overpressurization or material flaw, its fragments could penetrate nearby spacecraft propellant tanks. No failure has been reported that resulted in the severe event described. The damage caused by such an event, however, could result in an explosion, loss of building containment, and possible release of toxic vapors.

If a release and dispersion of toxic vapors were to occur, the maximum estimated amount is 30 gallons, because this is the approximate amount that would be contained in one spacecraft tank. The release of 30 gallons of hydrazine, if building containment were completely lost, would result in a toxic vapor of 0.12 ppm at approximately 1,200 feet, based on 4 knot winds during daytime conditions.

Explosion Resulting From a Spin Balance Accident. A spin balance table is used to precisely measure the center of mass and moments of inertia of the major elements of a payload. Normally the spacecraft is attached to the table and spun at a slow rate to make these measurements prior to propellant loading. Some payloads require spin balance after propellant loading, at other times solid rocket motors are attached to the table. Fire could result from a leak in hydraulic oil if an ignition source is present. Because of the small amounts of propellant used in these stages and vehicles, however, these hazards would not be expected to affect off-site populations (ACTA Inc., Appendix VIC).

Ignition of a Solid Rocket Motor Solid propellant motors are normally classified as a fire hazard, but they cannot be detonated even when exposed to fires or explosions of the type possible resulting from a payload accident. Ignition of a motor by external heating or penetration by a destruct charge will normally produce external low pressure burning of the solid propellant contained in the motor. Once ignited, the solid propellant motor cannot normally be extinguished until all the propellant is consumed. If initiated while attached to the fueled payload, the heat released is likely to cause failure to the liquid propellant tanks and lead to the involvement of liquid propellants in a fire and possible explosion.

Accidental internal ignition of a motor with the payload attached may result in restrained propulsion of SRM and payload within the processing building and explosion on impact. Fragments generated by this type of explosion could cause severe damage to the payload; however, they are not expected to penetrate the walls of the facility.

Unrestrained motors accidentally ignited can become propulsive and accelerate into the walls or ceiling. Because of the limited distance involved, impact velocities would be low and any damage to the facility would most likely be confined to the ignition area.

3.0 Hazard Analysis and Risk Assessment

A qualitative hazard analysis and risk assessment was performed by ACTA Inc. (DEIS Appendix VIC) to identify risks to the public that may result from accidents at the Palima Point launch facility during payload preparation and processing for launch. Contributing events that must occur for an accident to result were evaluated and the probability of each contributing event estimated. The identification of contributing events necessary for each of the accident scenarios did not result in the identification of any unacceptable risks. Risk factors were assigned for the immediate area of activity. Distances from the payload processing area to any public property means there is less risk to the public than identified for the processing facility itself.

The reviewer will note that the conceptual layout presented in DEIS Appendix VIC has been revised in the Conceptual Plan (Chapter Two, Figure II-1.1); the payload processing area was relocated based on the information presented in the Appendix.

4.0 Mitigating Measures

Mitigating measures related to facility design are presented at the end of this Section. Measures directed to preventing accidents during spin-balancing operations include:

- Isolating the spin table from the control center and restricting non-essential personnel from both the building and a specified area outside of the building;
- Thoroughly inspecting the spin balance table prior to each use;
- Scheduling and performing frequent detailed inspections and maintenance on the spin table;
- Providing on-line redundant leak detection measures;
- Locating the motor in a separate area, not directly under the spin table;
- ensuring that the motor is totally encased and purged by two-way air flow;
- Providing for automatic detection of dangerous out-of-balance situations; and

- Ensuring that visual and audio signals are activated and shutdown automatically at pre-set limits.

B. ELECTROMAGNETIC ENERGY AND IONIZING RADIATION

1.0 Radio Frequency Emissions

Possible sources of electromagnetic energy include visible/infrared sources (lasers), microwave and radio frequency (RF) transmitters, and ultraviolet radiation (arc welders). The low power RF sources on the launch vehicles normally consist of telemetry transmitters and radar tracking transponders.

RF emissions from a satellite could occur during pre-launch check-out, however the radiated power output of these transmitters is low.

High power RF emitters such as radars are carefully controlled to ensure that emissions do not exceed dangerous levels in areas outside the spaceport. Safeguards including power management and "sector blanking" will insure that dangerously high levels of RF energy are not beamed into nearby areas.

2.0 Ionizing Radiation Sources

Some launch vehicles and spacecraft use low energy sources of ionizing radiation for measurement and calibration purposes. These sources produce only micro- and millicurie levels and therefore are not expected to affect human health or the environment. Spacecraft operators should comply with all Federal Nuclear Regulatory Commission and State requirements when processing any material that produces ionizing radiation. Spacecraft powered by radioactive materials are prohibited by Section 201-75, Hawaii Revised Statute (See Chapter One).

C. HAZARD ANALYSIS OF PROPELLANT STORAGE AND HANDLING ON THE LAUNCH FACILITY SITE

1.0 Basic Conditions

The candidate vehicles proposed for the Hawaii commercial space launching facility utilize hypergolic, cryogenic, and solid propellants. In addition to the launch vehicle, the payloads of space boosters often use hypergolic and solid propellants, although in lesser quantities. Pressurization gasses are used to transfer liquids, pressurize components and purge systems. The types and quantities of chemicals anticipated for use and storage units at the Palima Point facility are identified in Tables 2.3.2 and 2.3.5.

MMH and UDMH are sometimes used as spacecraft propellants. The quantities required are relatively small and will be stored only as needed in the central hypergolic storage facility.

2.0 Potential Hazards

There are a number of hazards associated with rocket propellants. Rocket propellants are highly energetic and large quantities are involved in launch operations, which are inherently complex and have many potential failure modes. The hazards associated with handling and storage

of liquid propellants and oxidizers are present primarily during transfer operations. Transfer operations are performed when propellant or oxidizer is transferred to a central storage facility and from central storage to the launch vehicle or propellant transfer unit (PTU). If the propellant transfer unit is utilized, an added operation is necessary to transfer the material from the PTU to the launch vehicle. (Note: payload processing hazards are discussed separately in B. of this Section). See DEIS Appendix VIB for the steps required for fuel transfer operations. Propellants types and hazards are discussed in Section I of this Chapter.

During transfer operations the threat of toxic vapors, fire, and explosion is present. The contributing events necessary to produce a propellant/oxidizer spill during a transfer operation do not pose any risk to the public as a result of an on-site spill of any of the materials reviewed (ACTA Inc., DEIS Appendix VIB).

Solid propellant motors will be stored at the propellant and explosive area. During storage, explosions could result from pressure ruptures of containers, which may produce fragments. These explosions seldom produce propagating shock waves, or damaging blast overpressure beyond the storage distance. No hazards to off-site populations or the off-site environment should exist due to accidents associated with the processing of solid propellants (Ibid.).

3.0 Mitigation of Potential Impacts

In general, the most important mitigating measures involve reducing or eliminating the probability of accident occurrence, and reducing the effects of uncontrollable accidents. Operational/handling precautions, procedures, and requirements at hazardous facilities and hardware design reviews for critical equipment is essential. Strict safety measures must be implemented. Mitigating measures related to facility design are discussed later in this Section.

D. TOXIC RELEASES FROM SPILLS OF LIQUID PROPELLANTS ON THE LAUNCH FACILITY SITE.

1.0 Description and Overview

Accidental spills of liquid propellants can occur during routine handling operations. Spilled cryogenic propellants (such as liquid hydrogen and oxygen) will boil vigorously due to heat transfer from the relatively warm ground or floor. Some flash vaporization may occur because containers for cryogenic liquids are usually maintained at slightly above atmospheric pressure. A propellant at ambient temperature, such as RP-1, will evaporate more slowly. There are two general categories of spill: hot spills and cold spills.

Hot Spills. Ignition of a propellant spill produces a pool fire with a flame base. The flame spreads along the liquid film at a height determined by both the rate of evaporation and the rate of fuel and oxidizer mixing. The pool fire will either continue to expand (on flat ground) or will remain stationary (if the liquid has accumulated in a depression area) until it runs out of fuel. The fires could be a hazard to people and property.

If the pool of spilled liquid does not ignite immediately after the release, and the released propellant has a high vapor pressure (e.g., liquid hydrogen, oxygen, or nitrogen), then a vapor cloud will form and be transported by prevailing winds. The leading edge of this cloud advances with the wind; its trailing edge is at the evaporating pool. If ignited, a vapor cloud fire could result.

The vehicle deflagration scenario, which is assessed in Section III of this Chapter, characterizes the worst case potential hazard for a hot spill because it involves entire vehicle quantities of propellants.

Cold Spills. A cold spill is characterized as a pool of evaporating liquid or as a gaseous cloud that is neutrally buoyant. Generally, spills involving unreacted hypergolic propellants pose the greatest hazard because the minimum vapor concentrations with toxic impacts are much below those required to sustain a flame. This means the size of a toxic cloud is potentially much greater than that of a flammable cloud. For equal amounts of released propellants, therefore, the potential for toxic impacts is greater than for fire.

When a cold spill occurs, the evaporation rate is proportional to the surface area of the spill. The mass evaporation rate, therefore, increases with the size of the spill area, producing higher vapor concentrations. Standard containment design at the launch complex, such as grate-covered floor trenches to capture and divert spilled liquids to holding tanks, will limit the surface area of a potential spill. Application of a foam will also decrease the evaporation rate.

2.0 Spill Scenarios

Types of Spills. Three types of spills that may potentially occur as a result of routine storage, handling, and transportation operations on-site:

- o accidental launch vehicle tank spills (hydrazine, UDMH and N_2O_4);
- o storage container spills (hydrazine, UDMH, MMH and N_2O_4); and,
- o catastrophic rupture of cryogenic storage tanks (containing liquid oxygen, liquid hydrogen or liquid nitrogen).

Model simulations indicate that spills of individual containers, typically 55 gallon drums or 300 gallon cylinders, pose no threat to off-site communities. The hazards from complete rupture of large cryogenic tanks were also confined to within the boundaries of the PCZ (See ACTA Inc., DEIS Appendix VID). The greatest threat to off-site populations occurs in the event of a launch vehicle fuel or oxidizer tank spill.

Description of Worst Case Scenario. Prior to launch, fuel is transferred into the vehicle. Hypergolic propellants may be loaded up to 3 days prior to launch while cryogenic propellants are loaded within the last 3 hours of the countdown. The Delta II second stage contains 615 gallons of Aerozine-50 and 728 gallons of nitrogen tetroxide in separate tanks. If both tanks rupture of or leak, the resulting fuel and oxidizer mix would result in fire. The spill from either substance alone results in a more hazardous condition because the vapors from the unburned liquids are toxic. The rupture of a launch vehicle tank of hypergolic propellant after the rocket is fueled produces the greatest adverse effects.

Worst Case Assumptions and Methodology. In the analysis, the spill is characterized as a pool of evaporating liquid or a neutrally buoyant cloud of gas. The AFTOX (Air Force Toxic Program) cold spill dispersion model is used to estimate downwind concentrations. The concentration contours modeled are based on 1-Hour SPEGLs; it is possible that concentrations within these contours may be higher.

It should be noted that the field tests against which AFTOX and other cold spill dispersion models are evaluated, are typically limited to measurements of concentrations within several

kilometers of the source point. Some data measurements were taken out to 8 or 10 kilometers (about 5 to 6 miles). It is generally accepted that the Gaussian plume and puff models provide acceptable predictions over downwind distances of 5 to 10 kilometers in homogeneous terrain and under persistent meteorological conditions.

The model was applied to locations out to 50 kilometers (over 30 miles) from the source to provide estimates of chemical concentrations at designated receptors of interest to the State of Hawaii. The resulting prediction for receptors at locations over 6 miles downwind from the source are therefore conservative because the model is applied in a manner that errs toward over estimating concentrations at the more distant locations. It is appropriate in an environmental assessment, however, to consider that the winds could at some time carry the dispersing chemicals toward the receptors of interest.

The assumptions used in modeling of the worst case spill scenario are:

- A single chemical is released instantaneously (15 seconds or less). This minimizes the likelihood of an explosive reaction and maximizes the resulting pool area and subsequent total mass evaporation rate;

- The entire contents of the storage vessel are released; 615 gallons of Aerozine-50 or 728 gallons of nitrogen tetroxide.

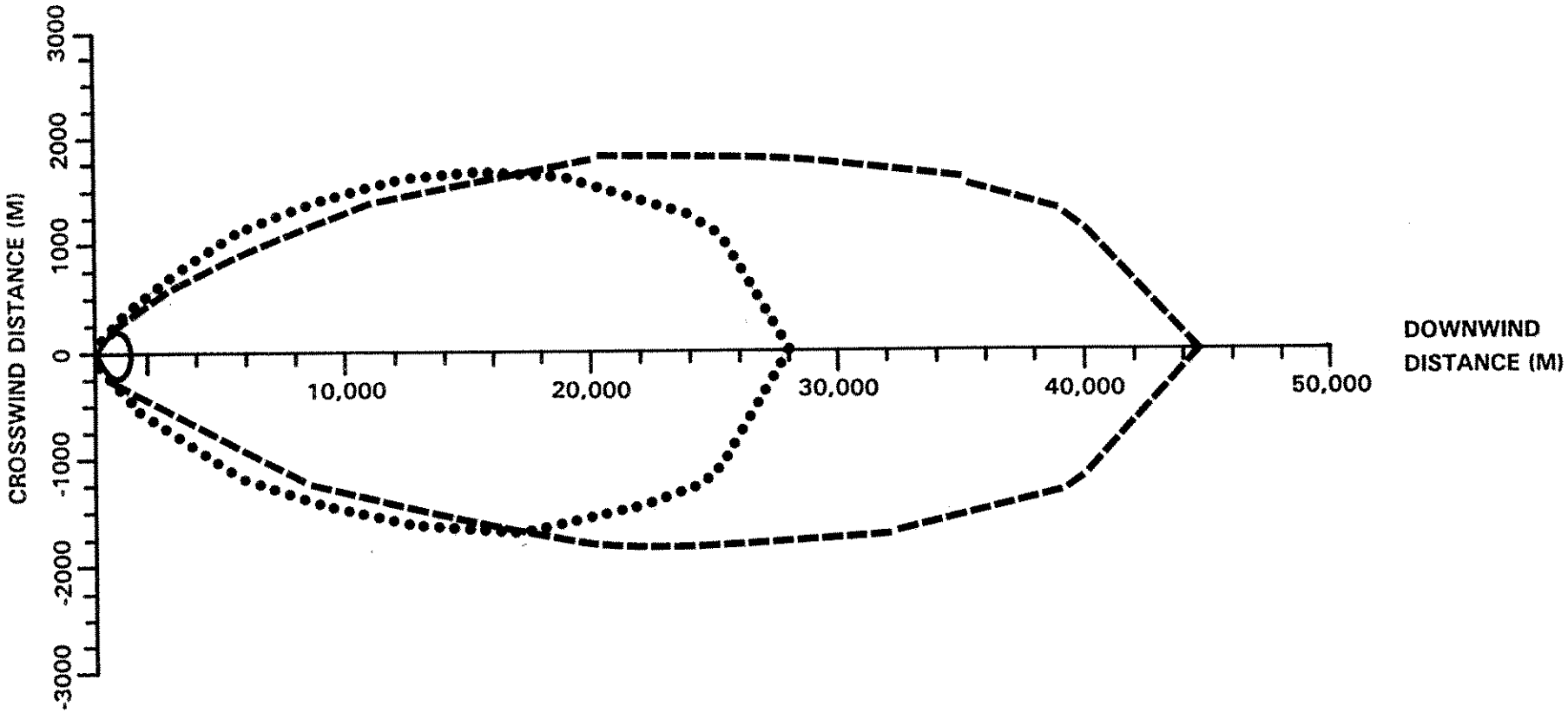
- The spill occurs during one of two types of worst case meteorological conditions: (1) a summer nighttime condition accompanied by a low level temperature inversion (60 m base) and a temperature of 22 °C, and (2) a summer daytime condition during which no temperature inversion occurs in the lower atmosphere up to 500 m (a condition which allows for greater vertical mixing) and the ambient temperature is 30°C.

- Although the worst possible case from the standpoint of toxic evaporation would be an uncontained, undiluted spill that is allowed to evaporate completely without blanketing, the case is not realistic because State and Federal regulations require containment.

The scenarios analyzed in this Section assume different pool depths that result in different spill pool areas to simulate the effects of containment by different sizes of holding ponds. Pool depths of 1 mm result in pool areas of 2,328 square meters for hydrazine and UDMH and 2,758 square meters for nitrogen tetroxide. Spill depths of 5 mm result in pool areas of 466 square meters and 552 square meters, respectively. A containment area of 37 square meters was also simulated for the respective quantities spilled for each chemical. The scenarios are worst case because they do not reflect active containment and clean-up efforts by a HAZMAT team. Figure V-4.1 depicts concentration isopleths from a nighttime spill (wind speed of 4 m/sec) of 615 gallons of A-50 with different pool areas. The 0.12 ppm contour lines represent the 1-Hour SPEGL value for hydrazine.

3.0 Effects on Human Health

Assumptions and Methodology. It is assumed that the entire contents of a storage vessel is released under the two previously described worst case meteorological conditions - a summer nighttime condition and a summer daytime condition. The analysis is also based on the assumption that the spilled liquid is allowed to remain and evaporate over time with no effort being made at remediation. This is an improbable situation which would not be allowed to happen. A spill would be actively contained and cleaned-up immediately, most likely within 5 to 20 minutes depending upon the size of the spill. With the source of the contaminant removed, airborne concentrations and hence exposures and risks would be significantly lower than predicted in this



POOL AREA = 2328 Sq. M.
POOL AREA = 466 Sq. M.
POOL AREA = 37 Sq. M.
SPILL QUANTITY = 2095 KG (615 Gal.) of Aerozine-50
WIND SPEED = 4M/S (Nighttime)

Source: ACTA, Inc.
DEIS Appendix VI-D

Figure V-4.1

CONTOURS SHOWING THE EFFECT OF VARYING POOL AREAS FOR ONE HOUR AVERAGE CONCENTRATIONS OF HYDRAZINE AT 0.12 PPM

analysis (RSA, DEIS Appendix VIIIA).

Peak 60-minute average concentrations of hydrazine, UDMH, and nitrogen tetroxide (N_2O_4) were predicted for 66 sensitive receptor sites under daytime and nighttime light and moderate wind conditions. Centerline one hour average concentrations downwind from the spill were calculated under the same assumptions for other receptor sites not included in the list of sensitive receptors, including the area within the PCZ.

Exposure Concentrations. The highest 60-minute average concentrations of hydrazine (1.3 ppm), UDMH (0.69 ppm), and N_2O_4 (3.6 ppm) are predicted to occur at Pahala under nighttime light wind conditions (2 m/sec) with a spill depth of 1 mm and a maximum spill pool area of 2,328 m^2 for hydrazine and UDMH and 2,758 m^2 for N_2O_4. Assuming the spill is contained and the spill depth is 5 mm, resulting in a spill area of 466 m^2 for hydrazine and UDMH, the predicted levels at Pahala are 0.26 ppm and 0.14 ppm, respectively. For N_2O_4 the spill area would be 552 m^2 and the predicted concentration at Pahala is 0.87 ppm. With immediate blanketing by a HAZMAT team, exposures would be significantly lower than predicted (RSA, DEIS Appendix VIIIA).

Maximum predicted centerline 1-hour average concentrations downwind from the spill for hydrazine, under nighttime light wind conditions (2 m/sec) assuming a pool depth of 1 mm (2,328 m^2 pool area), indicate that the short-term acceptable exposure (SPEGL) limit of 0.12 ppm will be exceeded up to a downwind distance of 29.5 km (about 18 miles) from the spill site. Assuming a pool depth of 5 mm (466 m^2 pool area), the corresponding downwind distance would be 11,000 km. For a fuel tank spill of hydrazine under conditions of daytime moderate winds (4 m/sec), and a pool depth of 5 mm, the 1-hour SPEGL would be exceeded up to a distance of 7.25 km (about 4.5 miles) from the spill site.

The maximum predicted centerline 1-hour average concentrations of UDMH under the same nighttime light wind conditions, assuming a spill depth of 1 mm, indicates that the 1-hour SPEGL of 0.24 ppm would be exceeded up to 18.5 km (about 11.5 miles) downwind from the spill site. Under conditions of daytime light winds, and the same spill pool depth and area, the SPEGL would be exceeded up to a distance of 5.4 km (about 3 miles) from the spill site.

The maximum predicted centerline 1-hour average concentrations of N_2O_4 under nighttime light wind conditions, assuming a 1 mm pool depth (2,758 m^2 pool area), the 1-hour SPEGL of 1.0 ppm is projected to be exceeded up to a downwind distance of 22 km (about 14 miles) from the spill site. Under conditions of daytime moderate winds, the SPEGL would be exceeded up to a distance of 6.25 km (about 4 miles) from the spill site. Assuming a mitigated depth of 5 mm (552 m^2 pool area), the corresponding downwind distance would be 6 km (about 3.7 miles) from the spill site.

Cancer Risk Analysis. The short-term maximum cancer risk due to hydrazine under conditions of nighttime light winds (2 m/sec) and a spill pool area of 2,328 m^2 occurs at Pahala and is equivalent to 9.5 per 10,000. The maximum cancer risk due to UDMH occurs under the same conditions at Pahala and is equivalent to 9.5 per 100,000.

Cancer Burden. Excess population cancer burden is the predicted number of cancer cases added to the community or study area due to an on-site spill of carcinogenic substances. In this health risk assessment, the added cancer cases are calculated by multiplying the individual cancer risk determined for Pahala (worst case estimate) by the number of people living and working in the Ka`u District. The total community excess cancer burden per 70-year lifetime is 4.0 estimated excess cancers based on 1990 population estimates (DBED 1990) and 4.2 excess cancers based on 2000 population projections (DEIS Appendix VIIIA and Addendum to this Chapter).

Noncancer Hazard Index Analysis. The maximum acute hazard index projected to occur due to a fuel tank spill of hydrazine, 10.6, occurs at Pahala under the nighttime light wind conditions and maximum spill pool area. Assuming a spill pool area of 466 m^2, the hazard index at Pahala drops to 2.1. Under daytime conditions, the acute hazard indices at Pahala are: 2.8 assuming light winds and maximum spill pool area; and 1.2 assuming moderate winds and contained pool area of 466 m^2.

The maximum acute hazard index of 2.9 for UDMH is predicted to occur at Pahala under nighttime light wind conditions and a maximum spill pool area. Under nighttime conditions and a contained spill pool area, the corresponding hazard index would be 0.58. Under daytime conditions with light winds, the hazard index is 0.75 (maximum pool area) and 1.7 (contained pool area). Maximum acute hazard indices from a nitrogen tetroxide spill also occur at Pahala. They are: 7.1 for nighttime conditions with light wind and maximum spill pool area; 1.7 for nighttime conditions with light wind and a contained spill pool area; and 1.9 for daytime conditions, light wind maximum spill pool area.

Hazard indices for facility workers, based on occupational exposure limits, range from 4 to 2,490, indicating that a significant health hazard may exist to workers due to spills of these substances.

Significance of Effects. The individual cancer risk from just one on-site spill is significant. Acute and chronic adverse health effects in the surrounding community will also occur under unfavorable wind conditions from just one on-site spill. The need for both passive containment (dikes, berms, etc.) and more importantly, active containment which consists of active emergency response to contain, collect, and remove the spilled fuel are clearly indicated. Active response will reduce exposure and therefore reduce risk significantly (RSA, DEIS Appendix VIIIA).

4.0 Effects on Sensitive Ecological Species

Assumptions and Methodology. The Air Force Toxic program (AFTOX) was used to model concentrations of chemicals of concern (COCs) produced by on-site spills. The model estimates concentration contours based on human 1-Hour SPEGLs of the spilled COCs in question. It is possible that concentrations within these contours may be higher.

Centerline time mean concentrations of hydrazine, UDMH and N_2O_4 for different pool sizes and weather conditions can be found in DEIS Appendix VIIIB. Estimates of the farthest downwind concentration contour distances for the worst case meteorological condition for each of the spill accident scenarios are also presented in DEIS Appendix VIIIB.

Analysis of Effects. Each chemical of concern has different effects, therefore, the discussion of exposure concentrations and effects which follows is by chemical rather than species.

Hydrazine. The worst case spill scenario concerning hydrazine occurs when a 616 gallon drum of Aerozine-50 spills, producing a pool area of 2328 m^2 during the night. The highest 1-hour centerline average concentration is 24.9 ppm occurring at 500 m downwind from the site. At 15 km downwind from the spill, the concentration of hydrazine is 0.6 ppm. A comparison of these ECs to adjusted TEC values indicates that there is a very low probability that adverse effects would occur to sensitive ecological receptors within the PCZ or the zone of ecological concern (Ibid).

UDMH. The worst case spill scenario for UDMH occurs during the daytime, assuming a pool

depth of 1 mm and a pool area of 2328 m^2. The highest 1-hour centerline average concentration is 20 ppm at 300 m downwind from the spill. At 15 km downwind from the spill, the concentration is 0.05 ppm. A comparison of these ECs to adjusted TEC values indicates that the EC is higher than the TEC within the PCZ and lower than the TEC within the larger ecological zone of concern. Adverse effects could be experienced by species within the PCZ but adverse effects are unlikely in the larger ecological zone of concern.

Nitrogen tetroxide. The worst case spill scenario for NO_2 occurs when a 728 gallon drum of N_2O_4 spills to a depth of 1 mm, producing a pool area of 2758 m^2 during the day. The highest 1-hour centerline average concentration is 195 ppm at 250 m downwind from the spill. At 15 km downwind from the spill, the concentration of NO_2 is 1.6 ppm. Both within the zone of ecological concern and the PCZ. The ECs are higher than the adjusted TECs for both the PCZ and zone of ecological concern (DEIS Appendix VIIIB). This indicates that under these spill condition there is a high probability that NO_2 could cause adverse effects in sensitive ecological receptors.

Significance of Effects. Worst case spill scenarios produce high concentration gradients emanating from the source of the spill for many kilometers downwind. The predicted exposure point concentrations depend on the spill pool area and the weather at the time of the spill. Mitigation measures that include immediate containment can quickly reduce the estimated concentration of COCs in the atmosphere. Both small and large pool areas release unacceptably high concentrations of COCs.

The risk to biota is difficult to assess. While the highest concentrations of COCs are estimated within the PCZ, the decrease in the concentration gradient still exposes sensitive ecological receptors outside this zone to high exposure point concentrations. Within the zone, the probability exists that mobile ecological receptors that utilize Palima Point (such as Hawaiian hoary bats, Hawaiian Hawk and sea turtles) could be exposed to concentrations of UDMH/FDH and N_2O_4/NO_2 higher than selected TEC values. Receptors that are distributed outside of the PCZ but within the 15 km zone of ecological concern could also be exposed to concentrations of N_2O_4/NO_2 above selected TEC values (Ibid.).

E. UNCONTAINED SPILLS ON THE GROUND SURFACE

1.0 Assumptions and Methodology

The quality of both groundwater and marine waters at Palima Point could be affected by leaks or spills of various types of liquid substances which will be used at the launch facility. Of particular concern are leaks or spills of liquid propellants. Among various rocket propellants that may be used, two liquid propellants were analyzed: Aerozine-50 which is miscible in water and RP-1 (kerosene) that is immiscible in water (HLA, DEIS Appendix IIIB).

The spill scenarios analyzed assume that the entire contents of a storage vessel--615 gallons of Aerozine-50 in a fully fueled Delta II or 15,676 gallons of RP-1 in an Atlas II--could be released in a sudden accident and infiltrate uncontained into the subsurface in a limited area near the launch pad. The spill scenarios also assume that the spills will occur at the central launch pad about 1,500 feet from the ocean shore at an average elevation of about 100 feet above mean sea level (MSL).

It is expected that propellants released over the ground surface will infiltrate, percolate downward through the unsaturated zone to the groundwater surface, and then migrate horizontally

with the groundwater either as a solute (in the case of miscible liquids) or a floating separate-phase liquid. Groundwater in the area of the proposed spaceport generally flows seaward and discharges from the subsurface at the shore of the ocean as dispersed fresh or brackish springs.

For the purpose of numerical modeling, the subsurface was assumed to be fresh, layered basalt with a hydraulic conductivity of 3,000 feet per day, porosity of 0.1, longitudinal dispersivity of 328 feet and transverse dispersivity of 98 feet. Based on measurements of wells in the region, the hydraulic gradient in the aquifer is about four feet per mile towards the sea.

The numerical modeling used to evaluate the migration of typical liquid propellants into the subsurface from spills and explosive releases is described in Section I of this Chapter.

2.0 Effects on Groundwater Quality

Aerozine-50 would dissolve in the groundwater and migrate toward the shore. The affected groundwater zone would spread laterally toward the shore and discharge into the ocean in a zone approximately 2,000 feet wide. The maximum peak concentration would be approximately 11 mg/l at the shore near the center of the zone and would decrease in both directions along the coast. Aerozine-50 would reach the shore approximately 20 days after the spill occurred and continue discharging into the ground water for about a year. Under the spill scenario assessed, the affected area of groundwater would be approximately 35 acres between the launch pad and the shore.

Kerosene is more viscous than Aerozine-50 and is immiscible in water. Based on the modeling, it would percolate vertically from the spill site and reach the groundwater approximately 15 days after the spill occurs. The daily amount of fuel reaching the water table would increase until about 40 days and then decrease asymptotically.

RP-1 (kerosene) would float on the groundwater surface as a thin separate layer. It would spread laterally in the direction of the groundwater gradient, which is toward the shore. It would eventually migrate to the shore in a zone approximately 3,500 feet wide and cover an area on the water table of approximately 50 acres. The kerosene would seep into the ocean at the shore for a period of 3.3 years. The peak discharge rate for kerosene would be approximately 320 pounds per day along 3,000 feet of shore. For comparison, the rate of groundwater discharge to the ocean is approximately 5 million pounds per day.

The groundwater will be unsuitable for drinking water supplies without treatment until the contaminants have completely discharged into the ocean. Existing drinking water wells are landward of the proposed facility near the town of Pahala and along the highway to the south of the site. Spills at the launch pads will not affect the wells.

The quality of water in anchialine ponds near the shore, if any exist downgradient from a spill, could be affected because the ponds are actually exposures of groundwater, and contaminants in the groundwater surrounding the ponds would be present in similar concentrations in pond waters.

The contaminants entering the ocean with migrating groundwater will be exposed to turbulent wave action and strong currents and would likely be difficult to detect.

3.0 Effects on Anchialine and Marine Biota

The assumption is made that any spilled materials would be toxic to biota both residing in

the groundwater and the anchialine pool on the project site as well as to nearshore marine biota. Qualitatively there appears to be a large groundwater input along much of the shoreline in the vicinity of the launch pads suggesting that spilled materials would quickly be delivered to the sea. Toxicity is a function of concentration. When any material reaches groundwater concentration declines. Once in the ocean the mixing processes are enhanced suggesting that a potentially harmful spill may not have an adverse impact (Brock, DEIS Appendix IIIE).

The extent of impacts on marine biota is difficult to assess because of the unknown nature of the materials involved; their initial distribution on and in the sea; the dilution and advection rates; and the toxicity of these materials to organisms. In sea turtles, changes in water quality from the addition of anthropogenic chemicals may all adversely effect their reproductive success, however, the concentrations at which these impacts may be manifested are unknown (Ibid.). The same statement may be made of all of the anchialine and marine organisms residing in the waters fronting the Palima Point Site.

F. SUMMARY OF MITIGATING MEASURES

1.0 Containment Systems

State and Federal regulations require that propellant storage areas incorporate proper containment. Design of the propellant storage, payload processing and launch areas must include containment. Liquid fuel storage tanks will be surrounded by dikes, barricades, berms or other suitable protective mounds. Reservoirs will have a capacity 10 percent greater than the propellant storage tanks. These measures will limit the surface area of a spill and prevent the contents of tanks from mixing with incompatible material that could result in fire, explosion or toxic conditions. The containment areas will have impervious linings to protect groundwater from contamination.

An example of a standard containment system is a "trenched island" which is usually a concrete island surrounded by a trench. The trench is usually covered by stainless steel grating and slopes to a common point, where it drains into a enclosed container. The container would confine a spill and facilitate cleanup operations. In the event of a spill that results in fire, the trench system would also confine the fire to the island. Special design features within buildings can continuously monitor vapor concentrations, confine spilled propellant vapors and collect all fugitive vapors and liquids for chemical treatment.

2.0 Earthquake Protective Safety Mitigations

Given the propensity for earthquakes in the project area, the following should be incorporated into the launch facility design. See HLA, DEIS Appendix IIIA for a discussion of the following mitigations.

- Facility layouts should consider the effects of potential earthquakes.
- All facilities on the launch site should be designed to UBC 4 standards. Strict quality control procedures should be employed during all phases of construction.
- The design of safety equipment should insure that the most stringent protective measures are constructed. This equipment should be continually maintained during the operation of the facility. Personnel should be trained in the maintenance of fire suppression and other safety equipment.

- Emergency procedures must be planned before completion and operation of the facility so that personnel can be trained and appropriate documentation of the procedures can be delivered to the facility and government (State and local) agencies for perusal and preparedness.

3.0 Emergency Response Capabilities

As of October 1991, the State assumed full responsibility for hazardous materials emergency response in accordance with the Emergency Response Law, HRS 128D. The local EPA office works closely with DOH, the lead agency for hazardous materials/substances accidents and emergency response. Hazardous accidents that occur on navigable waters response capability lies with the United States Coast Guard (USCG). For land incidents, EPA and DOH take the lead.

The responsibility for initial responders, or first response personnel, on the Island of Hawaii lies with the Hawaii County Fire Department. They have had chemical emergency response training to Level B capability. Levels refers to the protection level of safety clothing worn, a safety procedure put forth by NIOSH. Level B is where the body is not fully encapsulated, as compared with Level A, full encapsulation, or what is known as "moon suits" protection. Where the product is known and the hazard is not transmitted by skin or inhalation, Level B is sufficient.

Emergency response to hazardous incidents requires specialized and federally authorized training as per OSHA 29 CFR 1910.120. The State and County's emergency response staff include first responders and support staff. The Hawaii County Fire Department are the initial responders to a hazardous materials incident. Hawaii County Civil Defense and Police Department, as well as the Hawaii State Department of Health provide technical and personnel support to the Fire Department.

First responders can use CHRIS (Chemical Hazard Response Information System), as well as the Department of Transportation's "Emergency Response Guidebook" as a hazard assessment handbook. The USCG, DOH, Hawaii County Fire Department and Civil Defense employ CAMEO (Computer Aided Management of Emergency Operations), a hazard analysis computer program to determine the hazard characteristics of a spill, leak or emission. The launch facility will have its own hazardous materials (HAZMAT) team, or trained personnel on-site to deal with hazardous materials incidents. They will have an emergency response plan for the facility in case of a hazardous incident within the facility or on its grounds.

The launch site operators will provide additional training in emergency response for additional first responders in the Hawaii County fire, police and civil defense departments, in accordance with OSHA and EPA regulations. This should not preclude the need for the State DOH to institute a program to ensure timely response to the neighbor islands when a hazardous materials/substance incident occurs. The State and County should enter into a mutual aid agreement that explicitly defines their respective roles. For example, arrangements should be made to bring Honolulu's HAZMAT Team--which has Level A capability--to the Big Island to provide immediate response until local personnel are adequately trained.

4.0 Emergency Medical Services

There is one medical facility in Ka'u; a 15 bed hospital in Pahala services the Ka'u region. It provides limited basic life-support emergency care but no surgery or blood transfusions. The hospital personnel are not prepared or trained to handle a major hazardous materials accident at the present time. The launch facility will have its own emergency medical staff who will work with local medical personnel.

SECTION V: SPECIAL CONCERNS

A. MAUNA KEA OBSERVATORIES (MKO)

1.0 Existing Conditions

Mauna Kea Science Reserve. Since 1965, the University of Hawaii (UH) has been actively advancing mankind's understanding of the physical universe through its successful efforts to develop a major astronomical observatory on Mauna Kea, a 13,796-foot-high shield volcano located on the Island of Hawaii. In recognition of the unique properties of the higher elevations of Mauna Kea for astronomical research, the Board of Land and Natural Resources (BLNR) approved a 65-year lease with UH for the lands above the approximately 12,000-foot elevation. The lease, which began in January 1968, refers to these lands as the Mauna Kea Science Reserve.

Site Characteristics. Mauna Kea's excellent qualities for astronomical observation derive from its high altitude, atmospheric dryness, and minimal seasonal variation. In addition, its isolated location on an island in the Pacific and its tropical latitude which insure minimum cloud cover; the high altitude (45 degrees) at which the galactic center transits; and a large fraction of total sky-availability make it one of the best sites in the world for ground-based astronomy.

The summit area is well above the temperature inversion layer which limits the vertical convection transport of aerosols; light pollution - a condition which has degraded the quality of many North American observatory sites - is controlled through the Hawaii County Lighting Ordinance. In addition, potential radio frequency interference (RFI) has been minimized by prohibiting transmitters within the Science Reserve.

Existing and Planned Telescopes. Presently, 11 telescopes and one antenna facility are either in operation or under construction within the Mauna Kea Science Reserve. These include seven major optical/infrared telescopes; two smaller (24-inch) telescopes; and two millimeter and submillimeter-wavelength telescopes. The VLBA Antenna Facility is located at the 12,200-foot elevation of the Mauna Kea Science Reserve. Table 5.5.1 lists the telescopes on Mauna Kea by type and by year operational. Two additional telescopes are expected: Gemini 8-Meter optical/infrared telescope and the Smithsonian Astrophysical Observatory Submillimeter Array.

Astronomy Concerns. During the site selection process, the UH Institute for Astronomy (UH IfA) submitted a list of issues to OSI that should be addressed in an EIS for the proposed launch facility. Subsequently, the consultants and OSI staff coordinated with IfA throughout the EIS preparation in order to insure that these issues were addressed. The issues of concern are: (a) potential degradation of the naturally limited dark skies above Mauna Kea by scattering of light from the launch facilities into the line of sight of the telescopes and from night launches; (b) potential interference with observatory operations by harmful radio frequency interference (RFI); and, (c) potential obscuration of the sky by rocket exhaust plumes. Each of these issues is discussed below, in Baxter, DEIS Appendix XA and in Appendix C of the FEIS.

Table 5.5.1 **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-Franch-Hawaii Telescope (CFHT)	1979
United Kingdom Infrared Telescope (IKIRT)	1979
W.M. Keck Observatory (Keck I)	1992
W.M. Keck Observatory (Keck II)	1996*
Subaru (Japan National Large Telescope)	1999*
Millimeter Valley	
Caltech Submillimeter Observatory (CSO)	1987
James Clark Maxwell Telescope (JCMT)	1987
12,110-Foot Elevation	
VLBA Antenna Facility (VLBA)	1993

*Under Construction

2.0 Effects of Launch Site Lighting on MKO Operations

Description. Two classes of lighting of relevance to the launch facility are permitted under the Hawaii County Lighting Ordinance: Class I (repair and work areas where color rendition is important) and Class II (roadways, parking, security). Class I lighting may be incandescent, but Class II must be low pressure sodium. Mercury-vapor lamps may not be used. Light fixtures must be shielded to block upward directed light except for small low-pressure sodium fixtures (90 watts).

The proposed launch facility will require permanent outdoor lighting for security, walkway and general illumination, as well as additional lighting during the periods when launches are in preparation. The total low-pressure sodium lighting requirements for permanent outdoor lighting is estimated at 3,000,000 lumens (Table 2.3.9). Illumination levels of incandescent lighting, which may be used during night fueling and/or launching, range from 75,000 to 1,875,000 lumens. The range of illumination levels for this purpose is also shown on Table 2.3.9.

Some portion of the light will be radiated upwards into the sky and could possibly degrade the quality of nighttime observing conditions at the Mauna Kea Observatories (MKO). To evaluate the impact of this lighting, modeling was performed to determine if the addition of the Spaceport facilities and the associated growth in the surrounding population would have an adverse impact on observing conditions at MKO (DEIS Appendix XA).

Methodology. Two specific distributions of emitted light were used in the analysis. The first is based on the assumption that total light emissions from a city are proportional to its population. Based on historical data, a value of 1,000 lumens per person is used to generate a "population" that would represent the Spaceport facility. The second distribution is an emission of a cone of light upwards that simulates the illumination of the launch vehicle. Both of these types of light sources are included in the modeling with separate values representing the blue and visual light components. The initial modeling was performed using the lighting inventory provided in the Interim Project Description (DBEDT, 1991); the inventories were subsequently revised to reflect changes in projected facility lighting and the anticipated increase in the population in Pahala due to the addition of the Spaceport.

All of the following cases were evaluated: (a) 3,000,000 lumens of low pressure sodium light, fully shielded so that no light escaped upwards; (b) 200,000 lumens of incandescent light, fully shielded; (c) 20,000 lumens of incandescent light shining steeply upwards at a launch vehicle - modeled as an upwards cone of light, with a semi-angle of 30 degrees; (d) 3,000,000 lumens of low pressure sodium light, imperfectly shielded, so that 10 percent of the light was radiated above the horizontal, with concentration at low angles above the horizontal; (e) increasing the population of Pahala by 690 persons to reflect the additional population if the Spaceport is built; and, (f) increasing the amount of white light from 200,000 to 750,000 lumens (assumed to be fully shielded).

One additional scenario considered but not modeled was the addition of 1,875,000 lumens of light aimed down for a few minutes at the time of launch. This scenario was not considered important since the amount and duration of light is not significant relative to the brightness of the exhaust flame at launch.

The modeling incorporated the sky brightness due to the cities and towns on the Island of Hawaii, brightness due to natural sources and additional lighting due to the proposed facility at Palima Point. To assess the impact, sky brightness looking straight up (zenith angle of 0 degrees) and at angles of 30, 45, 60, 75, 85 and 90 degrees, all in the azimuth direction of Palima Point when viewed from MKO was calculated.

Model Results. A summary of model results in the visual spectrum (V band) is provided in Table 5.5.2. Table 5.5.3 presents the results in the blue (B band). The resulting increase in sky brightness due to the Spaceport is quite small for all but the largest zenith angles (See Baxter, DEIS Appendix XA).

Effects. The results for the visual region (V band) show that the operation of the facility will contribute very little to the night sky brightness at Mauna Kea. At all zenith angles less than 80°, the facilities would account for less than 5 percent of the anthropogenic contribution to the night sky brightness. The remainder (>95 percent) is caused by city lights. The contribution of the facility would be significant only for observations close to the horizon.

The primary light effects will occur during a nighttime launch. The light generated by a launch vehicle is very bright and can illuminate the nighttime sky for a number of seconds. The light is relatively broad-band with a significant portion in the visible spectrum. Exhaust temperatures of a typical Delta II are on the order of 2,300 to 3,000°K (5,500° F).

Potential Impacts. Based on an approximate launch rate of 30 per year, 20 percent occurring at night, there would be about six nighttime launches. When a vehicle is launched, the brightness of all other light sources on Hawaii will be small compared to the brightness of the exhaust flame. The impacts on observations at MKO will be limited to the duration of the exhaust burn and its exit from the field of view, which is the region above 15°.

For a typical Delta II, the launch vehicle will leave the field of view within 207 seconds (about 197,000 feet downrange from the pad). When this time is added to the few minutes prior to launch when the incandescent lighting may be increased to 1,875,000 lumens to aid in color rendition for photography and visual safety inspections, it is estimated that significant lighting would interfere with observations for less than 10 minutes per night launch.

Except during night launches and night fueling operations, the presence of the facility would be detectable as a small dome of light of a few degrees radius, centered at the site. Astronomical observations are only rarely made within a few degrees of the horizon, therefore outdoor lighting at the facility is unlikely to produce significant impacts on MKO observations. Results in the blue (B band) also show that the facility is will contribute very little light, and is unlikely to have any significant effect on the quality of observations.

Mitigations. All temporary and permanent outdoor lights at the launch facility will conform with the Hawaii County Lighting Ordinance. (The lighting inventory will be closely monitored to ensure that it does not differ significantly from that assumed in the EIS). They will be aimed downward and will be shielded to prevent the emission of stray light upward. There will be no night launches unless they are mission related and required by orbital mechanics. UH IfA will be given at least one month's advance notice of any night launch. When a night launch is required, lights will be operated at the minimum levels necessary to safely carry out pre-flight and launch operations. It is unlikely that more than a single launch area will require vehicle illumination lights on any given night.

3.0 Radio Frequency Interference (RFI)

Description. The Spaceport will operate several radio frequency (RF) transmitters as part of the range safety system. These include ground-based metric radar transmitters to determine position and velocity of rockets during flight; telemetry transmitters carried by the launch vehicle to send performance data to ground-based receivers; ground-based transmitters to send commands to the launch vehicle; and meteorological and surveillance radars to monitor weather and the location of ships and aircraft.

Table 5.5.2 **SUMMARY OF V BAND LIGHT IMPACTS**
(units are magnitudes/arc sec²)

	Zenith	30°	45°	60°	75°	80°	85°	90°
			Zenith Distance					
Sky Background	21.981	21.906	21.800	21.619	21.346	21.280	21.392	22.483
Sky + Cities	21.952	21.875	21.763	21.565	21.289	21.210	21.289	22.172
Total	21.952	21.875	21.763	21.565	21.287	21.205	21.271	21.988
Δm (cities)[1]	0.029	0.031	0.037	0.044	0.058	0.070	0.103	0.311
Δm (Facility)[2]	0.001	0.001	0.002	0.004	0.002	0.005	0.018	0.184

1 This represents the total contribution of all cities on Hawaii.
2 This represents the contribution of the facility, including the additional population in Pahala.
Source: R. H. Garstang in Baxter, Appendix XA (DEIS)

Table 5.5.3 **SUMMARY OF B BAND LIGHT IMPACTS**
(units are magnitudes/arc sec²)

	Zenith	30°	45°	60°	75°	80°	85°	90°
			Zenith Distance					
Sky Background	22.963	22.872	22.749	22.551	22.318	22.331	22.680	23.769
Sky + Cities	22.936	22.842	22.716	22.514	22.272	22.277	22.595	23.558
Total	22.936	22.842	22.716	22.514	22.272	22.277	22.595	23.551
Δm (cities)[1]	0.027	0.030	0.033	0.037	0.046	0.054	0.085	0.211
Δm (Facility)[2]	0	0	0	0	0.0001	0.0002	0.0009	0.007

1 This represents the total contribution of all cities on Hawaii.
2 This represents the contribution of the facility.
Source: R. H. Garstang in Baxter, Appendix XA (DEIS)

The ground-based radar and command transmitters must be sited so as to have an unobstructed view of the rockets during flight. It may be necessary to locate these systems at the Spaceport and also at remote sites such as the easternmost point of the Island of Hawaii (Figure V-5.1). As shown, a remote station would allow continuous command and tracking coverage.

It is anticipated that the transmitters will operate in the same specific frequency bands currently allocated for use at the national launch ranges. Table 2.3.3 gives radio frequency (RF) emitters by launch vehicle; Table 5.5.4 lists frequencies and characteristics for ground-based emitters.

RFI Levels. The level of harmful radio frequency interference for optical and infrared astronomy has been established as -57 $dBWm^{-2}$ (2 $\mu W/m^2$) by the International Astronomical Union (IAU).

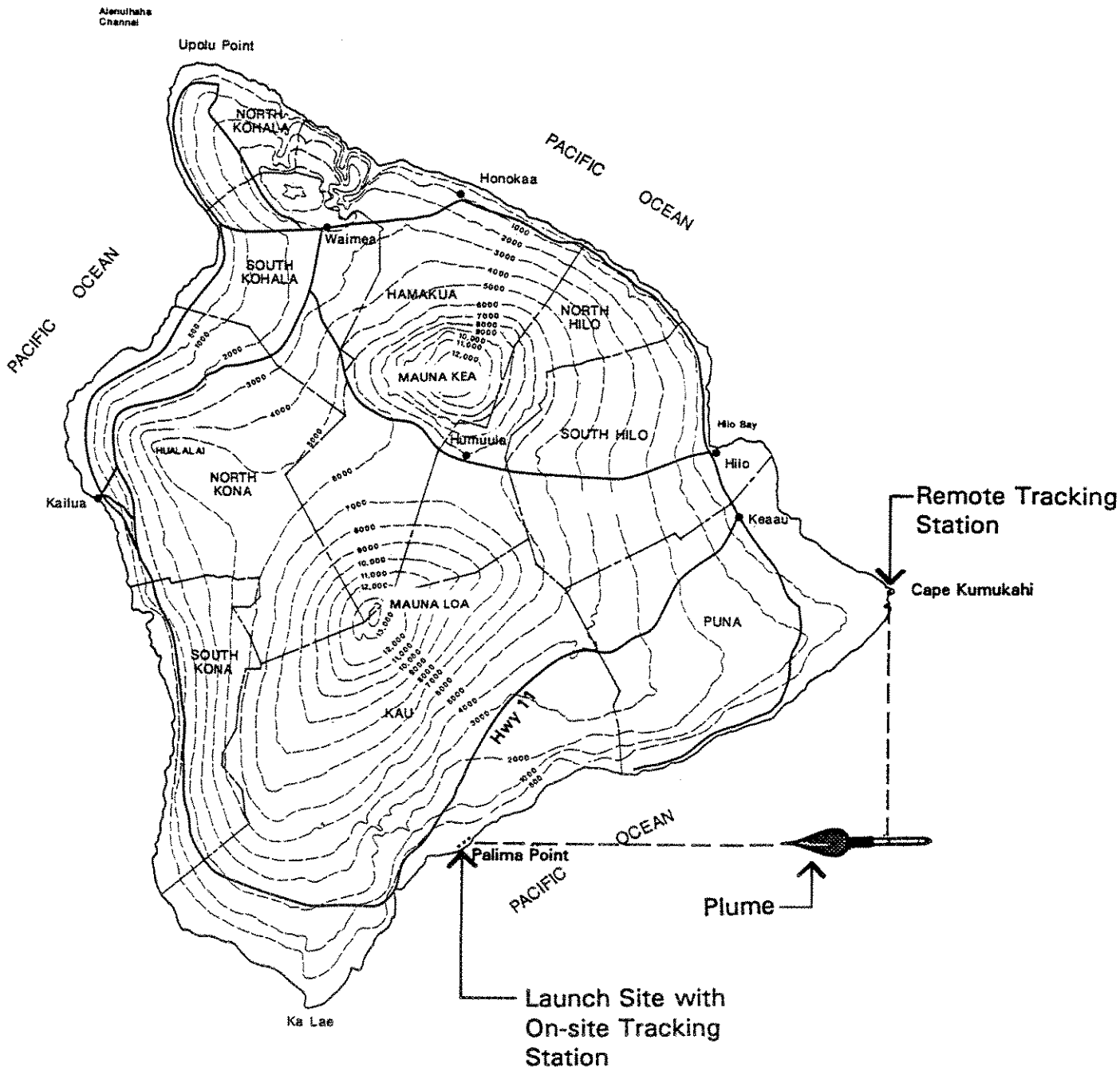
Two different levels of harmful interference have been calculated for radio astronomy by Thompson, Schlecht and Crane for signals received through the isotropic sidelobes of the VLBA antenna. The first is for interference at a frequency being observed by the VLBA that increases the system temperature by one percent. Signal levels ranging from -140 $dBWm^{-2}$ at 1.4 GHz to -127 $dBWm^{-2}$ at 6.1 GHz can cause such an increase in system temperature. The second is for an interfering signal anywhere within the passband of a VLBA receiver that is strong enough to cause non-linear behavior in the receiver, resulting in a one percent gain compression. Signal levels capable of causing this level of gain compression range from -59 $dBWm^{-2}$ at 1.4 GHz to -47 $dBWm^{-2}$ at 6.1 GHz.

Effects of Potential RFI on MKO Operations. Radar transmitters associated with Spaceport operations have the potential to cause interference to both optical/infrared and radio telescopes because of their high power levels. Calculations were made to predict signal levels at Mauna Kea due to RF emitters located at Palima Point and also at Cape Kumukahi on the eastern tip of the island.

The maximum potential for interference will occur if a radar antenna is aimed directly at MKO. In that case peak signal levels from Palima Point would exceed the IAU threshold for optical/infrared telescopes by 20 dB and the system temperature threshold for the VLBA radio telescope by 70 dB, assuming the VLBA is operating at the same frequency as the radar. The problem is much more severe for a radar at Cape Kumukahi with the IAU threshold being exceeded by 64 dB and both gain compression and system temperature thresholds being exceeded by 55 dB and 135 dB respectively. Such interference would be reduced by using "sector blanking."

Even when the radar antenna main beam is aimed away from the telescopes, it is possible for energy emitted in the antenna "sidelobes" to cause interference. Sidelobe emission from a Palima radar would be at least 33 dB below the IAU threshold so there would be no problem with interference to the electronics of an optical/infrared telescope during normal tracking activities. The same radar operating at Cape Kumukahi would exceed the IAU threshold by 11 dB assuming that the energy emitted in the sidelobes is the same as would be emitted from an omnidirectional or "isotropic antenna." A Palima radar would exceed the VLBA system temperature threshold due to isotropic sidelobe emission by 17 dB while the same radar at Kumukahi would exceed that threshold by 82 dB.

The emissions from radiosondes, telemetry transmitters, and radar transponders are omnidirectional and low power, so that gain compression would not be a problem. Power flux densities incident at the VLBA antenna would increase the system temperatures of its receivers by more than one percent at observing frequencies near the operating frequencies of the emitters.



Source: DBEDT, Office of Space Industry, 1993.

Figure V-5.1

CONCEPTUAL TRACKING STATION LOCATIONS

Table 5.5.4 **RF TRANSMITTER CHARACTERISTICS AT THE PROPOSED LAUNCH FACILITY**

Emitter Type	Freq. (GHZ)	Transmitter Power	Modulation Parameters	Antenna Type	Antenna Gain (DBI)	Antenna Half Power Beam-Width
FPS-16 Radar	5.4 to 5.9	1 MW (peak)	• Pulse • 0.25-1 µsec • 160/320 pps	Parabolic, 12 ft. diameter	44	1.2°
FPQ-14	5.4 to 5.9	2.8 MW (peak)	• Pulse • 0.25-5 µsec • 160/320 pps	Parabolic, 30 ft. diameter	53	0.38°
Launch Vehicle Transponder	5.4 to 5.9	500 W (peak)	• Pulse • 0.5 µsec • 160/320 pps	Omnidirectional	0	Omni
Command Destruct	0.406 to 0.450	5 KW	• FM tone	Helix or Parabolic	<18	>25°
Command Destruct	0.406 to 0.450	5 KW	• FM tone	Omnidirectional	3	Hemisphere
Launch Vehicle Telemetry Transmitter	2.2 to 2.4	5-10 W	• FM or PM	Omnidirectional	0	Omni
Radiosonde	1.680	100 MW	–	Omnidirectional	0	Omni
Uplink to Radiosonde Transponder	0.403	50 W	–	Parabolic, 8 ft. diameter	16	22°
Surveillance Radar	3.0	10 KW (peak)	• Pulse • 0.08-1 µsec • 250-3000 pps	Slot Array, rotating at 26 rpm.	28	1.9° horiz., 30° vertical
Weather Radar	5.3-5.8	250 KW (peak)	• Pulse • 0.8-3 µsec • 250-1200 pps	Parabola, 8 ft. diameter	39	1.5°

Source: DBEDT, Office of Space Industry, Feb. 1993.

Peak signals from meteorological radar at Palima would exceed the one percent system temperature threshold by 8 dB from isotropic sidelobes and 47 dB due to main beam illumination. Sector blanking would eliminate the main beam problem.

Mitigating Measures. Mauna Loa is between the proposed Spaceport and Mauna Kea. It will afford considerable protection to the telescopes by blocking RF signals generated at the Spaceport (approximately 65 dB of attenuation). There is no such blockage for a tracking station on the eastern tip of the island and the potential for interference is much greater.

In normal operation, a radar at the Spaceport would track a rocket along its flight path either toward the east or in a southerly direction. The radar would not aim directly at the telescopes during normal tracking activities. In addition, in order to minimize power levels received from radars pointed away from Mauna Kea, the radar system must be designed to reduce energy in the antenna sidelobes.

Frequency coordination will be used to avoid some of the potential interference with the VLBA antenna. That is, the frequencies of the launch facility transmitters will be selected to avoid VLBA observing frequencies.

Terrain shielding and management of radiated power level, sector blanking, sidelobe energy control, frequency coordination and reduction of out-of-band emissions will be implemented to reduce the potential for radio frequency interference to acceptable levels as specified by the International Astronomical Union for optical/IR telescopes (power density less than $2.\mu W/m^2$) and as specified by the National Radio Astronomy Observatory for radio telescopes. These mitigations will be strictly enforced.

As the Spaceport moves to the design phase, continued coordination with UH IfA will be mandatory and enforced. Actual measurements of radar signal propagation will be necessary to establish acceptable locations and operating parameters. Guidelines for the location and operation of range instrumentation systems will be made in coordination with and approved by the UH Institute for Astronomy.

Correspondence with UH IfA and analyses of potential RFI by Pat Crane and Richard Sramek of the National Radio Astronomy Observatory (NRAO) are included in DEIS Appendix XA.

4.0 Particulate Contamination

Emissions Scenario. Following a launch, a column of warm temperatures (relative to the surrounding atmosphere) will occur in the exhaust plume. The warm temperatures could interfered with measurements made in the IR energy spectrum. Light and heat from rocket exhausts, particulate and/or condensation trails during night launches, and any carryover remaining in the field of view after sunset, following the daytime launches, are of concern to UH IfA.

A principal exhaust product from the Solid Rocket Motors (SRMs) is particulate aluminum oxide (Al_2O_3) which accounts for about 30 percent of the exhaust products. Much of the alumina is reported to be in the form of particles with radii greater than one micron. These larger particles fall out of the stratosphere more rapidly than the gaseous products which are removed by the circulation exchanging air between the stratosphere and the troposphere (Baxter, DEIS Appendix XA).

Atmospheric measurements of Space Shuttle exhaust indicate that about one-half of the mass of particulate aluminum oxide is in particles with radii less than one micron and, thus, may behave more like a gas in dispersion. These smaller particles may act as nuclei for ice

deposition in the lower stratosphere thus forming obscurations for measurements made from the telescopes.

The three general transport patterns for the particles are northeast winds (transport to the southwest) from surface to about 10,000 feet, west to southwest winds (transport to the east to northeast) from 10,000 to about 50,000 feet, and varied speed and direction above 50,000 feet. Impacts from both southerly and easterly launches were evaluated based on the above conditions.

Effects From a Southern Launch. A southern launch directed along a 180° azimuth flies almost directly away from Mauna Kea. Based on an assumed observatory field of view starting at 15°, and a typical Delta II 7925 launch, the rocket exhaust nozzle would be in the field of view for approximately 81 seconds. Figure V-5.2 shows the launch trajectory and impingement on the field of view.

The altitude where the rocket enters the field of view is approximately 125,000 feet. It then exits the field of view at about 250,000 feet. Under the typical wind scenario described above, the exhaust plume will be carried away from Mauna Kea both below and above the tradewind inversion but could be carried back into the field of view in the stratosphere. The time for the transport will depend on the speed and direction of the winds. Figure V-5.3 shows the general trajectory away from the launch site.

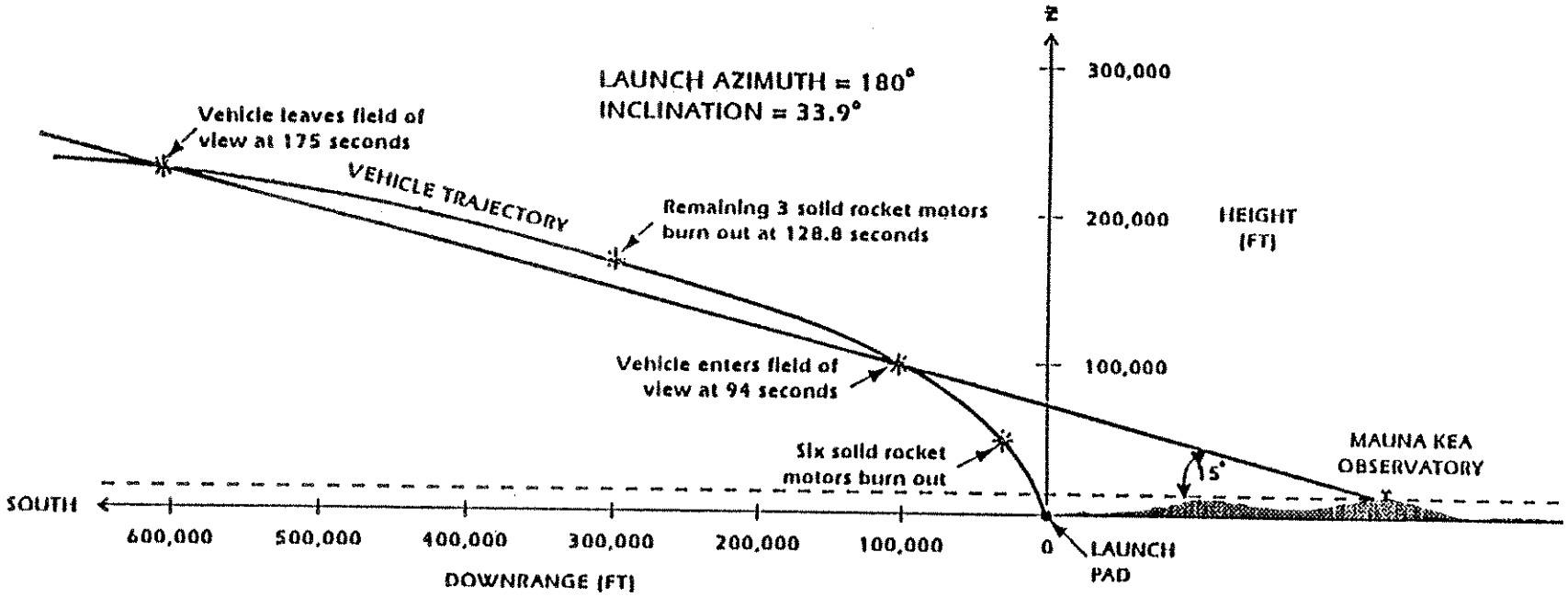
During a nighttime launch, light will be visible from the exhaust from initial firing up through burn-out of the SRMs and continuing through the main engine burn until the launch vehicle leaves the 15° field of view at 175 seconds after launch.

The aluminum oxide particles and other aerosols released during the burning of the solid rocket motors will produce a plume that will scatter light. The amount of light scattering will depend on the concentration, size distribution and scattering characteristics of the particles themselves. The primary region where light scattering will affect the astronomical observations will be when the observation angle is greater than 15° above the horizon. During a southern launch this will occur when the vehicle is above 125,000 feet.

As discussed in Appendix XA of the dEIS, a Delta II plume is estimated to be about 235 feet in diameter when it reaches the stratosphere. Based on the high concentrations of aluminum oxide in the plume and condensation of the water vapor from the main engine, the plume will initially be opaque. As the plume grows in diameter, it will become more transparent, however, the number of factors that influence the light scattering properties of the exhaust plume, including water vapor, and ice formation on the Al_2O_3 particles makes it difficult to quantify the light attenuation and/or scattering.

Assuming an initial diameter of 235 feet, the exhaust column would represent approximately 0.04° or about two minutes of horizontal arc when the vehicle entered the field of view above 15°. This entry point represents the closest distance from the observatory to the launch vehicle and thus the widest plume diameter. The plume would slowly grow in size due to diffusion and shears within the stratosphere. The rate of growth of the plume is difficult to quantify since data on the growth characteristics could not be identified.

Table 5.5.5 presents pertinent launch trajectory data, Al_2O_3 plume concentrations and calculations for relative brightness and initial angular size of the plume for a southerly launch from Palima Point. The normalized exhaust brightness was calculated based on the inverse square law. The initial angular plume size was calculated using the distance from the observatories to the launch vehicle at each of the indicated altitudes. The analysis



Source: Baxter (Engineering-Science, Inc.)
DEIS Appendix X-A

Figure V-5.2
IMPINGEMENT OF A DELTA SOUTHERN LAUNCH ON THE FIELD OF VIEW OF THE MAUNA KEA OBSERVATORIES

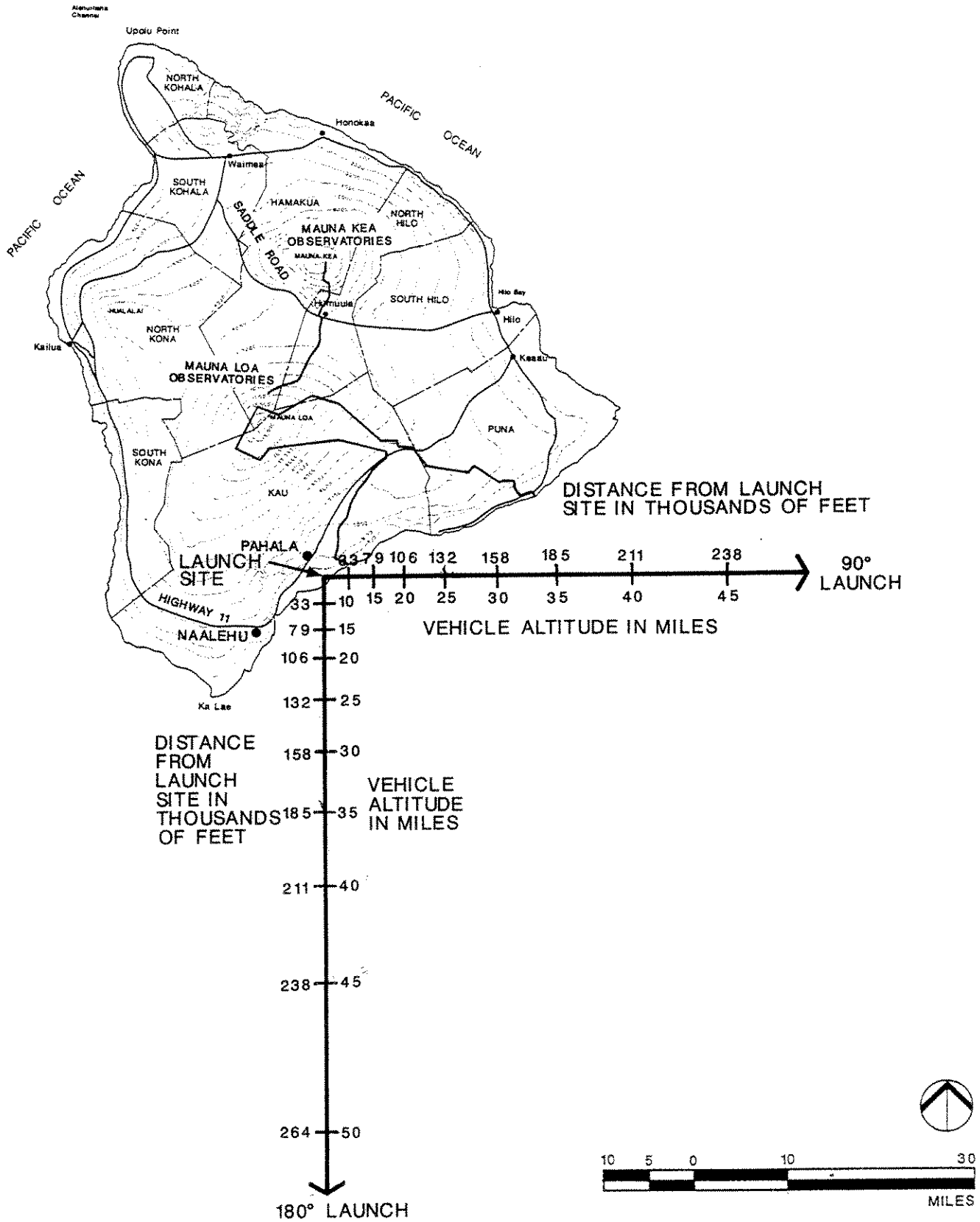


Figure V-5.3
LAUNCH VEHICLE ALTITUDE AS A FUNCTION OF DOWNRANGE DISTANCE (DELTA II)

Table 5.5.5 **DELTA II LAUNCH VEHICLE POSITION, Al_2O_3 PLUME CONCENTRATIONS, NORMALIZED EXHAUST BRIGHTNESS AND INITIAL ANGULAR PLUME SIZE FOR A 180° LAUNCH AZIMUTH**

Downrange Distance (ft)	Height Above Launch Pad (ft)	Time From Launch (a)	Height[a] Above Observatory (ft)	Downrange[b] Distance from Observatory (ft)	Distance to Launch Vehicle (ft)	Elevation Angle to Launch Vehicle (deg)	Azimuth Angle to Launch Vehicle (deg)	Plume Al_2O_3 Concentration (mg/m³)	Normalized[c] Exhaust Brightness	Initial[d] Angular Plume Size (min)
25,000	43,000	55	29,400	275,000	276,567	6.1	180.0	102	1.000	2.94
50,000	67,300	71	53,700	300,000	304,768	10.1	180.0	60	0.673	2.66
62,600	76,600	77	63,000	312,600	318,885	11.4	180.0	55	0.615	2.55
67,200	80,000	79	66,400	317,200	324,075	11.8	180.0	50	0.595	2.51
82,300	90,000	85	76,400	332,300	340,970	12.9	180.0	44	0.538	2.38
99,600	100,000	91	86,400	349,600	360,118	13.9	180.0	39	0.482	2.26
100.000	100,200	91	86,600	350,000	360,555	13.9	180.0	40	0.481	2.25
110,000	105,600	94	92,000	360,000	371,570	14.3	180.0	38	0.453	2.19
119,000	110,000	97	96,400	369,000	381,384	14.6	180.0	35	0.430	2.13
139,000	120,000	102	106,400	389,000	403,289	15.3	180.0	32	0.384	2.01
162,000	130,000	107	116,400	412,000	428,127	15.8	180.0	29	0.341	1.90
186,000	140,000	112	126,400	436,000	453,953	16.2	180.0	27	0.303	1.79
212,000	150,000	117	136,400	462,000	481,715	16.4	180.0	25	0.269	1.69
241,000	160,000	122	146,400	491,000	512,361	16.6	180.0	23	0.238	1.59
272,000	170,000	127	156,400	522,000	544,927	16.7	180.0	23	0.210	1.49
283,000	174,000	129	160,400	533,000	556,612	16.7	180.0		0.202	1.46
291,000	176,000	130	162,400	541,000	564,849	16.7	180.0		0.196	1.44
358,000	195,000	140	181,400	608,000	634,484	16.6	180.0		0.155	1.28
431,000	212,000	150	198,400	681,000	709,312	16.2	180.0		0.124	1.14
509,000	227,400	160	213,800	759,000	788,538	15.7	180.0		0.101	1.03
594,000	242,000	170	228,400	844,000	874,358	15.1	180.0		0.082	0.93
639,000	248,000	175	234,400	889,000	919,383	14.8	180.0		0.074	0.88
685,000	254,000	180	240,400	935,000	965,410	14.4	180.0		0.067	0.84
784,000	265,000	190	251,400	1,034,000	1,064,123	13.7	180.0		0.055	0.76
891,000	275,500	200	261,900	1,141,000	1,170,672	12.9	180.0		0.046	0.69
1,005,000	284,300	210	270,700	1,255,000	1,283,863	12.2	180.0		0.038	0.63
1,130,000	292,000	220	278,400	1,380,000	1,407,802	11.4	180.0		0.032	0.58

Launch Trajectory Source: ACTA, 1992.
a Assumes a nominal height of the observations of 13,600 feet
b Assumes a distance from the observatories to the launch pad of 250,000 feet.
c Calculation based on the inverse square law for the increased distance from the observatories.
d Calculation based on the initial plume size of 236 feet (ACTA, 1992).
Source: Baxter, Appendix XA (DEIS)

indicates that the plume would need to be at least 450 feet in diameter before it becomes transparent to visible light. (See DEIS Appendix XA for calculations concerning plume opacity).

Regardless of the concentration and composition of the exhaust plume, the key factor that will determine when the observatories field of view will clear is the horizontal stratospheric transport away from the launch site. The time it takes for a plume to clear the field of view was estimated based on data from a sounding to 56,000 feet at Honu`apo on May 16, 1989 that reflected northeast trades between the surface and 9,000 feet and westerly zonal winds above 10,000 feet) with speeds in excess of 10 m/sec at the highest altitudes. Assuming the highest viewing angle is about 17° (at 175,000 feet altitude), under the observed meteorological conditions, the plume would take about seven hours to clear the field of view above 15°. The clearing that occurs is relatively slow due to the initial launch vehicle trajectory due south of the observatories and transport winds normal to this trajectory.

Figure V-5.4 shows the observatory viewing angle of the launch vehicle during its ascent; Figure V-5.5 shows the relative position of the exhaust plume between the altitudes of 43,000 and 292,000 feet for each of three hours following the launch. The elevation angle is the viewing angle from the horizontal to the launch vehicle. The azimuth angle represents the viewing angle relative to north where north is 0° and east is 90°. Winds in a direction other than westerly and at speeds other than 10 m/sec would produce different clearing times.

There is no database of information specific to the launch facility, however, there is a significant quantity of meteorological sounding data available from Barking Sands on the island of Kauai (RCC, 1983). Barking Sands is representative of the stratospheric transport conditions over Palima Point and can be used to assess the typical transport conditions in the stratosphere. Winds within the troposphere will be influenced by terrain features, however, so the data from Barking Sands may not accurately represent the conditions near the launch site in the lower levels.

Based on data extracted from over 110 soundings, wind directions during July at altitudes from 20 km to 50 km show a dominant easterly flow nearly all of the time. The average wind speeds range from 15 m/sec at 20 km to 50 m/sec at 50 km. The wind flow patterns are more complex during the month of January. Significant differences in speed and direction occur between 20 and 50 km. At 20 km the easterly winds are present about 30 percent of the time with westerly winds accounting for the other major direction at about 20 percent. In this flow there are also southerly winds about 10 percent of the time with average speeds at the 20 km level of about 5 m/sec. Above 20 km the percentage of easterly winds decreases and average speeds increase to 13 m/sec at 30 km and up to 25 m/sec at the 50 km level.

The greatest potential for impact would occur during January flow conditions, or the winter months, when wind speeds are lower and directions could conceivably be from a southerly direction. A potential worst case situation is possible based on the January data where directions at 20 km may be from the south and speeds are on the order of 5 m/sec. A launch to the south could then result in plume clearing times of up to 7 hours. In this scenario the plume would travel over the observatories in the southerly winds. DEIS Appendix XA provides selected stratospheric wind data from Barking Sands.

Effects From an East Launch. An east launch directed along a 90° azimuth flies away from the Mauna Kea observatories. Based on the same field of view and launch vehicle as the southerly launch, the rocket exhaust nozzle would be in the field of view for approximately 130 seconds (ACTA, DEIS Appendix VID). Figure V-5.6 shows the launch trajectory and impingement on the field of view.

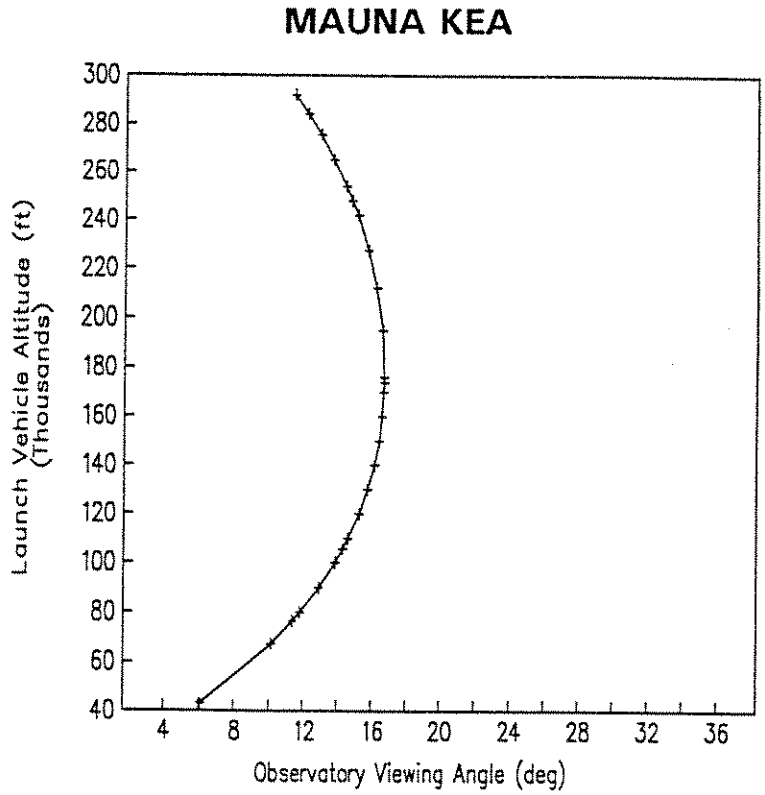
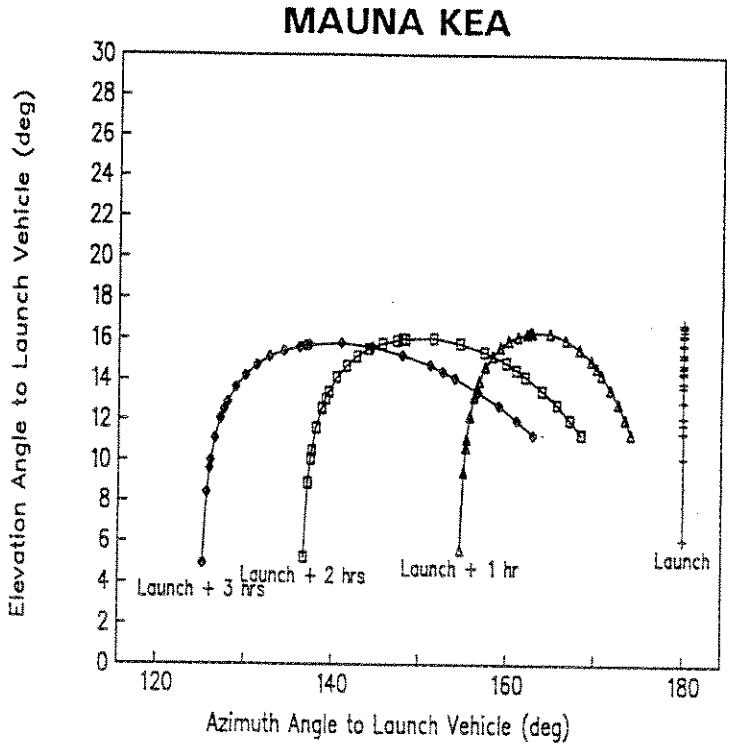


Figure V-5.4

VIEWING ANGLES DURING A DELTA II SOUTH LAUNCH

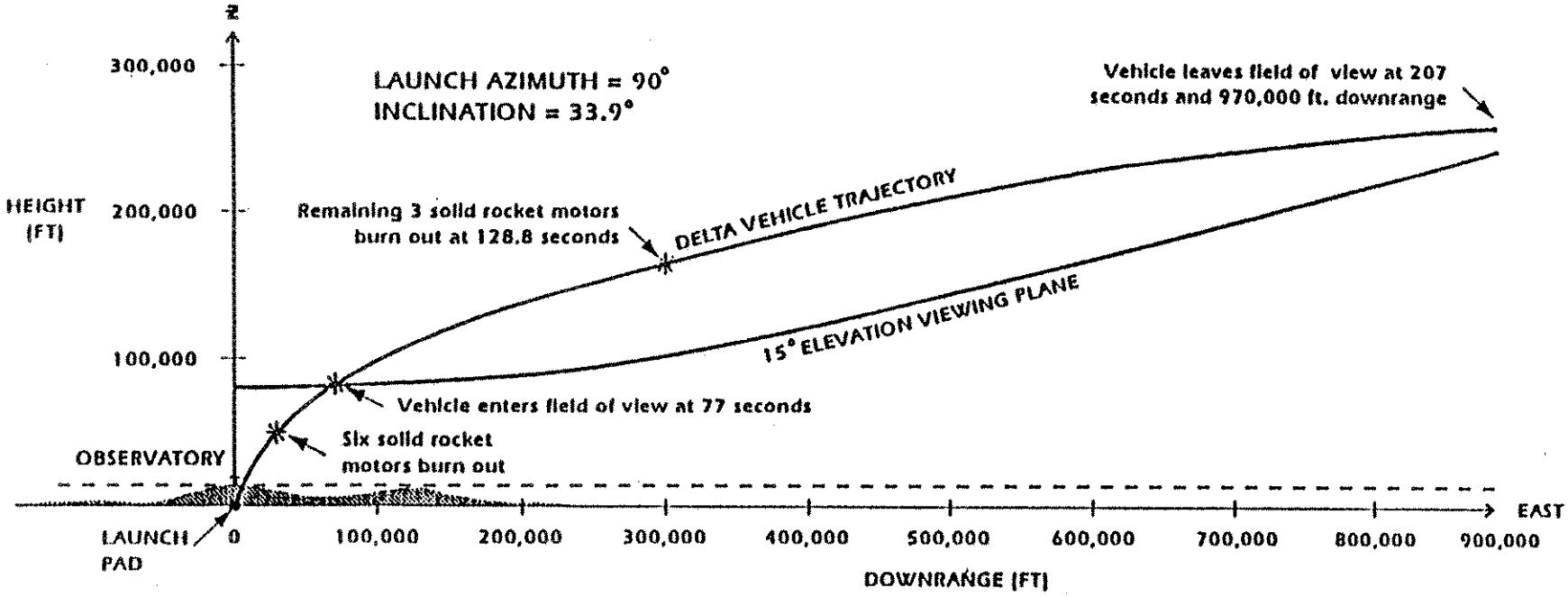


Note: Westerly Winds Assumed At 10 m/s.

Source: Baxter (Engineering-Science, Inc.)
DEIS Appendix X-A

Figure V-5.5

LAUNCH VEHICLE AZIMUTH VERSUS ELEVATION ANGLES FOR SOUTH LAUNCH OF A DELTA II



Source: Baxter (Engineering-Science, Inc.)
DEIS Appendix X-A

Figure V-5.6
IMPINGEMENT OF A DELTA EASTERN LAUNCH ON THE FIELD OF VIEW OF THE MAUNA KEA OBSERVATORIES

The rocket enters the field of view at an altitude of approximately 80,000 feet. It then exits the field of view at about 280,000 feet. Under the wind scenario described in the analysis for a southerly launch, the exhaust plume will be carried away from the Mauna Kea observatories both below and above the tradewind inversion but could be carried back into the field of view in the stratosphere. The initial impact of the exhaust plume on observations will occur when the launch vehicle is between 80,000 and 280,000 feet.

Based on upper air sounding data, the easterly winds that occur during July, and most likely representative of the summer months, are in a direction that will carry the exhaust plume from an easterly launch back toward, and to the south of the observatories. Because wind speeds during these conditions are relatively high, plume clearing times will be relatively short. Figure V-5.3 shows the initial launch trajectory away from the launch site.

During a nighttime launch, light will be visible from the exhaust from initial firing up through burn-out of the SRMs and continuing through the main engine burn until the launch vehicle leaves the 15° field of view at 207 seconds after launch (ACTA, DEIS Appendix VID).

The impact of an eastern launch on observation impairment can be estimated using the same assumptions as the southern launch. During an eastern launch, the observation angle will be above 15° when the launch vehicle travels above 79,000 feet. At this altitude and downrange distance the plume would represent approximately 0.05°, or about three minutes of horizontal arc. This entry point at 15° represents the closest distance from the observatory to the launch vehicle. Table 5.5.6 presents pertinent launch trajectory data.

Under the same transport conditions assumed for the southerly launch (westerly winds at 10 m/sec), and the highest viewing angle of 23° (at 175,000 feet altitude), the plume would take about three hours to clear the field of view above 15°.

Figure V-5.7 shows the observatory viewing angle of the launch vehicle during its ascent; and, Figure V-5.8 shows the relative position of the exhaust plume between the altitudes of 43,000 and 292,000 feet for each of three hours following the launch. The elevation angle is the viewing angle from the horizontal to the launch vehicle. The azimuth angle represents the viewing angle relative to north where north is 0° and east is 90°. The clearing is faster than the south launch because of the assumed transport winds in the same direction as the launch trajectory and away from the observatory.

Similar to the southerly launch, winds in a direction other than westerly and at speeds other than 10 m/sec would produce different clearing times. These will vary depending on the season.

Mitigation. Impacts from launch operations on the observations made at Mauna Kea must be reduced to an acceptable level by selecting launch periods that have typical lower-level winds--from the northeast up to the tradewind inversion and from the west above the inversion--and no <u>southerly component</u> of the upper-level (above 20 km) winds. This latter restriction is necessary because southerly upper-level winds could transport the plume back over the observatories, which is unacceptable. The limited data available indicates that these stratospheric winds vary in speed and direction with both altitude and season.

In addition to the general wind-pattern restrictions described above, there should be a requirement that the plume will be transported out of the observatories' field of view within a specified length of time. The field of view is defined as the region of sky above 15° from the horizon (zenith angles $<75°$). Discussions with IfA (McLaren, 1993) have identified a tentative acceptable plume clearing time of about two hours. The two-hour maximum clearing time

Table 5.5.6 **DELTA II LAUNCH VEHICLE POSITION, Al_2O_3 PLUME CONCENTRATIONS, NORMALIZED EXHAUST BRIGHTNESS AND INITIAL ANGULAR PLUME SIZE FOR A 90° LAUNCH AZIMUTH**

Downrange Distance (ft)	Height Above Launch Pad (ft)	Time From Launch (a)	Height[a] Above Observatory (ft)	Downrange[b] Distance from Observatory (ft)	Distance to Launch Vehicle (ft)	Elevation Angle to Launch Vehicle (deg)	Azimuth Angle to Launch Vehicle (deg)	Plume Al_2O_3 Concentration (mg/m^3)	Normalized[c] Exhaust Brightness	Initial[d] Angular Plume Size (min)
25,000	43,000	55	29,400	251,247	252,961	6.7	174.3	102	1.000	3.21
50,000	67,300	71	53,700	254.951	260,545	11.9	168.7	60	0.921	3.12
62,600	76,600	77	63,000	257,718	265,307	13.7	165.9	55	0.888	3.06
67,200	80,000	79	66,400	258,874	267,254	14.4	165.0	50	0.875	3.04
82,300	90,000	85	76,400	263,198	274,062	16.2	161.8	44	0.832	2.96
99,600	100,000	91	86,400	269,258	282,640	17.8	158.3	39	0.782	2.87
100.000	100,200	91	86,600	273,130	282,842	17.8	158.2	40	0.781	2.87
110,000	105,600	94	92,000	276,877	288,208	18.6	156.3	38	0.752	2.82
119,000	110,000	97	96,400	286,044	293,179	19.2	154.5	35	0.727	2.77
139,000	120,000	102	106,400	297,899	305,192	20.4	150.9	32	0.671	2.66
162,000	130,000	107	116,400	311,602	319,833	21.3	147.1	29	0.611	2.54
186,000	140,000	112	126,400	327,786	336,263	22.1	143.4	27	0.553	2.42
212,000	150,000	117	136,400	327,786	355,034	22.6	139.7	25	0.496	2.29
241,000	160,000	122	146,400	347,248	376,847	22.9	136.1	23	0.440	2.15
272,000	170,000	127	156,400	369,437	401,179	22.9	132.6	23	0.388	2.02
283,000	174,000	129	160,400	377,610	410,265	23.0	131.5		0.371	1.98
291,000	176,000	130	162,400	383,642	416,599	22.9	130.7		0.360	1.95
358,000	195,000	140	181,400	436,651	472,832	22.6	124.9		0.280	1.72
431,000	212,000	150	198,400	498,258	536,305	21.7	120.1		0.217	1.51
509,000	227,400	160	213,800	567,081	606,046	20.7	116.2		0.170	1.34
594,000	242,000	170	228,400	644,466	683,742	19.5	112.8		0.134	1.19
639,000	248,000	175	234,400	686,164	725,096	18.9	111.4		0.119	1.12
685,000	254,000	180	240,400	729,195	767,800	18.2	110.1		0.106	1.06
784,000	265,000	190	251,400	822,895	860,441	17.0	107.7		0.084	0.94
891,000	275,500	200	261,900	925,409	961,755	15.8	105.7		0.068	0.84
1,005,000	284,300	210	270,700	1,035,628	1,070,422	14.6	104.0		0.055	0.76
1,130,000	292,000	220	278,400	1,157,325	1,190,339	13.5	102.5		0.044	0.68

Launch Trajectory Source: ACTA, 1992.
a Assumes a nominal height of the observations of 13,600 feet.
b Assumes a distance from the observatories to the launch pad of 250,000 feet.
c Calculation based on the inverse square law for the increased distance from the observatories.
d Calculation based on the initial plume size of 236 feet (ACTA, 1992).
Source: Baxter, Appendix XA (DEIS)

MAUNA KEA

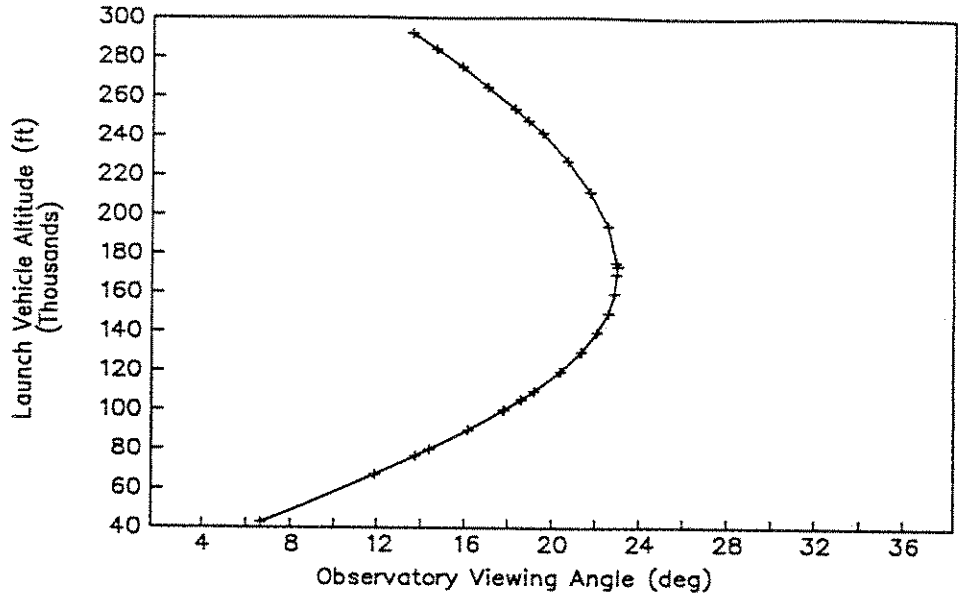
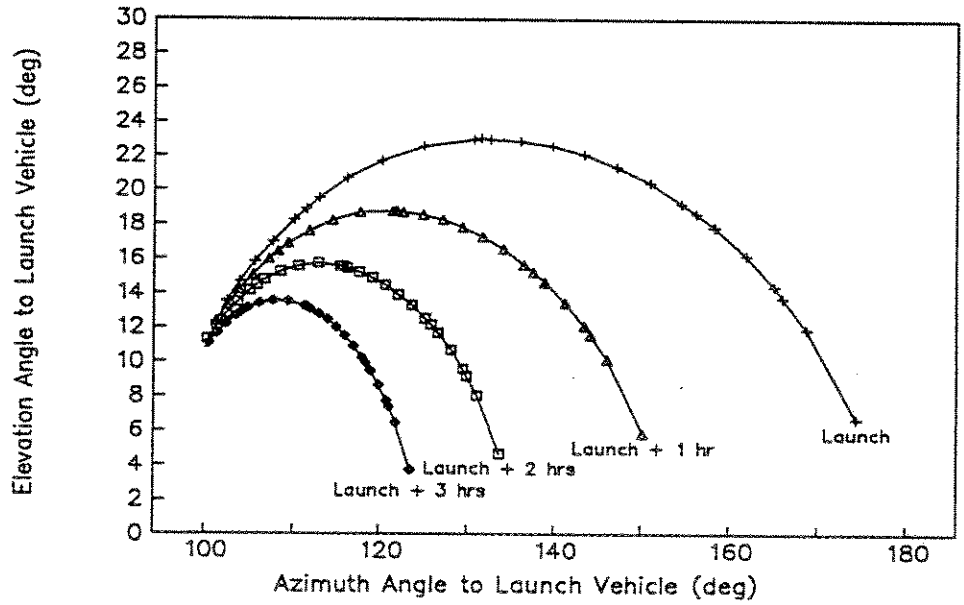


Figure V-5.7
VIEWING ANGLES DURING A DELTA II EAST LAUNCH

MAUNA KEA



Note: Westerly Winds Assumed At 10 m/s.

Source: Baxter (Engineering-Science, Inc.)
DEIS Appendix X-A

Figure V-5.8
LAUNCH VEHICLE AZIMUTH VERSUS ELEVATION ANGLES FOR EAST LAUNCH OF A DELTA II

would apply from an hour after sunset to an hour before sunrise and is a starting point that could change depending on the frequency of launches and other factors.

To determine the anticipated clearing time will require development of a multiple level transport model that would use flight trajectory information as well as pre-launch sounding data to calculate the plume transport and anticipated clearing times in advance of the actual launch. The sounding rocket itself may have an adverse impact on the observations but the magnitude will be far smaller than a satellite launch vehicle. The results of the modeling of the pre-flight winds would then provide data to see if the measured transport winds met the plume clearing time criteria. (See Appendix C of the FEIS for additional analysis of stratospheric wind data).

In addition to the stratospheric wind issues, the tropospheric wind flow patterns associated with Kona storms are from a southerly direction and will increase the impacts from both a southerly and easterly launch. A wind measurement and forecast methodology and associated criteria should be established to select optimal launch conditions and adequately forecast transport at the time of launch as well as for several days beyond the launch to assure transport of the launch vehicle plume away from the observatories.

5.0 Summary of Mitigation Measures to Prevent Deterioration of the MKO Site

- All temporary and permanent outdoor lights at the launch facility will conform with the Hawaii County Lighting Ordinance. The lighting inventory will be closely monitored to ensure that it does not differ significantly from that assumed in the EIS.

- There will be no night launches unless they are mission related and required by orbital mechanics. UH IfA will be given at least one month's advance notice of any night launches.

- Terrain shielding and management of radiated power level, sector blanking, sidelobe energy control, frequency coordination and reduction of out-of-band emissions will be implemented to reduce the potential for radio frequency interference to acceptable levels as specified by the International Astronomical Union for optical/IR telescopes and as specified by the National Radio Astronomy Observatory for radio telescopes. These mitigations will be strictly enforced.

  As the Spaceport moves to the design phase, continued coordination with UH IfA will be mandatory and enforced. Actual measurements of radar signal propagation will be necessary to establish acceptable locations and operating parameters. Guidelines for the location and operation of range instrumentation systems will be made in coordination with and approved by the UH Institute for Astronomy.

- There will be no launches--day or night--when there is a southerly component to the wind at any level, including upper-level winds.

- Launches will be restricted to times when the exhaust plume will be transported out of the field of view (sky above 15° elevation) within two hours of launch.

- All rocket launches will be coordinated with UH IfA. Calculations of plume clearing time will be made on a case-by-case basis in order to insure that there is no impact on observatory operations.

It may be necessary to pass special legislation to insure that the mitigating measures are enforceable.

B. MAUNA LOA OBSERVATORY

1.0 Existing Conditions

A number of solar, gaseous and aerosol observatories are located on Mauna Loa. The Observatory hosts a variety of atmospheric measurements that are made during all hours of the day and night. The newest addition to the Mauna Loa measurements is the station that is part of the Network for the Detection of Stratospheric Change (NDSC). The NDSC is a set of high-quality, remote-sounding research stations for observing and understanding the physical and chemical state of the stratosphere. The station in Mauna Loa will be starting up in the summer of 1993 and is anticipated to be in full operation by the fall of 1994 (Schnell, 1993). A launch could affect the ability to make representative observations at the Mauna Loa facilities through partial obscuration of the sky.

A specific concern at Mauna Loa, where operations are performed around the clock, is emitted particulates, gases and condensation trails, and their effects on the variety of measurements performed. These impacts will occur on the day of the launch and possibly subsequent days, if horizontal atmospheric transport is minimal.

2.0 Analysis of Effects

Effects From a Southerly Launch. A southerly launch directed along a 180° azimuth flies away from the Mauna Loa observatories. Because the Mauna Loa observatories are closer to the proposed launch site than those on Mauna Kea, the viewing angles to a launch vehicle are greater. Figure V-5.9 shows the viewing angle to a typical Delta II 7925 launch vehicle as a function of altitude.

The effect of a southerly launch on measurements made at the Mauna Loa observatories will depend on the types of measurements made. Measurements of direct incoming solar radiation are made in a line of sight with the sun. The minimum elevation angle of the sun during winter at the time of solar noon is about 47°. This angle is well above the calculated viewing angles shown in Figure V-5.9, therefore, no impacts on direct solar measurements are anticipated. In addition, under typical low level meteorological flow regimes, the transport of the plume will be in a direction away from the observatory so the plume would not obscure the measurements. Flow in the stratosphere however, may carry the plume back into the field of view.

For measurements of indirect solar radiation or any type of measurement that encompasses a hemispheric measurement, a launch will create a partial obscuration of the sky in the southerly direction. This obscuration will include water vapor, various gases and aerosol, and will be present until the winds transport the plume away from the viewing area.

A number of the measurements made at the observatories measure the atmospheric burden of various gases and aerosols through spectral analysis over a specified path. A southerly launch should not impact measurements made for vertically oriented paths or paths that look at angles greater than 22° from the horizon. This assumes the launch is performed under typical meteorological flow regimes with flow from a westerly direction above the trade wind inversion and stratospheric winds are from a direction other than southerly. In addition, under these flow patterns there will be no surface transport from the launch site to the observatories so direct measurements at the surface of gases or aerosols will not be affected.

Effects From an Easterly Launch. An easterly launch directed along a 90° azimuth flies away from the Mauna Loa observatories. Because of the close proximity to the proposed

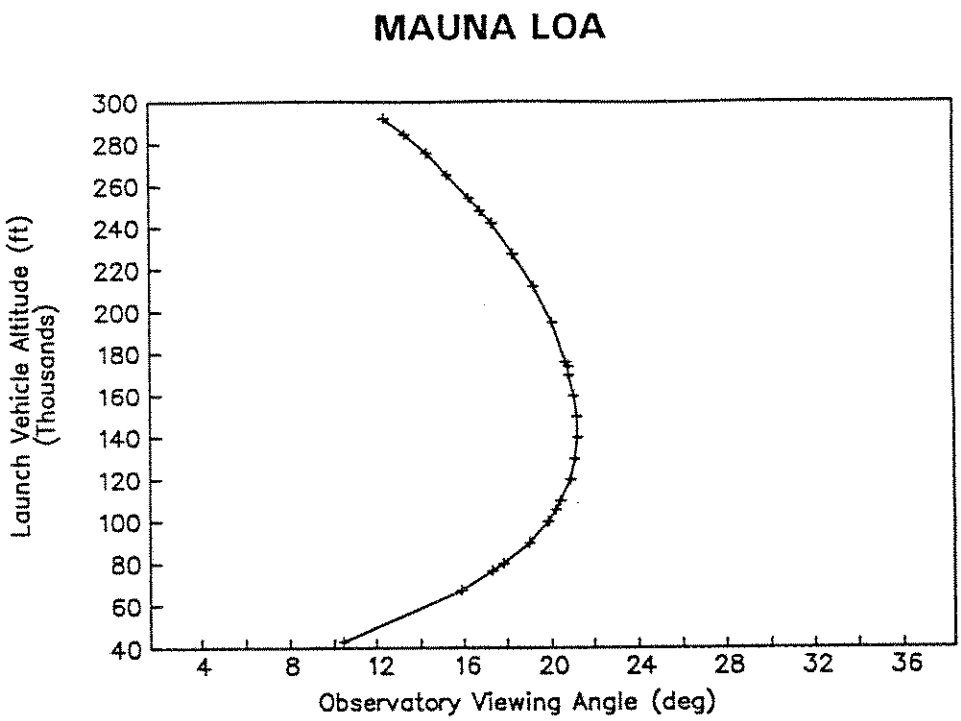
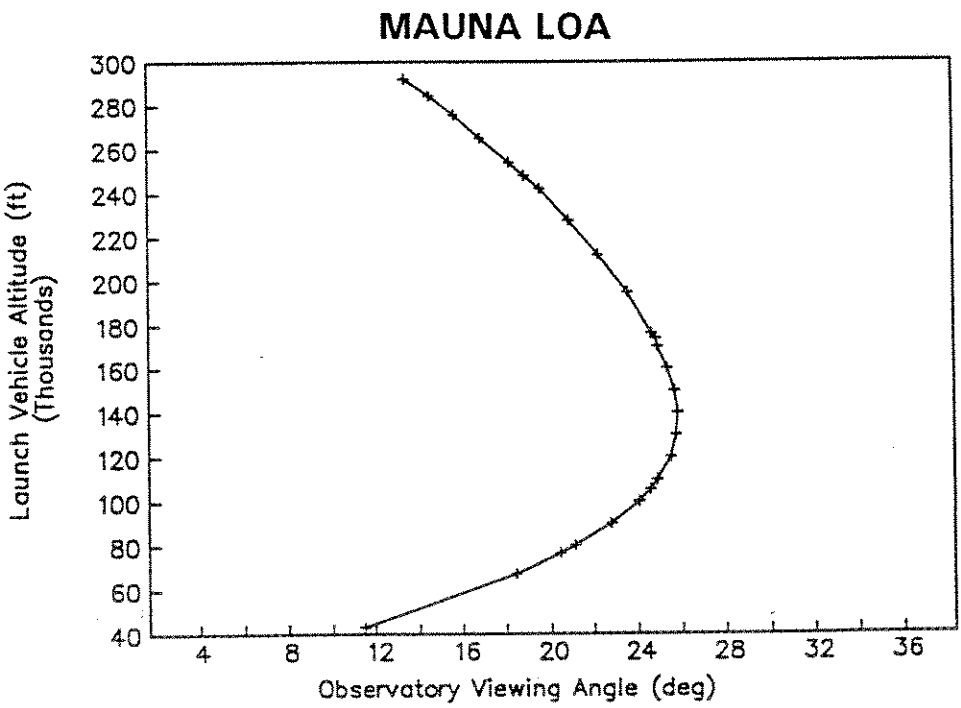


Figure V.5.9
VIEWING ANGLES DURING A DELTA II SOUTH LAUNCH



Note: Westerly Winds Assumed At 10 m/s.

Source: Baxter (Engineering-Science, Inc.)
DEIS Appendix X-A

Figure V-5.10
VIEWING ANGLES DURING A DELTA II EAST LAUNCH

launch site, the viewing angles to a launch vehicle are greater than from MKO. Figure V-5.10 shows the viewing angle to a typical Delta II 7925 launch vehicle as a function of altitude.

As with a southerly launch, the effect of an easterly launch on measurements made at the Mauna Loa observatories will depend on the types of measurements made. For direct incoming solar radiation, measurements could potentially be impacted by a morning launch. Figure V-5.11 presents a plot of the launch vehicle azimuth and elevation angles for the portion of the flight below 300,000 feet. The approximate position of the sun in the morning hours on two days, one on September 22 and one on December 22, the autumnal equinox and winter solstice, respectively, are shown on the same figure. For the time period between these dates and from December 22 until about March 22, as represented by the cross-hatched area, there is a potential for a launch vehicle to pass between the sun and the Mauna Loa observatories. The greatest potential is in the months immediately around the winter solstice.

Discussions with operators of the NDSC (Schnell, 1993) indicated that many of the measurements made from their instrumentation will focus on sunrise direct solar measurements. These will be situations where light attenuation and spectral characteristics of the sun may be affected by a launch vehicle or plume coming between the sun and the measurement instrumentation. Because of the indicated launch frequency and the relatively narrow field of view of the instrumentation, however, problems from the launch activities are not anticipated.

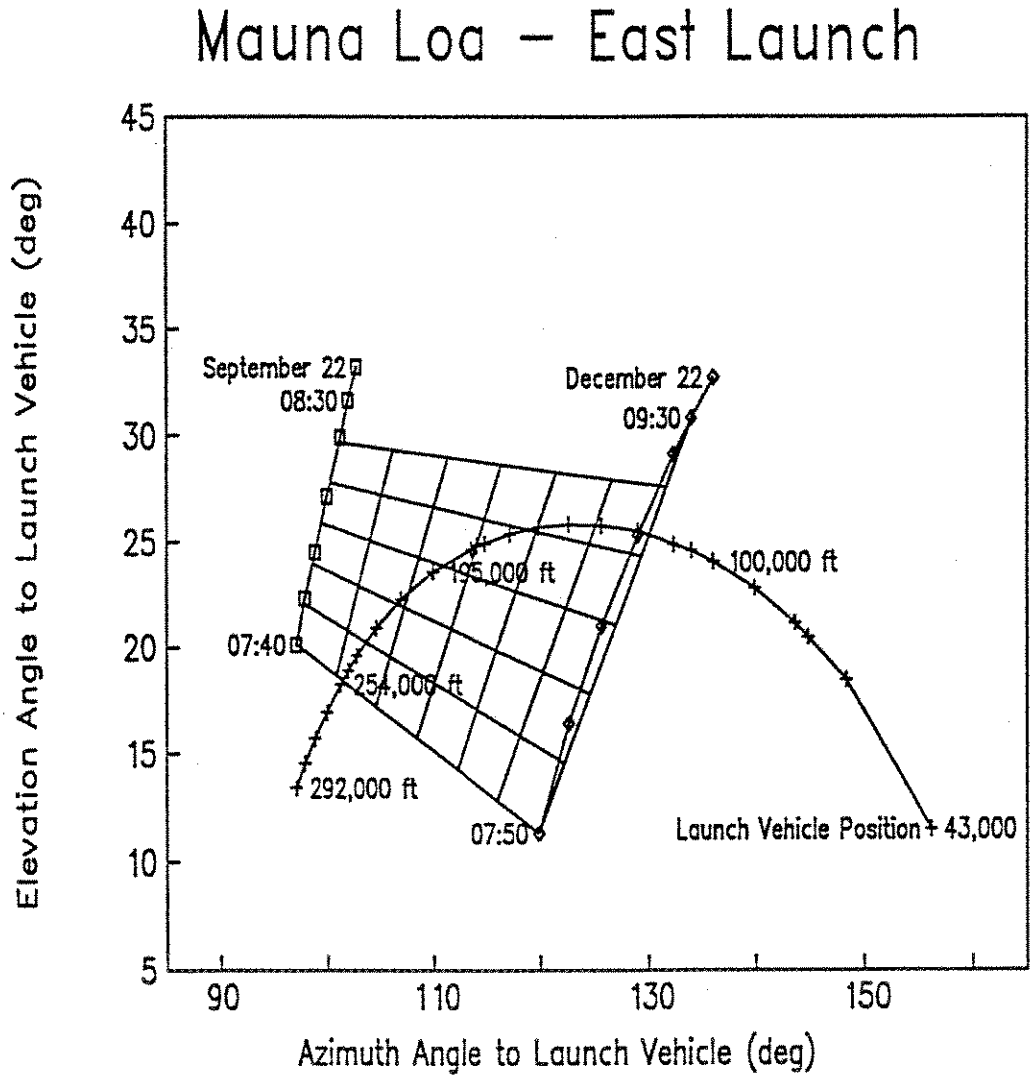
For measurements of indirect solar radiation or any type of measurement that encompasses a hemispheric measurement, a launch will create a partial obscuration of the sky in the easterly direction. This obscuration will include water vapor, various gases and aerosol, and will be present until the winds transport the plume away from the viewing area. Because of the higher viewing angles associated with the eastern launch, impacts will be greater than with the southern launch. The time for the obscuration to clear will depend on the transport winds.

For measurements of the atmospheric burden of various gases and aerosols using spectral analysis, the direct optical paths above 27° from the horizon will not be impacted. Paths below 27° in an easterly direction will be impacted by the ascending launch vehicle. This assumes the launch is performed under typical meteorological flow regimes with flow from a westerly direction above the trade wind inversion. In addition, under these flow patterns there will be no surface transport from the launch site to the observatories so direct measurements at the surface of gases or aerosols will not be affected. Launches under conditions where the transport could carry the plume back toward the Observatory may impact observations. These conditions are discussed in Part A of this section in relation to Mauna Kea.

C. VOG AND LAZE

Emissions from volcanic activity at Kilauea Volcano have been categorized locally into volcanic fog or "vog" and lava haze or "laze". Vog results from direct emissions from volcanic vents with the principal components being water vapor, carbon dioxide, and sulfur dioxide. Lesser amounts of hydrogen sulfide, hydrogen, carbon monoxide, hydrogen chloride, and hydrogen fluoride are also found. Laze is formed from the flash evaporation of sea water when the lava from the volcano enters the ocean. The large steam plumes that are formed in the laze contain extremely acidic condensates (ES, DEIS Appendix XC).

Due to the terrain and the wind patterns of the Island, the most prevalent and visible vog is found on the opposite side of Mauna Loa from the volcano, along the West Hawaii (Kona) coast. Of concern is the contribution of proposed launch activities to volcanic related emissions and



Source: Baxter (Engineering-Science, Inc.)
DEIS Appendix X-A

Figure V-5.11
DELTA II AZIMUTH VS. ELEVATION ANGLES COMPARED TO POSITION OF SUN ON SEPTEMBER 22 AND DECEMBER 22

subsequent impacts and health effects on this area.

The principal exhaust components of a typical Delta II launch vehicle are carbon monoxide, carbon dioxide, hydrogen chloride, aluminum oxides, oxides of nitrogen and water. During a launch, emissions that occur in the first 5,000 feet (27 seconds) - primarily near the ground when the vehicle is traveling at relatively low speeds - have the potential for merging with the vog or laze. The primary contribution of a space launch to vog would be increased acidity due to the hydrogen chloride and aluminum oxide particles that act as condensation nuclei or provide a mechanism for the formation of secondary aerosol and water vapor (ES, DEIS Appendix XC).

A worst case scenario was constructed which combined plumes from vog and laze sources with a plume from a launch under northeast tradewind conditions. This would transport the combined plume southward with a fraction of the plume turning around the southern end of the island and moving northward along the Kona coast. In addition, chronic and acute hazard indices, based on existing maximum and mean levels of substances measured at the air quality monitoring station in Captain Cook, were determined in order to evaluate the potential for cumulative impacts due to volcanic emissions and rocket exhaust (normal and accident scenarios).

The baseline hazard index for chronic effects based on the maximum levels of volcanic emissions and other substances detected at Captain Cook was determined to be 2.2. The baseline chronic hazard index based on average levels of volcanic emissions was determined to be 0.6. For acute effects the baseline hazard indices were determined to be 0.8 based on maximum levels of volcanic emissions and 0.3 based on average levels. Substances for which an acute or chronic acceptable exposure level was not available were not evaluated (RSA, DEIS Appendix VIIIA).

The cumulative effects of pollutants emitted during launch episodes (from both successful launches and launch accidents) do not significantly contribute to the effects of chronic volcano emissions. The contribution of emissions resulting from a successful rocket launch to the hazard index at Captain Cook is 0.05 for chronic effects and 0.02 for acute effects. This would not add significantly to the present chronic and acute hazard indices, due to maximum volcanic emissions, of 2.2 and 0.8, respectively. The contribution of emissions resulting from a launch accident to the chronic and acute hazard indices at Captain Cook, 0.03 and 0.18 respectively, also do not add significantly to the hazard indices of volcanic emissions.

RSA (DEIS Appendix VIIIA) concludes that the airborne concentrations of rocket exhaust or unburned rocket fuel are so low by the time they are transported to the Kona Coast that no measurable increase in respiratory irritation, cancer or other adverse effects is expected in the population on the West side of the island from either successful launches or launch failures. This is true even when the emissions are added to those presently occurring from the volcano.

D. GLOBAL WARMING AND OZONE DEPLETION

Some of the chemicals associated with rocket launches contain ozone depleting compounds. An analysis was made of the potential contribution of the emissions from the launch of fifteen Delta II vehicles per year. This analysis showed a reduction in the stratospheric ozone of about 0.009 percent, resulting in an increase in the UV-B radiation by about 0.045 percent. Given the current annual incidence rate for melanoma of 10 per 100,000 persons, the proposed action would raise this rate to approximately 10.045 per 100,000 per year. This translates to a risk level of 0.045 per one million persons, a level considerably below the commonly acceptable level of one excess cancer per one million persons used for environmental analyses (ES, DEIS Appendix XD).

Global warming is also related to chemicals associated with rocket launches. The emissions of greenhouse compounds from space launches could have an impact on the tropospheric and stratospheric concentrations of these compounds. Unlike ozone depletion, however, the significance of the impact on global warming is unknown. The current state of knowledge on the interaction and effects of different gases is incomplete and it is unknown whether the total effect will result in global warming or in cooling.

It should be noted that the contribution of gases related to global climatic effects would not be eliminated if the launch facility is not constructed in Hawaii. The launches will still take place somewhere else.

SECTION VI: ADDENDUM

During preparation of responses to comments from the State Department of Health, Risk Science Associates (RSA) discovered an error in their cancer risk calculations for UDMH and FDH during deflagration. The inhalation unit risk factor for UDMH and FDH used in the HRA was 4.9 x 10^{-7} $(\mu g/m^3)^{-1}$, while the CAPCOA document (1992 and 1993) lists a screening unit risk for UDMH of 4.9 x 10^{-4} $(\mu g/m^3)^{-1}$, a factor of 1000 higher than the value used in the assessment. RSA has no explanation for this error except that it was most likely a typographical error made early in the preparation of the risk assessment that was unfortunately carried through.

Release of UDMH and FDH can occur during a deflagration event or an accidental spill. Cancer risk due to the release of UDMH from deflagration is presented in Table 8-52 of the Health Risk Assessment. Using the correct inhalation unit risk for UDMH results in a maximum cancer risk at Pahala Preschool and Ka`u Hospital under Nocturnal Drainage scenario of 3.72 x $10^{-8}$ compared to the cancer risk of 3.72 x $10^{-11}$ reported in the HRA. Likewise, using the correct inhalation unit risk for FDH results in a maximum cancer risk at Pahala Preschool and Ka`u Hospital under Nocturnal Drainage scenario of 2.98 x 10^{-10} compared to the cancer risk of 2.98 x 10^{-13} reported in the HRA. The overall inhalation cancer risk due to release of hydrazine, UDMH, FDH, and DMNA during a deflagration episode becomes 4.35 x 10^{-7} compared to 3.97 x 10^{-7} reported in Table 8-55 of the HRA. Cancer risk resulting from cumulative impacts of conflagration and deflagration at Pahala, Na`alehu, and Captain Cook using the correct inhalation unit risk for UDMH are 4.3 x 10^{-7}, 1.5 x 10^{-7}, and 2.5 x 10^{-8}, respectively. The risks reported in the HRA are: 4.0 x 10^{-7}, 1.4 x 10^{-7}, and 2.1 x 10^{-8}.

Corrected cancer risk due to release of UDMH by an accidental spill of 615 gallons of UDMH from a vehicle fuel tank is given in attached Revised Table 9-16. The corrected value is 9.5 x 10^{-5} compared to the value reported in the HRA of 9.5 x 10^{-8} (Table 9-16 of the HRA).

The corrected pages for DEIS Appendix VIIIA are reprinted on the following pages. It should be emphasized that the computational error did not affect the overall conclusions that were presented in the draft EIS and the Health Risk Assessment (DEIS Appendix VIIIA).

HUMAN HEALTH RISK ASSESSMENT FOR THE PROPOSED PALIMA POINT SPACE LAUNCH COMPLEX EXECUTIVE SUMMARY

The State of Hawaii Office of Space Industry is facilitating the development of a commercial satellite launch facility proposed to be located on the southeast coast of the Big Island of Hawaii.

The proposed project will require approval by a number of regulatory agencies, including the State of Hawaii Department of Health and Region IX US EPA, among others. To determine the potential impacts to human populations, a health risk assessment has been prepared. The purpose of the risk assessment is to address the potential health effects of exposure to emissions of air pollutants from the candidate launch vehicles during both normal launches and launch failures. Additionally, impacts from releases due to accidental spills of rocket fuel on-site and while being transported to the site have been assessed. The potential effects considered include increased cancer risks as well as non-cancer health impacts.

PROCEDURES USED

In preparing this health risk assessment, procedures recommended by the U.S. Environmental Protection Agency (EPA 1989) and EPA Region IX (for Hawaii, California, Arizona, and Nevada) were followed. Standard methods for calculating exposures and health risks were used and appropriate conservative (health-protective) assumptions were applied in all cases where data was lacking to assure that potential risks were not underestimated.

Estimates were made of short-term airborne concentrations of chemicals emitted from rocket exhaust during a successful launch, conflagration and deflagration episodes during a launch failure, leaks of rocket fuel from on-site storage tanks, and leaks of rocket fuel during transportation accidents. The emissions were modeled to predict dispersion and deposition of pollutants in the region surrounding the project site and along the transportation corridor. Additional modeling was conducted to estimate long-range transport to distant receptors on the Kona side of the island. The results of this modeling were used to estimate potential human exposure to contaminants through a variety of pathways, including direct inhalation, soil ingestion, skin absorption of

contaminated soil, and ingestion of contaminated local supplies of drinking water. A hypothetical Reasonable Maximum Exposure (RME) scenario was used to estimate potential adverse health effects to an individual at highest risk from the proposed project emissions. In addition, health risks to the population within a study area surrounding the project site and along the Kona coast were estimated.

NONCANCER ADVERSE HEALTH EFFECTS

The results of the noncancer adverse health effects analysis are presented for the population and the on-site spaceport workers. A hazard index approach was used in this health risk assessment for the evaluation of acute and chronic noncancer health effects due to exposure to rocket exhaust emissions and spills. Acute noncancer health effects may occur as a result of a short-term, 1-hour or less, exposure to an emitted substance. Chronic noncancer health effects may occur as a result of long-term exposure occurring over a period of months or years. Although a hazard index was not delineated by all target organ systems (respiratory system, central nervous system, kidney, etc.) in this approach, all compounds were found to affect the respiratory system and thus a total hazard index was determined for this system only. A total hazard index of less than 1 is considered to represent no hazard of noncancer adverse health effects. Because of the short-term, transitory, and infrequent nature of exposure, a hazard index of greater than 1.0 indicates that some members of the population may experience adverse effects, however brief or minor. These effects could range from mild respiratory irritation to an exacerbation of a pre-existing condition (e.g., asthma or emphysema). At exposures where the hazard index exceeds 100, more severe effects such as pulmonary edema could possibly occur in the exposed population. The more severe effects would only occur during a spill of hydrazine either on-suite or during transport under unfavorable weather conditions. Results for the hazard index assessment are summarized below and in Table ES-1.

	Chronic Hazard Index	Acute Hazard Index
Individual in Pahala:		
Normal Launch	0.50	0.14
Launch Accident	0.45	2.0
On-Site Spill*	----	2.9 - 10.6
Individual in Naalehu:		
Normal Launch	0.30	0.11
Launch Accident	0.16	0.64
On-Site Spill*	----	1.0 - 3.8

	Chronic Hazard Index	Acute Hazard Index
Individual in Captain Cook:		
Normal Launch	0.05	0.02
Launch Accident	0.03	0.18
On-Site Spill*	not evaluated	not evaluated
Individual Spaceport Employee:		
Normal Launch	----	0.20
Launch Accident	----	9.1
On-Site Spill*	----	65 - 2490
Individual Within 20 m of Transportation Spill**	----	34 - 510

* assumes no clean-up action taken

**assumes 15-minute exposure time

CANCER RISK

The results of the cancer risk assessment are presented for the nearby communities and the employees at the proposed facility from exposure to carcinogenic substances.

The cancer risk to the individual is shown in the report in exponential notation (for example, 1.0 E-7 which corresponds to 1 in 10,000,000 chance of developing cancer in a lifetime). The "excess cancer burden" for a community was also calculated. Excess cancer burden is the predicted number of cancer cases added to the community or study area. The added cancer cases are calculated by multiplying the individual cancer risk by the number of people living and working in the community. Results for the cancer risk assessment are shown below and in Table ES-1.

	Cancer Risk	
Individual in Pahala:		
Launch Accident	4.3 E-7	(4.3 in 10,000,000)
On-Site Spill (hydrazine)	9.5 E-4	(9.5 in 10,000)
Individual in Naalehu:		
Launch Accident	1.5 E-7	(1.5 in 10,000,000)
On-Site Spill (hydrazine)	3.4 E-4	(3.4 in 10,000)

	Cancer Risk
Individual in Captain Cook:	
Launch Accident	2.5 E-8 (2.5 in 100,000,000)
On-Site Spill	not evaluated
Individual Within 20 m of Transportation Spill	1.1 E-4 (1.1 in 10,000)

The total excess cancer burden due to the launch failure scenario is estimated, based on a 70-year facility lifetime, to be 0.0016 within the total study area population (estimated for 1990) for a 70-year individual lifetime. Based on the projected population for the year 2000, this excess cancer burden increases to 0.0018 (Table 8-68). The total excess cancer burden due to on-site hydrazine spills which are not remediated (cleaned-up) is estimated to be 3.6 (for 1990 population) and 3.8 (for the projected 2005 population) (Table 9-20).

CONCLUSIONS

The maximum individual cancer risks calculated in this assessment for normal successful launches and launch failures are similar to the level of risks termed *negligible* by the U.S. Environmental Protection Agency. As a point of comparison, the national cancer rate is estimated at 25% or 250,000 per 1,000,000. Thus, the probability of rocket exhaust or launch failures causing cancer in the general population residing near the proposed spaceport or on the Kona Coast is so low that excess cancers are not predicted to occur due to reasonably anticipated spaceport operations. Also, individual rainwater collection systems will not be affected by successful or unsuccessful launches.

Noncancer adverse health effects during normal successful launches are also not expected to occur. However, launch failures under certain wind conditions may result in exposures to rocket fuels that may cause noncancer adverse effects, as would spills which occur on-site and during transport of fuels from Hilo to the site.

Additionally, the risk of cancer to the population during on-site spills and off-site transportation spills that are not immediately remediated would be *significant* as defined by the US EPA and noncancer health effects could be experienced in the population. This result underscores the need for adequate on-site emergency response and emergency response accompanying transportation vehicles.

Revised Table ES-1. SUMMARY OF RESULTS FOR PAHALA, NAALEHU AND CAPTAIN COOK UNDER WORST CASE WEATHER CONDITIONS

PAHALA	Normal Launch	Chronic Hazard Index		0.50
		Acute Hazard Index		0.14
	Launch Accident	Chronic Hazard Index		0.45
		Acute Hazard Index		2.0
		Cancer Risk		4.3E-07
	On-Site Spill	Acute Hazard Index	Hydrazine	10.6
			UDMH	2.9
			NO2	7.1
		Cancer Risk	Hydrazine	9.5E-04
			UDMH	9.5E-05
NAALEHU	Normal Launch	Chronic Hazard Index		0.30
		Acute Hazard Index		0.11
	Launch Accident	Chronic Hazard Index		0.16
		Acute Hazard Index		0.64
		Cancer Risk		1.5E-07
	On-Site Spill	Acute Hazard Index	Hydrazine	3.8
			UDMH	1.0
			NO2	2.6
		Cancer Risk	Hydrazine	3.4E-04
			UDMH	3.4E-05
CAPTAIN COOK	Normal Launch	Chronic Hazard Index		0.05
		Acute Hazard Index		0.02
		Chronic Cumulative Impact with Volcanic Emissions		2.2
		Acute Cumulative Impact with Volcanic Emissions		0.83
	Launch Accident	Chronic Hazard Index		0.03
		Acute Hazard Index		0.18
		Chronic Cumulative Impact with Volcanic Emissions		2.2
		Acute Cumulative Impact with Volcanic Emissions		0.98
		Cancer Risk		2.5E-08
SPACEPORT WORKER	Normal Launch	Hazard Index		0.20
	Launch Accident	Hazard Index		9.1
	On-Site Spill	Hazard Index	Hydrazine	2490
			UDMH	2000
			NO2	65
EXPOSURE TO CONTAMINANTS IN DRINKING WATER RESULTING FROM WET DEPOSITION				
	Normal Launch	Hazard Index		0.17
	Launch Accident	Hazard Index		2.77
		Cancer Risk		5.8E-06
TRANSPORTATION SPILL		Hazard Index	Hydrazine	34
			NO2	510
		Cancer Risk		1.1E-04

Revised Table 5-1. UNIT RISK AND SLOPE FACTORS USED IN THIS ANALYSIS

Substance	Inhalation Unit Risk (µg/m3)-1	Inhalation Potency Value (mg/kg/day)-1	Oral Potency Value (mg/kg/day)-1
1,1-Dimethylhydrazine (UDMH)	4.90E-04	1.72E+00	
Hydrazine	4.90E-03	1.72E+01	3.00E+00
Nitrogen Dioxide (NO2)			
Formaldehyde dimethylhydrazine (FDH)	4.90E-04	1.72E+00	
Nitrosodimethylamine (DMNA)	1.40E-02	4.90E+01	5.10E+01

Revised Table 5-2. NONCANCER ACCEPTABLE EXPOSURE LEVELS (AELs) USED IN THIS ASSESSMENT

Substance	Acute Inhalation (µg/m3)	Chronic Inhalation (µg/m3)	Chronic Inhalation (mg/kg/day)	Chronic Oral (mg/kg/day)	Chronic Dermal (mg/kg/day)
1,1-Dimethylhydrazine (UDMH)	5.90E+02	2.00E-03	5.71E-07	5.71E-07	5.71E-07
Hydrazine	1.60E+02	2.00E-04	5.71E-08	5.71E-08	5.71E-08
Nitrogen Dioxide (NO2)	1.90E+03	7.50E+01	2.14E-02	2.14E-02	2.14E-02
Formaldehyde dimethylhydrazine (FDH)	5.90E+02	2.00E-03	5.71E-07	5.71E-07	5.71E-07
Nitrosodimethylamine (DMNA)	1.60E+02	2.20E-04	6.29E-08	6.29E-08	6.29E-08
Hydrogen chloride (HCl)	5.00E+03	7.00E+00	2.00E-03	2.00E-03	2.00E-03

8.3.1.3 Dermal Absorption Pathway

Substances emitted during a vehicle deflagration episode are gaseous, not particulate, and thus not expected to deposit to the ground and are not available for exposure via dermal absorption.

8.3.1.4 Drinking Water Ingestion Pathway

In this assessment it is assumed that drinking water from residential rain catchment systems may be impacted by wet deposition of hydrazine as a result of emissions from a vehicle deflagration. The average concentration of pollutants projected to occur in a rain catchment system is a function of direct wet deposition onto the roof of a house. In this assessment it is assumed that dilution of the hydrazine in catchment water will occur at a rate of 50% per month for a period of one year after the deflagration event at which time the concentration is assumed to be zero. Based upon the resulting average concentration over this one year period, the projected dose of hydrazine due to a deflagration episode via ingestion of drinking water from a residential rain catchment system is 8.1×10^{-4} mg/kg/day. Algorithms and assumptions used in the evaluation of the drinking water exposure pathway are described in Appendix B.1.4.

8.3.2 CANCER RISK ANALYSIS RESULTS

8.3.2.1 Inhalation Exposure Pathway

Results of the cancer risk calculations for exposure to a receptor via inhalation of airborne vapors released during a launch deflagration episode are shown in Tables 8-51 through 8-54 for hydrazine, UDMH, FDH, and DMNA, respectively. The overall cancer risk to a receptor is shown in Table 8-55 and indicates that the maximum cancer risk projected to occur due to a deflagration episode, 4.3×10^{-7}, occurs at Pahala under the nocturnal drainage weather condition. At Punaluu, a maximum cancer risk of 4.0×10^{-7} exists under this scenario assuming nocturnal drainage weather conditions. 92% of the overall cancer risk at Pahala is due to hydrazine.

8.3.2.2 Drinking Water Ingestion Pathway

Cancer risk due to ingestion of drinking water to which hydrazine has been deposited following a deflagration episode is determined in Table B-3. Based upon an average hydrazine water concentration of 4.7×10^{-3} mg/l, a corresponding daily dose of 1.3×10^{-4} mg/kg, and the assumptions presented in Section B.1.4.b, the estimated lifetime cancer risk if a person drinks this water for one year is 5.8×10^{-6}.

8.3.3 NONCANCER HAZARD INDEX ANALYSIS RESULTS

8.3.3.1 Inhalation Exposure Pathway

Tables 8-56 through 8-60 present the chronic hazard index due to hydrazine, UDMH, N_2O_4, FDH, and DMNA release during a deflagration episode. The overall chronic hazard index to a receptor is shown in Table 8-61 and indicates that the maximum hazard index projected to occur due to a deflagration event, 0.44, occurs at Pahala under the nocturnal drainage weather condition. At Punaluu, a maximum hazard index of 0.41 exists under this scenario assuming nocturnal drainage weather conditions. 91% of the overall chronic hazard index at Pahala is due to hydrazine.

Results of the acute hazard index calculations for exposure to a receptor via inhalation of airborne emissions released during a deflagration episode are shown in Tables 8-62 through 8-66 for hydrazine, UDMH, N_2O_4, FDH, and DMNA. The overall acute hazard index to a receptor is shown in Table 8-67 and indicates that the maximum hazard index projected to occur due to a deflagration event, 0.86, occurs at Pahala under the nocturnal drainage weather condition. At Punaluu, a maximum hazard index of 0.79 exists under this scenario assuming nocturnal drainage weather conditions. 36% of the overall acute hazard index at Pahala is due to hydrazine, 54% is due to N_2O_4, and 9% is due to UDMH.

8.3.3.2 Drinking Water Ingestion Pathway

Noncancer risk due to ingestion of drinking water to which hydrazine has been deposited following deflagration of an ascending vehicle is determined in Table B-3. Based upon an average hydrazine water concentration of 4.7×10^{-3} mg/l, the corresponding daily dose was determined to be 1.3×10^{-4} mg/kg. The chronic oral

acceptable exposure level for hydrazine based on the inhalation AEL is 6.9×10^{-5} and thus the resulting noncancer hazard index due to this exposure pathway is 2.0.

8.3.4 Cancer Burden

Excess population cancer burden is the predicted number of cancer cases added to the community or study area due to rocket exhaust emissions of carcinogenic substances. In this health risk assessment, the added cancer cases are calculated by multiplying the individual cancer risk determined for Pahala (worst case estimate) by the number of people living and working in the Kau District. The total community excess cancer burden per 70-year lifetime is 0.0016 estimated excess cancers due to rocket exhaust emissions based on 1990 population estimates (DBED 1990) and 0.0018 based on 2000 population projections (Table 8-68).

8.4 CUMULATIVE IMPACTS OF CONFLAGRATION AND DEFLAGRATION

A launch accident may involve both conflagration and deflagration which can result in the release of HCl and aluminum oxide from a burning SRB and the release of unburned hydrazine, UDMH, and nitrogen tetroxide from a ruptured second stage rocket, as well as the combustion by-products of second stage fuel burning, FDH and DMNA. In this section, the cumulative health impacts of a launch accident involving both conflagration and deflagration is evaluated.

Results of the cumulative cancer risk analysis due to conflagration and deflagration are shown in Table 8-69. On-pad conflagration and conflagration during vehicle ascent at 10 seconds after liftoff are both evaluated. Review of Table 8-69 indicates that the cumulative cancer risk is due entirely to deflagration (carcinogenic substances are not released during conflagration). At Pahala the cumulative cancer risk is 4.3×10^{-7} while at Naalehu and Captain Cook, the values are 1.5×10^{-7} and 2.5×10^{-8}, respectively.

Cumulative chronic hazard indices are presented in Table 8-70 for Pahala, Naalehu, and Captain Cook. Hazard indices due to on-pad conflagration and deflagration and due to conflagration during vehicle ascent and deflagration are equivalent (due entirely to deflagration): 0.44 for Pahala, 0.16 for Naalehu, and 0.03 for Captain Cook.

Revised Table 8-52. CANCER RISK DUE TO INHALATION OF UDMH
RELEASED DURING A DEFLAGRATION EPISODE
(Inhalation Potency Slope Value for UDMH = 1.72 (mg/kg/day)-1)

Rec. #	Receptor Name	Wind Bearing	WEATHER CASE KONA (Worst case)	TRADE 1	TRADE 2	WEAKTR	KONA	TRAN1	TRAN2	NOCTDRN
1	Aloha Montessori Preschool	58	1.37E-08	1.96E-09	0.00E+00	1.96E-09	1.18E-08	1.96E-09	1.96E-09	1.57E-08
2	Creative Day Preschool Inc.	137	1.96E-09	1.96E-09	0.00E+00	1.96E-09	1.96E-09	1.96E-09	1.96E-09	3.92E-09
3	Keauhou Day Care - Kona	132	1.96E-09	1.96E-09	0.00E+00	1.96E-09	1.96E-09	1.96E-09	1.96E-09	3.92E-09
4	Head Start Kailua	134	1.96E-09	1.96E-09	0.00E+00	1.96E-09	1.96E-09	1.96E-09	1.96E-09	3.92E-09
5	Head Start Ka'u Home Base	58	1.37E-08	1.96E-09	0.00E+00	1.96E-09	1.18E-08	1.96E-09	1.96E-09	1.57E-08
6	Kamehameha Schools	128	1.96E-09	1.96E-09	0.00E+00	1.96E-09	1.96E-09	1.96E-09	1.96E-09	3.92E-09
7	Kona Baptist Keikiland	131	1.96E-09	1.96E-09	0.00E+00	1.96E-09	1.96E-09	1.96E-09	1.96E-09	3.92E-09
8	Kona Hongwanji Preschool	129	1.96E-09	1.96E-09	0.00E+00	1.96E-09	1.96E-09	1.96E-09	1.96E-09	3.92E-09
9	Mokuaikaua Church Nursery School	134	1.96E-09	1.96E-09	0.00E+00	1.96E-09	1.96E-09	1.96E-09	1.96E-09	3.92E-09
10	Pahala Preschool	143	1.76E-08	0.00E+00	0.00E+00	0.00E+00	1.57E-08	1.57E-08	5.88E-09	3.72E-08
11	Pali Uli Waldorf School	128	1.96E-09	1.96E-09	0.00E+00	1.96E-09	1.96E-09	1.96E-09	1.96E-09	3.92E-09
12	Salvation Army Ohana Keiki Day Care Center	134	1.96E-09	1.96E-09	0.00E+00	1.96E-09	1.96E-09	1.96E-09	1.96E-09	3.92E-09
13	University of the Nations	134	1.96E-09	1.96E-09	0.00E+00	1.96E-09	1.96E-09	1.96E-09	1.96E-09	3.92E-09
14	Sherry Alves	128	1.96E-09	1.96E-09	0.00E+00	1.96E-09	1.96E-09	1.96E-09	1.96E-09	3.92E-09
15	Maija Abaya	136	1.96E-09	1.96E-09	0.00E+00	1.96E-09	1.96E-09	1.96E-09	1.96E-09	3.92E-09
16	Trina Alapai	134	1.96E-09	1.96E-09	0.00E+00	1.96E-09	1.96E-09	1.96E-09	1.96E-09	3.92E-09
17	Joann Bishaw	126	1.96E-09	1.96E-09	0.00E+00	1.96E-09	1.96E-09	1.96E-09	1.96E-09	3.92E-09
18	Dawn Bradford	137	1.96E-09	1.96E-09	0.00E+00	1.96E-09	1.96E-09	1.96E-09	1.96E-09	3.92E-09
19	Keiki Corner	134	1.96E-09	1.96E-09	0.00E+00	1.96E-09	1.96E-09	1.96E-09	1.96E-09	3.92E-09
20	Lucy Delaries	136	1.96E-09	1.96E-09	0.00E+00	1.96E-09	1.96E-09	1.96E-09	1.96E-09	3.92E-09
21	Cammy Featherstone	133	1.96E-09	1.96E-09	0.00E+00	1.96E-09	1.96E-09	1.96E-09	1.96E-09	3.92E-09
22	Nancy Fujimoto	133	1.96E-09	1.96E-09	0.00E+00	1.96E-09	1.96E-09	1.96E-09	1.96E-09	3.92E-09
23	Pat Gibson	139	1.96E-09	1.96E-09	0.00E+00	1.96E-09	1.96E-09	1.96E-09	1.96E-09	3.92E-09
24	Chris Hagerman	134	1.96E-09	1.96E-09	0.00E+00	1.96E-09	1.96E-09	1.96E-09	1.96E-09	3.92E-09
25	Kathy Losasso Hanlon	136	1.96E-09	1.96E-09	0.00E+00	1.96E-09	1.96E-09	1.96E-09	1.96E-09	3.92E-09
26	Sandra Hanson	138	1.96E-09	1.96E-09	0.00E+00	1.96E-09	1.96E-09	1.96E-09	1.96E-09	3.92E-09
27	Debbie Hedemann	128	1.96E-09	1.96E-09	0.00E+00	1.96E-09	1.96E-09	1.96E-09	1.96E-09	3.92E-09
28	Linda Hester	136	1.96E-09	1.96E-09	0.00E+00	1.96E-09	1.96E-09	1.96E-09	1.96E-09	3.92E-09
29	Merna Kin In	136	1.96E-09	1.96E-09	0.00E+00	1.96E-09	1.96E-09	1.96E-09	1.96E-09	3.92E-09
30	B.J. Lemnah	137	1.96E-09	1.96E-09	0.00E+00	1.96E-09	1.96E-09	1.96E-09	1.96E-09	3.92E-09
31	Kristen Leorna	130	1.96E-09	1.96E-09	0.00E+00	1.96E-09	1.96E-09	1.96E-09	1.96E-09	3.92E-09
32	Barbara Legg	138	1.96E-09	1.96E-09	0.00E+00	1.96E-09	1.96E-09	1.96E-09	1.96E-09	3.92E-09
33	Gail McLeod	136	1.96E-09	1.96E-09	0.00E+00	1.96E-09	1.96E-09	1.96E-09	1.96E-09	3.92E-09
34	Lydia Pope	138	1.96E-09	1.96E-09	0.00E+00	1.96E-09	1.96E-09	1.96E-09	1.96E-09	3.92E-09
35	Inma Rittmeister	137	1.96E-09	1.96E-09	0.00E+00	1.96E-09	1.96E-09	1.96E-09	1.96E-09	3.92E-09
36	Debbie Saito	138	1.96E-09	1.96E-09	0.00E+00	1.96E-09	1.96E-09	1.96E-09	1.96E-09	3.92E-09
37	Jill Terwilliger	134	1.96E-09	1.96E-09	0.00E+00	1.96E-09	1.96E-09	1.96E-09	1.96E-09	3.92E-09
38	Alisa Vegas	139	1.96E-09	1.96E-09	0.00E+00	1.96E-09	1.96E-09	1.96E-09	1.96E-09	3.92E-09
39	Loran Victorino	128	1.96E-09	1.96E-09	0.00E+00	1.96E-09	1.96E-09	1.96E-09	1.96E-09	3.92E-09
40	Angela Walton	135	1.96E-09	1.96E-09	0.00E+00	1.96E-09	1.96E-09	1.96E-09	1.96E-09	3.92E-09
41	Jodi Walton	142	1.96E-09	1.96E-09	0.00E+00	1.96E-09	1.96E-09	1.96E-09	1.96E-09	3.92E-09
42	Patri Yamashita	134	1.96E-09	1.96E-09	0.00E+00	1.96E-09	1.96E-09	1.96E-09	1.96E-09	3.92E-09
43	Hawaii Preparatory Academy, Kona Campus	131	1.96E-09	1.96E-09	0.00E+00	1.96E-09	1.96E-09	1.96E-09	1.96E-09	3.92E-09
44	Hawaii Preparatory Academy, South Kona	128	1.96E-09	1.96E-09	0.00E+00	1.96E-09	1.96E-09	1.96E-09	1.96E-09	3.92E-09
45	Henry Opukahaia School, Kona Campus	137	1.96E-09	1.96E-09	0.00E+00	1.96E-09	1.96E-09	1.96E-09	1.96E-09	3.92E-09
46	Holûaloa School	135	1.96E-09	1.96E-09	0.00E+00	1.96E-09	1.96E-09	1.96E-09	1.96E-09	3.92E-09
47	Honaunau School	126	1.96E-09	1.96E-09	0.00E+00	1.96E-09	1.96E-09	1.96E-09	1.96E-09	3.92E-09
48	Hookena School	120	1.96E-09	1.96E-09	0.00E+00	1.96E-09	1.96E-09	1.96E-09	1.96E-09	5.88E-09
49	Kahakai Elementary School	133	1.96E-09	1.96E-09	0.00E+00	1.96E-09	1.96E-09	1.96E-09	1.96E-09	3.92E-09
50	Kau High & Pahala Elementary School	143	1.96E-08	0.00E+00	0.00E+00	0.00E+00	1.76E-08	1.37E-08	5.88E-09	3.53E-08
51	Kealakehe Elementary School	136	1.96E-09	1.96E-09	0.00E+00	1.96E-09	1.96E-09	1.96E-09	1.96E-09	3.92E-09
52	Kealakehe Intermediate School	136	1.96E-09	1.96E-09	0.00E+00	1.96E-09	1.96E-09	1.96E-09	1.96E-09	3.92E-09
53	Kona Adventist School	128	1.96E-09	1.96E-09	0.00E+00	1.96E-09	1.96E-09	1.96E-09	1.96E-09	3.92E-09
54	Konawaena Elementary School	129	1.96E-09	1.96E-09	0.00E+00	1.96E-09	1.96E-09	1.96E-09	1.96E-09	3.92E-09
55	Konawaena High & Intermediate School	129	1.96E-09	1.96E-09	0.00E+00	1.96E-09	1.96E-09	1.96E-09	1.96E-09	3.92E-09
56	Naalehu School	57	1.37E-08	1.96E-09	0.00E+00	1.96E-09	1.18E-08	1.96E-09	1.96E-09	1.57E-08
57	Oceanview Estates School	79	3.92E-09	1.96E-09	0.00E+00	1.96E-09	3.92E-09	1.96E-09	1.96E-09	7.84E-09
58	University of Hawaii	129	1.96E-09	1.96E-09	0.00E+00	1.96E-09	1.96E-09	1.96E-09	1.96E-09	3.92E-09
59	University of the Nations	134	1.96E-09	1.96E-09	0.00E+00	1.96E-09	1.96E-09	1.96E-09	1.96E-09	3.92E-09
60	Kau Hospital	147	1.76E-08	0.00E+00	0.00E+00	0.00E+00	1.57E-08	1.57E-08	5.88E-09	3.72E-08
61	Kona Hospital	130	1.96E-09	1.96E-09	0.00E+00	1.96E-09	1.96E-09	1.96E-09	1.96E-09	3.92E-09
62	Hillhaven Kona Healthcare Center	131	1.96E-09	1.96E-09	0.00E+00	1.96E-09	1.96E-09	1.96E-09	1.96E-09	3.92E-09
63	Kona Adult Day Care Center	128	1.96E-09	1.96E-09	0.00E+00	1.96E-09	1.96E-09	1.96E-09	1.96E-09	3.92E-09
64	Punaluu Restaurant	77	1.96E-08	0.00E+00	0.00E+00	0.00E+00	1.76E-08	1.37E-08	5.88E-09	3.33E-08
65	Punaluu Condos	75	2.16E-08	0.00E+00	0.00E+00	0.00E+00	1.96E-08	1.18E-08	3.92E-09	3.14E-08
66	Punaluu Beach Park	73	1.96E-08	0.00E+00	0.00E+00	0.00E+00	1.76E-08	1.37E-08	5.88E-09	3.33E-08

Maximum occurs at Pahala Preschool and Kau Hospital under Noctdrn scenario 3.72E-08

Revised Table 8-53. CANCER RISK DUE TO INHALATION OF FDH
RELEASED DURING A DEFLAGRATION EPISODE
(Inhalation Potency Slope Value for FDH = 1.72 (mg/kg/day)-1)

Rec. #	Receptor Name	Wind Bearing	WEATHER CASE KONA (Worst case)	TRADE 1	TRADE 2	WEAKTR	KONA	TRAN1	TRAN2	NOCTDRN
1	Aloha Montessori Preschool	58	2.02E-10	2.11E-11	0.00E+00	4.70E-12	1.67E-10	3.52E-11	1.17E-11	2.89E-10
2	Creative Day Preschool Inc.	137	9.86E-11	2.11E-11	0.00E+00	7.05E-12	6.58E-11	2.82E-11	1.17E-11	2.96E-10
3	Keauhou Day Care - Kona	132	9.86E-11	2.11E-11	0.00E+00	7.05E-12	6.81E-11	2.82E-11	1.17E-11	2.98E-10
4	Head Start Kailua	134	9.86E-11	2.11E-11	0.00E+00	7.05E-12	6.58E-11	2.82E-11	1.17E-11	2.98E-10
5	Head Start Ka'u Home Base	58	2.02E-10	2.11E-11	0.00E+00	4.70E-12	1.67E-10	3.52E-11	1.17E-11	2.89E-10
6	Kamehameha Schools	128	1.01E-10	2.11E-11	0.00E+00	7.05E-12	7.05E-11	2.82E-11	1.17E-11	2.98E-10
7	Kona Baptist Keikiland	131	9.86E-11	2.11E-11	0.00E+00	7.05E-12	6.81E-11	2.82E-11	1.17E-11	2.98E-10
8	Kona Hongwanji Preschool	129	9.86E-11	2.11E-11	0.00E+00	7.05E-12	7.05E-11	2.82E-11	1.17E-11	2.98E-10
9	Mokuaikaua Church Nursery School	134	9.86E-11	2.11E-11	0.00E+00	7.05E-12	6.58E-11	2.82E-11	1.17E-11	2.96E-10
10	Pahala Preschool	143	9.39E-11	0.00E+00	0.00E+00	0.00E+00	7.75E-11	6.58E-11	1.64E-11	2.30E-10
11	Pali Uli Waldorf School	128	1.01E-10	2.11E-11	0.00E+00	7.05E-12	7.05E-11	2.82E-11	1.17E-11	2.98E-10
12	Salvation Army Ohana Keiki Day Care Center	134	9.86E-11	2.11E-11	0.00E+00	7.05E-12	6.58E-11	2.82E-11	1.17E-11	2.98E-10
13	University of the Nations	134	9.86E-11	2.11E-11	0.00E+00	7.05E-12	6.58E-11	2.82E-11	1.17E-11	2.98E-10
14	Sherry Alves	128	1.01E-10	2.11E-11	0.00E+00	7.05E-12	7.05E-11	2.82E-11	1.17E-11	2.98E-10
15	Maija Abaya	136	9.86E-11	2.11E-11	0.00E+00	7.05E-12	6.58E-11	2.82E-11	1.17E-11	2.96E-10
16	Trina Alapai	134	9.86E-11	2.11E-11	0.00E+00	7.05E-12	6.58E-11	2.82E-11	1.17E-11	2.98E-10
17	Joann Bishaw	126	1.01E-10	2.11E-11	0.00E+00	7.05E-12	7.05E-11	2.82E-11	1.17E-11	2.98E-10
18	Dawn Bradford	137	9.86E-11	2.11E-11	0.00E+00	7.05E-12	6.34E-11	2.82E-11	1.17E-11	2.96E-10
19	Keiki Corner	134	9.86E-11	2.11E-11	0.00E+00	7.05E-12	6.58E-11	2.82E-11	1.17E-11	2.98E-10
20	Lucy Delaries	136	9.86E-11	2.11E-11	0.00E+00	7.05E-12	6.58E-11	2.82E-11	1.17E-11	2.96E-10
21	Cammy Featherstone	133	9.86E-11	2.11E-11	0.00E+00	7.05E-12	6.58E-11	2.82E-11	1.17E-11	2.98E-10
22	Nancy Fujimoto	133	9.86E-11	2.11E-11	0.00E+00	7.05E-12	6.58E-11	2.82E-11	1.17E-11	2.98E-10
23	Pat Gibson	139	9.86E-11	2.11E-11	0.00E+00	7.05E-12	6.34E-11	2.82E-11	1.17E-11	2.96E-10
24	Chris Hagerman	134	9.86E-11	2.11E-11	0.00E+00	7.05E-12	6.58E-11	2.82E-11	1.17E-11	2.98E-10
25	Kathy Losasso Hanlon	136	9.86E-11	2.11E-11	0.00E+00	7.05E-12	6.58E-11	2.82E-11	1.17E-11	2.96E-10
26	Sandra Hanson	138	9.86E-11	2.11E-11	0.00E+00	7.05E-12	6.34E-11	2.82E-11	1.17E-11	2.96E-10
27	Debbie Hedemann	128	1.01E-10	2.11E-11	0.00E+00	7.05E-12	7.05E-11	2.82E-11	1.17E-11	2.98E-10
28	Linda Hester	136	9.86E-11	2.11E-11	0.00E+00	7.05E-12	6.58E-11	2.82E-11	1.17E-11	2.96E-10
29	Merna Kin In	136	9.86E-11	2.11E-11	0.00E+00	7.05E-12	6.58E-11	2.82E-11	1.17E-11	2.96E-10
30	B.J. Lemnah	137	9.86E-11	2.11E-11	0.00E+00	7.05E-12	6.34E-11	2.82E-11	1.17E-11	2.96E-10
31	Kristen Leorna	130	9.86E-11	2.11E-11	0.00E+00	7.05E-12	6.58E-11	2.82E-11	1.17E-11	2.98E-10
32	Barbara Legg	138	9.86E-11	2.11E-11	0.00E+00	7.05E-12	6.34E-11	2.82E-11	1.17E-11	2.96E-10
33	Gail McLeod	136	9.86E-11	2.11E-11	0.00E+00	7.05E-12	6.34E-11	2.82E-11	1.17E-11	2.96E-10
34	Lydia Pope	138	9.86E-11	2.11E-11	0.00E+00	7.05E-12	6.34E-11	2.82E-11	1.17E-11	2.96E-10
35	Inma Rittmeister	137	9.86E-11	2.11E-11	0.00E+00	7.05E-12	6.34E-11	2.82E-11	1.17E-11	2.96E-10
36	Debbie Saito	138	9.86E-11	2.11E-11	0.00E+00	7.05E-12	6.34E-11	2.82E-11	1.17E-11	2.96E-10
37	Jill Terwilliger	134	9.86E-11	2.11E-11	0.00E+00	7.05E-12	6.58E-11	2.82E-11	1.17E-11	2.98E-10
38	Alisa Vegas	139	9.86E-11	2.11E-11	0.00E+00	7.05E-12	6.34E-11	2.82E-11	1.17E-11	2.96E-10
39	Loran Victorino	128	1.01E-10	2.11E-11	0.00E+00	7.05E-12	7.05E-11	2.82E-11	1.17E-11	2.98E-10
40	Angela Walton	135	9.86E-11	2.11E-11	0.00E+00	7.05E-12	6.58E-11	2.82E-11	1.17E-11	2.98E-10
41	Jodi Walton	142	9.86E-11	2.11E-11	0.00E+00	7.05E-12	6.34E-11	2.82E-11	1.17E-11	2.96E-10
42	Patri Yamashita	134	9.86E-11	2.11E-11	0.00E+00	7.05E-12	6.58E-11	2.82E-11	1.17E-11	2.98E-10
43	Hawaii Preparatory Academy, Kona Campus	131	9.86E-11	2.11E-11	0.00E+00	7.05E-12	6.81E-11	2.82E-11	1.17E-11	2.98E-10
44	Hawaii Preparatory Academy, South Kona	128	1.01E-10	2.11E-11	0.00E+00	7.05E-12	7.05E-11	2.82E-11	1.17E-11	2.98E-10
45	Henry Opukahaia School, Kona Campus	137	9.86E-11	2.11E-11	0.00E+00	7.05E-12	6.58E-11	2.82E-11	1.17E-11	2.96E-10
46	Holualoa School	135	9.86E-11	2.11E-11	0.00E+00	7.05E-12	6.58E-11	2.82E-11	1.17E-11	2.98E-10
47	Honaunau School	126	1.03E-10	2.11E-11	0.00E+00	7.05E-12	7.51E-11	2.82E-11	1.17E-11	2.98E-10
48	Hookena School	120	1.06E-10	2.11E-11	0.00E+00	7.05E-12	7.98E-11	2.82E-11	1.17E-11	2.98E-10
49	Kahakai Elementary School	133	9.86E-11	2.11E-11	0.00E+00	7.05E-12	6.58E-11	2.82E-11	1.17E-11	2.98E-10
50	Kau High & Pahala Elementary School	143	1.15E-10	0.00E+00	0.00E+00	0.00E+00	9.39E-11	6.34E-11	1.64E-11	2.40E-10
51	Kealakehe Elementary School	136	9.86E-11	2.11E-11	0.00E+00	7.05E-12	6.58E-11	2.82E-11	1.17E-11	2.96E-10
52	Kealakehe Intermediate School	136	9.86E-11	2.11E-11	0.00E+00	7.05E-12	6.58E-11	2.82E-11	1.17E-11	2.96E-10
53	Kona Adventist School	128	1.01E-10	2.11E-11	0.00E+00	7.05E-12	7.28E-11	2.82E-11	1.17E-11	2.98E-10
54	Konawaena Elementary School	129	1.01E-10	2.11E-11	0.00E+00	7.05E-12	7.05E-11	2.82E-11	1.17E-11	2.98E-10
55	Konawaena High & Intermediate School	129	1.01E-10	2.11E-11	0.00E+00	7.05E-12	7.05E-11	2.82E-11	1.17E-11	2.98E-10
56	Naalehu School	57	2.02E-10	2.11E-11	0.00E+00	4.70E-12	1.67E-10	3.52E-11	1.17E-11	2.89E-10
57	Oceanview Estates School	79	1.34E-10	1.88E-11	0.00E+00	7.05E-12	1.10E-10	2.82E-11	1.17E-11	2.98E-10
58	University of Hawaii	129	9.86E-11	2.11E-11	0.00E+00	7.05E-12	7.05E-11	2.82E-11	1.17E-11	2.98E-10
59	University of the Nations	134	9.86E-11	2.11E-11	0.00E+00	7.05E-12	6.58E-11	2.82E-11	1.17E-11	2.98E-10
60	Kau Hospital	147	9.39E-11	0.00E+00	0.00E+00	0.00E+00	7.75E-11	6.58E-11	1.64E-11	2.30E-10
61	Kona Hospital	130	9.86E-11	2.11E-11	0.00E+00	7.05E-12	7.05E-11	2.82E-11	1.17E-11	2.98E-10
62	Hillhaven Kona Healthcare Center	131	9.86E-11	2.11E-11	0.00E+00	7.05E-12	6.58E-11	2.82E-11	1.17E-11	2.98E-10
63	Kona Adult Day Care Center	128	1.01E-10	2.11E-11	0.00E+00	7.05E-12	7.05E-11	2.82E-11	1.17E-11	2.98E-10
64	Punaluu Restaurant	77	1.20E-10	0.00E+00	0.00E+00	0.00E+00	9.63E-11	6.11E-11	1.64E-11	2.42E-10
65	Punaluu Condos	75	1.41E-10	0.00E+00	0.00E+00	0.00E+00	1.13E-10	5.87E-11	1.41E-11	2.51E-10
66	Punaluu Beach Park	73	1.24E-10	0.00E+00	0.00E+00	0.00E+00	1.01E-10	6.11E-11	1.64E-11	2.44E-10

Maximum occurs at under Noctdrn condition 2.98E-10

Revised Table 8-55. OVERALL INHALATION CANCER RISK DUE TO RELEASE OF HYDRAZINE, UDMH, FDH, AND DMNA DURING A DEFLAGRATION EPISODE

Rec. #	Receptor Name	Wind Bearing	WEATHER CASE							
			KONA (Worst case)	TRADE 1	TRADE 2	WEAKTR	KONA	TRAN1	TRAN2	NOCTDRN
1	Aloha Montessori Preschool	58	1.39E-07	3.34E-08	6.71E-11	1.25E-08	1.27E-07	2.30E-08	1.25E-08	1.52E-07
2	Creative Day Preschool Inc.	137	1.26E-08	1.25E-08	6.71E-11	1.25E-08	1.25E-08	1.25E-08	1.25E-08	1.47E-08
3	Keauhou Day Care - Kona	132	1.26E-08	1.25E-08	6.71E-11	1.25E-08	1.25E-08	1.25E-08	1.25E-08	2.52E-08
4	Head Start Kailua	134	1.26E-08	1.25E-08	6.71E-11	1.25E-08	1.25E-08	1.25E-08	1.25E-08	2.52E-08
5	Head Start Ka'u Home Base	58	1.39E-07	3.34E-08	6.71E-11	1.25E-08	1.27E-07	2.30E-08	1.25E-08	1.52E-07
6	Kamehameha Schools	128	1.26E-08	1.25E-08	6.71E-11	1.25E-08	1.26E-08	1.25E-08	1.25E-08	2.52E-08
7	Kona Baptist Keikiland	131	1.26E-08	1.25E-08	6.71E-11	1.25E-08	1.25E-08	1.25E-08	1.25E-08	2.52E-08
8	Kona Hongwanji Preschool	129	1.26E-08	1.25E-08	6.71E-11	1.25E-08	1.26E-08	1.25E-08	1.25E-08	2.52E-08
9	Mokuaikaua Church Nursery School	134	1.26E-08	1.25E-08	6.71E-11	1.25E-08	1.25E-08	1.25E-08	1.25E-08	1.47E-08
10	Pahala Preschool	143	2.16E-07	6.71E-11	6.71E-11	1.05E-08	1.94E-07	1.83E-07	6.87E-08	4.35E-07
11	Pali Uli Waldorf School	128	1.26E-08	1.25E-08	6.71E-11	1.25E-08	1.26E-08	1.25E-08	1.25E-08	2.52E-08
12	Salvation Army Ohana Keiki Day Care Center	134	1.26E-08	1.25E-08	6.71E-11	1.25E-08	1.25E-08	1.25E-08	1.25E-08	2.52E-08
13	University of the Nations	134	1.26E-08	1.25E-08	6.71E-11	1.25E-08	1.25E-08	1.25E-08	1.25E-08	2.52E-08
14	Sherry Alves	128	1.26E-08	1.25E-08	6.71E-11	1.25E-08	1.26E-08	1.25E-08	1.25E-08	2.52E-08
15	Maija Abaya	136	1.26E-08	1.25E-08	6.71E-11	1.25E-08	1.25E-08	1.25E-08	1.25E-08	1.47E-08
16	Trina Alapai	134	1.26E-08	1.25E-08	6.71E-11	1.25E-08	1.25E-08	1.25E-08	1.25E-08	2.52E-08
17	Joann Bishaw	126	1.26E-08	1.25E-08	6.71E-11	1.25E-08	1.26E-08	1.25E-08	1.25E-08	2.52E-08
18	Dawn Bradford	137	1.26E-08	1.25E-08	6.71E-11	1.25E-08	1.25E-08	1.25E-08	1.25E-08	1.47E-08
19	Keiki Corner	134	1.26E-08	1.25E-08	6.71E-11	1.25E-08	1.25E-08	1.25E-08	1.25E-08	2.52E-08
20	Lucy Delaries	136	1.26E-08	1.25E-08	6.71E-11	1.25E-08	1.25E-08	1.25E-08	1.25E-08	1.47E-08
21	Cammy Featherstone	133	1.26E-08	1.25E-08	6.71E-11	1.25E-08	1.25E-08	1.25E-08	1.25E-08	2.52E-08
22	Nancy Fujimoto	133	1.26E-08	1.25E-08	6.71E-11	1.25E-08	1.25E-08	1.25E-08	1.25E-08	2.52E-08
23	Pat Gibson	139	1.26E-08	1.25E-08	6.71E-11	1.25E-08	1.25E-08	1.25E-08	1.25E-08	1.47E-08
24	Chris Hagerman	134	1.26E-08	1.25E-08	6.71E-11	1.25E-08	1.25E-08	1.25E-08	1.25E-08	2.52E-08
25	Kathy Losasso Hanlon	136	1.26E-08	1.25E-08	6.71E-11	1.25E-08	1.25E-08	1.25E-08	1.25E-08	1.47E-08
26	Sandra Hanson	138	1.26E-08	1.25E-08	6.71E-11	1.25E-08	1.25E-08	1.25E-08	1.25E-08	1.47E-08
27	Debbie Hedemann	128	1.26E-08	1.25E-08	6.71E-11	1.25E-08	1.26E-08	1.25E-08	1.25E-08	2.52E-08
28	Linda Hester	136	1.26E-08	1.25E-08	6.71E-11	1.25E-08	1.25E-08	1.25E-08	1.25E-08	1.47E-08
29	Merna Kin In	136	1.26E-08	1.25E-08	6.71E-11	1.25E-08	1.25E-08	1.25E-08	1.25E-08	1.47E-08
30	B.J. Lemnah	137	1.26E-08	1.25E-08	6.71E-11	1.25E-08	1.25E-08	1.25E-08	1.25E-08	1.47E-08
31	Kristen Leorna	130	1.26E-08	1.25E-08	6.71E-11	1.25E-08	1.25E-08	1.25E-08	1.25E-08	2.52E-08
32	Barbara Legg	138	1.26E-08	1.25E-08	6.71E-11	1.25E-08	1.25E-08	1.25E-08	1.25E-08	1.47E-08
33	Gail McLeod	136	1.26E-08	1.25E-08	6.71E-11	1.25E-08	1.25E-08	1.25E-08	1.25E-08	1.47E-08
34	Lydia Pope	138	1.26E-08	1.25E-08	6.71E-11	1.25E-08	1.25E-08	1.25E-08	1.25E-08	1.47E-08
35	Inma Rittmeister	137	1.26E-08	1.25E-08	6.71E-11	1.25E-08	1.25E-08	1.25E-08	1.25E-08	1.47E-08
36	Debbie Saito	138	1.26E-08	1.25E-08	6.71E-11	1.25E-08	1.25E-08	1.25E-08	1.25E-08	1.47E-08
37	Jill Terwilliger	134	1.26E-08	1.25E-08	6.71E-11	1.25E-08	1.25E-08	1.25E-08	1.25E-08	2.52E-08
38	Alisa Vegas	139	1.26E-08	1.25E-08	6.71E-11	1.25E-08	1.25E-08	1.25E-08	1.25E-08	1.47E-08
39	Loran Victorino	128	1.26E-08	1.25E-08	6.71E-11	1.25E-08	1.26E-08	1.25E-08	1.25E-08	2.52E-08
40	Angela Walton	135	1.26E-08	1.25E-08	6.71E-11	1.25E-08	1.25E-08	1.25E-08	1.25E-08	2.52E-08
41	Jodi Walton	142	1.26E-08	1.25E-08	6.71E-11	1.25E-08	1.25E-08	1.25E-08	1.25E-08	1.47E-08
42	Patri Yamashita	134	1.26E-08	1.25E-08	6.71E-11	1.25E-08	1.25E-08	1.25E-08	1.25E-08	2.52E-08
43	Hawaii Preparatory Academy, Kona Campus	131	1.26E-08	1.25E-08	6.71E-11	1.25E-08	1.25E-08	1.25E-08	1.25E-08	2.52E-08
44	Hawaii Preparatory Academy, South Kona	128	1.26E-08	1.25E-08	6.71E-11	1.25E-08	1.26E-08	1.25E-08	1.25E-08	2.52E-08
45	Henry Opukahaia School, Kona Campus	137	1.26E-08	1.25E-08	6.71E-11	1.25E-08	1.25E-08	1.25E-08	1.25E-08	1.47E-08
46	Holualoa School	135	1.26E-08	1.25E-08	6.71E-11	1.25E-08	1.25E-08	1.25E-08	1.25E-08	2.52E-08
47	Honaunau School	126	1.26E-08	1.25E-08	6.71E-11	1.25E-08	1.26E-08	1.25E-08	1.25E-08	3.56E-08
48	Hookena School	120	1.26E-08	1.25E-08	6.71E-11	1.25E-08	1.26E-08	1.25E-08	1.25E-08	3.76E-08
49	Kahakai Elementary School	133	1.26E-08	1.25E-08	6.71E-11	1.25E-08	1.25E-08	1.25E-08	1.25E-08	2.52E-08
50	Kau High & Pahala Elementary School	143	2.29E-07	6.71E-11	6.71E-11	1.05E-08	2.06E-07	1.60E-07	5.82E-08	4.01E-07
51	Kealakehe Elementary School	136	1.26E-08	1.25E-08	6.71E-11	1.25E-08	1.25E-08	1.25E-08	1.25E-08	1.47E-08
52	Kealakehe Intermediate School	136	1.26E-08	1.25E-08	6.71E-11	1.25E-08	1.25E-08	1.25E-08	1.25E-08	1.47E-08
53	Kona Adventist School	128	1.26E-08	1.25E-08	6.71E-11	1.25E-08	1.26E-08	1.25E-08	1.25E-08	3.56E-08
54	Konawaena Elementary School	129	1.26E-08	1.25E-08	6.71E-11	1.25E-08	1.26E-08	1.25E-08	1.25E-08	2.52E-08
55	Konawaena High & Intermediate School	129	1.26E-08	1.25E-08	6.71E-11	1.25E-08	1.26E-08	1.25E-08	1.25E-08	2.52E-08
56	Naalehu School	57	1.39E-07	3.34E-08	6.71E-11	1.25E-08	1.27E-07	2.30E-08	1.25E-08	1.52E-07
57	Oceanview Estates School	79	3.55E-08	1.25E-08	6.71E-11	1.25E-08	3.55E-08	1.25E-08	1.25E-08	7.09E-08
58	University of Hawaii	129	1.26E-08	1.25E-08	6.71E-11	1.25E-08	1.26E-08	1.25E-08	1.25E-08	2.52E-08
59	University of the Nations	134	1.26E-08	1.25E-08	6.71E-11	1.25E-08	1.25E-08	1.25E-08	1.25E-08	2.52E-08
60	Kau Hospital	147	2.16E-07	6.71E-11	6.71E-11	1.05E-08	1.94E-07	1.83E-07	6.87E-08	4.35E-07
61	Kona Hospital	130	1.26E-08	1.25E-08	6.71E-11	1.25E-08	1.26E-08	1.25E-08	1.25E-08	2.52E-08
62	Hillhaven Kona Healthcare Center	131	1.26E-08	1.25E-08	6.71E-11	1.25E-08	1.25E-08	1.25E-08	1.25E-08	2.52E-08
63	Kona Adult Day Care Center	128	1.26E-08	1.25E-08	6.71E-11	1.25E-08	1.26E-08	1.25E-08	1.25E-08	2.52E-08
64	Punaluu Restaurant	77	2.39E-07	6.71E-11	6.71E-11	1.05E-08	2.16E-07	1.60E-07	5.82E-08	4.00E-07
65	Punaluu Condos	75	2.52E-07	6.71E-11	6.71E-11	1.05E-08	2.29E-07	1.37E-07	4.58E-08	3.66E-07
66	Punaluu Beach Park	73	2.39E-07	6.71E-11	6.71E-11	1.05E-08	2.16E-07	1.50E-07	5.82E-08	3.89E-07

Maximum occurs at Pahala Preschool and Kau Hospital under Noctdrn scenario 4.35E-07

Revised Table 8-57. CHRONIC HAZARD INDEX VIA INHALATION OF UDMH
RELEASED DURING A DEFLAGRATION EPISODE
(Chronic Inhalation AEL for UDMH = 5.7E-07 mg/kg/day)

Rec. #	Receptor Name	Wind Bearing	WEATHER CASE KONA (Worst case)	TRADE 1	TRADE 2	WEAKTR	KONA	TRAN1	TRAN2	NOCTDRN
1	Aloha Montessori Preschool	58	1.40E-02	2.00E-03	0.00E+00	2.00E-03	1.20E-02	2.00E-03	2.00E-03	1.60E-02
2	Creative Day Preschool Inc.	137	2.00E-03	2.00E-03	0.00E+00	2.00E-03	2.00E-03	2.00E-03	2.00E-03	4.00E-03
3	Keauhou Day Care - Kona	132	2.00E-03	2.00E-03	0.00E+00	2.00E-03	2.00E-03	2.00E-03	2.00E-03	4.00E-03
4	Head Start Kailua	134	2.00E-03	2.00E-03	0.00E+00	2.00E-03	2.00E-03	2.00E-03	2.00E-03	4.00E-03
5	Head Start Ka'u Home Base	58	1.40E-02	2.00E-03	0.00E+00	2.00E-03	1.20E-02	2.00E-03	2.00E-03	1.60E-02
6	Kamehameha Schools	128	2.00E-03	2.00E-03	0.00E+00	2.00E-03	2.00E-03	2.00E-03	2.00E-03	4.00E-03
7	Kona Baptist Keikiland	131	2.00E-03	2.00E-03	0.00E+00	2.00E-03	2.00E-03	2.00E-03	2.00E-03	4.00E-03
8	Kona Hongwanji Preschool	129	2.00E-03	2.00E-03	0.00E+00	2.00E-03	2.00E-03	2.00E-03	2.00E-03	4.00E-03
9	Mokuaikaua Church Nursery School	134	2.00E-03	2.00E-03	0.00E+00	2.00E-03	2.00E-03	2.00E-03	2.00E-03	4.00E-03
10	Pahala Preschool	143	1.80E-02	0.00E+00	0.00E+00	0.00E+00	1.60E-02	1.60E-02	6.00E-03	3.80E-02
11	Pali Uli Waldorf School	128	2.00E-03	2.00E-03	0.00E+00	2.00E-03	2.00E-03	2.00E-03	2.00E-03	4.00E-03
12	Salvation Army Ohana Keiki Day Care Center	134	2.00E-03	2.00E-03	0.00E+00	2.00E-03	2.00E-03	2.00E-03	2.00E-03	4.00E-03
13	University of the Nations	134	2.00E-03	2.00E-03	0.00E+00	2.00E-03	2.00E-03	2.00E-03	2.00E-03	4.00E-03
14	Sherry Alves	128	2.00E-03	2.00E-03	0.00E+00	2.00E-03	2.00E-03	2.00E-03	2.00E-03	4.00E-03
15	Maija Abaya	136	2.00E-03	2.00E-03	0.00E+00	2.00E-03	2.00E-03	2.00E-03	2.00E-03	4.00E-03
16	Trina Alapai	134	2.00E-03	2.00E-03	0.00E+00	2.00E-03	2.00E-03	2.00E-03	2.00E-03	4.00E-03
17	Joann Bishaw	126	2.00E-03	2.00E-03	0.00E+00	2.00E-03	2.00E-03	2.00E-03	2.00E-03	4.00E-03
18	Dawn Bradford	137	2.00E-03	2.00E-03	0.00E+00	2.00E-03	2.00E-03	2.00E-03	2.00E-03	4.00E-03
19	Keiki Corner	134	2.00E-03	2.00E-03	0.00E+00	2.00E-03	2.00E-03	2.00E-03	2.00E-03	4.00E-03
20	Lucy Delaries	136	2.00E-03	2.00E-03	0.00E+00	2.00E-03	2.00E-03	2.00E-03	2.00E-03	4.00E-03
21	Cammy Featherstone	133	2.00E-03	2.00E-03	0.00E+00	2.00E-03	2.00E-03	2.00E-03	2.00E-03	4.00E-03
22	Nancy Fujimoto	133	2.00E-03	2.00E-03	0.00E+00	2.00E-03	2.00E-03	2.00E-03	2.00E-03	4.00E-03
23	Pat Gibson	139	2.00E-03	2.00E-03	0.00E+00	2.00E-03	2.00E-03	2.00E-03	2.00E-03	4.00E-03
24	Chris Hagerman	134	2.00E-03	2.00E-03	0.00E+00	2.00E-03	2.00E-03	2.00E-03	2.00E-03	4.00E-03
25	Kathy Losasso Hanlon	136	2.00E-03	2.00E-03	0.00E+00	2.00E-03	2.00E-03	2.00E-03	2.00E-03	4.00E-03
26	Sandra Hanson	138	2.00E-03	2.00E-03	0.00E+00	2.00E-03	2.00E-03	2.00E-03	2.00E-03	4.00E-03
27	Debbie Hedemann	128	2.00E-03	2.00E-03	0.00E+00	2.00E-03	2.00E-03	2.00E-03	2.00E-03	4.00E-03
28	Linda Hester	136	2.00E-03	2.00E-03	0.00E+00	2.00E-03	2.00E-03	2.00E-03	2.00E-03	4.00E-03
29	Merna Kin In	136	2.00E-03	2.00E-03	0.00E+00	2.00E-03	2.00E-03	2.00E-03	2.00E-03	4.00E-03
30	B.J. Lemnah	137	2.00E-03	2.00E-03	0.00E+00	2.00E-03	2.00E-03	2.00E-03	2.00E-03	4.00E-03
31	Kristen Leorna	130	2.00E-03	2.00E-03	0.00E+00	2.00E-03	2.00E-03	2.00E-03	2.00E-03	4.00E-03
32	Barbara Legg	138	2.00E-03	2.00E-03	0.00E+00	2.00E-03	2.00E-03	2.00E-03	2.00E-03	4.00E-03
33	Gail McLeod	136	2.00E-03	2.00E-03	0.00E+00	2.00E-03	2.00E-03	2.00E-03	2.00E-03	4.00E-03
34	Lydia Pope	138	2.00E-03	2.00E-03	0.00E+00	2.00E-03	2.00E-03	2.00E-03	2.00E-03	4.00E-03
35	Inma Rittmeister	137	2.00E-03	2.00E-03	0.00E+00	2.00E-03	2.00E-03	2.00E-03	2.00E-03	4.00E-03
36	Debbie Saito	138	2.00E-03	2.00E-03	0.00E+00	2.00E-03	2.00E-03	2.00E-03	2.00E-03	4.00E-03
37	Jill Terwilliger	134	2.00E-03	2.00E-03	0.00E+00	2.00E-03	2.00E-03	2.00E-03	2.00E-03	4.00E-03
38	Alisa Vegas	139	2.00E-03	2.00E-03	0.00E+00	2.00E-03	2.00E-03	2.00E-03	2.00E-03	4.00E-03
39	Loran Victorino	128	2.00E-03	2.00E-03	0.00E+00	2.00E-03	2.00E-03	2.00E-03	2.00E-03	4.00E-03
40	Angela Walton	135	2.00E-03	2.00E-03	0.00E+00	2.00E-03	2.00E-03	2.00E-03	2.00E-03	4.00E-03
41	Jodi Walton	142	2.00E-03	2.00E-03	0.00E+00	2.00E-03	2.00E-03	2.00E-03	2.00E-03	4.00E-03
42	Patri Yamashita	134	2.00E-03	2.00E-03	0.00E+00	2.00E-03	2.00E-03	2.00E-03	2.00E-03	4.00E-03
43	Hawaii Preparatory Academy, Kona Campus	131	2.00E-03	2.00E-03	0.00E+00	2.00E-03	2.00E-03	2.00E-03	2.00E-03	4.00E-03
44	Hawaii Preparatory Academy, South Kona	128	2.00E-03	2.00E-03	0.00E+00	2.00E-03	2.00E-03	2.00E-03	2.00E-03	4.00E-03
45	Henry Opukahaia School, Kona Campus	137	2.00E-03	2.00E-03	0.00E+00	2.00E-03	2.00E-03	2.00E-03	2.00E-03	4.00E-03
46	Holualoa School	135	2.00E-03	2.00E-03	0.00E+00	2.00E-03	2.00E-03	2.00E-03	2.00E-03	4.00E-03
47	Honaunau School	126	2.00E-03	2.00E-03	0.00E+00	2.00E-03	2.00E-03	2.00E-03	2.00E-03	4.00E-03
48	Hookena School	120	2.00E-03	2.00E-03	0.00E+00	2.00E-03	2.00E-03	2.00E-03	2.00E-03	6.00E-03
49	Kahakai Elementary School	133	2.00E-03	2.00E-03	0.00E+00	2.00E-03	2.00E-03	2.00E-03	2.00E-03	4.00E-03
50	Kau High & Pahala Elementary School	143	2.00E-02	0.00E+00	0.00E+00	0.00E+00	1.80E-02	1.40E-02	6.00E-03	3.60E-02
51	Kealakehe Elementary School	136	2.00E-03	2.00E-03	0.00E+00	2.00E-03	2.00E-03	2.00E-03	2.00E-03	4.00E-03
52	Kealakehe Intermediate School	136	2.00E-03	2.00E-03	0.00E+00	2.00E-03	2.00E-03	2.00E-03	2.00E-03	4.00E-03
53	Kona Adventist School	128	2.00E-03	2.00E-03	0.00E+00	2.00E-03	2.00E-03	2.00E-03	2.00E-03	4.00E-03
54	Konawaena Elementary School	129	2.00E-03	2.00E-03	0.00E+00	2.00E-03	2.00E-03	2.00E-03	2.00E-03	4.00E-03
55	Konawaena High & Intermediate School	129	2.00E-03	2.00E-03	0.00E+00	2.00E-03	2.00E-03	2.00E-03	2.00E-03	4.00E-03
56	Naalehu School	57	1.40E-02	2.00E-03	0.00E+00	2.00E-03	1.20E-02	2.00E-03	2.00E-03	1.60E-02
57	Oceanview Estates School	79	4.00E-03	2.00E-03	0.00E+00	2.00E-03	4.00E-03	2.00E-03	2.00E-03	8.00E-03
58	University of Hawaii	129	2.00E-03	2.00E-03	0.00E+00	2.00E-03	2.00E-03	2.00E-03	2.00E-03	4.00E-03
59	University of the Nations	134	2.00E-03	2.00E-03	0.00E+00	2.00E-03	2.00E-03	2.00E-03	2.00E-03	4.00E-03
60	Kau Hospital	147	1.80E-02	0.00E+00	0.00E+00	0.00E+00	1.60E-02	1.60E-02	6.00E-03	3.80E-02
61	Kona Hospital	130	2.00E-03	2.00E-03	0.00E+00	2.00E-03	2.00E-03	2.00E-03	2.00E-03	4.00E-03
62	Hillhaven Kona Healthcare Center	131	2.00E-03	2.00E-03	0.00E+00	2.00E-03	2.00E-03	2.00E-03	2.00E-03	4.00E-03
63	Kona Adult Day Care Center	128	2.00E-03	2.00E-03	0.00E+00	2.00E-03	2.00E-03	2.00E-03	2.00E-03	4.00E-03
64	Punaluu Restaurant	77	2.00E-02	0.00E+00	0.00E+00	0.00E+00	1.80E-02	1.40E-02	6.00E-03	3.40E-02
65	Punaluu Condos	75	2.20E-02	0.00E+00	0.00E+00	0.00E+00	2.00E-02	1.20E-02	4.00E-03	3.20E-02
66	Punaluu Beach Park	73	2.00E-02	0.00E+00	0.00E+00	0.00E+00	1.80E-02	1.40E-02	6.00E-03	3.40E-02

Maximum occurs at Pahala Preschool and Kau Hospital under Noctdrn scenario 3.80E-02

Revised Table 8-59. CHRONIC HAZARD INDEX VIA INHALATION OF FDH
RELEASED DURING A DEFLAGRATION EPISODE
(Chronic Inhalation AEL for FDH = 5.7E-07 mg/kg/day)

Rec. #	Receptor Name	Wind Bearing	WEATHER CASE KONA (Worst case)	TRADE 1	TRADE 2	WEAKTR	KONA	TRAN1	TRAN2	NOCTDRN
1	Aloha Montessori Preschool	58	2.06E-04	2.16E-05	0.00E+00	4.79E-06	1.70E-04	3.59E-05	1.20E-05	2.95E-04
2	Creative Day Preschool Inc.	137	1.01E-04	2.16E-05	0.00E+00	7.19E-06	6.71E-05	2.88E-05	1.20E-05	3.02E-04
3	Keauhou Day Care - Kona	132	1.01E-04	2.16E-05	0.00E+00	7.19E-06	6.95E-05	2.88E-05	1.20E-05	3.04E-04
4	Head Start Kailua	134	1.01E-04	2.16E-05	0.00E+00	7.19E-06	6.71E-05	2.88E-05	1.20E-05	3.04E-04
5	Head Start Ka'u Home Base	58	2.06E-04	2.16E-05	0.00E+00	4.79E-06	1.70E-04	3.59E-05	1.20E-05	2.95E-04
6	Kamehameha Schools	128	1.03E-04	2.16E-05	0.00E+00	7.19E-06	7.19E-05	2.88E-05	1.20E-05	3.04E-04
7	Kona Baptist Keikiland	131	1.01E-04	2.16E-05	0.00E+00	7.19E-06	6.95E-05	2.88E-05	1.20E-05	3.04E-04
8	Kona Hongwanji Preschool	129	1.01E-04	2.16E-05	0.00E+00	7.19E-06	7.19E-05	2.88E-05	1.20E-05	3.04E-04
9	Mokuaikaua Church Nursery School	134	1.01E-04	2.16E-05	0.00E+00	7.19E-06	6.71E-05	2.88E-05	1.20E-05	3.02E-04
10	Pahala Preschool	143	9.59E-05	0.00E+00	0.00E+00	0.00E+00	7.91E-05	6.71E-05	1.68E-05	2.35E-04
11	Pali Uli Waldorf School	128	1.03E-04	2.16E-05	0.00E+00	7.19E-06	7.19E-05	2.88E-05	1.20E-05	3.04E-04
12	Salvation Army Ohana Keiki Day Care Center	134	1.01E-04	2.16E-05	0.00E+00	7.19E-06	6.71E-05	2.88E-05	1.20E-05	3.04E-04
13	University of the Nations	134	1.01E-04	2.16E-05	0.00E+00	7.19E-06	6.71E-05	2.88E-05	1.20E-05	3.04E-04
14	Sherry Alves	128	1.03E-04	2.16E-05	0.00E+00	7.19E-06	7.19E-05	2.88E-05	1.20E-05	3.04E-04
15	Maija Abaya	136	1.01E-04	2.16E-05	0.00E+00	7.19E-06	6.71E-05	2.88E-05	1.20E-05	3.02E-04
16	Trina Alapai	134	1.01E-04	2.16E-05	0.00E+00	7.19E-06	6.71E-05	2.88E-05	1.20E-05	3.04E-04
17	Joann Bishaw	126	1.03E-04	2.16E-05	0.00E+00	7.19E-06	7.19E-05	2.88E-05	1.20E-05	3.04E-04
18	Dawn Bradford	137	1.01E-04	2.16E-05	0.00E+00	7.19E-06	6.47E-05	2.88E-05	1.20E-05	3.02E-04
19	Keiki Corner	134	1.01E-04	2.16E-05	0.00E+00	7.19E-06	6.71E-05	2.88E-05	1.20E-05	3.04E-04
20	Lucy Delaries	136	1.01E-04	2.16E-05	0.00E+00	7.19E-06	6.71E-05	2.88E-05	1.20E-05	3.02E-04
21	Cammy Featherstone	133	1.01E-04	2.16E-05	0.00E+00	7.19E-06	6.71E-05	2.88E-05	1.20E-05	3.04E-04
22	Nancy Fujimoto	133	1.01E-04	2.16E-05	0.00E+00	7.19E-06	6.71E-05	2.88E-05	1.20E-05	3.04E-04
23	Pat Gibson	139	1.01E-04	2.16E-05	0.00E+00	7.19E-06	6.47E-05	2.88E-05	1.20E-05	3.02E-04
24	Chris Hagerman	134	1.01E-04	2.16E-05	0.00E+00	7.19E-06	6.71E-05	2.88E-05	1.20E-05	3.04E-04
25	Kathy Losasso Hanlon	136	1.01E-04	2.16E-05	0.00E+00	7.19E-06	6.71E-05	2.88E-05	1.20E-05	3.02E-04
26	Sandra Hanson	138	1.01E-04	2.16E-05	0.00E+00	7.19E-06	6.47E-05	2.88E-05	1.20E-05	3.02E-04
27	Debbie Hedemann	128	1.03E-04	2.16E-05	0.00E+00	7.19E-06	7.19E-05	2.88E-05	1.20E-05	3.04E-04
28	Linda Hester	136	1.01E-04	2.16E-05	0.00E+00	7.19E-06	6.71E-05	2.88E-05	1.20E-05	3.02E-04
29	Merna Kin In	136	1.01E-04	2.16E-05	0.00E+00	7.19E-06	6.71E-05	2.88E-05	1.20E-05	3.02E-04
30	B.J. Lemnah	137	1.01E-04	2.16E-05	0.00E+00	7.19E-06	6.47E-05	2.88E-05	1.20E-05	3.02E-04
31	Kristen Leorna	130	1.01E-04	2.16E-05	0.00E+00	7.19E-06	6.71E-05	2.88E-05	1.20E-05	3.04E-04
32	Barbara Legg	138	1.01E-04	2.16E-05	0.00E+00	7.19E-06	6.47E-05	2.88E-05	1.20E-05	3.02E-04
33	Gail McLeod	136	1.01E-04	2.16E-05	0.00E+00	7.19E-06	6.47E-05	2.88E-05	1.20E-05	3.02E-04
34	Lydia Pope	138	1.01E-04	2.16E-05	0.00E+00	7.19E-06	6.47E-05	2.88E-05	1.20E-05	3.02E-04
35	Inma Rittmeister	137	1.01E-04	2.16E-05	0.00E+00	7.19E-06	6.47E-05	2.88E-05	1.20E-05	3.02E-04
36	Debbie Saito	138	1.01E-04	2.16E-05	0.00E+00	7.19E-06	6.47E-05	2.88E-05	1.20E-05	3.02E-04
37	Jill Terwilliger	134	1.01E-04	2.16E-05	0.00E+00	7.19E-06	6.71E-05	2.88E-05	1.20E-05	3.04E-04
38	Alisa Vegas	139	1.01E-04	2.16E-05	0.00E+00	7.19E-06	6.47E-05	2.88E-05	1.20E-05	3.02E-04
39	Loran Victorino	128	1.03E-04	2.16E-05	0.00E+00	7.19E-06	7.19E-05	2.88E-05	1.20E-05	3.04E-04
40	Angela Walton	135	1.01E-04	2.16E-05	0.00E+00	7.19E-06	6.71E-05	2.88E-05	1.20E-05	3.04E-04
41	Jodi Walton	142	1.01E-04	2.16E-05	0.00E+00	7.19E-06	6.47E-05	2.88E-05	1.20E-05	3.02E-04
42	Patri Yamashita	134	1.01E-04	2.16E-05	0.00E+00	7.19E-06	6.71E-05	2.88E-05	1.20E-05	3.04E-04
43	Hawaii Preparatory Academy, Kona Campus	131	1.01E-04	2.16E-05	0.00E+00	7.19E-06	6.95E-05	2.88E-05	1.20E-05	3.04E-04
44	Hawaii Preparatory Academy, South Kona	128	1.03E-04	2.16E-05	0.00E+00	7.19E-06	7.19E-05	2.88E-05	1.20E-05	3.04E-04
45	Henry Opukahaia School, Kona Campus	137	1.01E-04	2.16E-05	0.00E+00	7.19E-06	6.71E-05	2.88E-05	1.20E-05	3.02E-04
46	Holualoa School	135	1.01E-04	2.16E-05	0.00E+00	7.19E-06	6.71E-05	2.88E-05	1.20E-05	3.04E-04
47	Honaunau School	126	1.05E-04	2.16E-05	0.00E+00	7.19E-06	7.67E-05	2.88E-05	1.20E-05	3.04E-04
48	Hookena School	120	1.08E-04	2.16E-05	0.00E+00	7.19E-06	8.15E-05	2.88E-05	1.20E-05	3.04E-04
49	Kahakai Elementary School	133	1.01E-04	2.16E-05	0.00E+00	7.19E-06	6.71E-05	2.88E-05	1.20E-05	3.04E-04
50	Kau High & Pahala Elementary School	143	1.17E-04	0.00E+00	0.00E+00	0.00E+00	9.59E-05	6.47E-05	1.68E-05	2.44E-04
51	Kealakehe Elementary School	136	1.01E-04	2.16E-05	0.00E+00	7.19E-06	6.71E-05	2.88E-05	1.20E-05	3.02E-04
52	Kealakehe Intermediate School	136	1.01E-04	2.16E-05	0.00E+00	7.19E-06	6.71E-05	2.88E-05	1.20E-05	3.02E-04
53	Kona Adventist School	128	1.03E-04	2.16E-05	0.00E+00	7.19E-06	7.43E-05	2.88E-05	1.20E-05	3.04E-04
54	Konawaena Elementary School	129	1.03E-04	2.16E-05	0.00E+00	7.19E-06	7.19E-05	2.88E-05	1.20E-05	3.04E-04
55	Konawaena High & Intermediate School	129	1.03E-04	2.16E-05	0.00E+00	7.19E-06	7.19E-05	2.88E-05	1.20E-05	3.04E-04
56	Naalehu School	57	2.06E-04	2.16E-05	0.00E+00	4.79E-06	1.70E-04	3.59E-05	1.20E-05	2.95E-04
57	Oceanview Estates School	79	1.37E-04	1.92E-05	0.00E+00	7.19E-06	1.13E-04	2.88E-05	1.20E-05	3.04E-04
58	University of Hawaii	129	1.01E-04	2.16E-05	0.00E+00	7.19E-06	7.19E-05	2.88E-05	1.20E-05	3.04E-04
59	University of the Nations	134	1.01E-04	2.16E-05	0.00E+00	7.19E-06	6.71E-05	2.88E-05	1.20E-05	3.04E-04
60	Kau Hospital	147	9.59E-05	0.00E+00	0.00E+00	0.00E+00	7.91E-05	6.71E-05	1.68E-05	2.35E-04
61	Kona Hospital	130	1.01E-04	2.16E-05	0.00E+00	7.19E-06	7.19E-05	2.88E-05	1.20E-05	3.04E-04
62	Hillhaven Kona Healthcare Center	131	1.01E-04	2.16E-05	0.00E+00	7.19E-06	6.71E-05	2.88E-05	1.20E-05	3.04E-04
63	Kona Adult Day Care Center	128	1.03E-04	2.16E-05	0.00E+00	7.19E-06	7.19E-05	2.88E-05	1.20E-05	3.04E-04
64	Punaluu Restaurant	77	1.22E-04	0.00E+00	0.00E+00	0.00E+00	9.82E-05	6.23E-05	1.68E-05	2.47E-04
65	Punaluu Condos	75	1.44E-04	0.00E+00	0.00E+00	0.00E+00	1.15E-04	5.99E-05	1.44E-05	2.56E-04
66	Punaluu Beach Park	73	1.27E-04	0.00E+00	0.00E+00	0.00E+00	1.03E-04	6.23E-05	1.68E-05	2.49E-04

Maximum occurs at under Noctdrn condition 3.04E-04

Revised Table 8-61. OVERALL CHRONIC INHALATION HAZARD INDEX DUE TO RELEASE OF HYDRAZINE, UDMH, NO2, FDH, AND DMNA DURING A DEFLAGRATION EPISODE

Rec. #	Receptor Name	Wind Bearing	WEATHER CASE							
			KONA (Worst case)	TRADE 1	TRADE 2	WEAKTR	KONA	TRAN1	TRAN2	NOCTDRN
1	Aloha Montessori Preschool	58	1.42E-01	3.40E-02	2.19E-05	1.27E-02	1.30E-01	2.34E-02	1.27E-02	1.55E-01
2	Creative Day Preschool Inc.	137	1.28E-02	1.27E-02	2.18E-05	1.27E-02	1.28E-02	1.27E-02	1.27E-02	1.50E-02
3	Keauhou Day Care - Kona	132	1.28E-02	1.27E-02	2.18E-05	1.27E-02	1.28E-02	1.27E-02	1.27E-02	2.57E-02
4	Head Start Kailua	134	1.28E-02	1.27E-02	2.18E-05	1.27E-02	1.28E-02	1.27E-02	1.27E-02	2.57E-02
5	Head Start Ka'u Home Base	58	1.42E-01	3.40E-02	2.19E-05	1.27E-02	1.30E-01	2.34E-02	1.27E-02	1.55E-01
6	Kamehameha Schools	128	1.28E-02	1.27E-02	2.18E-05	1.27E-02	1.28E-02	1.27E-02	1.27E-02	2.57E-02
7	Kona Baptist Keikiland	131	1.28E-02	1.27E-02	2.18E-05	1.27E-02	1.28E-02	1.27E-02	1.27E-02	2.57E-02
8	Kona Hongwanji Preschool	129	1.28E-02	1.27E-02	2.18E-05	1.27E-02	1.28E-02	1.27E-02	1.27E-02	2.57E-02
9	Mokuaikaua Church Nursery School	134	1.28E-02	1.27E-02	2.18E-05	1.27E-02	1.28E-02	1.27E-02	1.27E-02	1.50E-02
10	Pahala Preschool	143	2.21E-01	2.18E-05	2.18E-05	1.07E-02	1.97E-01	1.87E-01	7.00E-02	4.44E-01
11	Pali Uli Waldorf School	128	1.28E-02	1.27E-02	2.18E-05	1.27E-02	1.28E-02	1.27E-02	1.27E-02	2.57E-02
12	Salvation Army Ohana Keiki Day Care Center	134	1.28E-02	1.27E-02	2.18E-05	1.27E-02	1.28E-02	1.27E-02	1.27E-02	2.57E-02
13	University of the Nations	134	1.28E-02	1.27E-02	2.18E-05	1.27E-02	1.28E-02	1.27E-02	1.27E-02	2.57E-02
14	Sherry Alves	128	1.28E-02	1.27E-02	2.18E-05	1.27E-02	1.28E-02	1.27E-02	1.27E-02	2.57E-02
15	Maija Abaya	136	1.28E-02	1.27E-02	2.18E-05	1.27E-02	1.28E-02	1.27E-02	1.27E-02	1.50E-02
16	Trina Alapai	134	1.28E-02	1.27E-02	2.18E-05	1.27E-02	1.28E-02	1.27E-02	1.27E-02	2.57E-02
17	Joann Bishaw	126	1.28E-02	1.27E-02	2.18E-05	1.27E-02	1.28E-02	1.27E-02	1.27E-02	2.57E-02
18	Dawn Bradford	137	1.28E-02	1.27E-02	2.18E-05	1.27E-02	1.28E-02	1.27E-02	1.27E-02	1.50E-02
19	Keiki Corner	134	1.28E-02	1.27E-02	2.18E-05	1.27E-02	1.28E-02	1.27E-02	1.27E-02	2.57E-02
20	Lucy Delaries	136	1.28E-02	1.27E-02	2.18E-05	1.27E-02	1.28E-02	1.27E-02	1.27E-02	1.50E-02
21	Cammy Featherstone	133	1.28E-02	1.27E-02	2.18E-05	1.27E-02	1.28E-02	1.27E-02	1.27E-02	2.57E-02
22	Nancy Fujimoto	133	1.28E-02	1.27E-02	2.18E-05	1.27E-02	1.28E-02	1.27E-02	1.27E-02	2.57E-02
23	Pat Gibson	139	1.28E-02	1.27E-02	2.18E-05	1.27E-02	1.28E-02	1.27E-02	1.27E-02	1.50E-02
24	Chris Hagerman	134	1.28E-02	1.27E-02	2.18E-05	1.27E-02	1.28E-02	1.27E-02	1.27E-02	2.57E-02
25	Kathy Losasso Hanlon	136	1.28E-02	1.27E-02	2.18E-05	1.27E-02	1.28E-02	1.27E-02	1.27E-02	1.50E-02
26	Sandra Hanson	138	1.28E-02	1.27E-02	2.18E-05	1.27E-02	1.28E-02	1.27E-02	1.27E-02	1.50E-02
27	Debbie Hedemann	128	1.28E-02	1.27E-02	2.18E-05	1.27E-02	1.28E-02	1.27E-02	1.27E-02	2.57E-02
28	Linda Hester	136	1.28E-02	1.27E-02	2.18E-05	1.27E-02	1.28E-02	1.27E-02	1.27E-02	1.50E-02
29	Merna Kin In	136	1.28E-02	1.27E-02	2.18E-05	1.27E-02	1.28E-02	1.27E-02	1.27E-02	1.50E-02
30	B.J. Lemnah	137	1.28E-02	1.27E-02	2.18E-05	1.27E-02	1.28E-02	1.27E-02	1.27E-02	1.50E-02
31	Kristen Leorna	130	1.28E-02	1.27E-02	2.18E-05	1.27E-02	1.28E-02	1.27E-02	1.27E-02	2.57E-02
32	Barbara Legg	138	1.28E-02	1.27E-02	2.18E-05	1.27E-02	1.28E-02	1.27E-02	1.27E-02	1.50E-02
33	Gail McLeod	136	1.28E-02	1.27E-02	2.18E-05	1.27E-02	1.28E-02	1.27E-02	1.27E-02	1.50E-02
34	Lydia Pope	138	1.28E-02	1.27E-02	2.18E-05	1.27E-02	1.28E-02	1.27E-02	1.27E-02	1.50E-02
35	Inma Rittmeister	137	1.28E-02	1.27E-02	2.18E-05	1.27E-02	1.28E-02	1.27E-02	1.27E-02	1.50E-02
36	Debbie Saito	138	1.28E-02	1.27E-02	2.18E-05	1.27E-02	1.28E-02	1.27E-02	1.27E-02	1.50E-02
37	Jill Terwilliger	134	1.28E-02	1.27E-02	2.18E-05	1.27E-02	1.28E-02	1.27E-02	1.27E-02	2.57E-02
38	Alisa Vegas	139	1.28E-02	1.27E-02	2.18E-05	1.27E-02	1.28E-02	1.27E-02	1.27E-02	1.50E-02
39	Loran Victorino	128	1.28E-02	1.27E-02	2.18E-05	1.27E-02	1.28E-02	1.27E-02	1.27E-02	2.57E-02
40	Angela Walton	135	1.28E-02	1.27E-02	2.18E-05	1.27E-02	1.28E-02	1.27E-02	1.27E-02	2.57E-02
41	Jodi Walton	142	1.28E-02	1.27E-02	2.18E-05	1.27E-02	1.28E-02	1.27E-02	1.27E-02	1.50E-02
42	Patri Yamashita	134	1.28E-02	1.27E-02	2.18E-05	1.27E-02	1.28E-02	1.27E-02	1.27E-02	2.57E-02
43	Hawaii Preparatory Academy, Kona Campus	131	1.28E-02	1.27E-02	2.18E-05	1.27E-02	1.28E-02	1.27E-02	1.27E-02	2.57E-02
44	Hawaii Preparatory Academy, South Kona	128	1.28E-02	1.27E-02	2.18E-05	1.27E-02	1.28E-02	1.27E-02	1.27E-02	2.57E-02
45	Henry Opukahaia School, Kona Campus	137	1.28E-02	1.27E-02	2.18E-05	1.27E-02	1.28E-02	1.27E-02	1.27E-02	1.50E-02
46	Holualoa School	135	1.28E-02	1.27E-02	2.18E-05	1.27E-02	1.28E-02	1.27E-02	1.27E-02	2.57E-02
47	Honaunau School	126	1.28E-02	1.27E-02	2.18E-05	1.27E-02	1.28E-02	1.27E-02	1.27E-02	3.63E-02
48	Hookena School	120	1.28E-02	1.27E-02	2.18E-05	1.27E-02	1.28E-02	1.27E-02	1.27E-02	3.83E-02
49	Kahakai Elementary School	133	1.28E-02	1.27E-02	2.18E-05	1.27E-02	1.28E-02	1.27E-02	1.27E-02	2.57E-02
50	Kau High & Pahala Elementary School	143	2.33E-01	2.18E-05	2.18E-05	1.07E-02	2.10E-01	1.63E-01	5.94E-02	4.10E-01
51	Kealakehe Elementary School	136	1.28E-02	1.27E-02	2.18E-05	1.27E-02	1.28E-02	1.27E-02	1.27E-02	1.50E-02
52	Kealakehe Intermediate School	136	1.28E-02	1.27E-02	2.18E-05	1.27E-02	1.28E-02	1.27E-02	1.27E-02	1.50E-02
53	Kona Adventist School	128	1.28E-02	1.27E-02	2.18E-05	1.27E-02	1.28E-02	1.27E-02	1.27E-02	3.63E-02
54	Konawaena Elementary School	129	1.28E-02	1.27E-02	2.18E-05	1.27E-02	1.28E-02	1.27E-02	1.27E-02	2.57E-02
55	Konawaena High & Intermediate School	129	1.28E-02	1.27E-02	2.18E-05	1.27E-02	1.28E-02	1.27E-02	1.27E-02	2.57E-02
56	Naalehu School	57	1.42E-01	3.40E-02	2.19E-05	1.27E-02	1.30E-01	2.34E-02	1.27E-02	1.55E-01
57	Oceanview Estates School	79	3.62E-02	1.27E-02	2.18E-05	1.27E-02	3.61E-02	1.27E-02	1.27E-02	7.23E-02
58	University of Hawaii	129	1.28E-02	1.27E-02	2.18E-05	1.27E-02	1.28E-02	1.27E-02	1.27E-02	2.57E-02
59	University of the Nations	134	1.28E-02	1.27E-02	2.18E-05	1.27E-02	1.28E-02	1.27E-02	1.27E-02	2.57E-02
60	Kau Hospital	147	2.21E-01	2.18E-05	2.18E-05	1.07E-02	1.97E-01	1.87E-01	7.00E-02	4.44E-01
61	Kona Hospital	130	1.28E-02	1.27E-02	2.18E-05	1.27E-02	1.28E-02	1.27E-02	1.27E-02	2.57E-02
62	Hillhaven Kona Healthcare Center	131	1.28E-02	1.27E-02	2.18E-05	1.27E-02	1.28E-02	1.27E-02	1.27E-02	2.57E-02
63	Kona Adult Day Care Center	128	1.28E-02	1.27E-02	2.18E-05	1.27E-02	1.28E-02	1.27E-02	1.27E-02	2.57E-02
64	Punaluu Restaurant	77	2.44E-01	2.18E-05	2.18E-05	1.07E-02	2.21E-01	1.63E-01	5.94E-02	4.08E-01
65	Punaluu Condos	75	2.57E-01	2.18E-05	2.18E-05	1.07E-02	2.33E-01	1.40E-01	4.67E-02	3.74E-01
66	Punaluu Beach Park	73	2.44E-01	2.18E-05	2.18E-05	1.07E-02	2.21E-01	1.53E-01	5.94E-02	3.97E-01

Maximum occurs at Pahala Preschool and Kau Hospital under Noctdrn scenario 4.44E-01

Revised Table 8-68. EXCESS POPULATION CANCER BURDEN DUE TO LAUNCH ACCIDENT

	1990 Estimate	2000 Projection
Kau District Population	3,782	4,035
Cancer Risk at Pahala	4.3E-07	4.3E-07
Cancer Burden	0.0016	0.0018

Revised Table 8-69. CUMULATIVE IMPACTS OF CONFLAGRATION AND DEFLAGRATION: CANCER RISK

	ON-PAD CONFLAGRATION	DEFLAGRATION	CUMULATIVE
Pahala	0	4.3E-07	4.3E-07
Naalehu	0	1.5E-07	1.5E-07
Captain Cook	0	2.5E-08	2.5E-08

	CONFLAGRATION DURING VEHICLE ASCENT	DEFLAGRATION	CUMULATIVE
Pahala	0	4.3E-07	4.3E-07
Naalehu	0	1.5E-07	1.5E-07
Captain Cook	0	2.5E-08	2.5E-08

Revised Table 8-70. CUMULATIVE IMPACTS OF CONFLAGRATION AND DEFLAGRATION: CHRONIC HAZARD INDEX

	ON-PAD CONFLAGRATION	DEFLAGRATION	CUMULATIVE
Pahala	1.5E-05	0.44	0.44
Naalehu	1.3E-04	0.15	0.16
Captain Cook	1.5E-04	0.03	0.03

	CONFLAGRATION DURING VEHICLE ASCENT	DEFLAGRATION	CUMULATIVE
Pahala	2.4E-03	0.44	0.45
Naalehu	4.8E-04	0.15	0.16
Captain Cook	6.4E-05	0.03	0.03

hydrazine and UDMH from a vehicle tank under various weather conditions at the 66 sensitive receptor sites are listed in Tables 9-15 and 9-16, respectively. The maximum cancer risk due to hydrazine under conditions of nighttime light winds (2 m/sec) and an unmitigated spill pool area occurs at Pahala and is equivalent to 9.5×10^{-4}. The maximum cancer risk due to UDMH occurs under the same conditions at Pahala and is equivalent to 9.5×10^{-5}.

9.3 NONCANCER HAZARD INDEX ANALYSIS RESULTS

Results of the acute hazard index calculations for exposure to a receptor via inhalation of airborne emissions released during a launch vehicle fuel tank spill are shown in Tables 9-17 through 9-19 for hydrazine, UDMH, and N_2O_4. The maximum hazard index projected to occur due to a fuel tank spill of hydrazine, 10.6, occurs at Pahala under the nighttime light wind conditions and maximum spill pool area. Assuming a "mitigated" spill pool area, the acute hazard index at Pahala drops to 2.1. Under daytime conditions, the acute hazard indices at Pahala are: 2.8 assuming light winds, maximum spill pool area and 1.2 assuming moderate winds, mitigated spill pool area.

For a fuel tank spill involving UDMH, the maximum hazard index is predicted to occur at Pahala under nighttime light wind conditions and a maximum spill pool area. This value is equivalent to 2.9. Under nighttime conditions and a mitigated spill pool area, the corresponding hazard index would be 0.58. Under daytime conditions, light winds, the hazard index is 0.75 (maximum pool area) and 1.7 (mitigated pool area). Maximum hazard indices occur at Pahala due to a spill of nitrogen tetroxide would be: 7.1 for nighttime conditions, light wind, maximum spill pool area; 1.7 for nighttime conditions, light wind, mitigated spill pool area; and 1.9 for daytime conditions, light wind maximum spill pool area.

9.4 CANCER BURDEN

Excess population cancer burden is the predicted number of cancer cases added to the community or study area due to an on-site spill of carcinogenic substances. In this health risk assessment, the added cancer cases are calculated by multiplying the individual cancer risk determined for Pahala (worst case estimate) by the number of people living and working in the Kau District. The total community excess cancer burden per 70-year lifetime due to a hydrazine spill is 3.6 estimated excess cancers based

on 1990 population estimates (DBED 1990) and 3.8 excess cancers based on 2000 population projections (Table 9-20). Due to a spill of UDMH, these values would be 0.36 and 0.38, respectively.

Revised Table 9-16. CANCER RISK DUE TO RELEASE OF UDMH BY AN ACCIDENTAL SPILL OF 615 GAL. OF UDMH FROM VEHICLE FUEL TANK UNDER VARIOUS WEATHER CONDITIONS
(Inhalation Unit Risk for UDMH = 4.90E-04 (µg/m3)-1)

WIND SPEED (m/sec)		2	4	2	2
POOL AREA (m2)		2328	466	2328	466
TIME OF DAY (hr)		1200	1200	0400	0400
Rec. #	Receptor Name	Wind Bearing			
1	Aloha Montessori Preschool	58	3.8E-06	1.8E-06	3.4E-05	4.3E-06
2	Creative Day Preschool Inc.	137	0.0E+00	0.0E+00	0.0E+00	0.0E+00
3	Keauhou Day Care - Kona	132	0.0E+00	0.0E+00	0.0E+00	0.0E+00
4	Head Start Kailua	134	0.0E+00	0.0E+00	0.0E+00	0.0E+00
5	Head Start Ka'u Home Base	58	3.8E-06	1.8E-06	3.3E-05	4.3E-06
6	Kamehameha Schools	128	0.0E+00	0.0E+00	0.0E+00	0.0E+00
7	Kona Baptist Keikiland	131	0.0E+00	0.0E+00	0.0E+00	0.0E+00
8	Kona Hongwanji Preschool	129	0.0E+00	0.0E+00	0.0E+00	0.0E+00
9	Mokuaikaua Church Nursery School	134	0.0E+00	0.0E+00	0.0E+00	0.0E+00
10	Pahala Preschool	143	2.5E-05	1.0E-05	9.5E-05	1.9E-05
11	Pali Uli Waldorf School	128	0.0E+00	0.0E+00	0.0E+00	0.0E+00
12	Salvation Army Ohana Keiki Day Care Center	134	0.0E+00	0.0E+00	0.0E+00	0.0E+00
13	University of the Nations	134	0.0E+00	0.0E+00	0.0E+00	0.0E+00
14	Sherry Alves	128	0.0E+00	0.0E+00	0.0E+00	0.0E+00
15	Maija Abaya	136	0.0E+00	0.0E+00	0.0E+00	0.0E+00
16	Trina Alapai	134	0.0E+00	0.0E+00	0.0E+00	0.0E+00
17	Joann Bishaw	126	0.0E+00	0.0E+00	0.0E+00	0.0E+00
18	Dawn Bradford	137	0.0E+00	0.0E+00	0.0E+00	0.0E+00
19	Keiki Corner	134	0.0E+00	0.0E+00	0.0E+00	0.0E+00
20	Lucy Delaries	136	0.0E+00	0.0E+00	0.0E+00	0.0E+00
21	Cammy Featherstone	133	0.0E+00	0.0E+00	0.0E+00	0.0E+00
22	Nancy Fujimoto	133	0.0E+00	0.0E+00	0.0E+00	0.0E+00
23	Pat Gibson	139	0.0E+00	0.0E+00	0.0E+00	0.0E+00
24	Chris Hagerman	134	0.0E+00	0.0E+00	0.0E+00	0.0E+00
25	Kathy Losasso Hanlon	136	0.0E+00	0.0E+00	0.0E+00	0.0E+00
26	Sandra Hanson	138	0.0E+00	0.0E+00	0.0E+00	0.0E+00
27	Debbie Hedemann	128	0.0E+00	0.0E+00	0.0E+00	0.0E+00
28	Linda Hester	136	0.0E+00	0.0E+00	0.0E+00	0.0E+00
29	Merna Kin In	136	0.0E+00	0.0E+00	0.0E+00	0.0E+00
30	B.J. Lemnah	137	0.0E+00	0.0E+00	0.0E+00	0.0E+00
31	Kristen Leorna	130	0.0E+00	0.0E+00	0.0E+00	0.0E+00
32	Barbara Legg	138	0.0E+00	0.0E+00	0.0E+00	0.0E+00
33	Gail McLeod	136	0.0E+00	0.0E+00	0.0E+00	0.0E+00
34	Lydia Pope	138	0.0E+00	0.0E+00	0.0E+00	0.0E+00
35	Inma Rittmeister	137	0.0E+00	0.0E+00	0.0E+00	0.0E+00
36	Debbie Saito	138	0.0E+00	0.0E+00	0.0E+00	0.0E+00
37	Jill Terwilliger	134	0.0E+00	0.0E+00	0.0E+00	0.0E+00
38	Alisa Vegas	139	0.0E+00	0.0E+00	0.0E+00	0.0E+00
39	Loran Victorino	128	0.0E+00	0.0E+00	0.0E+00	0.0E+00
40	Angela Walton	135	0.0E+00	0.0E+00	0.0E+00	0.0E+00
41	Jodi Walton	142	0.0E+00	0.0E+00	0.0E+00	0.0E+00
42	Patri Yamashita	134	0.0E+00	0.0E+00	0.0E+00	0.0E+00
43	Hawaii Preparatory Academy, Kona Campus	131	0.0E+00	0.0E+00	0.0E+00	0.0E+00
44	Hawaii Preparatory Academy, South Kona	128	0.0E+00	0.0E+00	0.0E+00	0.0E+00
45	Henry Opukahaia School, Kona Campus	137	0.0E+00	0.0E+00	0.0E+00	0.0E+00
46	Holualoa School	135	0.0E+00	0.0E+00	0.0E+00	0.0E+00
47	Honaunau School	126	0.0E+00	0.0E+00	0.0E+00	0.0E+00
48	Hookena School	120	0.0E+00	0.0E+00	0.0E+00	0.0E+00
49	Kahakai Elementary School	133	0.0E+00	0.0E+00	0.0E+00	0.0E+00
50	Kau High & Pahala Elementary School	143	2.1E-05	8.8E-06	8.5E-05	1.6E-05
51	Kealakehe Elementary School	136	0.0E+00	0.0E+00	0.0E+00	0.0E+00
52	Kealakehe Intermediate School	136	0.0E+00	0.0E+00	0.0E+00	0.0E+00
53	Kona Adventist School	128	0.0E+00	0.0E+00	0.0E+00	0.0E+00
54	Konawaena Elementary School	129	0.0E+00	0.0E+00	0.0E+00	0.0E+00
55	Konawaena High & Intermediate School	129	0.0E+00	0.0E+00	0.0E+00	0.0E+00
56	Naalehu School	57	3.8E-06	1.8E-06	3.4E-05	4.3E-06
57	Oceanview Estates School	79	1.4E-07	2.7E-07	3.4E-06	1.6E-06
58	University of Hawaii	129	0.0E+00	0.0E+00	0.0E+00	0.0E+00
59	University of the Nations	134	0.0E+00	0.0E+00	0.0E+00	0.0E+00
60	Kau Hospital	147	2.5E-05	1.0E-05	9.5E-05	1.9E-05
61	Kona Hospital	130	0.0E+00	0.0E+00	0.0E+00	0.0E+00
62	Hillhaven Kona Healthcare Center	131	0.0E+00	0.0E+00	0.0E+00	0.0E+00
63	Kona Adult Day Care Center	128	0.0E+00	0.0E+00	0.0E+00	0.0E+00
64	Punaluu Restaurant	77	2.0E-05	8.5E-06	8.4E-05	1.6E-05
65	Punaluu Condos	75	1.7E-05	7.3E-06	7.7E-05	1.4E-05
66	Punaluu Beach Park	73	1.9E-05	8.1E-06	8.2E-05	1.5E-05
Maximum occurs at Pahala Preschool and Kau Hospital under nighttime light wind situation, pool area = 2328 m2			9.5E-05			

CANCER BURDEN

Deflagration

Excess population cancer burden is the predicted number of cancer cases added to the community or study area due to rocket exhaust emissions of carcinogenic substances. Because rocket exhaust emits no carcinogens and no risk of cancer exists due to successful launches, the cancer burden results only from launch accidents. Total community excess cancer burden per 70-year lifetime is 0.0015 estimated excess cancers due to based on 1990 population estimates and 0.0016 based on 2000 population projections. *Thus, no cancer is expected to occur in the surrounding community as a result of both successful launches and launch accidents.*

On-Site Spills

Excess population cancer burden to the study area due to an on-site spill of hydrazine is 3.6 estimated excess cancers due to rocket exhaust emissions based on 1990 population estimates and 3.8 excess cancers based on 2000 population projections. *Thus, if spills are not properly and promptly cleaned-up, an additional 3.8 cancers per spill event could occur in the surrounding community.*

CUMULATIVE IMPACTS OF ROCKET EXHAUST AND VOLCANIC EMISSIONS

The hazard index for chronic effects due to volcanic emissions based on the maximum contaminant levels detected at Captain Cook is 2.2. The chronic hazard index based on mean levels is 0.6. For acute effects the hazard indices were determined to be 0.8 based on maximum levels and 0.3 based on mean levels. Cumulative impacts of pollutants emitted during launch episodes (successful and accident) do not significantly contribute to the impacts of chronic volcano emissions. The contribution due to emissions resulting from a successful rocket launch at Captain Cook, in which the hazard index is equivalent to 0.05 for chronic effects and 0.02 for acute effects would not add significantly to the chronic and acute hazard indices due to volcanic emissions at that site of 2.2 and 0.8, respectively. Likewise, the chronic and acute hazard indices at Captain Cook due to a launch accident, 0.02 and 0.18, respectively, do not add significantly (all are less than 10%) to the hazard indices due to volcano emissions.

Revised Table 13-1. SUMMARY OF RESULTS FOR PAHALA, NAALEHU AND CAPTAIN COOK UNDER WORST CASE WEATHER CONDITIONS

PAHALA	Normal Launch	Chronic Hazard Index		0.50
		Acute Hazard Index		0.14
	Launch Accident	Chronic Hazard Index		0.45
		Acute Hazard Index		2.0
		Cancer Risk		4.3E-07
	On-Site Spill	Acute Hazard Index	Hydrazine	10.6
			UDMH	2.9
			NO2	7.1
		Cancer Risk	Hydrazine	9.5E-04
			UDMH	9.5E-05
NAALEHU	Normal Launch	Chronic Hazard Index		0.30
		Acute Hazard Index		0.11
	Launch Accident	Chronic Hazard Index		0.16
		Acute Hazard Index		0.64
		Cancer Risk		1.5E-07
	On-Site Spill	Acute Hazard Index	Hydrazine	3.8
			UDMH	1.0
			NO2	2.6
		Cancer Risk	Hydrazine	3.4E-04
			UDMH	3.4E-05
CAPTAIN COOK	Normal Launch	Chronic Hazard Index		0.05
		Acute Hazard Index		0.02
		Chronic Cumulative Impact with Volcanic Emissions		2.2
		Acute Cumulative Impact with Volcanic Emissions		0.83
	Launch Accident	Chronic Hazard Index		0.03
		Acute Hazard Index		0.18
		Chronic Cumulative Impact with Volcanic Emissions		2.2
		Acute Cumulative Impact with Volcanic Emissions		0.98
		Cancer Risk		2.5E-08
SPACEPORT WORKER	Normal Launch	Hazard Index		0.20
	Launch Accident	Hazard Index		9.1
	On-Site Spill	Hazard Index	Hydrazine	2490
			UDMH	2000
			NO2	65
EXPOSURE TO CONTAMINANTS IN DRINKING WATER RESULTING FROM WET DEPOSITION				
	Normal Launch	Hazard Index		0.17
	Launch Accident	Hazard Index		2.77
		Cancer Risk		5.8E-06
TRANSPORTATION SPILL		Hazard Index	Hydrazine	34
			NO2	510
		Cancer Risk		1.1E-04

Revised Table A-2. SUMMARY OF CHRONIC CANCER HEALTH EFFECTS OF EMITTED SUBSTANCES

Substance	MW g/gmol	Carc. Class	EPA 1992 Oral Potency Factor (µg/kg/day)-1 (ppm/day)-1 or (mg/kg/day)-1	EPA 1992 Inh. Unit Risk (µg/m3)-1 (ppm)-1	CAPCOA (OTBC 1992) Oral Potency Factor (µg/kg/day)-1 (ppm/day)-1 or (mg/kg/day)-1	CAPCOA (OTBC 1992) Inh. Unit Risk (µg/m3)-1 (ppm)-1	CAPCOA (OTBC 1992) 1.0E-06 Risk Level µg/m3 ppm	Prop. 65 (State of CA 1991) Listed	Prop. 65 (State of CA 1991) No sig. risk level µg/day µg/kg/day ppm/day	ATSDR Screening Values 1990 Inh. Value µg/m3 ppm	ATSDR Screening Values 1990 Soil Ing. µg/kg ppm	ATSDR Screening Values 1990 Soil Ing. Child µg/kg ppm
Aluminum oxide (Al2O3)	101.94											
1,1-Dimethylhydrazine (UDMH)	60.1	B2				4.9E-04 1.2E+00 Basis: development of cancer; irreversible.	2.0E-03 8.3E-07 Basis: CAPCOA inh. unit risk; irreversible.	C	NL			
Formaldehyde dimethylhydrazone	72											
Hydrazine	32.05	B2	3.0E-03 3.0E+00 Basis: hepatomas in male mice exposed via gavage to hydrazine sulfate in drinking water; irreversible.	4.9E-03 6.4E+00 Basis: nasal cavity tumors in male rats exposed to hydrazine via inh.; irreversible.		4.9E-03 6.4E+00 Basis: development of cancer; irreversible.	2.0E-04 1.6E-07 Basis: CAPCOA inh. unit risk; irreversible.	C	0.04 5.7E-04 5.7E-07 Basis: development of cancer; irreversible.	2.0E-04 1.5E-07 Basis: EPA inh. unit risk at 1 in a million excess cancer risk; irreversible.	4.0E+02 4.0E-01 Basis: EPA oral potency factor at 1 in a million excess risk; irreversible.	8.0E-01 8.0E-04 Basis: EPA oral potency factor at 1 in a million excess risk; irreversible.
Hydrogen chloride (HCl)	36.47											
Nitrogen dioxide (NO2)	46.01											
Nitrogen tetroxide (N2O4)	92.02											
Nitrosodimethylamine (DMNA)	74.08	B2	5.1E-02 5.1E+01 Basis: liver tumors in female rats exposed to DMN in drinking water; irreversible.	1.4E-02 4.2E+01 Basis: oral potency factor; irreversible.	1.6E-02 1.6E+01 Basis: development of cancer; irreversible.	4.6E-03 1.4E+01 Basis: development of cancer; irreversible.	2.2E-04 7.2E-08 Basis: CAPCOA inh. unit risk; irreversible.	C	0.04 5.7E-04 5.7E-07 Basis: development of cancer; irreversible.	6.0E-05 2.0E-08 Basis: EPA inh. unit risk at 1 in a million excess cancer risk; irreversible.	2.0E+01 2.0E-02 Basis: EPA oral potency factor at 1 in a million excess risk; irreversible.	4.0E-02 4.0E-05 Basis: EPA oral potency factor at 1 in a million excess risk; irreversible.

Table A-4. ACCEPTABLE EXPOSURE LEVELS (AELS)

Substance	MW	Short-Term 1-hour or less		Short-Term 1-24 hours		Chronic Noncancer Average Annual		Chronic Cancer	
	g/gmol	µg/m3	ppm	µg/m3	ppm	µg/m3	ppm	µg/m3	ppm
Aluminum oxide (Al2O3)	101.94	15,000	3.6	---	---	500	0.12	---	---
		Basis: 1 hr EEGL (NRC 1985) from Table A-1.				Basis: 7-day SNARL (NRC 1982) from Table A-3			
1,1-Dimethylhydrazine (UDMH)	60.1	590	0.24	26	0.01	---	---	2.0E-03	8.3E-07
		Basis: 1 hr SPEGL (NRC 1985) from Table A-1.		Basis: 24 hr SPEGL (NRC 1985) from Table A-1.				Basis: 1 in a million cancer risk based on CAPCOA 1992 inhalation unit risk; from Table A-2.	
Formaldehyde dimethylhydrazone	72	590	0.20	25	0.01	---	---	2.0E-03	8.3E-07
		Basis: assumed same as UDMH 1 hr SPEGL (NRC 1985) from Table A-1.		Basis: assumed same as UDMH 24 hr SPEGL (NRC 1985) from Table A-1.				Basis: 1 in a million cancer risk based on CAPCOA 1992 inhalation unit risk; from Table A-2.	
Hydrazine	32.05	160	0.12	6.5	0.005	---	---	2.0E-04	1.6E-07
		Basis: 1 hr SPEGL (NRC 1985) from Table A-1.		Basis: 24 hr SPEGL (NRC 1985) from Table A-1.				Basis: 1 in a million cancer risk based on CAPCOA 1992 inhalation unit risk; from Table A-2.	
Hydrogen chloride (HCl)	36.47	5,000	3	7	0.0047	7	0.0047	---	---
		Basis: 1 hr MLE (EPA 1991) from Table A-1.		Basis: Inhalation RfC (EPA 1992). from Table A-3.		Basis: Inhalation RfC (EPA 1992). from Table A-3.			
Nitrogen dioxide (NO2)	46.01	1,900	1.0	75	0.04	---	---	---	---
		Basis: 1 hr SPEGL (NRC 1985) from Table A-1.		Basis: 24 hr SPEGL (NRC 1985) from Table A-1.					
Nitrogen tetroxide (N2O4)	92.02	(Assumed N2O4 present as NO2).		(Assumed N2O4 present as NO2).		---	---	---	---
Nitrosodimethylamine (DMNA)	74.08	160	0.05	6.5	0.005	---	---	2.2E-04	7.2E-08
		Basis: assumed same as Hydrazine 1 hr SPEGL (NRC 1985) from Table A-1.		Basis: assumed same as Hydrazine 24 hr SPEGL (NRC 1985) from Table A-1.				Basis: 1 in a million cancer risk based on CAPCOA 1992 inhalation unit risk; from Table A-2.	

SECTION I: EMPLOYMENT OPPORTUNITIES

The assessments in this Section are from Decision Analysts Hawaii, Inc. (DAHI), DEIS Appendix IXA. The assumptions on which the analyses are based are found in Table 6.1.1. (See FEIS Appendix D for the OSI financial model underlying some of the assumptions).

A. CONSTRUCTION EMPLOYMENT

1.0 Basic Conditions

Improvements Required. The developed area of the launch facility is expected to cover approximately 1,000 acres, and to have about 275,000 square feet of building space. Various support businesses will be also be required - e.g., an estimated 170 hotel rooms will be required to house about 150 transient workers who will stay in Hawaii a few weeks at a time to help prepare a payload or rocket for launch, and to monitor the launch.

In addition, an estimated 180 new homes will be required to house 550 new residents who will be attracted to the Big Island to work for the launch facility or support businesses. It is expected that some of the new residents will live outside Ka`u, particularly in South Hilo and Puna.

Goods and services purchased by companies at the launch facility and by families supported by the launch facility will generate a requirement for an estimated 18,000 square feet of additional commercial and industrial space. Some of the commercial space is expected to be located outside of Ka`u, such as South Hilo.

Off-site improvements that may have to be constructed are: improvements to the HELCO transmission and distributions systems; State and County road and bridge improvements; and additional public school classrooms.

Construction Schedule. After land rights and major development permits are obtained, an undetermined amount of time will be required to negotiate major agreements among the Authority representing the State of Hawaii and the launch companies that form the Consortium. Once construction begins (which could be some years after completion of permitting and land acquisition, it is expected that it will take about 2.5 years to build the launch facility. Support facilities (hotel rooms, homes, commercial and industrial space, school rooms, etc.) are likely to lag behind the initial development until demand is demonstrated. As a result, the entire construction period for the launch facility and major support facilities is expected to take about 4 years.

Jobs. The launch facility is expected to require about 920 man-years of effort to build, which translates into an average of about 370 construction workers over the 2.5-year construction period. Peak employment is expected to reach about 600 workers. Most of the construction workers will not be on site during the entire construction phase, but only during particular phases, many of which may last only a few months.

As shown on Table 6.1.1, the total construction effort for both the launch facility and off-site construction will total about 1,600 man-years of effort, resulting in an average of

Table 6.1.1— HAWAII SPACEPORT, IMPACT ON STATE AND COUNTY REVENUES AND EXPENDITURES: ASSUMPTIONS [1]
[In 1992 dollars]

Item	Amount	
PROJECT FEATURES		
Land Area:		
Spaceport	10,400	acres
Improved Area	1,000	"
Building Space	275,000	sq. ft.
SUPPORT BUSINESSES		
Hotel Rooms (1.25 transient workers per room, 70% occupancy)	170	rooms
Commercial and Industrial (Based on sales of $150 per sf for Contract Maintenance and 9 sf of commercial space per New Resident and Visitor, but excluding supporting office and warehouse space.)	18,000	sq. ft.
CONSTRUCTION ACTIVITY		
Duration of Construction (includes support facilities)	4.0	years
Construction Costs:		
Spaceport	$ 185.0	million
New Homes (60% of the Value of New Homes)	17.3	"
Hotel Rooms (80% of the Value of Hotel Rooms)	17.0	"
Support Businesses ($125 per sf)	2.3	"
Power System Improvements	2.4	"
State and County Improvements (from Table 8-3)	8.6	"
Total Construction Costs	$ 233.0	million
Spaceport Equipment Costs:		
Fixed ("real property")	$ 200.0	million
Moveable	35.0	"
Total Equipment Costs	$ 235.0	million
Profit from Construction Activity (8% of Construction Costs) (Excludes Hawaii allocation of profit from equipment sales.)	$ 18.6	million

1. Assumptions from OSI or DAHI.

Source: Decision Analysts Hawaii, Inc., DEIS, Appendix IXA.

Table 6.1.1— HAWAII SPACEPORT, IMPACT ON STATE AND COUNTY REVENUES AND EXPENDITURES: ASSUMPTIONS
(continued)

Item	Amount	
CONSTRUCTION ACTIVITY (continued)		
Construction Effort:		
Spaceport	920	man-years
New Homes (2 man-years per New Home)	360	"
Hotel Rooms (1.5 man-years per Hotel Room)	260	"
Commercial and Industrial Space (1.2 man-years per 2,000 sf)	10	"
Power System Improvements (1 man-year per $200,000)	10	"
Government Improvements (1 man-year per $200,000)	40	"
Total Construction Effort	1,600	man-years
Construction-Related Employment (average over 3 years):		
Construction Employment	400	jobs
Support Employment (multiplier of 1.5)	600	"
Total Construction-Related Employment	1,000	jobs
Construction-Related Payroll (average over 3 years):		
Construction Payroll ($40,000 per job)	$ 16.0	million per year
Support Payroll ($25,000 per job)	15.0	"
Total Construction-Related Payroll	$ 31.0	million per year
INCREASED PROPERTY TAX BASE		
Spaceport:		
Improvements (Construction and Fixed Equipment Costs)	$ 385.0	million
Land ($10,000 per acre for the improved area, and $650 per acre for the remaining area)	16.0	"
Assessed Value of Spaceport	$ 401.0	million
New Homes:		
Value of New Homes (Average of $160,000 per home)	$ 28.8	million
Less Owner Exemption ($40,000 per home)	($7.2)	"
Assessed Value of Homes	$ 21.6	million
Hotel Rooms:		
Improvements (from Construction Costs)	$ 17.0	million
Land	4.3	"
Assessed Value of Hotel Rooms ($125 per room)	$ 21.3	million
Commercial and Industrial Space:		
Improvements (from Construction Costs)	$ 2.3	million
Land	0.4	"
Assessed Value of Support Businesses ($150 per sf)	$ 2.7	million
Total Assessed Property Value	$ 446.6	million

Source: Decision Analysts Hawaii, Inc., DEIS, Appendix IXA.

Table 6.1.1— HAWAII SPACEPORT, IMPACT ON STATE AND COUNTY REVENUES AND EXPENDITURES: ASSUMPTIONS
(continued)

Item	Amount		
HOTEL ROOM REVENUES ($100 room rate, 70% occupancy)	$	4.3	million per year
OPERATING REVENUES			
Spaceport	$	31.0	million per year
Contract Maintenance, Spaceport		2.2	"
Other Businesses (Consumption Expenditures)		18.1	"
Total Operating Revenues	$	51.3	million per year
OPERATING PROFIT			
Spaceport (45% of Spaceport Operating Revenues)	$	14.0	million per year
Other Businesses (10% of Operating Revenues, Contract Maintenance and Other Businesses)	$	2.0	"
Total Operating Profits	$	16.0	million per year
OPERATING EMPLOYMENT			
Spaceport		270	jobs
Indirect Employment in Ka'u		250	"
Indirect Employment outside Ka'u		170	"
Total Employment		690	jobs
Senior Managers and Specialists (33.3%)		230	"
Other		460	"
Average Transient Employment (Visitors)		150	jobs
OPERATING PAYROLL			
Hawaii Workers:			
Spaceport ($34,000 per job)	$	9.2	million per year
Indirect Employment ($25,000 per job)		10.5	"
Total Payroll of Hawaii Workers	$	19.7	million per year
Transient Workers ($38,000)		5.7	"
Total Payroll (subject to Hawaii taxes)	$	25.4	million per year

Source: Decision Analysts Hawaii, Inc., DEIS, Appendix IXA.

Table 6.1.1— HAWAII SPACEPORT, IMPACT ON STATE AND COUNTY REVENUES AND EXPENDITURES: ASSUMPTIONS
(continued)

Item	Amount	
CONSUMPTION EXPENDITURES		
Hawaii Workers (50% of Total Payroll of Hawaii Workers)	$ 9.9	million per year
Transient Workers ($150 per day, including per diem)	8.2	"
Total Consumption Expenditures	$ 18.1	million per year
RESIDENTS		
Residents Supported by Spaceport (2.4 people per Job)	1,650	residents
Less Residents Living in Hawaii (2.4 people per Other Job)	-1,100	"
New Residents	550	residents
New Students, Aged 5-17 (21.5%)	120	students
HOMES		
Homes Supported by Spaceport (3 people per home)	550	homes
Less Existing Homes	-370	"
New Homes	180	homes

Source: Decision Analysts Hawaii, Inc., DEIS, Appendix IXA.

about 400 construction jobs during the 4-year construction period. The number of jobs will vary over time.

Construction Salaries. Salaries for construction workers will range from about $25,000 annually to over $75,000, and are estimated to average about $40,000 per year.

2.0 Potential Impacts

Local Versus New Residents. A number of construction workers for the launch facility and support facilities could come from Ka`u--in 1987, about 160 construction workers lived in the District. In addition, a number of other construction workers will commute from other parts of the Big Island. A large number of construction workers, however, will probably come from off island, particularly workers having the specialized skills required for building a launch facility and installing specialized equipment.

Construction Worker Housing. Construction workers who already live in Ka`u, or who live within a commute distance to Ka`u, have housing, however, shelter must be secured for workers from off island. Visiting construction workers will stay in Ka`u or neighboring districts for periods ranging from as short as a few weeks to as long as a few years, depending upon the duration of the particular phase of construction they are working on.

Units potentially available to house construction workers within a 25-mile commute include: about 50 short-term rental units in Ka`u, about 290 vacant homes in Ka`u that are not used for second homes, and about 75 short-term rental units in the volcano area. The number of potentially available units in Ka`u and Volcano totals over 400 which, at double occupancy, can house over 800 people. This exceeds the number of units needed to house construction workers, since some construction workers will come from Ka`u, and a number of others will commute from outside Ka`u. In addition to the units within 25 miles from the launch site, a large number of units are available in Puna, South Hilo and North Kona.

Even with adequate supply, the construction of the launch facility may create a tighter housing market, resulting in rents being bid up for a period of 2 to 3 years--an impact similar to that which has occurred with the construction of large resorts in South Kohala. Owners of rental property will benefit while some, but not all, renters may be adversely affected. Renters who will benefit include those who will secure employment and earn more than enough to pay the higher rents.

Indirect Employment. Goods and services purchased by construction companies and their workers will support about 600 additional jobs during the 4-year construction period. This is based on an estimated 1.5 indirect jobs per construction job. Thus, construction and construction-related employment will average about 1,000 jobs during the construction phase. These jobs will be distributed throughout the economy and the County, and will range over a variety of skills and pay levels. Indirect jobs would be similar to those supported by any large construction project.

3.0 Mitigations for Potential Negative Impacts

Job Training. Training for construction workers consists of formal training programs, apprenticeship programs, and on-the-job training. It appears to be unwarranted, however, to provide special training programs to increase the number of construction workers for the launch facility since construction activity in Hawaii has shifted from a prolonged "boom" period to one of slower growth.

Housing. Measures that can be taken to mitigate the impact of higher rents caused by the construction of the launch facility include:

- o encourage developers to build the estimated 170 hotel rooms that will be needed for the projected transient workers early enough to be used by construction workers;
- o encourage developers to build the estimated 160 new homes in Ka`u that will be needed for the permanent workers at the launch facility and related businesses in time for the homes to be used by construction workers; and
- o if needed, provide temporary housing by using mobile homes.

B. PROJECT-GENERATED EMPLOYMENT AT FULL OPERATIONS

1.0 Direct Employment

Launch Facility Jobs. The launch facility is expected to create about 270 jobs. Considerable uncertainty exists, however, regarding the number of jobs: it may be higher or lower by 60 jobs, or more. Table 6.1.2 summarizes the employment provided by the launch facility once it becomes fully operational.

Salaries. Annual salaries at the launch facility will be comparatively high, ranging from a low of about $15,000 for entry-level positions to a high of nearly $90,000 for the Director, with an average of about $34,000. Salary ranges for various jobs are listed in DAHI, Appendix IXA. Only about 25 employees will earn less than the Big Island private-sector average salary of about $20,000 per year.

Types of Direct Jobs. Many different job opportunities will be available at the launch facility, and will encompass a wide variety of jobs at many different skill levels. Job categories will include laborers, semi-skilled workers, skilled tradesmen, technicians, engineers, administrators, support staff, managers, etc.

Employment Qualifications. The levels of education, skills, and job experience required for the variety of jobs that will be available at the launch facility are:

Managers, Assistant Managers, and Supervisors. Individuals filling these positions in technical areas will generally be required to have considerable experience and will normally be drawn from the ranks of trained engineers and scientists. For non-technical areas, experience would suffice as qualifications for supervisors.

Administrative Support. Personnel responsible for contracts, finance, personnel, public relations and other administrative support functions would generally have a bachelor's degree and at least 2 years' experience. Experience at a launch facility is not required.

Engineers. A BS degree in a relevant field--e.g., electrical, mechanical, aeronautical, or industrial engineering would be required for most positions. A few entry-level positions, which would require little or no experience, may be available. Engineers will typically be required to have 4 or more years' experience; senior positions require 6 or more years. Experience at a launch facility will be advantageous but not mandatory for some of the positions.

Technicians. Two years of community-college-level coursework and at least 2 years' experience would be required for most positions. A few may require little or no experience.

Table 6.1.2 LAUNCH FACILITY EMPLOYMENT AT FULL OPERATION
(Potentially higher or lower by about 25%)

Item	Ka'u	Remainder Big Island	TOTAL Big Island
Jobs by Place of Employment			
Spaceport Jobs:			
Management and Highly-Skilled Jobs [1]	150		150
Semi-Skilled and Labor Jobs	120		120
Total Spaceport Jobs	270		270
Indirect Jobs Supported by Spaceport:			
Management and Highly-Skilled Jobs [1]	50	30	80
Semi-Skilled and Labor Jobs	200	140	340
Total Indirect Jobs	250	170	420
Total Spaceport and Indirect Jobs:			
Management and Highly-Skilled Jobs [1]	200	30	230
Semi-Skilled and Labor Jobs	320	140	460
Total Jobs Supported by Spaceport	520	170	690
Workers by Place of Residence			
Management and Highly-Skilled Workers [1]	200	30	230
Semi-Skilled and Labor Workers	290	170	460
Total Workers Supported by Spaceport	490	200	690
Transient Workers (average number of visiting workers)	150		150

1. Jobs filled by workers from the mainland and other islands.

Source: Decision Analysts Hawaii, Inc., Appendix IXA (DEIS)

Experience at a launch facility would only be required for senior positions.

Office Support. Assistants, secretaries, clerks, and other office support staff require at least a high school education, although 2 years of college is preferable for some positions. Experience at a launch facility is not required.

Other Special Skills. Attorneys and medical personnel require postgraduate training. Nurses, technical writers, librarians, and training specialists generally require a college education. Graphic artists, photo processors, draftsmen, and firefighters require about 2 years of special training. Experience at a launch facility is not required.

Grounds Maintenance and Support. An apprenticeship, a trade-school or community-college education, and/or relevant experience are necessary for carpenters, plumbers, welders, electricians, heavy-equipment operators, motor vehicle mechanics and repair workers, pipefitters, painters, cooks and similar workers. Security personnel, groundskeepers, janitors, truck drivers, cafeteria workers, mail sorters and deliverers are generally not required to have special training. Experience at a launch facility is generally not required for these positions.

2.0 Transient and Indirect Employment

Transient Jobs. A number of scientists, engineers and technicians from organizations outside of Hawaii will stay in Ka`u a few weeks at time to assist in preparing payloads and launching rockets. The number of these transient workers will vary considerably over time, but the number is expected to average about 150 workers.

Indirect Jobs. In addition to direct and transient jobs, employment will be generated by Spaceport companies and employees who purchase goods and services in the area. This indirect employment is expected to total about 420 jobs, plus or minus about 100 jobs.

Types of Indirect Jobs. Indirect jobs will be distributed throughout the economy, and will include hotel workers (for an estimated 170 hotel rooms needed to house visiting workers), airport employees, dock workers, truck drivers, fabricators, warehouse workers, store clerks, restaurant employees, service station workers, medical workers, travel agents, barbers, accountants, bank employees, real estate brokers, attorneys, insurance agents, teachers, landscapers, gardeners, tree trimmers, house cleaners, painters, interior decorators, home remodelers, plumbers, etc. The jobs will range over a variety of skills, including entry-level, semi-skilled, skilled, and management positions.

C. EMPLOYMENT EFFECTS

Sources of Workers. Workers new to the County are expected to fill only about 230 of the 690 direct and indirect jobs. Most of these workers will be specialists and senior managers who will have to be recruited to help operate Spaceport and the various support businesses. The remaining 460 jobs will be semi-skilled and labor jobs, of which about 320 jobs will be located in the District of Ka`u and 140 jobs located in South Hilo, Puna, and other districts.

Workers employed at the launch facility will come from Ka`u, other parts of the Big Island, other islands, and the mainland. They will be drawn from the unemployed, recent graduates, or people who may wish to switch jobs because of better employment opportunities and/or a desire to live on the Big Island. In this last situation - where individuals transfer from existing jobs to Spaceport - job opportunities will open up at their former places of employment.

Current residents, and residents who will be attracted to Ka`u and surrounding communities for reasons unrelated to Spaceport, are expected to fill most non-specialized jobs. This is because the affected communities have, and are expected to continue to have, a supply of potential workers which exceeds the number of available jobs, even with Spaceport.

**Employment Opportunities for Ka`u Residents.** The launch facility will add an estimated 520 jobs to the District: about 270 direct jobs plus 250 indirect jobs. Residents of Ka`u (and surrounding districts) are expected to be qualified for an estimated 120 of the 270 direct jobs at Spaceport, or slightly less than half of the total number of jobs to be provided at the facility. (Ka`u residents include not only people who are already living in the Ka`u District, but also people who will move to Ka`u because of the availability of housing lots that are affordable - whether or not Spaceport is built). About 200 of the 250 indirect jobs to be located in Ka`u could be filled by current Ka`u residents. It is expected that the 50 management and highly-skilled jobs would be filled by new workers from off-island.

The estimate of 120 direct jobs available to local residents is based upon: education, experience and skill requirements; a projected labor surplus in Ka`u, even with the Project; known skill levels of Ka`u workers; and, the hiring experiences of other remote high-technology organizations in Hawaii and on the mainland. Because of the availability of local labor for non-specialist jobs, Spaceport and related activities are not expected to require a large influx of new workers.

Direct jobs available to Ka`u residents will be in grounds maintenance and support, office support and, to a lesser extent, administrative support and other special skills. Many of the employees of Spaceport can be drawn from Ka`u Ag and other sugar companies. Another major employer in the Ka`u District is the Punalu`u Resort. Many of these employees have skills that would be transferable to such Spaceport jobs as purchasing agents, cafeteria workers, groundskeepers, janitors, accountants, wastewater treatment technicians, security, office clerks, etc.

**Workers From Outside Ka`u.** Skilled labor could be drawn from the sugar operations on the Hilo and Hamakua coast since the sugar companies there are in the process of closing. A large and growing labor pool exists in Hawaii that will be appropriate for Spaceport. Many of these people will be available in Ka`u, some will come from other parts on the Big Island, and some from other islands. Others are expected to be former residents returning from the mainland.

Summary of Effects. Jobs at the launch facility will offer work at a state-of-the-art facility. The new jobs will result in higher incomes for many families, and a higher standard of living. Initially, due to the specialized nature of the work, most of the more senior administrative, engineering and technical positions will be filled by applicants who have received the requisite experience elsewhere. As the project matures, an increasing number of Hawaii residents could be promoted from within the organization to the more senior positions after they gain on-the-job experience and training.

It is expected that there will be few mainland hires for non-management and non-specialized jobs. This is partly due to the labor surplus and skills available in Ka`u and the surrounding districts, and also because local hires offer a number of advantages over mainland hires.

A large and growing labor pool exists in Hawaii that will be appropriate for Spaceport. Many of these people will be available in Ka`u (particularly from the declining sugar industry), some will come from other parts on the Big Island, and some from other islands. Others are expected to be former residents returning from the mainland.

D. RECOMMENDATIONS

Education, job training and placement programs will help Hawaii residents become qualified for the better jobs at the launch facility, help them get hired into these jobs, and then help advance into still better jobs. Programs are available from various universities, colleges, high schools, State agencies, and private organizations. In addition, the Consortium and the individual launch companies will provide appropriate programs and will also contribute to the education, training, and placement programs of other organizations.

A special program to recruit former Hawaii residents to Spaceport (particularly those from Ka`u) who are now working in high-technology positions on the mainland is not recommended: it would be expensive and difficult to target effectively. Instead, family and friends can be expected to be good conduits about job opportunities in Hawaii.

SECTION II: ECONOMIC AND POPULATION GROWTH

Impacts assessed in this Section are from DAHI, DEIS Appendix IXA. The assumptions and projections on which the analyses are based are found in Table 6.2.1.

A. ECONOMIC AND POPULATION GROWTH PROJECTIONS

Estimates of 1990 Conditions. Population and housing estimates for 1990 are from the U.S. Census. The number of jobs in the Ka`u District and the labor force living there in 1990 are estimated, based on a detailed analysis of data from the 1980 Census, the 1987 Survey by the Department of Health (DOH), the 1990 Census, and employment data from the Department of Labor and Industrial Relations (DLIR). The analysis - which was developed based on recent conditions, trends, comparisons among various communities in Ka`u, and comparisons to other districts and the entire County - addressed the number of working-age adults living in Ka`u, the estimated percentage of them who are in the labor force, the percentage who are employed, commute patterns, people per job, and workers per home.

In 1990, Ka`u housed 2,441 working-age adults, aged 18 to 64. Of this number, about 1,700 were in the labor force (70 percent), about 1,600 were working (94 percent), and about 100 commuted to jobs outside the District, leaving about 1,500 working at jobs in Ka`u.

**Primary Factors Affecting Ka`u Growth.** The projections in Table 6.2.1 reflect the following assumptions regarding the primary factors affecting growth in Ka`u:

Spaceport. Spaceport will provide about 270 permanent jobs, and require an average of 150 transient workers.

Sazale Black Sands Resort. Although optimistic, full development of 100 luxury hotel rooms and 600 new resort condominiums is assumed. If the market fails to materialize, development may cease after Phase I - 100 hotel rooms and 120 condominiums - is developed.

Hawaiian Riviera Resort. No development is assumed since this project is no longer regarded as economically feasible.

*Ka`u Agribusiness Co., Inc.* By the year 2005, it is assumed that Ka`u Ag will lose about 100 jobs. This reflects a contraction in sugar operations that is partially offset by growth in diversified agriculture. The employment loss is regarded as conservative given the possibility that sugar operations will close by 2005.

*Population Growth Independent of Ka`u Jobs.* During the 1980s, about 100 people per year moved into unimproved subdivisions in Ka`u. The main attraction was affordable lots for housing, not increased employment opportunities. This trend is expected to continue, resulting in 1,500 new residents moving into these subdivisions by the year 2005. In addition, awards of homestead lots in Ka`u to native Hawaiians by the Department of Hawaiian Home Lands will contribute to population growth.

Table 6.2.1--PROJECTED ECONOMIC AND POPULATION GROWTH FOR KA'U, WITH AND WITHOUT SPACEPORT: 1990 AND 2005

Item	1990 Actual or Estimated	Projected at Full Development: 2005			
		Increase without Spaceport	TOTAL without Spaceport	Increase from Spaceport	TOTAL with Spaceport
Primary Factors Affecting Growth					
Spaceport:					
On-site Employment, Residents				270	270
Average Transient Employment (Rocket and Payload Specialists)				150	150
Sazale Black Sands Resort:					
Hotel Rooms	0	100	100		100
Resort Condominiums	nil	600	600		600
Total Units	nil	700	700		700
Hawaiian Riviera Resort					
Hotel Rooms	0	0	0		0
Ka'u Agribusiness Co., Inc., Jobs	n.e.	-100	n.e.		n.e.
Population Growth Independent of Ka'u Jobs (Attracted to Ka'u because of cheap land)	—	1,500	—		—
Jobs Located in Ka'u					
Estimated Jobs, 1990	1,500		1,500		1,500
Spaceport Jobs:					
Management, Professional and Skilled Jobs				150	150
Other Direct Jobs				120	120
Total Direct Jobs				270	270
Indirect Jobs in Ka'u				250	250
Resort Jobs (direct and indirect):	in above	460	460		460
Agriculture jobs:					
Direct Jobs	in above	-100	n.e.		n.e.
Indirect Jobs	in above	-60	n.e.		n.e.
Jobs to Service Residents Attracted to Ka'u Because of Cheap Land	in above	300	n.e.		n.e.
Total Jobs in Ka'u	1,500	600	2,100	520	2,620
Workers Living in Ka'u					
Jobs in Ka'u	1,500	600	2,100	520	2,620
Less Commuters to Ka'u	nil	-40	-40	-30	-70
Plus Commuters from Ka'u	100	50	150	0	150
Total Workers Living in Ka'u	1,600	610	2,210	490	2,700

convenient; the private and public cost of providing an access road, water, electrical power, school facilities, police protection, fire protection, health services, etc. would be low compared to developing a project in isolation.

At Pahala, only one parcel is suitable for development of employee housing. Other parcels are too small, already developed, planted in orchards, or downwind of from the sugar mill. The parcel suitable for development is an 87-acre parcel east of the town owned. The parcel is in the State "Urban" District, however, it does not as yet have County "Residential" zoning.

As demand develops, C. Brewer plans to develop 250 to 300 homes on this parcel for employees of Spaceport and/or new resort development. This housing project would be sufficiently large to accommodate "market" and "affordable" housing needs. Given the market conditions in Ka`u, the prices of new homes will have to be reasonably affordable in order to attract buyers. C. Brewer is also amenable to pursuing a joint venture with the State. Low-cost housing could be provided by C. Brewer in exchange for State financing at below-market interest rates and exemption from the State excise tax.

Other lands potentially available for development include undeveloped Bishop Estate lands on the western side of Pahala, provided that the nearby sugar mill closes. In Na`alehu, considerable in-fill land is available, all of which is owned by C. Brewer; housing has been planned for the larger parcels. In addition, State land is available about one-third mile east of Na`alehu.

4.0 Impacts of Spaceport on the Ka`u Housing Market

Impact on Supply. With regard to existing homes in Ka`u, Spaceport is expected to have little or no impact on housing prices, property values, or property taxes because the required 160 new homes required for employees of Spaceport and related activities can be supplied by a relatively modest housing project without creating an imbalance between supply and demand. Furthermore, 160 new homes represents only about 22 percent of the demand for new homes that is projected for the District by the year 2005.

Most important, however, the enormous supply of unimproved housing lots in Ka`u will keep the prices of homes relatively low and affordable, even those homes on lots having full improvements.

Impact on Land Values. In order to insure public safety, owners of land located within the PCZ will not be permitted to build homes or most other structures - except for those structures which are part of Spaceport or an agricultural activity. The resulting loss in development potential will result in lower land values, thereby adversely affecting landowners. However, the loss in value is expected to be small since the area is not subject to development pressure, and development approvals are lacking. Whatever the loss in land values, the adverse impact can be mitigated by paying landowners for their losses.

Outside the PCZ, land values generally will not be affected. However, there could be exceptions, particular for the limited amount of commercial and industrial land near Spaceport. Because of increased demand, these properties could increase in value somewhat, thereby benefiting the landowners. For each $1,000 increase in land values, property taxes will increase by $10 per year, based on 1991/1992 tax rates.

Need For State-Sponsored Housing Project. A State-sponsored housing project to supply homes for low-income workers of Spaceport appears unwarranted for the following reasons:

- Spaceport jobs will be provided in an environment of labor surpluses, with many jobs being filled by workers already owning or renting homes.
- Most Spaceport jobs will pay well, particularly for employees who will be new to the District and in need of housing.
- The jobs will be provided in an environment of affordable homes provided by the private market.
- Needed affordable housing can be provided as part of a joint venture with a private developer.

Appropriate State programs to assist development of affordable housing by private developers are discussed in DEIS Appendix IXA.

D. SUMMARY OF SPACEPORT EFFECTS ON THE KA'U HOUSING MARKET

In summary, the demand for new homes in Ka`u created by both Spaceport and resort development at Punalu`u is expected to prompt the development of a housing project abutting Pahala, and possibly another project in Na`alehu if demand warrants. Housing in these towns would provide opportunities for new families to integrate into an existing community having schools, police and fire protection, stores, services, etc. Given the market conditions in Ka`u, the prices of new homes will have to be reasonably affordable in order to attract buyers.

Most of the new families attracted to Ka`u by Spaceport will be able to afford market-priced homes since they will have comparatively high incomes, and housing prices in Ka`u are low in comparison to other communities in Hawaii; a special affordable-housing project for Spaceport workers is not warranted. Only about 25 employees of Spaceport are expected to earn incomes below the County average wage; in most cases, these lower-income jobs will provide supplemental income for families who are already living in Ka`u. Any affordable housing that is needed can be provided through a joint venture between the State and a private developer, whereby the State provides a low-interest construction loan and an excise-tax exemption to the developer in exchange for the needed number of homes priced below market.

SECTION III: STATE AND COUNTY REVENUES AND EXPENDITURES

Impacts assessed in this Section are from DAHI, DEIS Appendix IXA. The assumptions for the analyses presented in this Section are listed on Table 6.1.1.

A. ESTIMATED COUNTY AND STATE REVENUES FROM SPACEPORT

Table 6.3.1 shows projected taxes and other government revenues to be generated by Spaceport and related activities. The combined State and County revenues during full operation are expected to total $10.7 million per year.

1.0 County of Hawaii

Rollback Taxes From Land Development. When the launch site property is developed, about $100,000 in "rollback" taxes will become due to the County of Hawaii. Rollback taxes are levied when land which has been assessed and taxed at its agricultural value is subsequently developed. This tax recovers 10 years of back property taxes based on the difference between taxes computed on the market assessment and the agricultural assessment, plus a penalty of 10 percent.

Revenues From Spaceport Activities. County revenues from Spaceport at full development are expected to reach about $4.2 million per year, with $3.8 million of this being derived from property taxes and about $200,000 derived from hotel-room taxes collected by the State but returned to the County. The remaining $200,000 per year derives from a variety of sources related to population. This last revenue estimate, which is estimated at $295 per new resident and visitor, is based on a detailed analysis of County finances. Currently, the County derives about $6,000 per year from property taxes on the 1,000 acres planned for development.

2.0 State of Hawaii

Revenues From Construction Activities. Construction activity is expected to generate a total of about $23.8 million in excise and corporate-income tax revenues to the State of Hawaii during the 4-year construction period. Additional construction-related revenue to the State will come from individual income taxes; these revenues are not estimated since they are largely offset by State services in support of these workers.

Revenues From Spaceport Activities. At full development of the Spaceport, the increase in State tax and other revenues is expected to be about $6.5 million per year, with the largest revenues being derived from: (a) excise taxes of about $2.8 million per year based on a rate of 5.5 percent with (pyramiding) applied to operating revenues; (b) hotel-room taxes of about $200,000 per year based on 5 percent of hotel-room revenues (taxes which are collected by the State and returned to the County); (c) corporate income taxes of about $1.0 million per year based on a rate of 6.4 percent; and, (d) personal income taxes of about $1.4 million per year based on a rate of 5.5 percent. The remaining $1.1 million per year in State revenues derives from a variety of sources related to population. These revenues, which are estimated at $1,610 per new resident and visitor are based on a detailed analysis of State finances. (See DEIS Appendix IXA for a discussion of this revenue source). In addition, the State will derive lease

Table 6.3.1— HAWAII SPACEPORT, IMPACT ON STATE AND COUNTY REVENUES AND EXPENDITURES: REVENUES
[In 1992 dollars]

Item	Amount		
COUNTY			
Rollback Taxes ($50 per acre)	$	0.1	million
Full Development:			
Property Taxes (rates per $1,000):			
Spaceport ($8.50 for improvements, $10 for land)	$	3.4	million per year
Homes ($7 for both improvements and land)	$	0.2	"
Hotel Rooms ($8.50 for improvements, $10 for land)	$	0.2	"
Support Businesses ($8.50 for improvements, $10 for land)	$	0.0	"
Total Property Tax Revenues	$	3.8	million per year
State Grant of Hotel Room Tax (State tax of 5% of Hotel-Room Revenues returned to Counties)		0.2	"
Other Revenues ($295 per New Resident and per Visitor)		0.2	"
Total County Revenues	$	4.2	million per year
STATE			
Construction Activity:			
Excise Taxes:			
Construction (5.5% with pyramiding)	$	12.8	million
Equipment (4.17%)		9.8	"
Total Excise Taxes	$	22.6	million
Corporate Income Taxes (6.4%)	$	1.2	"
Personal Income Taxes, Construction Workers		n.e.	
Support Expenditures, Construction Workers		n.e.	
Net Tax Revenues from Construction Activity	$	23.8	million
Full Development:			
Land Rent	$	n.e.	million per year
Excise Taxes, Operating Revenues (5.5% with pyramiding)		2.8	"
Hotel Room Taxes (5% of Hotel-Room Revenues)		0.2	"
Corporate Income Taxes (6.4% of Profits)		1.0	"
Personal Income Taxes (5.5% of Household Income)		1.4	"
Other Revenues ($1,610 per New Resident and per Visitor)		1.1	"
Total State Revenues	$	6.5	million per year
TOTAL STATE AND COUNTY REVENUES (Excluding County Rollback Taxes and State Taxes on Construction Activity)	$	10.7	million per year

Source: Decision Analysts Hawaii, Inc., DEIS, Appendix IXA.

rent from the property, however, this will be offset by debt service incurred for purchasing rights to the property. Currently, the State derives negligible tax revenues from activities on the property.

B. ESTIMATED COUNTY AND STATE EXPENDITURES IN SUPPORT OF SPACEPORT

Estimates for County and State expenditures required to support the Spaceport project are given in Table 6.3.2.

1.0 Expenditures for Capital Improvements

County of Hawaii. No County capital improvements in direct support of Spaceport will be required. All on-site and some off-site infrastructure and other capital improvements required to develop and operate Spaceport will be provided by the Consortium. This will include interior roads, water development and a distribution system, drainage, collector sewers and trunks, wastewater treatment facilities, a fire station, a security building, a medical building, a helipad and hanger, etc.

In addition, no major capital improvements by the County are anticipated to support the estimated 550 new residents resulting from Spaceport, plus an average of about 150 transient workers. Most new residents are expected to be housed in existing housing or in a new subdivision in Pahala; while most visitors are expected to stay at or near Punalu`u. Developers of housing and resort projects generally provide such on-site improvements as interior roads, a water distribution system, drainage, and wastewater collection and disposal.

Even though no major capital improvements are anticipated to support new residents and visitors, an allowance of about $600,000 is assumed for new facilities. This amount is based on $800 per new resident and visitor, which is the approximate per capita debt for improvements that are currently being financed by the County. Given current facilities in Ka`u, this estimate is regarded as high.

State of Hawaii. The State will be responsible for most off-site infrastructure in support of Spaceport. However, the requirements are modest. Existing airport and harbor facilities appear to be adequate, with no improvements required for Spaceport. Some of the bridges between Hilo and Ka`u may need to be reinforced to handle the load of the heaviest rockets. To cover this cost, an allowance of $1 million is assumed. It is possible that no expenditure will be required, however, since the heaviest component currently anticipated, a GEM solid rocket motor which is strapped on to Delta rockets, weighs 14 tons, while the legal limit of the bridges is 36 tons.

Although not anticipated, the cost of bridge improvements could increase over time to $6 million if the Thiokol Castor 120 rocket motor is used to power a new type of rocket that would be launched from Spaceport. This new rocket motor weighs approximately 60 tons, and is carried on a 9-axle tractor/trailer which has an 9 ton-per-axle distribution. Although shipments of the Caster 120 would be infrequent (about once a month if this rocket is used), the heavy load would gradually weaken the bridges between Hilo and Ka`u, and they would eventually have to be reinforced.

Mamalahoa Highway will require drainage improvements. During heavy rains, the highway is closed because of flooding. Culverts and related improvements will cost an estimated $4 million.

The cost of improvements required to deliver electrical power to the launch site will be

Table 6.3.2— HAWAII SPACEPORT, IMPACT ON STATE AND COUNTY REVENUES AND EXPENDITURES: EXPENDITURES
[In 1992 dollars]

Item	Amount		
LAND COST	$	n.e.	million
MAJOR CAPITAL IMPROVEMENTS			
County:			
Spaceport: no County support facilities required	$	0.0	million
New Residents and Visitors:			
No major County support facilities anticipated, but an allowance of $800 per New Resident and Visitor		0.6	"
Total County Capital Improvements		0.6	million
County Annual Debt Service (9.1%, based on 6.5%, 20-year bond)		0.1	million per year
State:			
Spaceport:			
Bridge Improvements	$	1.0	million
Road Improvements to Control Flooding		4.0	"
Power System Improvements ($2.4 million paid by State, but reimbursed by HELCO over 5 years of electricity use)		0.0	"
New Residents and Visitors:			
School Improvements (25 students per classroom, and $350,000 per classroom and associated improvements)	$	1.7	"
No additional State support facilities anticipated, but an allowance of $1,840 per New Resident and Visitor	$	1.3	"
Total State Capital Improvements	$	8.0	million
State Annual Debt Service (9.1%, based on 6.5%, 20-year bond)	$	0.7	million per year
Total State and County Annual Debt Service	$	0.8	million per year
SERVICES, FULL DEVELOPMENT			
County ($600 per New Resident and per Visitor)	$	0.4	million per year
State:			
Hotel Room Tax Returned to County	$	0.2	million per year
Other ($2,590 per New Resident and $1,020 per Visitor)		1.6	"
Total State Services	$	1.8	million per year
Total State and County Services	$	2.2	million per year

Source: Decision Analysts Hawaii, Inc., DEIS, Appendix IXA.

about $2.4 million. This cost, which covers a switching station at Pahala, a transmission line to Spaceport, and a new substation, will initially be paid by the State, but will be reimbursed by HELCO over a 5-year period based on electricity usage. Ultimately, the Consortium and launch companies at Spaceport will pay for the improvements through their electric rates.

Except for school improvements, no major capital improvements by the State are anticipated in support of new residents and visitors due to Spaceport. School improvements are estimated to cost about $1.7 million. This is based on 120 students aged 5 to 17, 25 students per classroom, and $350,000 per classroom and associated improvements. However, this estimate may be high since the Department of Education favors the use of impact fees to finance school improvements. If applied to a new housing project in Ka`u, then the developer would provide a major portion of the funds for school improvements.

In addition, an allowance of about $1.3 million is assumed for new facilities in support of new residents and visitors. This amount is based on $1,840 per new resident and visitor, which is the approximate per capita debt for improvements that are currently being financed by the State. Given current facilities in Ka`u and the provisions for school improvements, this estimate is regarded as high.

For the State, the estimated cost of highway improvements, school improvements, and other support facilities totals $8 million. Assuming a 6.5 percent, 20-year bond, the debt service on this amount will be about $700,000 per year.

2.0 Estimated Expenditures for County and State Services

At full development, County and State expenditures on the services needed to support the new residents and visitors due to Spaceport is estimated to be $2.2 million per year. Annual expenditures for the County are estimated at $400,000. For the State, annual expenditures are estimated at $1.8 million, including about $200,000 in hotel-room taxes collected by the State but returned to the County. The remaining $1.6 million per year is based on annual expenditures for services of about $2,590 per new resident and $1,020 per new visitor; the higher cost for residents largely reflects education expenditures.

County and State expenditures on services are expected to provide approximately the same level of per-unit services to residents and visitors as is currently the case, or possibly more, given economies of scale (e.g., a 10-percent increase in population is likely to require an increase in general government of much less than 10 percent). The expenditures cover "general government," public safety, health, sanitation, education, culture and recreation, water, highways and streets, public transportation, economic development, housing, etc.

C. NET EFFECTS ON STATE AND COUNTY REVENUES AND EXPENDITURES

The net effects on County and State revenues and expenditures of the proposed Spaceport project are summarized in Table 6.3.3. In the case of the County, rollback taxes due to the withdrawal of the land from agriculture will amount to about $100,000. At project completion, revenues to the County are expected to exceed expenditures by $3.7 million per year. For the State, revenues generated by construction activity are estimated to generate $23.8 million. Upon completion of the project, State revenues are expected to exceed expenditures by about $4 million per year. The resulting combined fiscal impact on the County and State is that revenues are expected to exceed expenditures by an estimated $7.7 million per year.

Table 6.3.3— HAWAII SPACEPORT, IMPACT ON STATE AND COUNTY REVENUES AND EXPENDITURES: SUMMARY
[In 1992 dollars]

Item	Amount		
COUNTY:			
Rollback Taxes	$	0.1	million
Full Development:			
Revenues	$	4.2	million per year
Expenditures:			
Debt Service	$	0.1	million per year
Services	$	0.4	"
Total County Expenditures	$	0.5	million per year
Net County Revenues	$	3.7	million per year
STATE:			
Taxes on Construction Activity	$	23.8	million
Full Development:			
Revenues	$	6.5	million per year
Expenditures:			
Debt Service	$	0.7	million per year
Services		1.8	"
Total State Expenditures	$	2.5	million per year
Net State Revenues	$	4.0	million per year
STATE AND COUNTY, Full Development:			
Revenues	$	10.7	million per year
Expenditures		3.0	"
Net State and County Revenues	$	7.7	million per year

Source: Decision Analysts Hawaii, Inc., DEIS, Appendix IXA.

Construction and operation of the launch facility are expected to strengthen County and State finances by providing significant income. Annual revenues to be derived from this project are expected to be sufficient to finance highway, school and other improvements; provide the same level of per-unit services as are provided currently to island residents and visitors; and, serve additional community needs with the remaining $7.7 million per year in net revenues.

SECTION IV: OTHER ECONOMIC EFFECTS

A. AGRICULTURE

1.0 Agricultural Activities in the Ka`u District

Sugar. In recent years, sugar operations in the District have been declining as the poorer quality lands have been withdrawn from sugarcane. In 1991, Ka`u Agribusiness Company, Inc. (Ka`u Ag) had 12,559 acres in sugarcane, and produced 50,818 tons of raw sugar. This compares with 16,043 acres and 64,841 tons as recently as 1987. As of late 1992, the company employed approximately 275 sugar workers, compared to 430 workers in 1987. The plantation remains the largest employer in the Ka`u District.

Low sugar prices have caused a major and continuing contraction of Hawaii's sugar industry. Because of these low prices, the sugar operations of Ka`u Ag have an uncertain future, as is the case with most other sugar plantations in Hawaii. Sugar operations may survive for a number of years, but with declining employment. By the end of the decade, however, it is possible that sugar operations will no longer exist in the Ka`u District.

Macadamia Nuts. C. Brewer pioneered the development of macadamia nuts into a profitable industry in Hawaii. The gross land area converted to macadamia nut orchards totals 5,300 acres in Ka`u, with a net of 3,600 of these acres in trees. If sugar operations close, about one-third of the lands are expected to be replanted in macadamia nuts and other crops, with the remaining lands being used for grazing cattle.

The cultivation and harvesting of macadamia nuts provides significant employment, about 210 jobs for C. Brewer's Ka`u operations in 1992, including full time, intermittent and seasonal workers during the 10-month harvesting period. The macadamia nut industry also provides jobs to Ka`u residents who commute to farms in South Kona. Mac Farms of Hawaii, Inc. employs an estimated 20 regular and 140 seasonal workers who live in Ka`u.

Other Crops. C. Brewer has explored and is continuing to explore various crops as potential replacements for sugarcane in Ka`u. In addition to macadamia nuts, other crops grown and/or test-marketed by Ka`u Ag include oranges (28 acres), mangoes (5 acres irrigated with mill waste water), and tea. Other crops grown in Ka`u on a limited scale include bananas, avocados, papaya, tomatoes, and flowers.

Modest employment growth is anticipated in diversified agriculture crops other than macadamia nuts. A profitable crop that uses considerable acreage would probably replace sugarcane and accelerate the demise of sugar operations.

Cattle. Several cattle ranches are spread out over vast acreages of grazing lands, but provide relatively little employment. Kawaihae Ranch, which includes land at Palima Point, covers about 25,000 acres, has 5,000 head of beef cattle, and employs five workers. Similarly, Kahuku Ranch covers 11,000 acres, has 2,500 head of cattle, and employs eight workers. Other smaller ranches also operate in the District. If sugar operations close, about two-thirds of the fields could be used for grazing. Ranch employment, however, would be small.

Dairy Operations. S & S Dairy manages close to 900 head of cattle on about 1,200 acres of land in Na`alehu, including about 325 milking cows, and employs 10 workers. The dairy plans to move its operation onto about 1,600 acres of land at Palima Point, and plans to expand its operation to 600 or more milking cows. The land is now used by Kawaihae Ranch for grazing cattle.

2.0 Agriculture at the Palima Point Site

Existing and Planned Uses. Most of the 10,400 acres required for the launch facility are currently in the State Agricultural District (Figure II-4.3), including the 1,000 acres planned for development. Within the PCZ, about 600 acres of land near Pahala are planted in macadamia nut orchards, and about 5 acres are planted in an experimental mango orchard. In addition, about 3,800 acres are being used for grazing cattle, however, there are plans to use about 1,600 of these acres as a dairy. Also, tailwaters from the sugar mill flow onto lands within the PCZ. About 6,000 acres, formerly used for grazing cattle, are vacant.

Agronomic Conditions. The affected acreage at Palima Point consists primarily of ten soil types, which are listed on Table 6.4.1 and discussed in DEIS Appendix IXA. About 93 percent of the project area has rocky soils. The table also shows typical agricultural uses for each soil type. As indicated, about 77 percent of the area is unsuited for agriculture, about 21 percent is suited for pasture, and less than 2 percent is suited for sugarcane.

Soil Types and Ratings. The soils within the project area have been rated in terms of four classification systems commonly used in Hawaii. These classification systems are discussed in DEIS Appendix IXA; the ratings of the soils at Palima Point are provided in Table 6.4.2. As indicated in the Table, about 93 percent of the soils at Palima Point are rated VI or below by the Soil Conservation Service. Class VI soils have very severe limitations that reduce the choice of crops, require very careful management, or both. The best soil is Fill Land (FL) (Figure III-2.4) which was deposited from the tailwaters of the sugar mill at Pahala; it comes from the mud that is washed off the sugarcane before grinding.

Under the Agricultural Lands of Importance in the State of Hawaii (ALISH) ratings, approximately 15 acres, or 1/10 of 1 percent of the land in the entire area, is rated as "prime" agricultural land, about 10 percent is rated as "other" agricultural land. The remaining land is unrated. No land is rated as "unique."

The Overall Productivity Rating, by the UH Land Study Bureau (LSB) rates soils according to five levels, with "A" representing the class of highest productivity and "E" the lowest. No land in the petition area has the highest rating of "A," less than 2 percent has soils rated "B," nearly 12 percent is rated "C," nearly 11 percent is "D," and about 76 percent has the lowest rating of "E."

The Proposed Land Evaluation and Site Assessment (LESA) System, which is based on soil quality, locational attributes, improvements, nearby activities, and land-use plans, would designate a sufficient amount of the better agricultural lands to meet projected agricultural goals. If the LESA classification approach were applied to the proposed site, about 9 percent of the designated lands would be termed "important agricultural lands" (IAL), which would include all lands having a rating of 45 or above, out of a possible total of 100.

These four soil rating systems indicate that only about 10 percent of the project area has good soils.

Climatic Conditions. The project site is in an area which receives a moderate amount of

Table 6.4.1 **PALIMA POINT: SOIL TYPES, ACREAGES AND AGRICULTURAL USES**

	Soil Type	Approximate Acreage		Agricultural Uses
FL	Fill Land	556	5.3%	Pasture
NaC	Naalehu Silty Clay Loam 0 to 10% Slopes	11	0.1%	Sugarcane Pasture
NaD	Naalehu Silty Clay Loam 10 to 20% Slopes	160	1.5%	Sugarcane
RB	Rough Broken Land	21	0.2%	Pasture
rCL	Cinder Land	21	0.2%	None
rKED	Kaimu Extremely Stony Peat 6 to 20% Slopes	362	3.5%	None
rLV	Lava Flows, Aa	2,148	20.7%	None
rLW	Lava Flows, Pahoehoe	5,509	53.0%	None
rPYD	Punaluu Extremely Rocky Peat 6 to 20% Slopes	1,234	11.9%	Pasture
WKD	Waiaha Very Rocky Silt Loam 10 to 20% Slopes	380	3.7%	Pasture
		10,401	100.0%	

This assumes that the soils are not irrigated, except FL which is irrigated.

United States Department of Agriculture, Soil Conservation Service. *Soil Survey of Island of Hawaii, State of Hawaii.* December 1973.

Source: DAHI, Appendix IXA (DEIS)

Table 6.4.2 **PALIMA POINT: SOIL RATINGS AND ACREAGES**

Rating	Soil Type	Approximate Acreage	
SCS:[1]			
IIe	FL	556	5.3%
IIIe	NaC	11	0.1
IVe	NaD	160	1.5
VIs	WKD	380	3.7
VIIe	RB	21	0.2
VIIs	rPYD	1,234	11.9
VIIIs	rKED,rLV,rLW	8,039	773
		10,401	100.0%
ALISH:			
Prime	Not applicable	15	0.1%
Other	"	1.053	10.1
Not rated	"	9,333	89.7
		10,401	100.0%
LSB:			
B	Not applicable	151	1.4%
C	"	1,224	11.8
D	"	1,104	10.6
E	"	7,923	76.2
		10.401	100.0%
LESA:			
Important Ag Lands (IAL)	NaC(86)[2], NaD (73) rKED(50), WKD (49)	913	8.8%
Not IAL	FL,RB,rCL,rLV,rLW,rPYD	9,488	91.2
		10,401	100.0%

[1] Assuming that the soils are not irrigated, except FL which is irrigated.
[2] The number in parentheses after the soil type indicates the LESA rating. Any rating above 45 is considered "Important Agricultural Lands."
United States Department of Agriculture, Soil Conservation Service. *Soil Survey of Islands of Hawaii, State of Hawaii.* December 1973.

Source: DAHI, Appendix IXA (DEIS)

sunshine, with solar insolation of about 400 calories per centimeter. Rainfall at Palima Point averages about 40 inches per year, too low for growing crops without supplemental irrigation.

Availability of Irrigation Water. Water is available on the project site to irrigate orchards and to provide for the needs of cattle. Beyond this, however, an abundant supply of low-cost irrigation water is not available.

3.0 Potential Effects of the Project on Agriculture

Agricultural Activities Outside The PCZ Outside the PCZ, Spaceport will not adversely affect Ka`u Ag sugar operations. As with the sugar operations, Spaceport will not adversely affect any other agricultural operations outside the PCZ.

Agricultural Activities Within The PCZ. The Spaceport project may have effects on the following activities:

Sugar. Culverts will have to be provided in order to allow tailwaters from the Pahala mill to flow under the Spaceport roads.

Macadamia Nuts. About 600 acres of mature macadamia nut orchards are located within the PCZ. Some of these orchards are owned by the New Hawaii Macadamia Nut Company, Inc. which owns some of the land, but also leases some land from Bishop Estate. Other orchards and land within the PCZ are owned by the International Air Service Company, Ltd. (IASCO).

When Spaceport begins operating, modifications to orchard operations within the PCZ will be necessary. Immediately before and during the launching of the larger rockets, the orchards will have to be cleared of workers. Large harvest crews of 200 or more people will have to be paid even though they will be idle due to the launches. This will occur about once a month during the 10-month harvest season for about a 2-hour period. Night and weekend launches will not disrupt harvesting.

The economic impact of these launch-related restrictions could be mitigated by having the Consortium absorb the labor costs for workers who must be idle due to launch operations. The cost could exceed $50,000 per year.

Mango Operations. Ka`u Ag has established an experimental mango orchard on about 5 acres of unused land within the PCZ that are covered with soils deposited by the tailwaters from the sugar mill. A variety of trees were planted in an attempt to establish a year-round harvesting operation using special techniques to ripen the fruit. If it is successful, the orchard can be expanded to as much as 100 acres.

As with macadamia nuts, the mango orchard will have to be cleared of workers immediately before and during the launching of the larger rockets. This will occur about once a month for about a 2-hour period.

Dairy Operations. S&S Dairy plans to relocate its operation from Na`alehu onto about 1,600 acres of land located between Pahala and Punalu`u, abutting Mamalahoa Highway and makai of it. Land for the dairy falls primarily within the PCZ, but is also adjacent to it.

Dairy facilities will include a milking barn for 20 cows, a milk room with tanks for storing the milk, a barn for storing feed, a feeding area for cows, and five homes. The main facilities will be located near the highway about 1-1/2 miles from the main entrance to Pahala - a location as far removed from the resort operations at Punalu`u as the parcel allows.

The dairy plans to increase the number of milking cows from 325 to 600 or more at the Palima site. At the new site, the dairy will employ about a dozen workers, with about 4 or 5 working at any one time.

The cows are milked on a 12-hour schedule, once in the morning then again in the evening - this daily schedule must be maintained or the cows will drop their milk. Each cow will require about 45 to 50 gallons of water per day, a portion of which will be used to wash the cow before milking. Alfalfa may be grown to help feed the herd, in which case the crop will be irrigated with water recovered after washing the cows.

The impact of launch facility operations on S&S Dairy has not been fully determined. Milking and other operations can continue uninterrupted without risk to workers inside the dairy facilities if these structures are designed and built to withstand an accidental explosion on a launch pad 2.9 miles or more away. These facilities will be located on the edge of the PCZ, or just outside it if the distance to the highway allows this.

A few dairy workers must remain in the PCZ during daylight hours to tend the cows and herd them to the milking barn; it will not be practical for them to stop herding the cows to leave the PCZ during the occasional rocket launches since scheduled milkings would be missed. In turn, deliveries would be missed, and S&S Dairy would become known as an unreliable supplier, resulting in a loss of market share to competitors.

It may be possible to keep dairy workers within the PCZ and protect them from an accidental explosion on the launch pad by providing a number of strategically located safety shelters throughout the dairy lands. Sirens, flags, and portable radios could be used to provide notice about when to seek shelter, and when it is safe to resume work. The disruption of herding operations could be reduced to a period of about one-half hour. This period would have to be extended, however, if a rocket launch is delayed.

Ranch Operations. Due to the scheduled loss of land to the dairy and past acreage withdrawals by private landowners, grazing will occupy only about 2,000 acres in the PCZ. This land, which is leased from the State, forms a portion of the 25,000-acre Kawaihae Ranch which has about 5,000 head of cattle and five employees. Kawaihae Ranch lands are in various locations around Ka`u. The current herd at Palima Point numbers about 300 head, and generates annual revenues of about $90,000 per year.

The proposed launch facility will adversely affect the grazing operations. If Spaceport is not built, then the herd of approximately 300 head of cattle currently grazing within the PCZ will be increased to about 1,500 head, generating revenues of about $450,000 per year. Under these circumstances, employment at Kawaihae Ranch would increase by two workers to a total of seven.

If the project is developed, then grazing within the project area would be discontinued because of the difficulty and expense of containing the cattle on the affected lands, resulting in total ranch employment remaining unchanged at five workers.

4.0 Potential Effects of Resource Loss on Diversified Agriculture

The development of Spaceport will result in a resource loss of about 1,000 acres of agricultural land. This loss is not expected to adversely affect the growth of diversified agriculture for two reasons. First, the lands which are likely to be developed are poorly suited for growing commercial crops because of very poor soils over most (but not all) of the area, and the area lacks an abundant supply of low-cost irrigation water (DEIS Appendix IXA).

Second, ample land and water for diversified agriculture are available elsewhere in the State due to contractions in the sugar and pineapple industries. Although some of the land which has been freed from sugar and pineapple production has been or is scheduled to be converted to urban, diversified agriculture, and other uses, uncommitted acreage remaining available to diversified agriculture amounts to about 130,000 acres. Much of this land is or will soon be fallow, in pasture, or in some other low-value land-holding operation.

The Statewide supply of fallow prime agricultural land is likely to increase given the real possibility of future sugar plantation closings. Some of Hawaii's sugar plantations are unprofitable but remain in operation today only because they are committed to lease and/or energy contracts which make closing prohibitively expensive. However, these contracts will eventually come to an end.

In summary, the limiting factor to the growth of diversified agriculture is not the land supply, but rather the market demand for those crops that can be grown profitably in Hawaii. Spaceport will result in the development of far too little agricultural land to affect this conclusion, and will therefore not affect adversely the Statewide growth of diversified agriculture.

B. TOURISM

1.0 Existing and Projected Tourism Activity

Existing Conditions. Ka`u has a very small visitor industry. The largest center is The Punalu`u Resort. Components of the resort include 76 condominiums, 19 lots for single-family homes, an 18-hole golf course and clubhouse, the Black Sands Restaurant, tennis courts, retreat conference facilities (the Aspen Institute) and the Ka`u Center of History and Culture. About 35 condominium units are available for short-term rentals. The project employs about 70 people, most of whom work for the restaurant and golf course. The 13-room Shirakawa Motel, built in 1926, and a 2-unit Bed & Breakfast establishment, Islands's End, are also located in Ka`u.

In addition, the 37-unit Volcano House on the rim of Kilauea Caldera is located in the Ka`u District, although it is far from the towns and residential areas of Ka`u, and much closer to those of Puna. In 1987, an estimated 70 Ka`u residents commuted to jobs with the Volcano House, the National Park Service, and various other operations in the area.

Even though the number of visitor units in Ka`u is small, the District benefits by visitors passing through the area to and from Hawaii Volcanoes National Park, or other excursions around the island. Many of these visitors buy food, gasoline and souvenirs in Na`alehu.

Proposed Future Resort Development. In the late 1980s, two luxury resorts were proposed which would have added over 6,000 visitor and resort residential units to Ka`u. Expansion of Punalu`u Resort was to include a total of 2,100 units: 805 hotel rooms, 1,224 condominiums, and 71 single-family homes. The Hawaiian Riviera Resort, which was to be located about 10 miles west of South Point, would have added 3,927 units: 2,100 hotel rooms, 1,175 condominiums, and 652 single-family homes. Other project components included a marina, a commercial area, golf courses and club houses, a tennis stadium, a polo field, stables, riding paths, a medical center, and various support facilities.

If these two resorts had proceeded as originally planned then, once constructed, they would have added over 6,700 new jobs to the District, nearly 6,000 daily visitors and resort residents,

and nearly 5,300 new residents outside the resort. This compares with an estimated 1,500 jobs in the District in 1990, and a population of 4,440 people. Economic, population, and social impacts resulting from this development would have been large. Other projects, such as Spaceport, would not have been needed to provide full employment in the District.

The Punalu`u Resort was purchased by the Sazale Corporation, a Japanese company which runs high-quality small hotels. The project was renamed the Sazale Black Sands Resort, with initial plans to build 100 hotel rooms, 120 resort condominiums, a "Commercial Village Center," and an 18-hole golf course. If successful, a second phase would add about 480 condominiums. Development of the project has been delayed. Because of financing and other problems, development of the Hawaiian Riviera Resort is not expected in the foreseeable future.

Conditions which, to date, have prevented the development of a major visitor industry in Ka`u include: isolation; poor transportation (e.g. no major airport); few visitor attractions and few protected beaches; and, high development costs. Of significance, a number of resorts in isolated rural areas have been unsuccessful in Hawaii (e.g., Hana and West Moloka`i). Furthermore, the luxury market has proven to be vulnerable to recessions.

2.0 Potential Effects of the Project on Ka`u Tourism

Operation of the proposed launch facility is expected to increase tourism in Ka`u since transient workers, about 150 people, are in fact visitors and not permanent residents. These scientists, engineers and technicians from overseas organizations (primarily the U.S. mainland) will stay in Ka`u a few weeks at time to assist in preparing payloads and launching rockets. They will require about 170 hotel rooms. These accommodations, particularly those visiting without their families, can be relatively spartan rooms designed for single-occupancy, since most transient workers will spend most of their time at the launch site. These transient employees are expected to spend an average of $150 per person per day, about $8.2 million per year.

Additional tourism activity will result from visiting workers who bring their families, and/or extend their stays to explore the Big Island. Also, rocket launches will probably attract a number of visitors to Ka`u to witness the launches.

C. COMMERCIAL FISHING

1.0 Existing Conditions

Commercial fishing off the windward coast of Ka`u is done mostly in small boats (under 30 feet long) for semi-commercial purposes. Few small-boat operators are full-time commercial fishermen. Ka`u, particularly South Point, was one of the focal points of the tuna handline fishing industry a decade ago. The importance of South Point as a landing site declined through the 1980s. In addition, the Na`alehu company that served as the primary fish buyer and source of support services for the Ka`u handline fleet recently went out of business. For the future, the commercial fishing industry is not expected to generate significant new employment in Ka`u (DEIS Appendix IXB).

2.0 Potential Impacts

Spaceport will have minimal impact on the commercial fishing industry for three reasons: first, waters downrange of Spaceport will be closed to fishing and transit less than 2 percent of the time; second, few boats will be affected by the closures since the area is not heavily

fished by commercial fishermen; and, third, fishing can continue outside the area during range closures. Further discussion is provided in Appendix IXB of the dEIS.

D. SUBSISTENCE ACTIVITIES

A significant subsistence economy of an undetermined extent exists in Ka`u. Farming, fishing, and hunting provide food (and recreation) to some families outside the monetary economy. A number of native Hawaiians and other Ka`u residents fish the shoreline waters off the project area, and gather opihi and limu. These activities can continue unrestricted except for the 30 or so times a year when Spaceport is closed for a launch. This will last from the evening preceding a rocket launching to about 30 minutes after the launch. Subsistence activities are discussed further in DEIS Appendix IXD.

SECTION I: CULTURAL RESOURCES

Construction impacts and mitigating measures for archaeological sites are described in Chapter Four. The complete archaeological report is presented in Appendix IV of the dEIS. The text that follows incorporates DLNR Historic Preservation Division comments of late August 1993.

A. CULTURAL AND HISTORICAL BACKGROUND

The size (more than 600,000 acres), geologic complexity, and climatic variety of the District of Ka`u shaped the land and the lives of the Hawaiians of the District. Ka`u was considered a "fatal land to chiefs." It was the King's duty to seek the welfare of the common people, because they constituted the body politic. Many kings were put to death by the people because of their oppression of the makaaina

Lt. James King, sailing off the island of Hawaii on the 1779 voyage of Captain James Cook, described the coast of Ka`u as horrid and dreary, appearing to have undergone a total change from the effects of some dreadful convulsion. The only onshore exploration at Ka`u during this voyage involved a search for fresh water. When the party landed only rainwater deposited in holes upon the rocks was found; even that was brackish. The description by King was in distinct contrast to those of native Hawaiians. Where Lt. King saw only desolation, the first Hawaiian settlers sailing along the same coast centuries before envisioned a potentially rich existence.

In 1823, Rev. William Ellis described the valley of Wai`ohinu as open towards the sea and adorned with gardens on both sides. Ellis' account confirms the upland luxuriance that had made the ahupua`a of Wai`ohinu a center for the ali`i of Ka`u. He also mentioned specific villages including Honu`apo, Hokokano, and Hilea. Ellis also noted the intervening broad stretches of rough a'a between the habitation areas that were marked with waterworn boulder paths. Ellis concluded that the desolate coastline described 44 years earlier by James King was in fact the site of a well-populated, organically developed, active culture and economy where habitation centers, though isolated, were accessible to one another and to the resources of land and sea.

William Ellis may have been the first missionary to visit Ka`u, however, there was not a permanent missionary presence until the early 1840s. In 1841 a Catholic priest, Father Marechal, arrived in Ka`u; John Paris, a Protestant minister, arrived in 1842. Paris settled in Wai`ohinu where he founded a church and school. Later, in 1843, a stone church was also built at Punalu`u.

Mission station reports and censuses, and accounts by visitors to Ka`u during the second third of the nineteenth century document the changes to the District brought about by natural forces and by the pressures of an increasing western presence. A visitor to Wai`ohinu and its environs in 1849 published an anonymous account describing the devastating effects of a drought and fire that had occurred 3 years earlier in 1846.

An 1831 - 1832 census of Ka`u, the first taken within the District, recorded a total population of 5,800; a number which already reflected the District's depopulation--the effect of newly-introduced diseases, cultural unraveling and emigrations to new commercial centers. In 1835, the total population was 4,766. The first official government census, taken in 1847,

records the population as having dropped to 3,010. By the time of the 1853 government census only 2,210 people lived in Ka`u. By the mid-nineteenth century, the severely depopulated Ka`u District was encountering the same political and commercial stresses that were restructuring communities throughout the Hawaiian Islands.

A total of 317 Land Commission Award (LCA) claims were made in 47 ahupua'a within the District of Ka`u during the 1840s at the time of the Great Mahele. Of these 317, only two kuleana awards were recorded within two of the ahupua`a - Pa`au`au and Hionamoa - in which the launch facility area is located: LCA 7312 to Moses Keawe and LCA 10248 to Mahi. Land parcels associated with both of these awards are located above the present day town of Pahala, well mauka of the launch facility area. The paucity of land claims for traditional agricultural activities within the ahupua`a encompassing the launch facility area is evidence that such activities had been supplanted by other foreign-induced enterprises.

Clues to the nature of both pre-contact and post-contact life in some of the ahupua`a of the launch facility area are present in the records of Boundary Commission proceedings during the 1870s: as native Hawaiians testified to known landmarks along their ahupua`a boundaries they were simultaneously documenting details of their own lives that made those landmarks real. Among the things mentioned in the testimony was presence of a cave used as a burial place on the shore. This may correspond to State Site 50-10-69-17362 (Figure VII-1.1). It was also noted that the ahupua`a of Pa`au`au always had ancient fishing rights extending out to sea, as wide as the land at shore (Boundary Commission, Vol.A, No.1:160).

By the middle of the nineteenth century, imported livestock roaming freely throughout pasturelands of Ka`u were creating new aggravations. Organized cattle ranching was focussed at Kapapala, Kahuku, and Ka`alu`alu. Ka`alu`alu Bay was also the site of a fish pond. The bay provided a relatively safe - nearly year round - canoe launching and landing site. By the mid-1800s the bay had become a burgeoning harbor and the focus of activity as the export of agriculture and livestock began to dominate the Ka`u economy. About 1852, an improved cart road - 7 miles long - was constructed between the harbor and Wai`ohinu. Cattle were shipped out of Ka`alu`alu at least until the 1920s.

While cattle and other livestock raising were significant elements of the new western economic focus imposed upon Ka`u during the nineteenth century, it was agriculture that would have the most extensive impact on the land and people. Among new agricultural pursuits attempted in Ka`u was wheat growing. Contributing to the failure of wheat production was the harvesting of pulu--tree fern fiber used for stuffing mattresses and pillows--which during the 1860s constituted the major export crop from Ka`u. Life in Ka`u during the 1860s was further disrupted and devastated by the forces of nature.

In March 1868, a sequence of major earthquakes and eruptions of Mauna Loa resulted in many deaths and losses of property and livestock. These disasters were a prelude to an April 1868 earthquake that precipitated a tidal wave which destroyed coastal villages, dislodged a cliff at Kapapala, buried a village and opened the Great Crack at Kilauea, emptying the crater's lava lake into Punalu`u and Keauhou. A subsequent lava flow, this time at the west side of Ka`u, buried all of Waiahukini Valley.

In 1868, the same year as the great earthquake, Alexander Hutchinson established the Na`alehu Sugar Company and built a mill at that town. More enduring commercially than either wheat or pulu, sugar cultivation would become the major industry within Ka`u, appropriating the focus of life in the District. During the mid-1870s, Wai`ohinu Plantation was established by John Nott and Company. This operation was bought out in 1877 by Alexander Hutchinson who at the same time founded Hilea Plantation. By the end of the 1870s, sugar mills were operating at

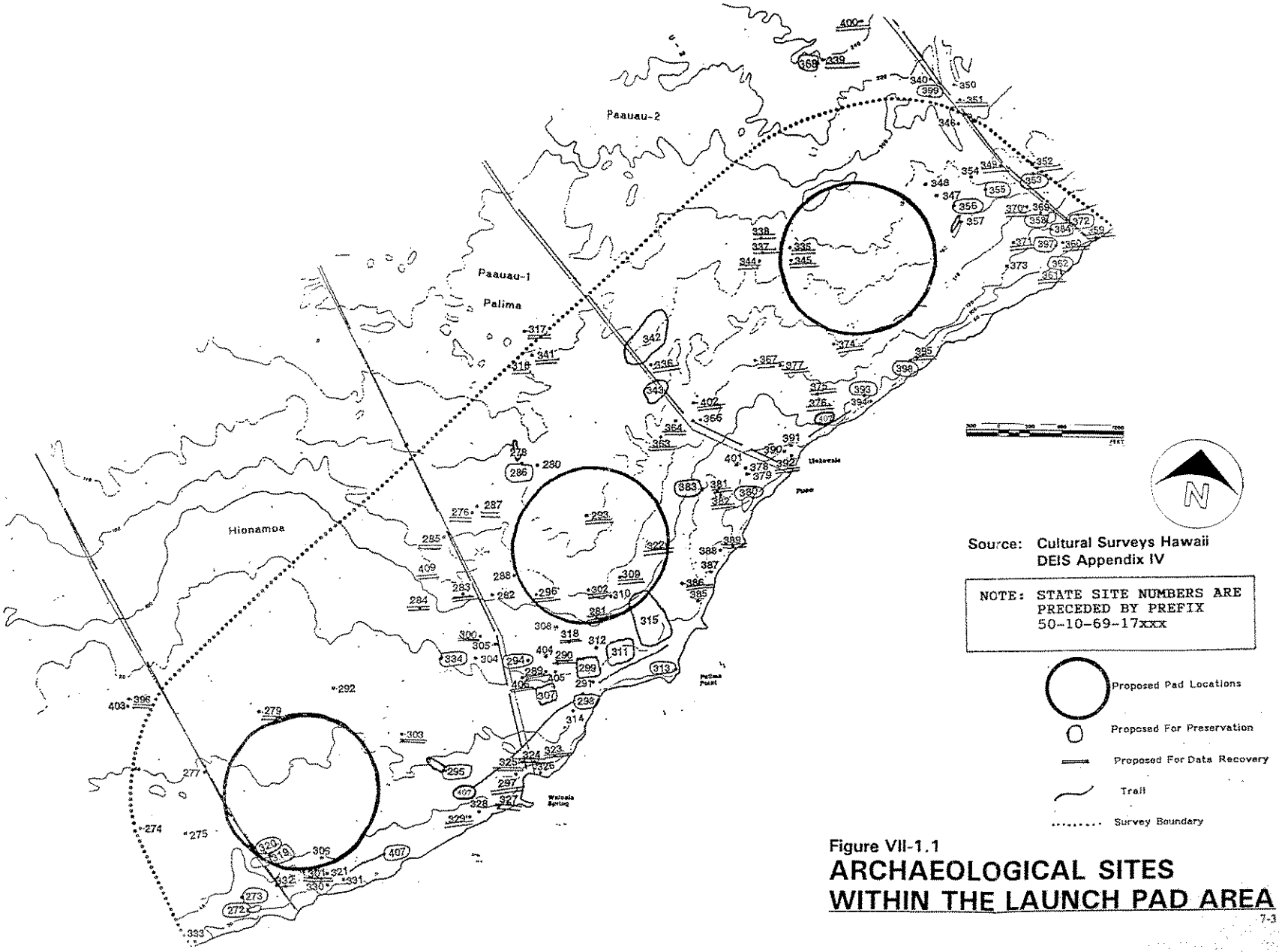


Figure VII-1.1

ARCHAEOLOGICAL SITES WITHIN THE LAUNCH PAD AREA

Na`alehu, Hilea and Honu`apo. Though Hutchinson died in 1879 his name survived in the Hutchinson Sugar Company which during the remainder of the nineteenth century continued to expand and consolidate existing plantation operations in Ka`u.

Another plantation operation, the Hawaiian Agricultural Company, was established in Pahala in 1876 by a consortium of Honolulu businessmen. A decade later the company controlled almost 10,000 acres of cane land and constituted the largest plantation in the Hawaiian Islands.

Change within the Ka`u District during the remainder of the nineteenth century and into the twentieth century centered around the activities of the two sugar operations. Wharves for shipping sugar were constructed at Honu`apo and Punalu`u. Railway lines ran from Na`alehu and Hilea to Honu`apo and from Punalu`u to Pahala. Railroads continued to operate in Ka`u until the 1940s.

The social landscape of Ka`u was also altered by the sugar companies. During the 1870s, Chinese laborers were brought in by Alexander Hutchinson and by the time of the 1884 government census, there were 568 Chinese in the District. Japanese laborers were imported beginning in the latter 1880s and Filipinos began arriving during the first decade of the twentieth century.

By the 1960s and 1970s, commercial interests in Ka`u began to look beyond the mainstay sugar had provided for almost a century. Macadamia nut growing and resort development were conspicuous attempts to move beyond the uncertain future portended for sugar.

B. GENERAL SETTLEMENT PATTERNS AND SITE DISTRIBUTION

Cultural and historical literature indicates a dramatic change in the traditional settlement pattern through the nineteenth century, culminating in the settlement pattern of present day Central Ka`u. The combination (marine and terrestrial) of resources required to sustain a sizeable, traditional Hawaiian subsistence-based population necessitated a pattern of permanent habitation at the coast and within the agriculturally productive uplands.

The survey conducted by Cultural Surveys Hawaii (DEIS Appendix IV) indicates a traditional settlement pattern of a village habitation complex within the coastal zone of Pa`au`au 1 (Palima) ahupua`a but not for the adjacent ahupua`a. Boundary commission records indicate that the Pa`au`au 1 (Palima) off-shore fishing rights superseded those of the adjacent ahupua`a, effectively cutting these (Hionamoa and Pa`au`au 2) ahupua`a fisheries at the shoreline. This suggests the permanent habitation complex at Pa`au`au 1 (Palima) predates the establishment of subsequent ahupua`a divisions.

Historically, the settlement pattern changed as the coastal zone, including the permanent habitation complex at Palima Point, was abandoned. Traditional sites associated with permanent habitation, like burials in lava tubes, pu`u(s), and a'a complexes were also abandoned. Specific to the project area ahupua`a was the establishment of commercial sugar cane and Pahala in the late 1800s. Immigrant labor was brought in to fill a void and Pahala expanded to become the focus of habitation, including activities such as employment, schooling, housing, and health for the entire Ka`u District.

As shown on Figure VII-1.1, archaeological sites and site complexes, although more concentrated in the coastal sections, are present throughout the intensively surveyed area. Two main themes of site distribution and land use were identified: (a) traditional Hawaiian habitation and subsistence and (b) historic and modern fishing activities. Both of these themes

reflect a concentration of sites along the coast. Although determining the age of many of the structures was difficult, confidence is high that a substantial majority of the sites found within the study area represent indigenous Hawaiian activity. Subsequent historic and modern utilization of some of these sites was documented. A few exclusively historic or modern sites were also observed on the coast and/or in association with four-wheel drive roads.

The historic/modern land use within the project area is distinctly concentrated along the coast--to an even greater extent than with the traditional land use noted in the project area. Numerous temporary--often consisting of a rough hearth--and recurrent habitation features were noted in the survey that, from the associated artifacts, site form, and site condition could be identified as historic or modern features. These features were concentrated along the main coastal trail and along the 4-wheel-drive road that runs along the coast in the project area. During the survey one of these recurrent-use sites was used by weekend fisherman. It is likely that nearly all the historic/modern features within the project area are associated with periodic habitation by fishermen and the storage of their gear. It is evident that nearly all of the prehistoric features along the coast have been used during historic and modern times as shelters.

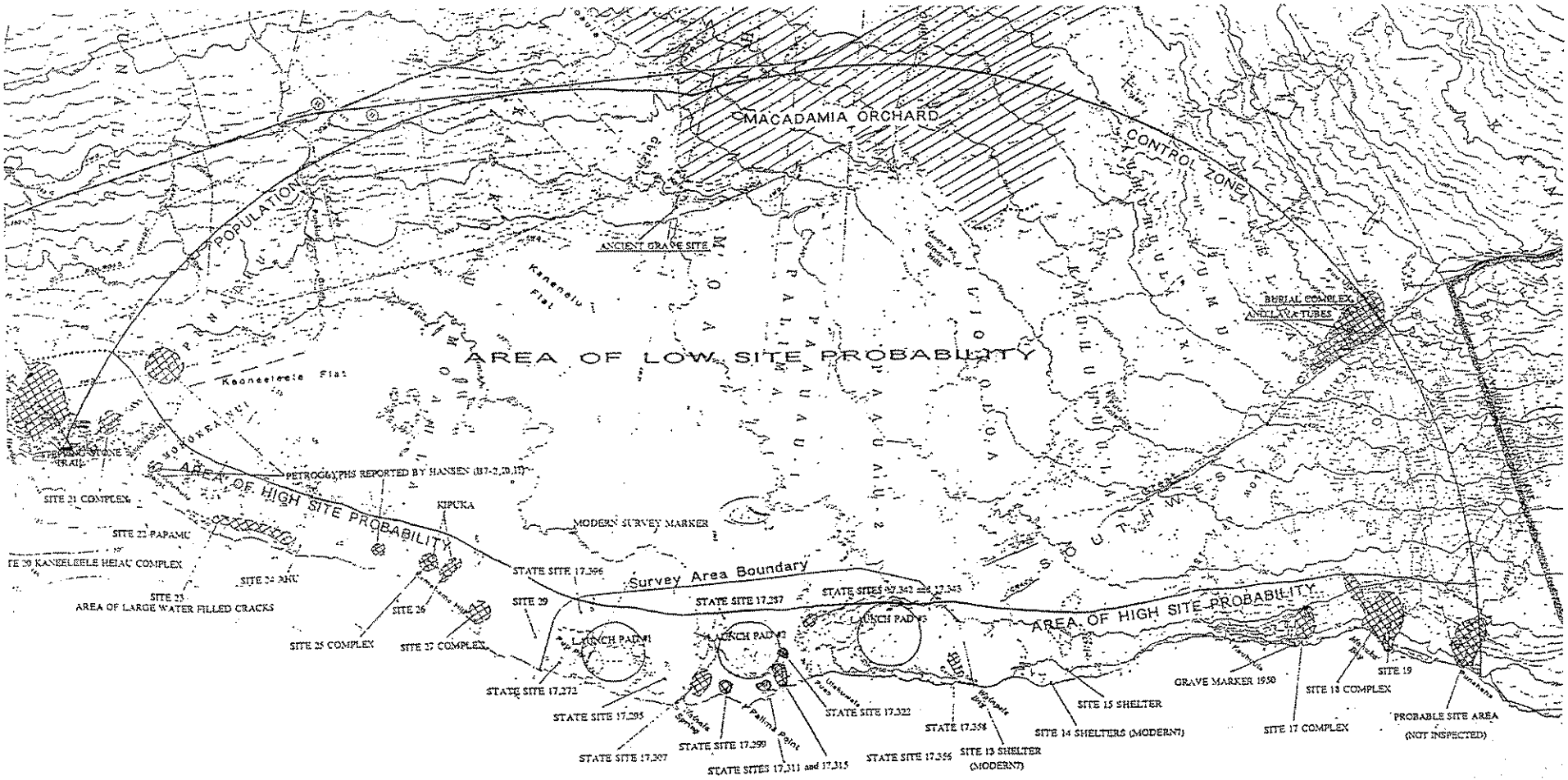
Figure VII-1.2 shows areas of high and low site probability within the PCZ at the Palima Point site. Cordy (1988) postulates that the permanent housing of Central Ka`u would occur in the interior agricultural lands and along the shore. Historic research conducted on the study area's five ahupua`a has documented two Land Commission Awards (LCA) in the upland sections of these ahupua`a. From this paucity of LCAs one could conclude that there was little permanent habitation in the inland areas in the mid-1800s.

The village complex of permanent habitations at Palima Point is in line with Cordy's predictions for coastal permanent habitation. The ahupua`a of Hionamoa and Pa`au`au 2, on either side of the ahupua`a of Palima, however, lack a similar village setting of permanent habitation. In Boundary Commission records it is reported that Pa`au`au 1 (Palima) had fishing rights which extended straight out to sea on the east boundary and on the west boundary swept to the southwest to include the offshore areas of Hionamoa. With the offshore fishing rights to two ahupua`a, it is understandable that Pa`au`au 1 could support a greater population than the surrounding land divisions. This broader food resource, could be a major factor responsible for the greater population concentrations around Palima Point.

The availability of fresh water is one of the major factors governing site distribution. Other than the drip water seen in the lava tubes, no water sources were observed in the study area. The place name Waioala Spring, just west of Palima Point, was investigated for any fresh or brackish water sources but none were located. It is possible that the spring is located just below sea level along the shore or perhaps tectonic activity has changed the drainage patterns of the area. Other possible sources of water are deep fissures which were observed in most parts of the study area. Several of these were explored but no water source was seen. No cultural modification suggesting recurrent use of any of these features (e.g. a modified route descending into them) was observed, either.

Another factor which appears to affect site distribution is the preference for building on a'a rather than pahoehoe. Site densities are greater on the a'a, which covers far less of the area than pahoehoe. Laura Carter and Gary Somers note a similar preference for the a'a in their work at Hawaii Volcanoes National Park (Carter and Somers 1990).

Figure VII-1.1 shows the Palima Point settlement to be a distinct concentration of various archaeological features including habitations, burials, ritual features and agricultural pits. A smaller, less distinct group of archaeological features can be seen along the Pa`au`au 2/Iliokoloa boundary. This group also consists of a variety of feature types including



Source: Cultural Surveys Hawaii
DEIS Appendix IV

0 2000 4000 6000 FEET

0 1/4 1/2 1 MILE

Figure VII-1.2

GENERAL SITE PATTERNS WITHIN POPULATION CONTROL ZONE

petroglyphs, shelters, burials, and several permanent and recurrent habitation sites. It is likely that these two concentrations of archaeological features, one at Palima Point and the other at the Pa`au`au 2/Iliokoloa boundary, were associated with the utilization of the adjacent agricultural features. The large, probable burial sites (Sites 342 and 343) located on the Palima/Pa`au`au 2 boundary are also thought to be directly associated with the coastal settlement around Palima Point.

Site 50-10-69-17407, the coastal trail, is an important component of the settlement pattern of the region. Cordy (1988) comments on the major trails running through central Ka`u. It is likely that this trail represents the remnants of the main coastal trail through the region during prehistoric and early historic times. Evidence that this trail is still in use to this day by fisherman and hikers was observed during the survey. This trail would have intersected mauka-makai trails, such as the one postulated from Palima Point along the train of ahu toward the interior.

Historical research on the intensively surveyed area found no references to claimed kuleana parcels in the study area. This does not mean that habitation in the coastal section around Palima Point had ceased by the time of the Great Mahele. It seems likely that, in this isolated area of the Ka`u coast, indigenous Hawaiian ways of life could survive longer than in other areas, although factors such as new diseases and population shifts due to new markets and social pressures would have undoubtedly worked against the stasis of pre-contact Hawaiian ways of life. The proposed data recovery research will answer many questions about the length of occupation and possibly the reasons for the abandonment of the Palima Point settlement.

The area of intensive survey shown on Figure VII-1.1 represents a coastal environment. Its overall site distribution corresponds to the high site density coastal zone. A low site density was observed in the mauka portion of the area; the habitation complexes at Palima Point are in an area of higher site density. Differential access to sea resources is a likely factor explaining concentrations of permanent settlement along certain coastal areas such as Palima Point.

The Palima Point settlement was made possible through a series of adaptive strategies which work with the harsh coastal environment. The pahoehoe and a'a excavation agricultural system, the apparent sufficient fresh water source, and the utilization of the a'a as a construction material resource are all examples of this adaptive strategy.

C. SITE SIGNIFICANCE AND MITIGATION RECOMMENDATIONS

Site Significance. Of the total 138 sites within the area that was surveyed intensively, 48 sites are designated no longer significant because they are deemed to lack cultural or scientific interest beyond the documentation and plotting of location achieved during the present survey. Modern sites and sites having very poor or no excavation potential, from which no additional information is obtainable, were given this designation. Generally, these sites included the following: modern fishing camp features such as wind breaks and hearths, ahu, alignments and enclosures constructed upon bare lava surfaces, and small lava tubes with no soil deposit nor observed prehistoric or historic cultural material.

All of the remaining 90 sites are considered likely to, or have, yielded information important to pre-history and history, Criterion D. Fifty-two of the 90 sites have been assessed solely under Criterion D and 38 were assessed under multiple significance criteria.

Twelve sites are considered to be excellent examples of site types (e.g. Criterion C) and

likely to yield information (Criterion D). Excellent examples of site types include sites in a good state of preservation that typify the site types of the region and/or environment, e.g., sites typical of the rugged eastern Ka`u coastline, including stacked-stone structures and lava tubes. The large site complexes and two of the larger lava tubes received this designation because of the information potential of their cultural deposits.

Nine sites are considered likely to yield information important to prehistory and history (Criterion D) as well as having cultural and/or religious significance (Criterion E or E*). These sites are important for cultural significance; e. g. probable burials and/or religious structures, and they could be better interpreted through additional investigation of their cultural deposits. Possible and probable burials received this designation.

Seventeen sites are excellent examples of site types (C), have ritual significance (E or E*), and may yield information important to pre-history and history (D). These sites include most petroglyph features and well preserved burial/possible burial sites.

It should be noted that following the field work in the study area, it was brought to the attention of Cultural Surveys Hawaii that the local community has a tradition which regards Pu`u Pili as a burial site. Although no surface structures or other evidence of burials were observed on the pu`u during the survey, Pu`u Pili is one of the only locations in the study area having sediments suitable for the excavation and internment of burials. Internments in this sediment, without surface platforms or mounds, would not be detected by the methods of the present survey. Other pu`u within the PCZ, such as Pu`u Ulaula, are presumed burial sites based on the number and form of observed platforms (Figure VII-1.2 and DEIS Appendix IV). Pu`u Pili should therefore be treated with deference in light of the local community's tradition and the possibility that interred human remains do exist at the locality.

Mitigation Recommendations. It is recommended that treatment of all 90 of the significant sites be addressed in a mitigation plan and that, preceding developmental impact, a majority of these sites be subjected to intensive documentation and excavation to address scientific and informational concerns. It is also recommended that, prior to commencement of the data recovery plan, all sites threatened or possibly threatened by developmental impact be precisely located by a professional survey company and their locations plotted in relation to the areas of impact. This will greatly assist in predicting the impact of development on the sites and will facilitate any mitigation that is deemed necessary.

Treatment of the 90 significant sites can be undertaken by data recovery and/or preservation. Data recovery entails the further study (e.g. subsurface testing and excavation) prior to development impact and the possible removal of the sites. Preservation safeguards sites from destruction. Sites are preserved for their humanistic/cultural value as well as for their scientific/research significance. Each archaeological site shown on Figure VII-1.1 is identified with a symbol indicating the preliminary recommendation for data recovery or preservation.

The treatment of sites immediately outside the areas to be impacted by the proposed facilities needs to be fully addressed by a preservation and data recovery plan. Sites designated for data recovery and/or those that are no longer significant may still be preserved based on the yet-to-be-formulated facility and construction plans, as well as the aforementioned preservation and data recovery plan.

Data Recovery Recommendations. Data recovery will provide additional data to evaluate site significance and function determinations. These data contribute to the overall understanding of the archaeology of the region by providing information on settlement patterns and resource utilization. Information obtained from data recovery also contributes to the

interpretation of preserved sites. Data recovery should proceed in accordance with a data recovery plan which should be submitted to DLNR Historic Sites Section and Hawaii County for review and approval.

Preservation Recommendations. Thirty sites within the intensively surveyed area are recommended for preservation. These sites are shown on Figure VII-1.1 and described in Appendix IV of the dEIS.

Although recommended for preservation, these sites should not be excluded from any additional work. Documentation and excavation, in order to help with site interpretation, can be carried out. Reconstruction of any dismantled sites would necessarily follow excavation, thereby maintaining the integrity of the site.

The largest concentration of sites recommended for preservation are located in and around the permanent habitation complexes found in the area of Palima Point in the central-makai portion of the intensively surveyed area (Figure VII-1.1). These sites (along with the chain of ahu interpreted as markers of a trail connecting this coastal settlement with the interior) are believed to represent a coastal village or hamlet.

The Palima Point settlement is an excellent example of a coastal village site in eastern Ka`u, where no such sites are yet preserved. Although many questions will be answered through the research of the data recovery plan, the archaeological remains of the settlement represent too great a cultural and scientific resource to be developed without a program of preservation. It is recommended that an Archaeological Preserve be created to ensure the preservation of this area for future research and public appreciation. The following site and features are recommended for preservation:

- Habitation complexes 50-10-69-17299, 307, 311, and 315 and several adjacent agricultural excavation features of site 365. The chain of ahu marking the trail which connected the Palima Point settlement with the areas mauka is considered an important component of this coastal settlement and should be thoroughly documented as part of the data recovery plan.

- Several recurrent habitation sites, including stacked-stone structures and lava tubes (Sites 50-10-69-17272, 295, 356, 358, 362, and 380). These sites are representative of the apparent trend of periodic re-occupation of structures and shelters while regional resources were being utilized. Recurrent use habitation sites are an integral part of the settlement pattern of the region and these sites are recommended for preservation as excellent examples in coastal eastern Ka`u.

- All known burials, because of their cultural importance. Possible and probable burials are recommended for preservation or data recovery. Testing of possible or probable burials during data recovery will substantiate or negate burial function designations. Burials, including possible and probable burials, recommended for preservation include sites 50-10-69-17273, 313, 342, 343 and 362.

- One temporary habitation site, 50-10-69-17294. Temporary habitation in the Palima Point region represents a substantial percentage of the habitation structures. This site, although modest, is an excellent example of the informal, temporary habitation structures of the region.

- Petroglyphs, papamu, and the probable pohaku piko are considered culturally significant should be preserved. The petroglyphs represent culturally/humanistically important symbols from the past. These sites include 50-10-69-17286, 298, 353, 355, 368, 372, 383, 384, 393, 397, 398, 399 and 409.

- The main coastal trail (50-10-69-17407) and one trail segment (50-10-69-17334) should be preserved. These trails are excellent examples of transportation features in the region.

SECTION II: SOCIAL IMPACT ASSESSMENT

See Matsuoka, DEIS Appendix IXC, for the complete sociocultural impact assessment.

A. EXISTING CONDITIONS

Beginning in 1960, new non-standard subdivisions opened up in Ka`u and attracted in-migrants from the mainland. Most of the people who chose to reside in the District sought an alternative life-style. Attracted by the rural agrarian life-style and cheap land, they were willing to do without the benefits of electric power lines, running water, paved roads, and other infrastructure. They gradually blended into the rural landscape, learning from their neighbors.

Tourist resort development which has spawned broad ranging social changes in many rural districts of Hawaii has remained at a low level in Ka`u. Many tourists pass through the District but it is not a major destination area.

By the 1990s, Ka`u had evolved into a multi-ethnic community with a high degree of racial and ethnic tolerance. Many residents rely on fishing and hunting to provide food for their families. These activities are also a major form of recreation and engender an active network of sharing and exchange between households in the District.

There are also some negative aspects to the rural character of Ka`u. Unemployment rates are thought to be slightly higher than the Island as a whole. Average income is also lower while the number of persons receiving public assistance is higher. It is also reported that higher-than-average rates of substance abuse and of child abuse and neglect occur. This is generally attributed to regional economic instability and frustration caused by a lack of opportunities for upward mobility. The closing of other sugar plantations on Hawaii during 1992 and 1993 leaves the plantation at Ka`u as the last operating sugar plantation and mill on the island. Uncertainty about the future of the mill and the prospect of job loss can be expected to exacerbate existing stress levels.

B. RESIDENT OPINIONS AND ATTITUDES

The results of a key informant survey of 231 residents of the Ka`u region indicated a strong preference for continuing existing life-styles. Respondents indicated that the economic options of diversified agriculture, small businesses, and commercial fishing are preferred over a launch facility, resorts and tourism, and aquaculture. Respondents indicated strongly that Hawaiian customs, beliefs and practices and the rural life-style in Ka'u should be protected. On the other hand, respondents felt that Ka`u lacks sufficient human services, housing, and infrastructure.

Respondents identified the potential social impacts of Spaceport development to be social disruption, health and environmental risks, new employment opportunities and life-style changes. The qualities of Ka`u that respondents felt should be preserved included its life-style, open

space and shoreline, historic and archaeological sites, and fishing and gathering grounds.

There was also some mention of "youth problems" and some conflict among some ethnic groups. Residents disagreed, however, on whether and how Ka`u's educational system and current population would be affected by the development of the Spaceport.

Although the sociocultural study results indicate strong opposition to the proposed facility (65 percent opposed), sub-group comparisons offer a more detailed analysis of attitudinal differences. Particular demographic "pockets" were not as opposed to the project and some even expressed support.

Older people (60 years and above) were generally at odds with their younger counterparts regarding economic development. They supported sugar, resorts and tourism, and Spaceport. All three alternatives were less popular among younger residents. Men were also generally more supportive of Spaceport than women. Attitudes also varied according to ethnicity. Native Hawaiians expressed the strongest opposition. Caucasians and most Filipinos also were opposed. Japanese were the only ethnic group that supported the proposed facility.

It should be noted that this survey was conducted in the summer of 1991, at a time when major resort development in Ka`u was planned and before the announcement of the closing of other Big Island sugar plantations. It is unknown whether or not these factors would affect the study results if the survey were taken today. A complete description of the methodology used in conducting the survey, the questions asked, and the responses given are contained in Appendix IXC of the dEIS.

C. ASSESSMENT OF PROJECT-RELATED CHANGES

If the launch facility is developed, it will provide short-term and long-term employment for both local and non-local workers. The project will generate both low- and high-technology employment opportunities for Hawaii residents. Other high-technology projects in Hawaii, such as astronomy operations on Mauna Kea, have a positive record of hiring support staff of various ranks from the local populace. Activities that require specialization, however, will require the recruitment of trained and experienced scientists (including former Hawaii residents) from the mainland and elsewhere.

Even in the "best case" scenario, where a high percentage of Hawaii-born individuals are hired, sociocultural adjustment impacts will be evident. Highly skilled professionals--even those born in Hawaii--will likely represent a transplanted group (from the mainland or Oahu) that is demographically divergent from the existing Ka`u population. For example, the State's more highly educated constituencies (who are best prepared to work in high-technology areas) are disproportionately represented by particular racial/ethnic groups, e.g., Japanese, Caucasian, and Chinese. The infusion of new groups into Ka`u may stir some discontent within a population that is predominantly Hawaiian and Filipino.

Anticipated problems relating to sociocultural adjustment will be more pronounced if the developer and/or operator of the launch facility ignores existing sociocultural conditions in Ka`u and transplants large teams of technicians from other projects on the mainland or abroad. The employment patterns at the proposed project, however, are more likely to resemble those of the telescope projects on the island, where support staff at various ranks have been recruited locally.

Although development of the launch facility will predispose Ka`u to numerous social changes, it may also serve to restrict the amount of growth and subsequent social changes that occur in the immediate region. As no development can occur within the specified boundaries of the PCZ, about 10,400 acres, the project area would be characterized by open space. From a social-impact perspective, the launch facility will induce fewer changes than development of the property for major resorts and associated housing developments.

D. EFFECTS OF THE PROJECT ON SERVICES

1.0 Educational Resources

The increase in population will bring an influx of new children which may cause some social disruption. One of the problems most frequently identified and discussed by respondents to the survey was the perceived "poor quality" of public education in Ka`u.

A projected increase of 100 school-age children resulting from Spaceport development would mean that about 4 more classrooms would be needed for the Ka`u Schools at a total cost of approximately $1.4 million (based on an estimated cost of each classroom at $350,000). If this cost is borne by developer assessments, the result could be additional educational resources and improvements to facilities that would not otherwise occur.

2.0 Health Services

Currently, the health services in Ka`u are barely adequate. Because of the large size of the District and the distance to other medical facilities, the hospital and its personnel provide a wide range of immediate-need services. Even though the conceptual plan proposes on-site medical facilities, the development of the launch facility will require an upgrading of the Ka`u hospital and possibly other medical facilities plus a more elaborate and sophisticated medical evacuation system. The existing hospital does not have the capacity to treat the injured if a major accident should occur at the launch site. Victims would have to be transported quickly to medical facilities outside of the District (e.g., Hilo, Kona).

To mitigate these deficiencies, the launch site operator must be required to provide both emergency medical facilities and appropriately equipped helicopters and ambulances. It would also be desirable to relocate the Ka`u hospital to a site farther away from the noise and activities at the Spaceport.

3.0 Police and Fire

The projected increase in the population due to Spaceport development could require expansion of the police force. Increases in crime and a corresponding need for police protection, however, may not correlate directly with population growth. Increased crime rates may be accentuated by other factors such as fluctuations in the economy, the number of tourists, and local residents' perceptions of social changes.

The proposed development would also require expansion of existing fire-fighting capabilities and additional personnel. Even though the Spaceport would provide on-site fire protection, the local fire department could be called upon for assistance during emergencies. Detailed contingency plans and appropriate training should address potential accidents that could occur at the Spaceport facility.

4.0 Human Services

There is a lack of programs and services available to address the current level of social problems in Ka`u. Population growth spurred by development could compound the problem if services do not increase. Social changes associated with changing economic conditions and an infusion of newcomers to Ka`u may also create new social problems or exacerbate existing ones, thus increasing the current service deficit. Community disruption or destabilization could predispose residents to psychological distress and declining mental health. On the other hand, it is also important to note that stable employment and increased income may serve to alleviate social problems in some families.

The actual quantity of government-sponsored and other structured human services required to sufficiently address social problems in Ka`u has not been determined. A "needs assessment" study would be useful to determine the efficacy of existing programs and services, and to identify human service deficits.

5.0 Recreation Facilities

An infusion of new people into the District who will necessarily represent divergent cultural experiences, will create a need for additional facilities and could create conflicts resulting from different recreational preferences (e.g., shoreline fishing versus recreational boating) or competition over scarce recreational resources. At the same time, a greater diversity of recreational options might be provided if a market exists for them. An example of this is the number of people in the community who have taken up golf as a recreational activity since the opening of the Sea Mountain Resort Golf Course.

An assessment of ocean and shoreline recreational/subsistence activity is presented in the following section. The natural (marine) environment supporting subsistence activity was a significant area of concern among survey respondents.

SECTION III: RECREATION AND SUBSISTENCE USES

Ocean and shoreline recreation and subsistence uses are documented in Akala Products, Inc., DEIS Appendix IXD.

A. EXISTING CONDITIONS

1.0 Access

The project area is one of the most isolated regions of coast in the State of Hawaii. A lack of access and physical constraints, such as barren lavas and arid climate, restrict current use. Most of the current activities within the project area are ocean-related uses which are concentrated along the shoreline. Much of the coast, including the three sites where rocket launching pads would be built, is accessible over several secondary four-wheel drive roads that lead from Mamalahoa Highway to the shoreline. These private roads are gated, so vehicular access is limited to those who have or can borrow keys. These *mauka-makai* roads connect to other secondary four-wheel drive roads which parallel the shoreline.

Four-wheel-drive traffic is mostly concentrated between Punalu`u and Palima Point. The reach of coast northeast of Palima Point attracts much less 4-wheel-drive traffic, in part because of the higher sea cliffs and poorer roads. Mountain bikers do not use the area.

Hikers and other pedestrians gain access to the shoreline by following existing shoreline trails or the secondary four-wheel drive roads which parallel the shore. Prehistoric foot trails are found along the entire shoreline from Punalu`u to the Hawaii Volcanoes National Park.

Recreational and subsistence activities in and near the project site are of two general types:

Family-oriented Activities. These are primarily recreation (and sometimes subsistence) and are highly dependent upon good shoreline access. These activities include swimming, picnicking, camping, bodyboarding and surfing, and family pole fishing and seaweed gathering. Punalu`u is the only area where the shoreline is readily accessible by road, so family activities which provide a combination of recreation and subsistence are concentrated there. Facilities at Punalu`u Beach Park were developed to meet the group-oriented recreational needs of the plantation community. Consequently, the density of users is relatively high.

Individual and Small Group Activities. These activities, which are a combination of recreation and subsistence, often take place in areas that are less accessible than those that are family-oriented. Most of the shoreline which borders Spaceport project area provides opportunities for undisturbed fishing, camping and other activities. Participants can undertake their activities in privacy and seclusion or in very small groups without having visual or physical contact with other users. Pole fishing, throw netting, and seafood gathering occur along the entire coast from southwest of Punalu`u to Palima Point. Activity falls off northeast of Palima Point.

Fishing and seafood gathering along the shore are often combined with overnight and weekend

camping trips. To maintain a sense of privacy and isolation, participants in these activities frequently use four-wheel drive vehicles to gain access to rugged, remote terrain. Although some of the same activities may also occur in areas of higher density use, such as Punalu`u, they are more rewarding when conducted in less accessible areas where natural resources are less exploited and resource density is high.

2.0 Existing Recreational Uses

Population Control Zone (PCZ). The coastal area along the PCZ can be subdivided into three segments; use diminishes with distance from Punalu`u. (Figure VII-3.1 identifies places of recreation use in the vicinity of the Palima Point launch site).

Keone`ele`ele to Kamehame. Limited vehicular access restricts the use of this area and protects the privacy of current users. The primary user groups are hikers, seaweed and shellfish gatherers, pole fishermen, throw-net fishermen, and scientific researchers. Users entering the area from Punalu`u usually park near the boat ramp. Hikers often walk from Punalu`u toward Kamehame and back. Hikers also visit the area to look at archaeological sites, such as Kane`ele`ele Heiau and the steppingstone trail. This is an easy day hike that can include a stop for lunch and an ocean swim at Kamehame or the brackish-water ponds at Maue. These ponds are found in a series of long, deep cracks that parallel the shoreline. The ponds are also used by `opihi collectors to clean and rinse their catches. The waters offshore of Maue are a good place for spearfishing when the ocean is calm. The area is said by informants to offer some of the best shore fishing on the Big Island.

Thrownet fishermen who frequent the area usually walk in from Punalu`u. The low, irregular rocky shoreline along this reach of coast offers some good opportunities for this type of fishing. Some of the pole fishermen who visit this area bring along throw nets. Some seaweed is harvested, but the species found along this reach also occur in areas closer to Punalu`u that are more accessible.

On days when the ocean is unusually calm, some `opihi picking is done from small boats, which drop off collectors who swim ashore. Little net fishing occurs offshore because the bottom drops off so steeply and the inshore shelf is so narrow. Small boats launched at Punalu`u ramp sometimes venture close to shore to handline for bottomfish off the narrow submarine shelf which borders the rocky shoreline. Rough seas frequently discourage boats from approaching shore, however. Small vessels launched at Punalu`u also troll for ahi (yellowfin tuna) and associated oceanic species in offshore waters.

Kamehame to Palima Point. The primary users of this reach of coast are pole fishermen. Secondary users are hikers, shellfish gatherers, and scientific researchers. The pole fishermen camp over the weekend at a number of sites on elevated rocky points. Fishermen seen during a survey of the project area reported excellent fishing.

Prominent camp sites are found at both Kamehame and Pu`u Pili. Fishermen usually drive to the shoreline across jeep roads. While fishing, they also pick `opihi. Large numbers of shells litter their camp sites. When the weather permits, fishermen can come up the coast from Punalu`u by skiff to collect `opihi by swimming ashore. The bottom drops off so steeply that handline fishing and net fishing off the narrow inshore shelf is very limited.

Users other than fishermen are infrequent. They include wilderness hikers and scientists, especially turtle researchers who visit Kamehame Beach, a turtle nesting site.

Palima to Punahaha. The primary users of this area are pole fishermen and scientific

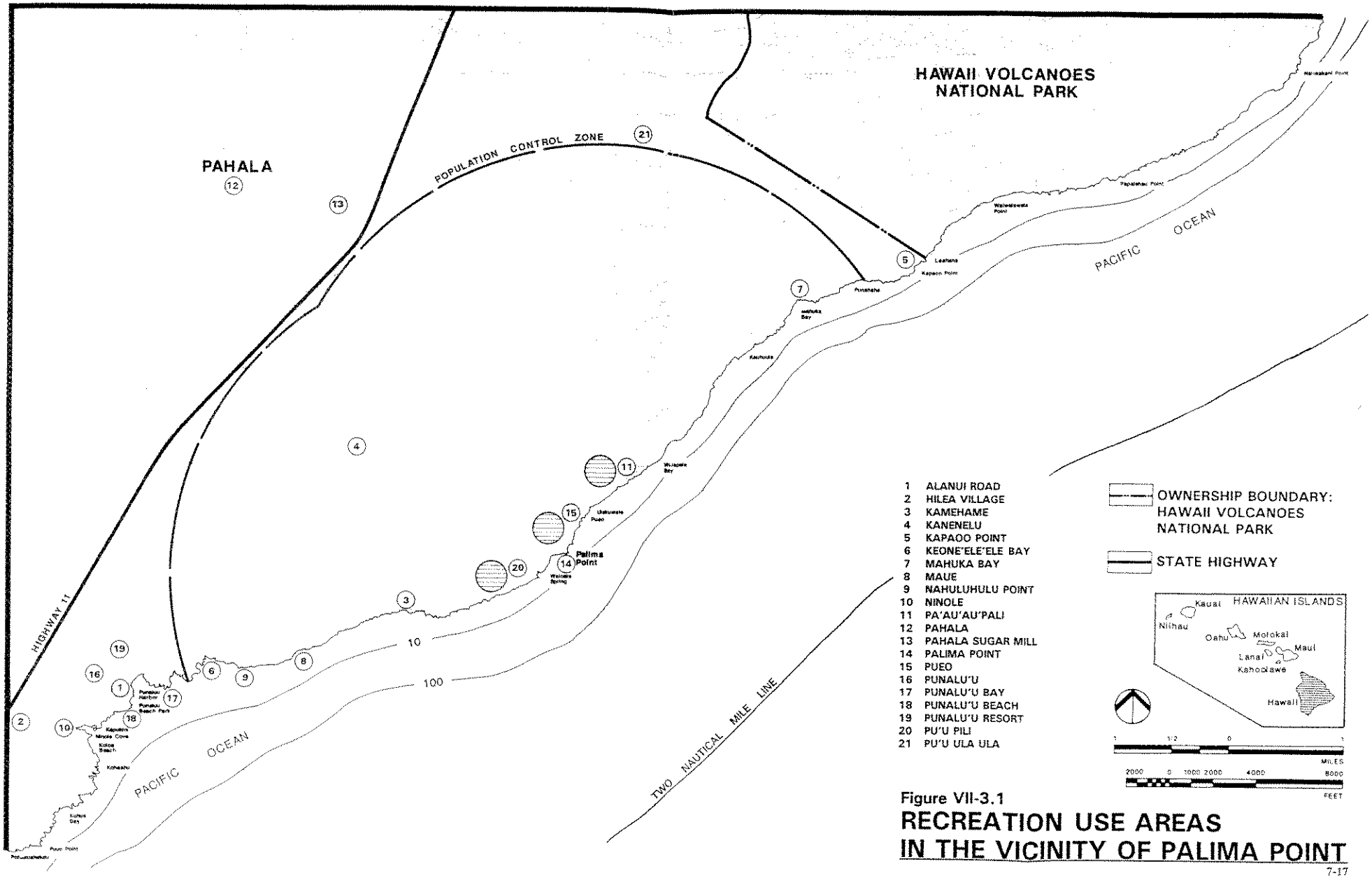


Figure VII-3.1

RECREATION USE AREAS IN THE VICINITY OF PALIMA POINT

researchers. Fishermen drive to the shoreline across jeep trails and camp at various sites over weekends. The area is said to offer some of the best inshore fishing on the Big Island but is less frequently used than the shoreline reaches closer to Punalu`u. Inshore fishing and `opihi collecting by boats is also less common than in the areas closer to Punalu`u boat ramp.

Scientific researchers to this area include archaeologists, geologists and others from the Hawaii Volcanoes National Park, Hawaii Volcanoes Observatory, and other agencies. They use a secondary mauka-makai access road near the northeastern boundary of the PCZ to access various sites within the park, such as the ruins at Kue`e, which are otherwise difficult to reach from within the park itself. The access route begins on Ka`u Agribusiness land and is called Kiawe Tree Road.

Archaeological sites along the shoreline are used as the camps of fishermen. The locations of many of the archaeological sites or ruins in the project area seem to coincide with the locations of existing or former freshwater seeps or springs.

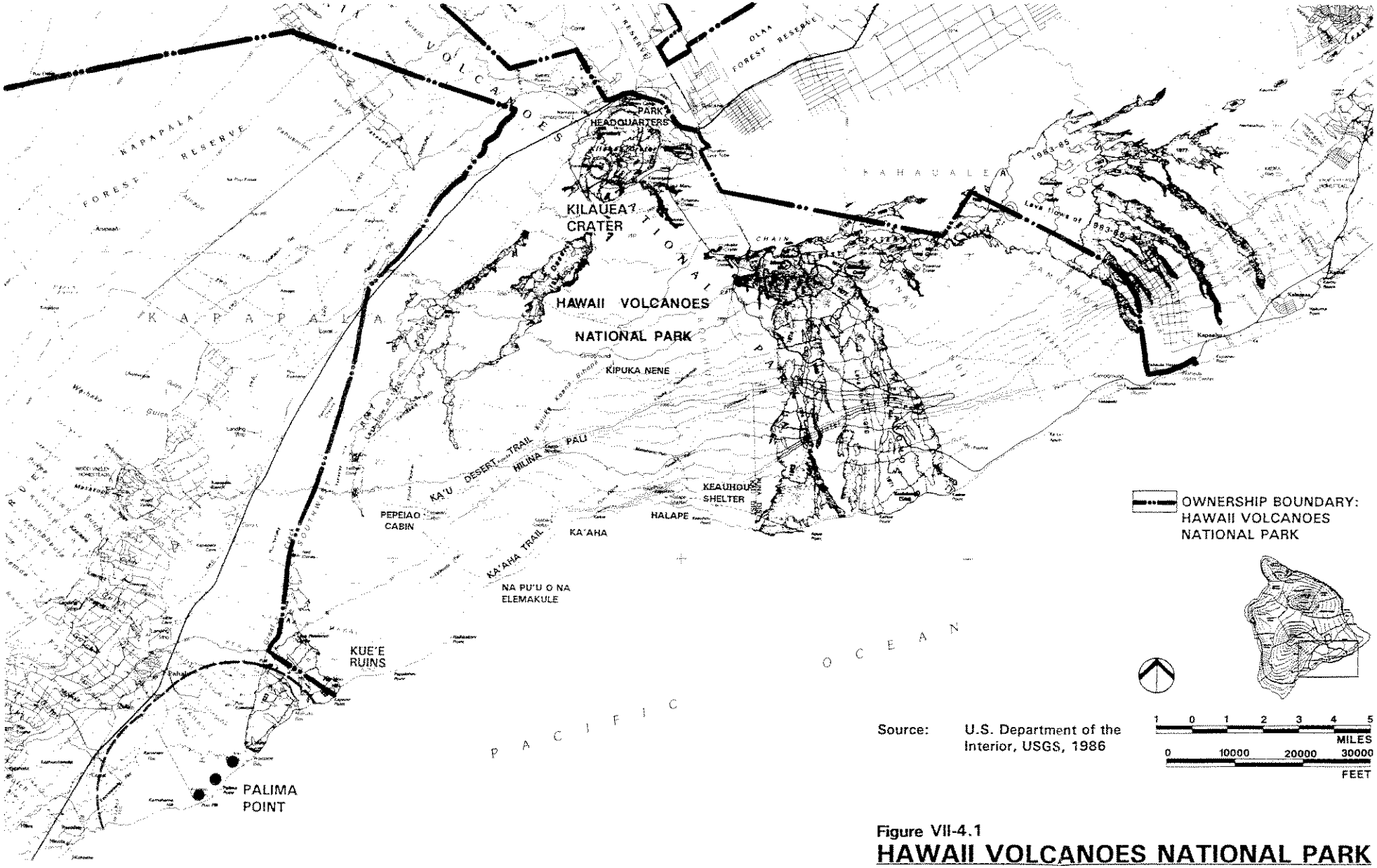
Infrequent secondary users of this remote and desolate area include shellfish gatherers, backcountry hikers and goat hunters. Wild goats fenced off from the Hawaii Volcanoes National Park are present and gamebirds are also present. The area is only infrequently used by hunters.

**Punalu`u.** The Punalu`u shoreline has a black sand beach that is a popular destination for tourists and is a regular stop for circle-island tour buses and vans. It is a heavily used recreation site for local residents and is especially attractive for family-oriented activities. Hawaiiana classes visit the area from schools in and out of the District. Senior citizens and, occasionally elderly hospital patients, are bussed in for day outings. Swimmers and sunbathers favor the northeast end of the beach, which is rock-free and is the most protected corner of the bay. The sea fronting this section of the beach is calm enough for children.

Immediately offshore and adjacent to the swimming area is an old wharf and boat ramp, which is privately owned. Punalu`u boat ramp is one of two boat launching sites on the windward coast of Ka`u. While not heavily used, the Punalu`u ramp is used regularly. It is also a popular site for shore fishing.

Punalu`u Beach Park is located on the point at the southwest end of the beach. Facilities include paved parking, showers, restrooms, picnic pavilions, drinking water, electricity and camping sites. The County-maintained park is an important recreational focal point for the residents of Ka`u and serves as a shoreline community center. It is especially popular for picnicking and camping, although there are only 20 campsites. A small surfing break forms offshore of the southeastern end of the beach; it is a very popular bodyboarding site. Surfing sites are also found at Kawa Bay south of Punalu`u but these are less accessible.

Punalu`u is one of the few areas along the windward coast of Ka`u District where the shoreline is readily accessible and inshore waters are somewhat protected for fishing. Activities include pole fishing, spear fishing, squidding, throw netting, as well as gathering of shellfish and seaweeds. Fishing is frequently done in conjunction with picnicking and camping. According to users, Punalu`u and adjacent shoreline areas accessible by hiking are the most popular sites for throw netting in the District; surround netting from boats occurs in Punalu`u Bay. Limu is gathered along the shoreline, commonly harvested seaweeds include pahee, `aki`aki, lipoa, kohu, lipalu and `ele`ele. Sea urchins (wana) are harvested to a lesser extent. Punalu`u Beach is a nesting site for green sea turtles, so the area is of great interest to turtle researchers.



Source: U.S. Department of the Interior, USGS, 1986

Figure VII-4.1

HAWAII VOLCANOES NATIONAL PARK

2.0 Wilderness Activities

Although paved roads circle Kilauea Caldera, and several other roads (Chain of Craters Road, Hilina Pali Road, and Mauna Loa Road) provide access to other notable portions of the Park, much of its lands are accessible only by hiking.

Wilderness activities include camping and hiking. There are rental cabins at Namakani Paio, 3 miles west of the park entrance. Camping is permitted only at designated campgrounds. Two of them (Namakani Paio and Kipuka Nene) may be reached by car. Backcountry sites, accessible only by hiking, include Keauhou, Halape and Ka`aha off Hilina Pali Road and Red Hill Cabin at 10,035 feet elevation on the slopes of Mauna Loa. In recent years, over 4,000 overnight visits have been recorded annually at backcountry destinations.

Most hiking within the Park takes place from Na Pu`u o na Elemakule north and east, at least 6 miles away from the PCZ boundary. The ruins at Kue`e, about 2 miles northeast of the PCZ boundary, receive limited use, primarily by Park personnel and researchers (Akala Products, Inc., DEIS Appendix IXD).

3.0 Wildlife

The park encompasses a significant range of the Island's native biota. The western coastal areas represent a biodiversity of arid components at one end, and at the other end, less than 20 miles away, a dense rain forest. The western coastal lowlands is an area that represents an ecosystem not well-protected in other parts of Hawaii. On the windward side of Kilauea (annual rainfall of more than 100 inches), is a rain forest consisting of `ohi`a-lehua tree canopy with the tree fern, hapu`u, beneath. The park has an active program of management and monitoring of various native ecosystem components.

The habitats which exist on the launch facility site also exist within the park, as do others not found at lower elevations (Freed, DEIS Appendix IIID). Additional native and protected species occur in the park. For example, the endangered Hawaiian goose or nene (*Nesochen sandvicensis*) is common on the grounds of the Volcano Golf and Country Club. A summary of listed species found within the boundaries of HVNP is given in Table 7.4.1.

B. POTENTIAL IMPACTS TO PARK RESOURCES AND THEIR USE

1.0 Land Use

The expressed goal of HVNP management is to create a compatible gradient of land uses across the ecosystem from inside to outside the park (Dan Taylor, pers. comm.). Park personnel cite some success in implementing this concept as evidenced by neighboring grazing and other agricultural operations. Many Park management and resource protection issues are not confined by Park boundaries. Since Park boundaries may not incorporate all of the natural resources, cultural sites, and scenic vistas that relate park resources to the quality of the visitor experience, the activities on adjacent lands may significantly affect the success of Park programs. In addition, the activities of the National Park Service (NPS) may have effects outside the boundaries of the Parks.

NPS may not consider the proposed rocket launch facility as a compatible adjacent land use. It should be noted, however, that it is unlikely that the lands in question will remain undeveloped indefinitely. In addition, at other launch facilities large undeveloped areas

Table 7.4.1 **LISTED SPECIES FOUND WITHIN HAWAII VOLCANOES NATIONAL PARK**

Scientific Name	Common Name	Federal Status
Plants		
Asplenium fragile	Fern	C1
Asplenium schizophyllum	Fern	C2
Adenophorus periens	Fern	C1
Bobea timoniodes	'Ahakea	C2
Clermontia peleana spp. peleana	'Oha, 'oha wai	C1
Cyanea tritomantha	Aku'aku	C2
Cyrtandra giffardii	Ha'iwale, kanawao ke'oke'o	C1
Cytandra ramosissima	Ha'iwale	3B
Eurya sandwicensis	Anini, wanini	C2
Exocarpus gaudchaudii	Heau	C2
Fimbristylis hawaiiensis		C2
Hibiscadelphus giffardianus	Hau-kuahiwi	C1
Ischaemem byrone		C1
Joinvillea ascendens spp. ascendens	'Ohe	C2
Kokia drynarioides	Hau-hele'ula	FE
Neraudia ovata	Ma 'aloa, ma'oloa 'oloa	C2
Melicope hawaiiensis	Alani	3C
Meliocope zahlbruckneri	Alani	C2
Ocrosia kilaueaensis	Holei	C1
Phyllostegia racemosa	Kipanapona	C2
Plantago hawaiiensis		C1
Pleomele hawaiiensis	Halapepe	C2
Portulaca sclerocarpa	'Ihi-makole	C1
Portulaca villosa	Hawaiian portulaca	C2
Ranunculus hawaiiensis		C2
Rubus macraei		C2
Pritchardia affinis	Loulu	C1
Scaveola kilaueae	Naupaka	3C
Sesbania tomentosa	'Ohai	C1
Silene hawaiiensis		C1
Spermolepis hawaiiensis		C1
Stenogyne macrantha		3C
Stenogyne scrophularioides		3C
Sicyos alba		C2
Trematolobelia grandifolia	Koli'i	C2
Trichomanes draytonianum	Fern	3C
Zanthoxylum dipetulum var. dipetulum	Kawa'u	3C
Zanthoxylum hawaiiense	A'e	C1

Table 7.4.1 **LISTED SPECIES FOUND WITHIN HAWAII VOLCANOES NATIONAL PARK** (continued)

Scientific Name	Common Name	Federal Status
Animals		
Birds		
Buteo solitarius	'Io Hawaiian Hawk	FE
Corvus hawaiiensis	'Alala Hawaiian Crow	FE
Hemingnathus munroi	'Akiapola'au	FE
Loxops coccineus coccineus	Hawaii 'Akepa	FE
Nesochen sandvicensis	Nene Hawaiian Goose	FE
Oreomystis mana	Hawaiian Creeper	FE
Psittarostra psittacea	'O'u	FE
Mammals		
Lasiurus cinereus semotus	'Ope'ape'a Hawaiian Hoary Bat	FE

Source: Risk Science Associates, DEIS Appendix VIII-B.

LISTING STATUS

FE: Species formally listed as endangered by the federal government.

C1: Category 1 candidate. Species for which the U.S.Fish and Wildlife Service (USFWS) has substantial information on biological vulnerability to support a proposal to list them as endangered or threatened.

C2: Category 2 candidate. Species for which the USFWS has information that they are possibly endangered or threatened. More data is needed.

3C: Species that are no longer being considered for listing as threatened or endangered.

3A: Species considered extinct.

provide undisturbed habitat for protected species of wildlife. It may be that the northern portion of the PCZ would provide a more appropriate gradient of land uses across the Park boundary than would some other types of development. The PCZ was established to maintain a safety buffer zone for launch operations. As no additional development will be allowed within the PCZ, the land in question will remain in its wilderness state as open space.

2.0 Cultural Resources

Cultural resources are located throughout the Park; some archaeological resources are located near the proposed PCZ boundary. A planning reconnaissance was conducted at the northeast end of the PCZ to determine the relationship between archaeological sites on either side of the HVNP boundary (CSH, DEIS Appendix IV).

Two major geologic features of this area, the 1823 lava flow and relatively high sea cliffs, influence site distribution. Any sites pre-dating the lava flow are likely to have been destroyed. The age of the 1823 flow indicates a short period of time for post-flow occupation and modification. The high cliffs fronting the coast in this area further decrease the likelihood that habitation complexes would be observed.

Along the coast and approximately 3,000 feet in from the southwest Park boundary, habitation site complexes were observed at Kue`e and Waiwelawela Point. These complexes are approximately 7,000 feet northeast of the nearest observed lava tube site at Punahaha, and approximately 9,000 feet northeast of the site complexes at Mahuka Bay which are located within the PCZ. The lava flow of 1823 has created an archaeological "barren" zone between the complexes located in the Park and those within the PCZ. Figure VII-4.2 shows that there is no evidence of a continuous band of archaeological activity along the coast.

The site complexes within the Park and those within the PCZ are two distinct areas. The 1823 lava flow--and to a lesser degree the high cliffs in the reconnaissance area--show that the coastal settlement pattern appears to be influenced primarily by topography. The delineation of the boundaries of the Puna/Ka`u Historical District in this area appears to be arbitrary, and certainly not based on archaeological continuity.

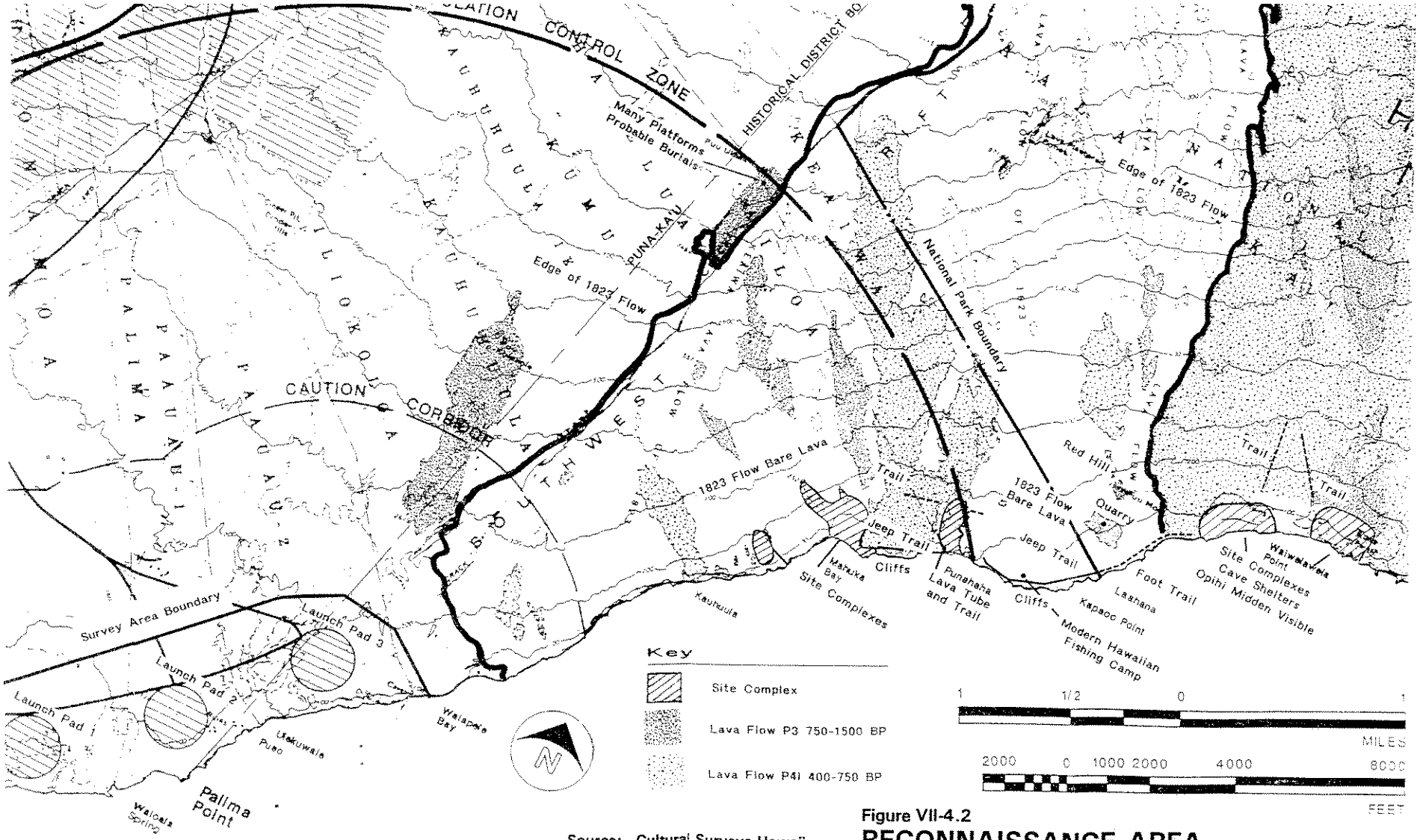
3.0 Recreational Uses

Launch facility operations are not expected to have a significant direct effect on recreational users of the HVNP, although rocket launches will occasionally disrupt the wilderness character of the backcountry portions of the Park.

The facility could, however, indirectly encourage greater recreational use of the shoreline southwest of the Park boundary by providing recreational support facilities, such as drinking water. If this occurs, some of the shoreline users may be encouraged to venture to the more remote shoreline at the southwestern boundary of the Park. Conversely, hikers in the Park may be encouraged to exit the Park via the Spaceport property. This may break down the NPS's present control of hiking and camping in the Park by inadvertently providing an unsupervised entry-exit point at the southeastern boundary of the Park.

4.0 Aesthetics and Visual Impact

For a few minutes during launches, visibility from certain viewpoints could be degraded by the ground cloud formed during a launch. Once the water vapor within the cloud evaporates, the remaining aerosol, primarily composed of aluminum oxides, will reduce visibility. Because most launches will take place when the winds are from the northeast, the only decrease in visibility



Source: Cultural Surveys Hawaii
DEIS Appendix IV

Figure VII-4.2
RECONNAISSANCE AREA NEAR THE NATIONAL PARK BOUNDARY

will be in views of the Pacific Ocean.

National Park integral vistas include Mauna Loa mid-slope and Mauna Kea. The primary observation point is the Hawaii Volcanoes Observatory with other viewpoints from Highway 11, Crater Rim Trail, Chain of Craters Road, Volcano House and elsewhere in the Park. During a launch, the ground cloud would move away from the launch facility and remain outside the Park. Observation points and integral vistas are not expected to be affected by the ground cloud.

A visual impact analysis of the conceptual Spaceport facilities, including viewplanes from the Park, is presented in Section V of this Chapter.

5.0 Night Sky

The darkness of the night sky is considered by NPS to be an important resource attribute of the Park. It is NPS policy to minimize the intrusion of artificial light in recognition that darkness and the night sky play an important role in the overall visitor experience as well as in the maintenance of wilderness values.

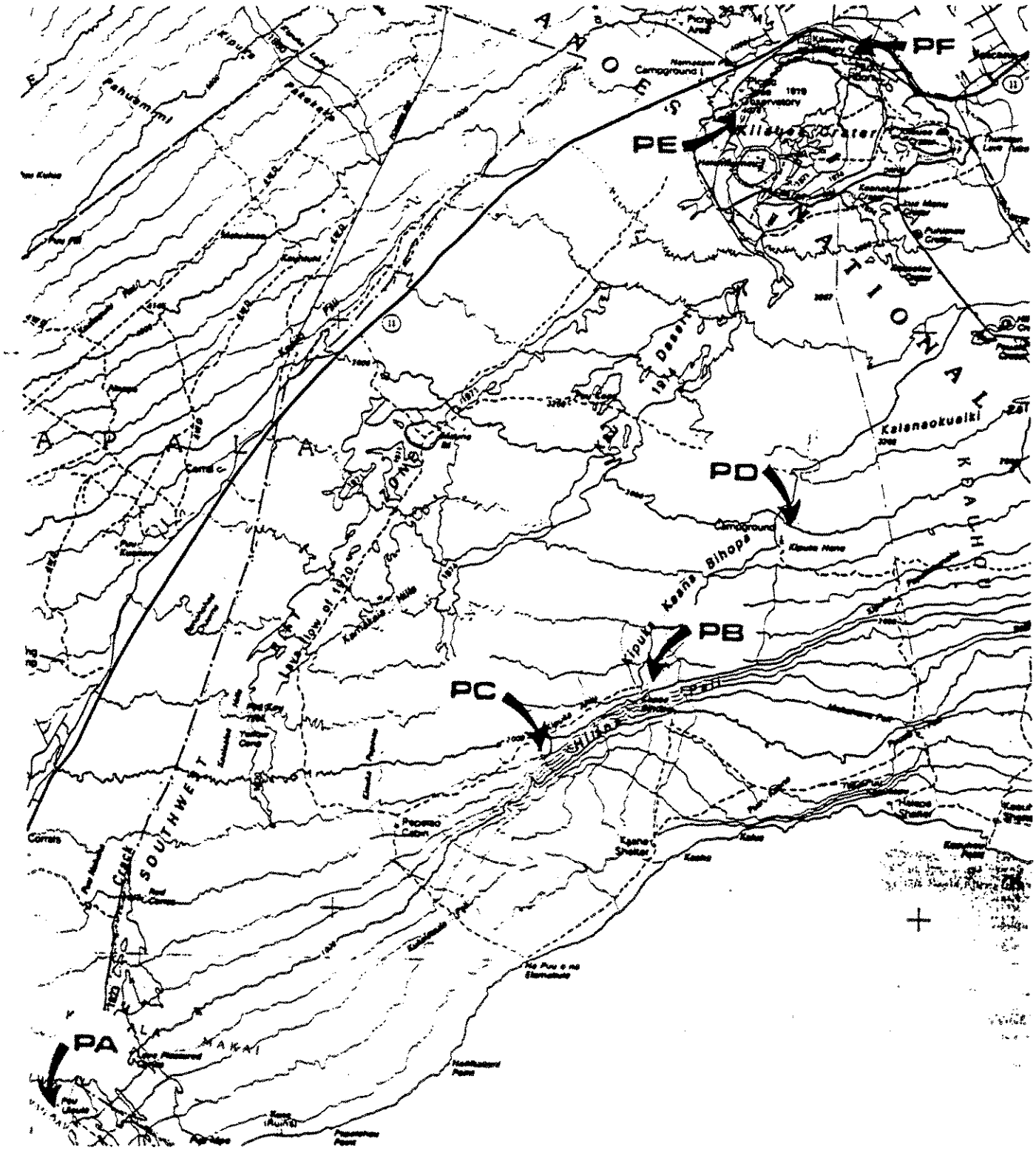
The southern portion of HVNP closest to the Spaceport site is wilderness, but it is accessed by Park personnel, researchers and visitors. To investigate the impacts of the proposed development on the night sky, visible light modeling was undertaken to determine the effects of additional light generated by the Spaceport activities as well as by the additional light in Pahala due to the increased population. The Kue`e Ruins site, approximately 9 km northeast of the Spaceport site, was used as representative of this area.

Results of the visible light modeling are given in two reports by Dr. Roy Garstang (DEIS, Appendix XA). The first report provides modeling results based on the lighting inventory provided by the 1991 Interim Project Description. Subsequent revisions to the inventory of light included that generated by the additional population in Pahala as well as increased white light prior to launches. It should be noted that the model ignores light shielding of reflected light by trees and buildings, and the effects of clouds, fog or haze. It also ignores the effect of the state of solar activity (sun-spot cycle) on natural sky brightness--a variable of greater significance than that projected for the Spaceport. The modeling results are, therefore, very conservative in that they maximize apparent impacts.

The proposed Spaceport would be recognized as visible glow and/or direct observation of lighting associated with operations. This has the potential to reduce the number of stars visible to the naked eye in that part of the sky by about 20 percent. For comparison, the sky brightness increase due to Spaceport activities was compared to sky brightness due to a moonlit sky. All outdoor lighting at the Spaceport will conform with the Hawaii County Lighting Ordinance which requires proper lamp shielding. As a result, the sky brightness at a zenith angle of 75° would be significantly less bright than a sky with just a first quarter-moon. The sky would be brighter at zenith angles closer to the horizon in the azimuth of the Spaceport. Most of the sky would remain quite dark, and significant effects on the enjoyment of the night sky by Park visitors would be unlikely.

6.0 Noise

Natural quiet is considered to be an important Park resource. Ambient noise levels were measured at six locations in HVNP (Figure VII-4.3); the results of these measurements are presented in Table 7.4.2. With generally windy background conditions, the noise levels ranged from 32 dBA at Hilina Pali to 48 dBA at the Visitors Center. Ambient noise in areas remote from the Visitor Center and roadways would be less during periods of light winds.



Source: Darby & Associates
DEIS Appendix VII-B

Figure VII-4.3

AMBIENT NOISE LEVEL MEASUREMENT LOCATIONS IN HAWAII VOLCANOES NATIONAL PARK

Table 7.4.2 **SPOT AMBIENT NOISE LEVELS (dB) OBTAINED IN HAWAII VOLCANO NATIONAL PARK ON SEPTEMBER 30, 1991**

				Octave Band Center Frequency (Hz)							
Location	Time	dBA	dBC	63	125	250	500	1000	2000	4000	Comments
Puu Ulaula (PA)	10:00 am	34-42	66-69	63	45-50	41-48	27-42	25-32	23-27	23-24	Very windy
Hilina Pali (PB)	11:00 am	32	52	48	35	24	22	21	17	15	Windy (end of road to Pepeiao cabin)
Pepeiao Cabin (PC)	12:00 pm	46	67	47	45	41	41	33	31	24	Gusty and windy
Kipuka Nene Picnic Area (PD)	1:00 pm	44-46	67-68	50-53	45	36-41	33-41	33-34	31	24-27	
Crater Observatory (PE)	2:00 pm	38	50	44	43	39	34	29	24	19	Windy
Visitors Center (PF)	3:10 pm	41-48	57-63	55-63	51-57	43-50	39-47	38-43	32-38	28-32	
Volcano House (PG)	3:30 pm	42-44	55-60	54-57	48-49	44-47	42	37-38	30-33	24-30	Windy

Source: Darby & Associates, DEIS Appendix VII-B.

A noise impact assessment (Darby & Associates, DEIS Appendix VIIB) considered the potential impacts of noise from construction, facility operations and launches (See DEIS Appendix VIIB and Chapters IV and V of the FEIS). The potential impacts on HVNP are:

- Noise from on-going operations at the Industrial Area should generally be inaudible in the National Park if major stationary noise sources; e.g., diesel generators, cooling towers, etc. have stock noise mitigation features implemented. If sirens or P.A. systems are used in the Industrial Area, they could be directed and/or shielded to perform their function and also be inaudible at Pepeiau Cabin in the Park.

- If the proposed emergency diesel generator unit in the Technical Operations Facility is muffled by 25 dB, it should be inaudible at all times at Pepeiau Cabin, but could be audible in the most southern end of the Park. Implementation of 40 to 45 dB mitigation measures to the diesel unit are necessary to approach inaudibility in all portions of the Park.

- The additional traffic generated by the launch facility should cause less than a 1.5 dB increase in the average traffic noise levels along Route 11. Such an increase is not considered significant.

- Helicopter operations are envisioned for Spaceport surveillance every few days and during launch operations. Predicted noise contours based on a busiest day involving 8 takeoffs and 8 landings show that the Ldn 55 contour line can be easily confined well within the PCZ. To minimize helicopter noise in the Park it is recommended that ingress and egress routes over the ocean and all routine sweeps be greater than one mile from the Park boundary and preferably at lower altitudes.

Rocket launch noise was predicted at seven locations including the Park. The basic findings relevant to the Park are:

- There should be intense sound levels for several minutes with maximums of about 110 dB overall (90 dBA) in Pahala and Punalu`u with the noisiest rockets if they are launched during favorable climatic conditions and no sound focussing occurs. The corresponding levels at the HVNP Visitor Center are 93 dB overall and 62 dBA. At this distance, little high frequency noise will be heard. The sounds of a rocket launch will be similar to the rumble of distant thunder.

- Due to the spectral content and short durations of rocket launch noise events, there is no danger of exceeding the noise exposure limits set by OSHA with respect to causing hearing damage in areas outside of the PCZ.

7.0 Sonic Boom

The potential of launches at Palima Point to generate sonic booms was investigated by ACTA Inc. (DEIS Appendix VIIE). Only Kapoho Point, Puna, is within the no-wind sonic boom footprint for an easterly launch. The Park would not be affected. The sonic boom footprint for a southerly launch does not intersect the island.

8.0 Explosive Overpressure

An accident on the pad or the fall-back of a rocket shortly after lift-off can, under some circumstances, produce a high-yield explosion which in turn will generate a shock wave that will propagate through the atmosphere and may affect distant areas. The shock wave is affected by

atmospheric conditions, but the overpressure generally drops with distance from the source. Sufficiently high overpressures can cause glass breakage and result in consequent casualties. The results of blast overpressure modeling are presented in Appendix VIIF of the dEIS.

The Park headquarters complex was considered to be a noise-sensitive location, and modeling included overpressures there. The modeling revealed that the Park headquarters is too distant to be impacted adversely. Overpressures in the range of 0.05 to 0.50 psi can break glass. The highest overpressure predicted at the Park under any of seven representative meteorological conditions was 0.0135.

9.0 Emissions from Rockets and Launch Site Spills

The Park is classified by the U.S. EPA (under the Clean Air Act) as Class I for Air Quality. The Park is nearly adjacent to the proposed launch facility and is a sensitive receptor for any emissions from the facility. Class I areas carry special air quality and visibility considerations.

The Prevention of Significant Deterioration (PSD) program (40 CFR 52.21) regulations establish acceptable levels of deterioration or increments (maximum allowable increases) of any criteria pollutant from a new major stationary source in attainment or unclassified areas (i.e., Class I, Class II and Class III Areas). National Parks and wilderness areas are examples of areas designated as Class I, where practically any deterioration is considered significant. The HVNP is a Mandatory Class I Federal area (as defined in 40 CFR Part 81.409).

The NPS operates an ambient air quality monitoring station in HVNP near the Kilauea Caldera, approximately 22 miles northeast of Palima Point (Figure III-1.6). Sulfur dioxide and O_3 data obtained from the station indicate that, because of the close proximity to volcanic vents, the NAAQS and HAAQS for SO_2 have been exceeded.

The results of the air quality analysis indicate that there will be no significant impact. The primary emissions will be from launches and will be intermittent and of short-duration. (See DEIS Appendix VB and Chapters Four and Five of the FEIS for a more detailed discussion of air quality effects).

The potential hazards caused by dispersion of airborne toxic chemicals produced by rocket exhaust plumes or accidental spills at the Spaceport were modeled by ACTA Inc. (DEIS Appendix VID). They conclude that launch operations at Palima Point should pose no toxic hazards to off-site populations as a result of normal launches or vehicles destructed in flight or on the pad. Accidental spills involving individual storage containers or cryogenic tanks present a hazard only to on-site personnel, who should be trained and equipped to respond to such spills. The potential exists to expose Pahala, Punalu`u, Na`alehu and the surrounding area (presumably also nearby portions of the Park) to unacceptable levels of hydrazine, UDMH, and nitrogen dioxide under the most unfavorable spill and weather conditions. Operational restrictions would be imposed to prohibit potentially hazardous activities during unfavorable weather conditions that might affect HVNP.

10.0 Debris

The dispersion of debris from a launch accident or command destruct action was modeled by ACTA, Inc. (DEIS Appendix VIIA). In theory, debris from an elevated explosion of a launch vehicle could land within Park boundaries. In practice, however, operational constraints based on real-time meteorological monitoring would not permit a launch under conditions where debris from an accident or destruct could land on Park lands or other areas outside the PCZ.

11.0 Effects of Transportation Spills

Assumptions and Methodology. Approximately 12 miles of Highway 11 traverses the National Park as the main road. Propellants and cryogenic liquids and gases destined for use at the Spaceport would have to transit through the Park. A description of these chemicals may be found in Chapter Five. Worst case spill scenarios of these substances were examined at two key sites within the Park (Figure V-2.1), the front gate and at Kilauea Military Camp (ACTA Inc., DEIS Appendix VIA and RSA, DEIS Appendices VIIIA and VIIIB).

Results of the accidental spill analysis are presented as 1-Hour SPEGL contour plots overlaid on the map of each spill location. All of the plots may be found in Appendix VIA; Figures VII-4.4 through VII-4.7 show the plots for the most hazardous substances (hydrazine and nitrogen tetroxide) within HVNP for both 30-minute and 15-minute blanketing times. The 15-minute blanketing time represents the mitigating effect of a HAZMAT team accompanying the shipment.

The toxic contours presented in these figures are based on SPEGLs that reflect mild effects to the most sensitive population groups. Even the most sensitive individuals exposed to these concentrations of chemicals will not be subjected to severe effects.

Human Health Effects. Potential health effects from spills resulting from transportation accidents were evaluated at the eight representative potential accident locations along the Hilo-Palima Point transportation route shown on Figure V-2.1. Peak 60-minute average ground level concentrations (GLCs) resulting from an accidental spill of a 55-gallon drum of hydrazine or one 300-gallon cylinder of nitrogen tetroxide near the eight locations were assessed.

Predicted Concentrations. The highest 60-minute average concentrations of hydrazine predicted to occur at a distance of 20 m (66 feet, the closest distance modeled) from the spill locations within the Park, assuming a 15-minute blanketing time, would be 24.9 ppm during daytime conditions and 4.2 ppm during nighttime conditions. The highest concentration of nitrogen tetroxide predicted at the same distance from the spill site under the same 15-minute blanketing assumption would be 549.4 ppm during daytime conditions and 225.1 ppm during nighttime conditions. Table 7.4.3 lists these values for distances ranging from 20 m to 1,000 m (0.62 mile).

Cancer Risk Analysis. A short-term cancer risk analysis was conducted in which spills are assumed to occur at a rate of one per lifetime (one per 70 years) assuming a 15-minute blanketing time. The cancer risks due to the accidental spills are listed in Table 7.4.4. The maximum cancer risk due to hydrazine under daytime conditions and a 15-minute blanketing time is equivalent to 6.5 in 100,000 at 20 m (66 feet) from the spill. Under nighttime conditions the maximum cancer risk is 1.1 in 100,000 at the same distance. Risks due to more than one transportation accident involving hydrazine per lifetime are directly proportional to the values determined in this cancer risk analysis.

Noncancer Hazard Analysis. A hazard index of less than one is considered to be a nonsignificant risk. Because of the short-term, transitory, and infrequent nature of exposure, a hazard index of greater than 1.0 indicates that some members of the population may experience adverse effects, however brief or minor. These effects could range from mild respiratory irritation to an exacerbation of a preexisting condition (e.g., asthma or emphysema). At exposures where the hazard index exceeds 100, more severe effects such as pulmonary edema could possibly occur in the exposed population.

Results of the acute hazard index calculations for exposure to a receptor via inhalation of airborne emissions released during a transportation spill in HVNP are shown in Table 7.4.5. The

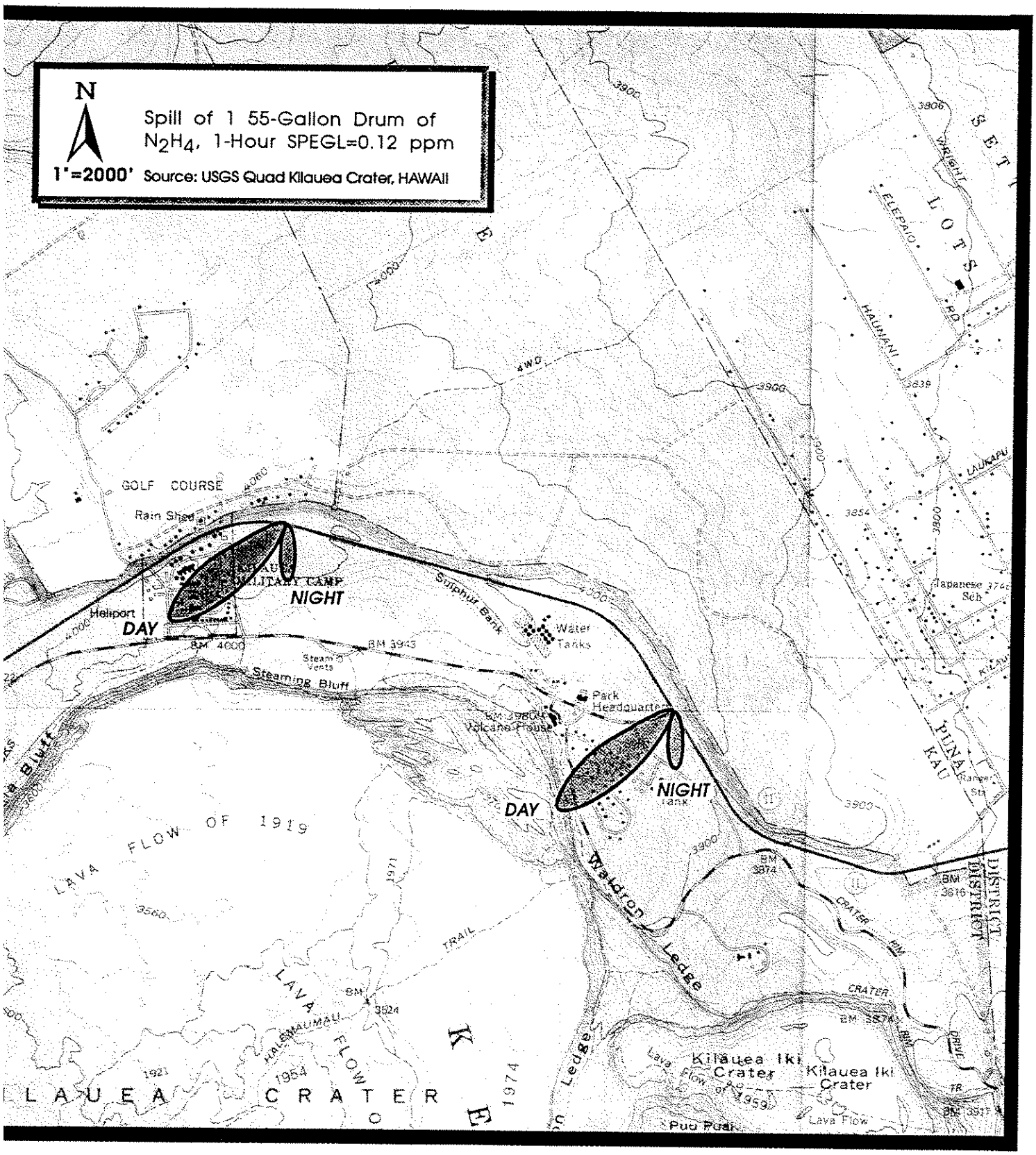


Figure VII-4.4

1 HR ISOPLETHS FROM ACCIDENTAL SPILL OF N2H4 AT LOCATIONS 6 AND 7 WITH 30 MINUTE BLANKETING TIME

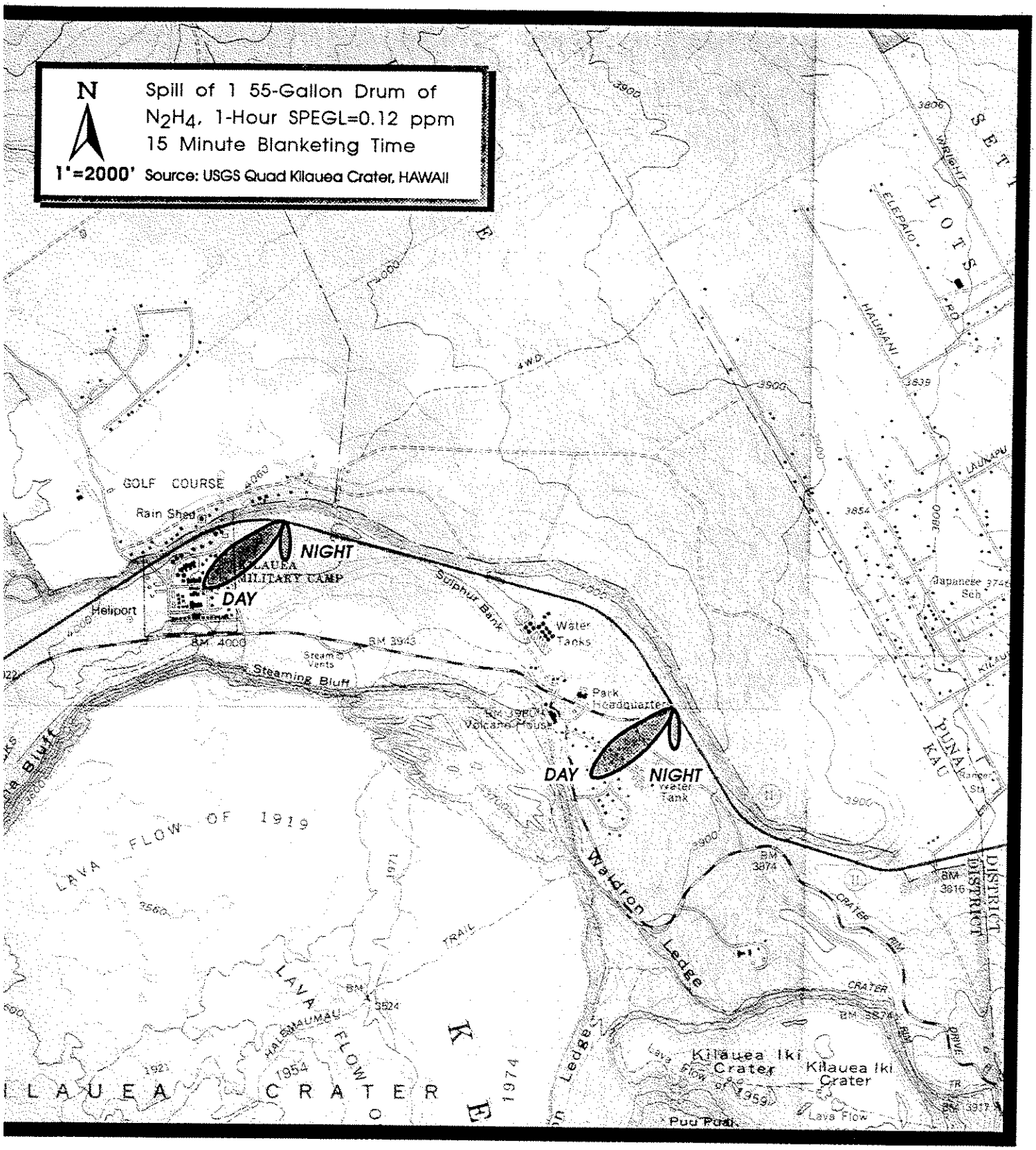


Figure VII-4.5

1 HR ISOPLETHS FROM ACCIDENTAL SPILL OF N2H4 AT LOCATIONS 6 AND 7 WITH 15 MINUTE BLANKETING TIME

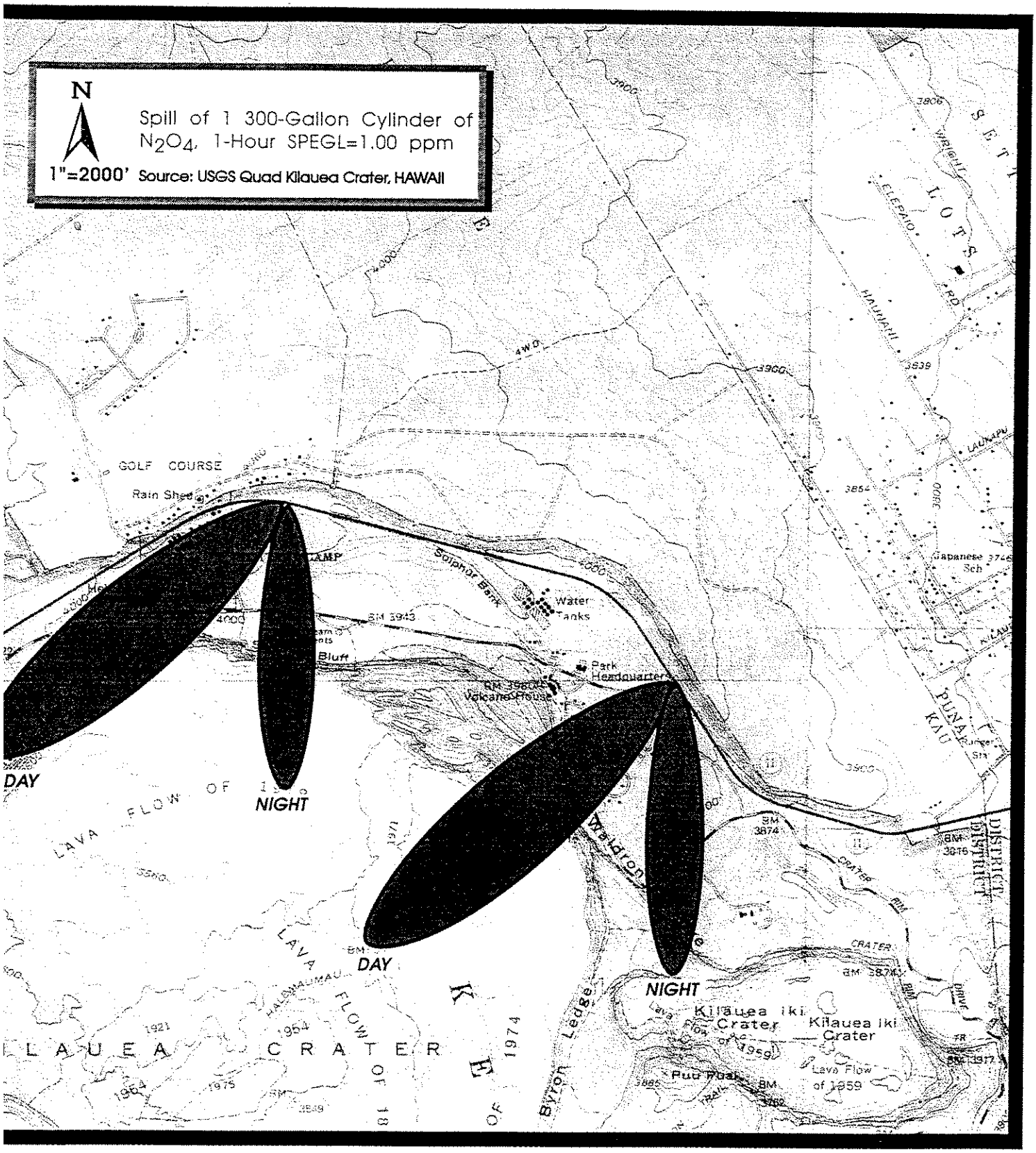


Figure VII-4.6

1 HR ISOPLETHS FROM ACCIDENTAL SPILL OF N2O4 AT LOCATIONS 6 AND 7 WITH 30 MINUTE BLANKETING TIME

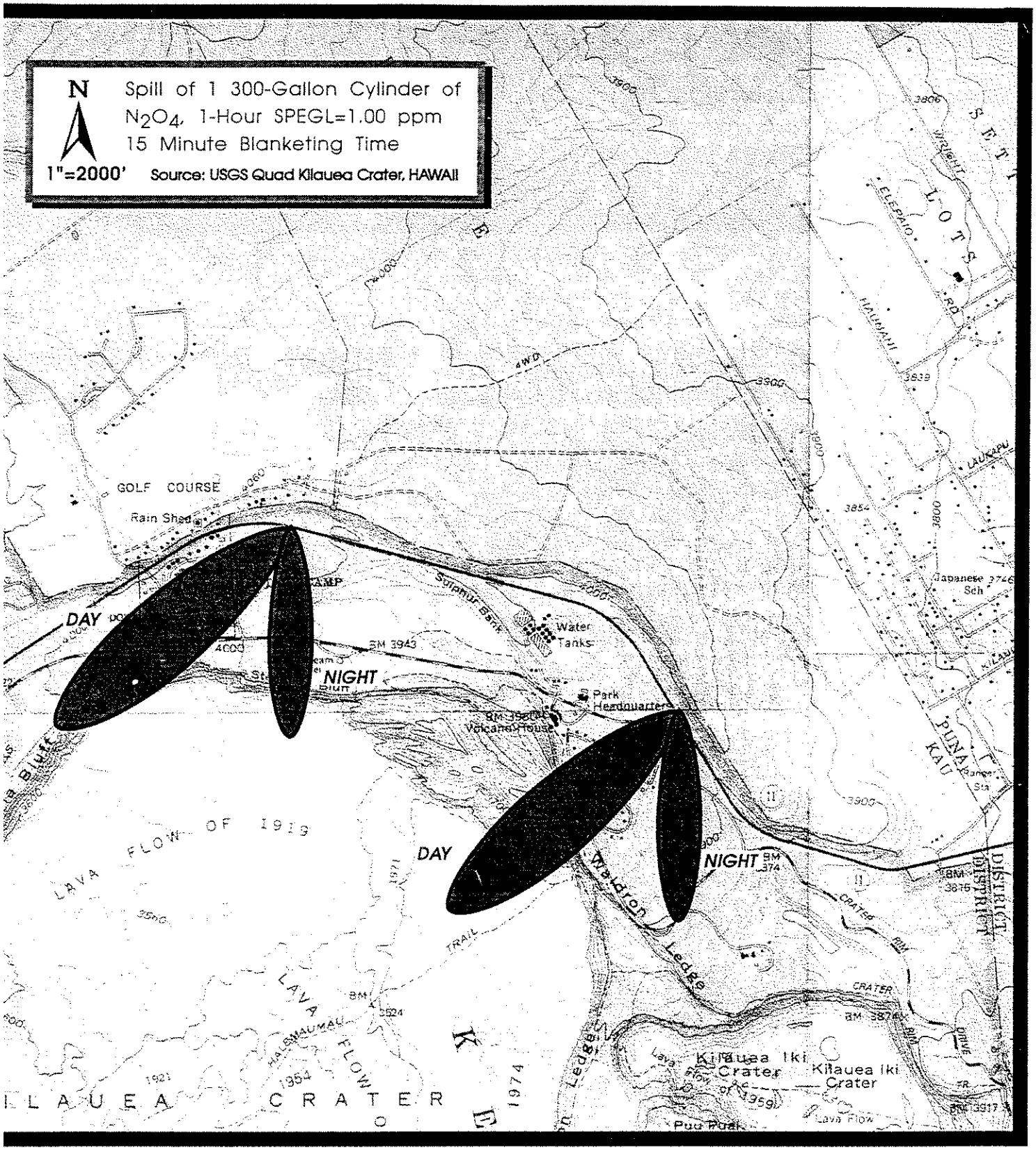


Figure VII-4.7

1 HR ISOPLETHS FROM ACCIDENTAL SPILL OF N2O4 AT LOCATIONS 6 AND 7 WITH 15 MINUTE BLANKETING TIME

Table 7.4.3 **PREDICTED PEAK 60-MINUTE TIME MEAN (1 HOUR AVERAGE) CONCENTRATIONS AT LOCATIONS 6 & 7, 15 MINUTE BLANKETING TIME**
(IN PPM)

Range (meters)	Hydrazine Day	Hydrazine Night	Nitrogen Tetroxide Day	Nitrogen Tetroxide Night
20	24.89	4.21	549.40	225.14
40	8.77	1.57	208.40	89.56
60	4.57	0.85	110.98	49.70
80	2.84	0.54	69.88	32.17
100	1.95	0.38	48.56	22.77
120	1.43	0.28	35.93	17.09
140	1.10	0.22	27.78	13.34
160	0.88	0.17	22.17	10.73
180	0.72	0.14	18.12	8.86
200	0.60	0.12	15.14	7.44
300	0.29	0.06	7.54	3.83
400	0.18	0.04	4.62	2.39
500	0.12	0.03	3.16	1.65
600	0.09	0.02	2.30	1.22
700	0.07	0.01	1.77	0.94
800	0.05	0.01	1.41	0.76
900	0.04	0.01	1.15	0.62
1000	0.04	0.01	0.96	0.52

Source: Risk Science Associates, DEIS Appendix VIII-A.

Table 7.4.4 **CANCER RISK DUE TO RELEASE OF HYDRAZINE WITHIN VOLCANOES NATIONAL PARK (LOCATIONS 6 & 7), 15-MINUTE BLANKETING TIME**

(Inhalation Unit Risk for Hydrazine = .0049 $(\mu g/m^3)^{-1}$)

Range (meters)	Hydrazine Day	Hydrazine Night
20	6.5E-05 (.000065)	1.1E-05 (.000011)
40	2.3E-05 (.000023)	4.1E-06 (.0000041)
60	1.2E-05 (.000012)	2.2E-06 (.0000022)
80	7.4E-06 (.0000074)	1.4E-06 (.0000014)
100	5.1E-06 (.0000051)	9.9E-07* (.00000099)
120	3.7E-06 (.0000037)	7.3E-07* (.00000073)
140	2.9E-06 (.0000029)	5.7E-07* (.00000057)
160	2.3E-06 (.0000023)	4.4E-07* (.00000044)
180	1.9E-06 (.0000019)	3.7E-07* (.00000037)
200	1.6E-06 (.0000016)	3.1E-07* (.00000031)
300	7.6E-07* (.00000076)	1.6E-07* (.00000016)
400	4.7E-07* (.00000047)	1.0E-07* (.0000001)
500	3.1E-07* (.00000031)	7.8E-08* (.000000078)
600	2.4E-07* (.00000024)	5.2E-08* (.000000052)
700	1.8E-07* (.00000018)	2.6E-08* (.000000026)
800	1.3E-07* (.00000013)	2.6E-08* (.000000026)
900	1.0E-07* (.0000001)	2.6E-08* (.000000026)
1000	1.0E-07* (.0000001)	2.6E-08* (.000000026)

Source: Risk Science Associates, DEIS Appendix VIII-A.

* Less than 1 in a million

Table 7.4.5 **ACUTE HAZARD INDEX - LOCATIONS 6 & 7, 15-MINUTE BLANKETING TIME**
(Acute inhalation AEL for Hydrazine = 160 μg/m³)
(Acute inhalation AEL for N2O4 = 1900 μg/m³)

Range (meters)	Hydrazine Day	Hydrazine Night	Nitrogen Tetroxide Day	Nitrogen Tetroxide Night
20	2.0E+02 (200)	3.4E+01 (34)	3.8E+02 (380)	1.6E+02 (160)
40	7.2E+01 (72)	1.3E+01 (13)	1.4E+02 (140)	6.2E+01 (62)
60	3.7E+01 (37)	6.9E+00 (6.9)	7.6E+01 (76)	3.4E+01 (34)
80	2.3E+01 (23)	4.4E+00 (4.4)	4.8E+01 (48)	2.2E+01 (22)
100	1.6E+01 (16)	3.1E+00 (3.1)	3.3E+01 (33)	1.6E+01 (16)
120	1.2E+01 (12)	2.3E+00 (2.3)	2.5E+01 (25)	1.2E+01 (12)
140	9.0E+00 (9)	1.8E+00 (1.8)	1.9E+01 (19)	9.2E+00 (9.2)
160	7.2E+00 (7.2)	1.4E+00 (1.4)	1.5E+01 (15)	7.4E+00 (7.4)
180	5.9E+00 (5.9)	1.1E+00 (1.1)	1.2E+01 (12)	6.1E+00 (6.1)
200	4.9E+00 (4.9)	9.8E-01 (0.98)	1.0E+01 (10)	5.1E+00 (5.1)
300	2.4E+00 (2.4)	4.9E-01 (0.49)	5.2E+00 (5.2)	2.6E+00 (2.6)
400	1.5E+00 (1.5)	3.3E-01 (0.33)	3.2E+00 (3.2)	1.6E+00 (1.6)
500	9.8E-01 (0.98)	2.5E-01 (0.25)	2.2E+00 (2.2)	1.1E+00 (1.1)
600	7.4E-01 (0.74)	1.6E-01 (0.16)	1.6E+00 (1.6)	8.4E-01 (0.84)
700	5.7E-01 (0.57)	8.2E-02 (0.082)	1.2E+00 (1.2)	6.5E-01 (0.65)
800	4.1E-01 (0.41)	8.2E-02 (0.082)	9.7E-01 (0.97)	5.2E-01 (0.52)
900	3.3E-01 (0.33)	8.2E-02 (0.082)	7.9E-01 (0.79)	4.3E-01 (0.43)
1000	3.3E-01 (0.33)	8.2E-02 (0.082)	6.6E-01 (0.66)	3.6E-01 (0.36)

Source: Risk Science Associates, DEIS Appendix VIII-A.

1-Hour SPEGLs for both of these substances (0.12 ppm for hydrazine and 1.0 ppm for nitrogen tetroxide) were used in the calculation of the hazard index. While use of a 1-Hour SPEGL may not accurately predict the potential hazards to humans exposed for periods of less than one hour, the absence of toxicological data in humans and animals for shorter exposure periods and the uncertainty that complete containment and removal of a spill could occur in less than one hour, dictates the use of the most health-protective yet scientifically-based standard.

The maximum hazard index for a spill of hydrazine, 200, occurs at 20 m (66 feet) from the spill site during daytime conditions. During nighttime conditions the maximum hazard index is 34. The maximum acute hazard index due to a spill of nitrogen tetroxide is 380 during daytime conditions. During nighttime conditions the maximum hazard index is 160. Generally, the airborne concentrations of hydrazine would fall below 0.12 ppm at 600 - 700 m (about 2,000 to 2,300 feet) from the spill. The concentrations of nitrogen tetroxide would only fall below 1.0 ppm at distances greater than 900 m (about 3,300 feet). It should also be noted that the IDLH level of 50 ppm for nitrogen tetroxide would be exceeded at distances up to 100 m (330 feet) from the spill site.

Significance of Effects. Although the spills analyzed for the Park do not pose a significant cancer risk as defined by EPA, it is important that an emergency response team be available to accompany transportation vehicles.

The results of the noncancer hazard analysis indicate that persons within 20 m (66 feet) of a spill of hydrazine or nitrogen tetroxide under unfavorable weather conditions could suffer severe adverse health effects, even if the HAZMAT team following the transportation truck is able to cordon off the spill area, contain the spilled product, and either cover the spill or remove it.

Ecological Risk Assessment. Of the eight different potential accident locations, those within the Park have the greatest densities of identified and reported special status species of all the locations modeled. Refer to Table 7.4.1 for a summary of listed species found within the Park.

As noted in Section I of Chapter Five, the only exposure pathway deemed complete in animals is exposure through inhalation, and for plants, dermal exposure and uptake through the surfaces of the leaf. After review of the available toxicological data, the most appropriate toxicity value was chosen (NOEL or LOEL values in species taxonomically related to the sensitive ecological receptors found in the transportation route). These selected values were then used to characterize risk by being compared to the estimated exposure point concentrations.

Table 7.4.6 lists toxicological endpoint concentrations (TECs), uncertainty factors (UF) and centerline one hour average concentrations (EC) for hydrazine, UDMH and nitrogen tetroxide at locations 6 and 7. Table 7.4.7 gives predicted peak 60-minute average concentrations at same locations with 15 and 30 minute blanketing times for the same chemicals. The effects of toxic spills on sensitive species is described below for each chemical of concern.

Hydrazine. An accidental spill of a 55-gallon drum of hydrazine during daytime conditions (30-minute blanketing time) produces a 1-Hour average centerline concentration of 47.48 ppm at 20 m from the spill. Small but measurable quantities are predicted beyond 1.0 km from the spill. Exposure to hydrazine could potentially produce adverse effects in sensitive ecological receptors located in proximity to the spill, but would be unlikely to produce adverse effects at distances of 1.0 km (0.62 miles) or greater.

Nitrogen Tetroxide. The highest concentration from a spill of a 300-gallon cylinder of

Table 7.4.6 **TRANSPORTATION SPILL SCENARIO RISK CHARACTERIZATION**

Substance	**Toxicological Endpoint Concentrations (TECs)**	**Uncertainty Factors (UF)**	**Centerline one hour time mean concentration (EC)**	**Risk Characterization Is EC<TEC(UF)*?**	**Potential Risk? Yes/No**
Hydrazine	animals = 634 ppm (1 hr LC50) plants = no data	species = 0.01 LC50 to NOEL/LOEL = 0.1	20 m downwind = 47.48 ppm 1 km downwind = 0.07 ppm	20 m = 47.48 ppm > 634 (0.01*0.1) ppm 1 km = 0.07 ppm < 634 (0.01*0.1) ppm	20 m: Yes 1 km: No
Nitrogen Tetroxide/ Nitrogen Dioxide N_2O_4/NO_2	animals = 30 ppm (1 hr LC50) plants = 0.5 µl/l LOEL	animal species = 0.01 LC50 to NOEL/LOEL = 0.1 plant species = 0.1	20 m downwind = 1047.37 ppm 1 km downwind = 1.68 ppm	Animals: 20 m = 1047 ppm > 30 (0.01*0.10) ppm 1 km = 1.68 ppm > 30 (0.01*0.10) ppm Plants : 20 m = 1047.37 ppm > 0.5 (0.1) ppm 1 km = 0.22 > 0.5 (0.1) ppm	Animals: 20 m: Yes 1 km: Yes Plants: 20 m: Yes 1 km: Yes
Unsymmetrical dimethyl-hydrazine (UDMH), FDH	animals = 981 ppm (1 hr LC50) plants = no data	species = 0.01 LC50 to NOEL/LOEL = 0.1	20 m downwind = 154.89 ppm 1 km downwind = 0.22 ppm	20 m = 154.89 ppm > 981 (0.01*0.1) ppm 1 km = 0.22 ppm < 981 (0.01*0.1) ppm	20 m: Yes 1 km: No

Source: Risk Science Associates, DEIS Appendix VIII-B.

* Is one-hour average concentration less than toxicological endpoint concentration times uncertainty factor?

Table 7.4.7 **PREDICTED PEAK 60-MINUTE TIME MEAN (1 HOUR AVERAGE) CONCENTRATIONS AT LOCATIONS 6 & 7, 15 MINUTE AND 30 MINUTE BLANKETING TIMES**
(IN PPM)

Range	30 min blanketing time			15 min blanketing time	
	Hydrazine (55 gal.)	N2O4 (300 gal.)	UDMH (55 gal.)	Hydrazine (55 gal.)	N2O4 (300 gal.)
20	47.48	1047.37	154.89	24.89	549.40
40	15.86	370.67	51.74	8.77	208.40
60	8.14	195.04	26.57	4.57	110.98
80	5.04	122.25	16.43	2.84	69.88
100	3.46	84.64	11.28	1.95	48.56
120	2.59	63.91	8.45	1.43	35.93
140	2.0	49.47	6.52	1.10	27.78
160	1.59	39.55	5.2	0.88	27.17
180	1.3	32.43	4.25	0.72	18.12
200	1.09	27.14	3.55	0.60	15.14
300	0.54	13.56	1.77	0.29	7.54
400	0.33	8.19	1.06	0.18	4.62
500	0.22	5.53	0.72	0.12	3.16
600	0.16	4.05	0.52	0.09	2.30
700	0.12	3.12	0.4	0.07	1.77
800	0.1	2.48	0.32	0.05	1.41
900	0.08	2.02	0.26	0.04	1.15
1000	0.07	1.68	0.22	0.04	0.96

Source: Risk Science Associates, DEIS Appendix VIII-A.

N_2O_4 would be found 20 m (66 feet) from source and would produce an EC of 1047.37 ppm. Small quantities of nitrogen tetroxide would be measured beyond 1.0 km from the spill. A comparison of the ECs with the adjusted TECs shows that there is the potential for adverse effects to occur to sensitive species located up to 1.0 km from the spill. Predicted concentrations for N_2O_4 at distances ranging from 20 to 1,000 m (66 to 3,300 feet) are listed in Table 7.4.7.[4]

UDMH. An accidental spill of a 55 gal drum of UDMH is estimated to produce an EC of 154.89 ppm at a distance of 20 m from the spill (Table 7.4.7). Small quantities of UDMH would be measured beyond 1.0 km from the spill. Exposure to this concentration of UDMH could potentially produce adverse effects in sensitive ecological species located in proximity to the spill, but would be unlikely to produce adverse effects at distances greater than 1.0 km.

Significance of Effects. For the worst case scenario assessed, the highest concentrations were estimated to be closest to the highway. Within 20 m of the highway, estimated concentrations of all three substances - hydrazine, UDMH and nitrogen tetroxide - were above levels that have been found to produce adverse effects. The concentrations of these compounds, however, decreased in distance from the site. Only N_2O_4/NO_2 was still unacceptably high at 1 km from the site.

While estimated concentrations of the three substances could potentially produce adverse effects to biota close to the highway (there have been reports of listed species within 1 km of the highway), the three most sensitive habitats within the Park are located farther away from Highway 11 and it is unlikely that they would be affected by spills.

Other Effects. If an accident involving a hazardous propellant occurs--even if there is no leak or spill--a safety zone would be established to protect the public from danger. The extent of this zone would vary by type of accident and release. The duration would also vary; therefore, certain highway segments could be closed for hours, which is significant because there are no alternate roads to Highway 11. This type of closure is expected to be very infrequent.

SECTION V: VISUAL IMPACT ANALYSIS

A. METHODOLOGY

Field analyses were undertaken to identify the most significant view corridors and vantage points in the vicinity of the proposed project. Factors considered in evaluating the potential visual impact from each viewing point were: distance of the view, duration of the view when driving along the highway, and number of potential viewers. Various landscape characteristics were identified along Highway 11 that would affect visibility of the site from specific vantage points. These were: "enclosed landscape" (view screened by orchards); mixed forest with occasional view corridors; and, open pasture/shrubland. Photos were taken from each viewing point to show how the site would appear from various locations. Launch facilities were superimposed on photos taken from four locations in the vicinity of the site. In all cases, the site is viewed from above.

B. EXISTING CONDITIONS

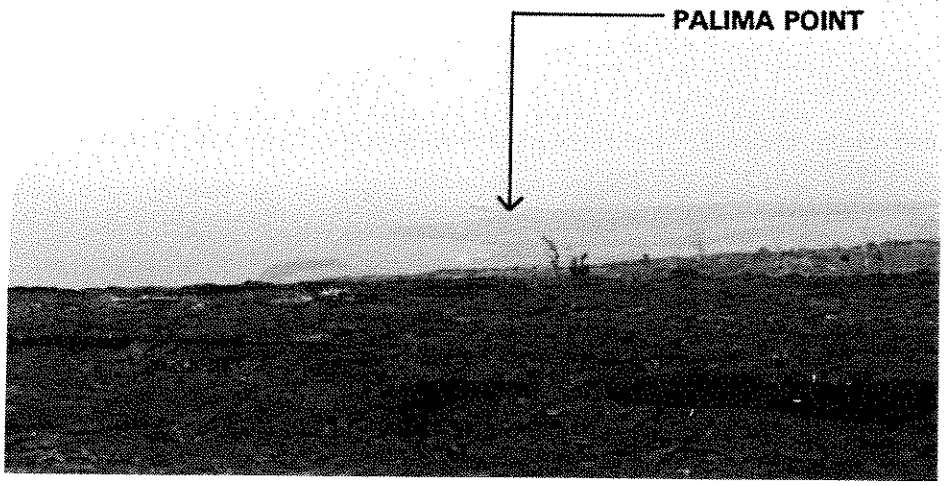
The Palima Point site can be described as having a flat to undulating terrain which is primarily of wild coastline character. The site slopes towards the sea and with the exception of several small cinder cones, has no landform to contrast its flat character.

The site can be seen from several locations within HVNP and from Highway 11 and Pahala. The visual character of the site is a "natural" or undisturbed coastal area, except that the higher elevations are planted in macadamia nuts. The visual attributes of the site are similar to the wilderness area of the adjacent HVNP. Due to the open flat terrain that slopes towards the ocean, the entire Spaceport facility will be visible from offshore.

C. LONG-RANGE VIEWS

Long-Range Views From HVNP. The project area is visible from two lookouts along Chain of Craters Road: Muliwai a Pele and Ke Ala Komo. The lookout at Muliwai a Pele provides visitors with a panoramic view of various landscape features within the Park and a portion of the Ka'u coastline. Palima Point forms part of the background of the view from this lookout (Figure VII-5.1). This viewpoint is about 20 miles from the proposed launch site: therefore, project facilities would be barely perceptible as small elements of contrasting color and shape in the distance.

Ke Ala Komo lookout is located at the top of the Holei Pali and provides Park visitors with a spectacular view of the Puna/Ka`u coastline. Palima Point is visible in the background, approximately 21 miles away (Figure VII-5.2). Although the launch facilities would be barely visible from that distance because the orientation of the view is towards the coastline, the project facilities will become evident to Park users with sufficient viewing duration.



VIEW OF PALIMA POINT FROM MULIWAI Ā PELE LOOKOUT, HAWAII VOLCANOES NATIONAL PARK

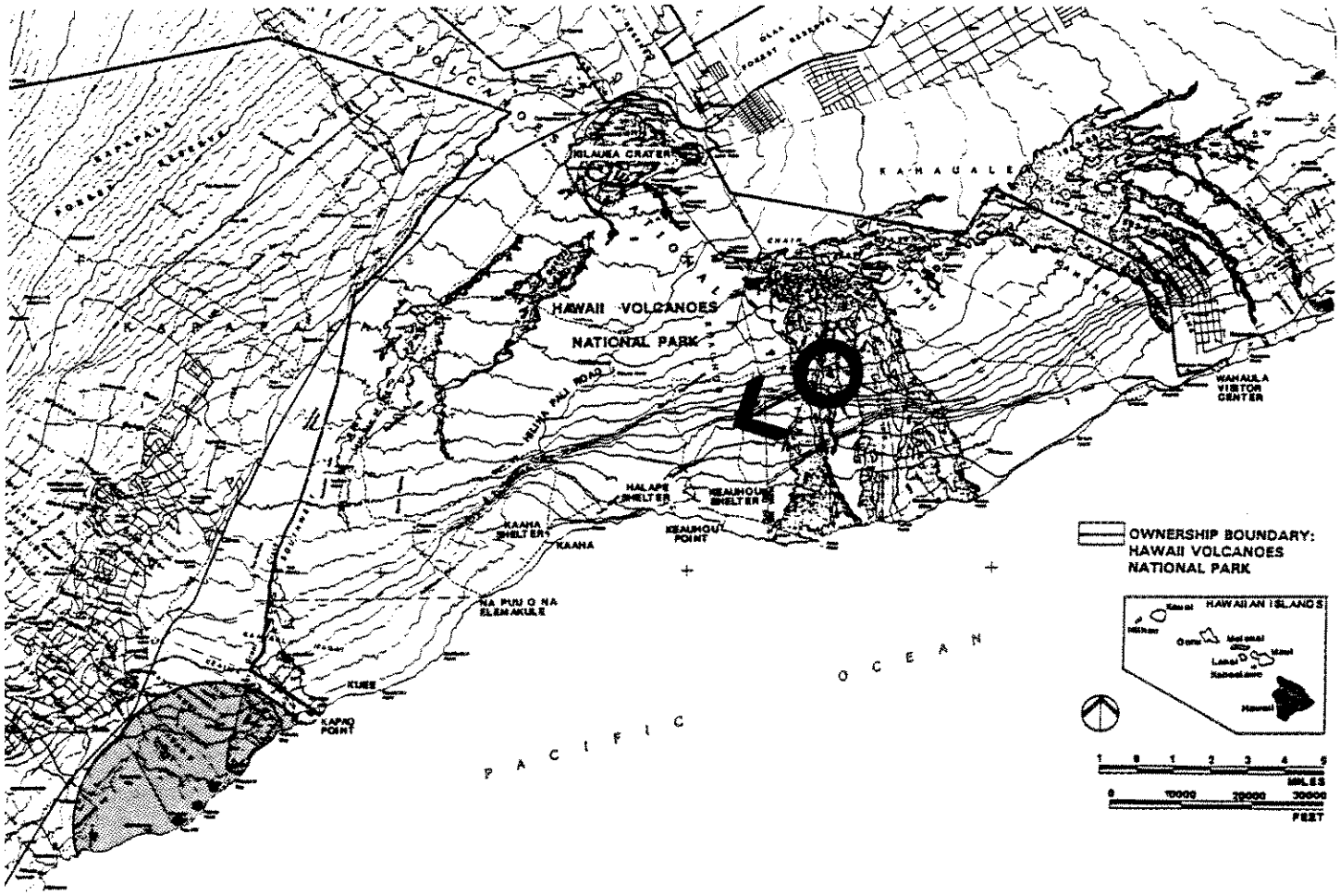
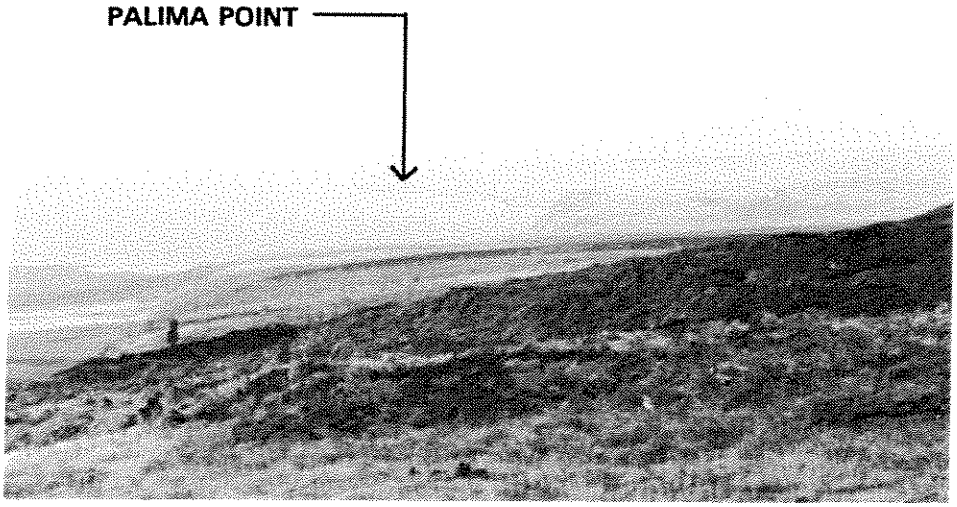


Figure VII-5.1

LONG RANGE VIEW OF PALIMA POINT SITE FROM MULIWAI Ā PELE LOOKOUT



VIEW OF PALIMA POINT FROM KE ALA KOMO LOOKOUT, HAWAII VOLCANOES NATIONAL PARK

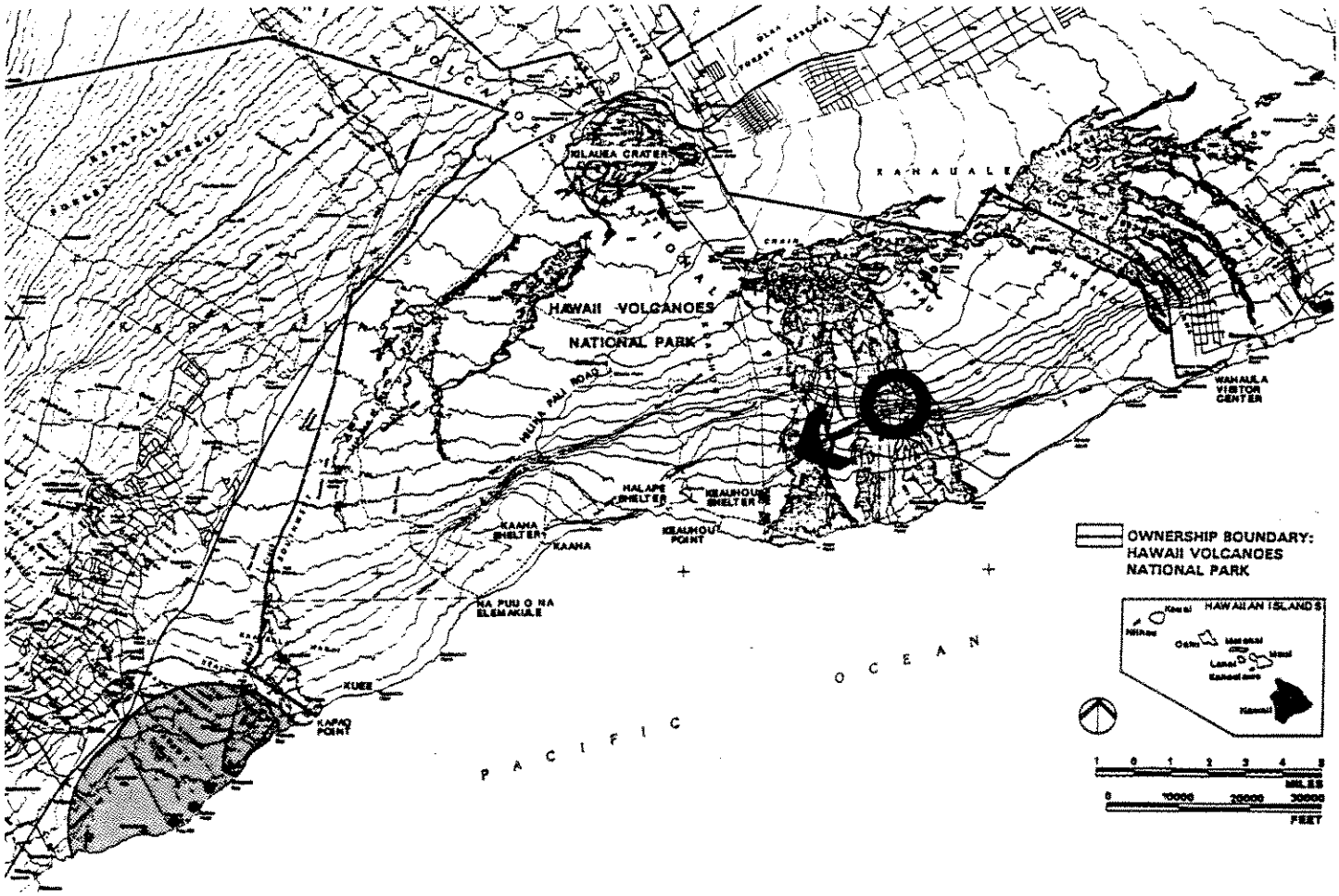


Figure VII-5.2
LONG RANGE VIEW OF PALIMA POINT SITE FROM KE ALA KOMO LOOKOUT

The project site would also be visible from the shelter at Hilina Pali, the southernmost point within the Park that is accessible by improved road. This area has panoramic views of the coastline which include Palima Point in the background about 13 miles away (Figure VII-5.3).

Long-Range View From Highway 11. The project area is visible from various locations along the highway. While traveling southbound, the Palima Point site is first visible from a point about 5 miles away, at an elevation of 1500 feet (Figure VII-5.4). Much of the site will be visible from here, however, there is no scenic lookout at this location. Because people will be in moving vehicles, the duration of the view at this location will be very brief.

While traveling northbound, the site is first visible from a location above Honu`apo Bay, just south of Na`alehu (Figure VII-5.5). At this point the highway has a wide shoulder which appears to be used as a lookout/pullover area. This location provides the first view to northbound motorists of the coastline and the National Park. The entire project will be visible from this point at a distance of about 9 miles.

D. VISUAL IMPACT ANALYSIS FROM LOCATIONS NEAR PALIMA POINT

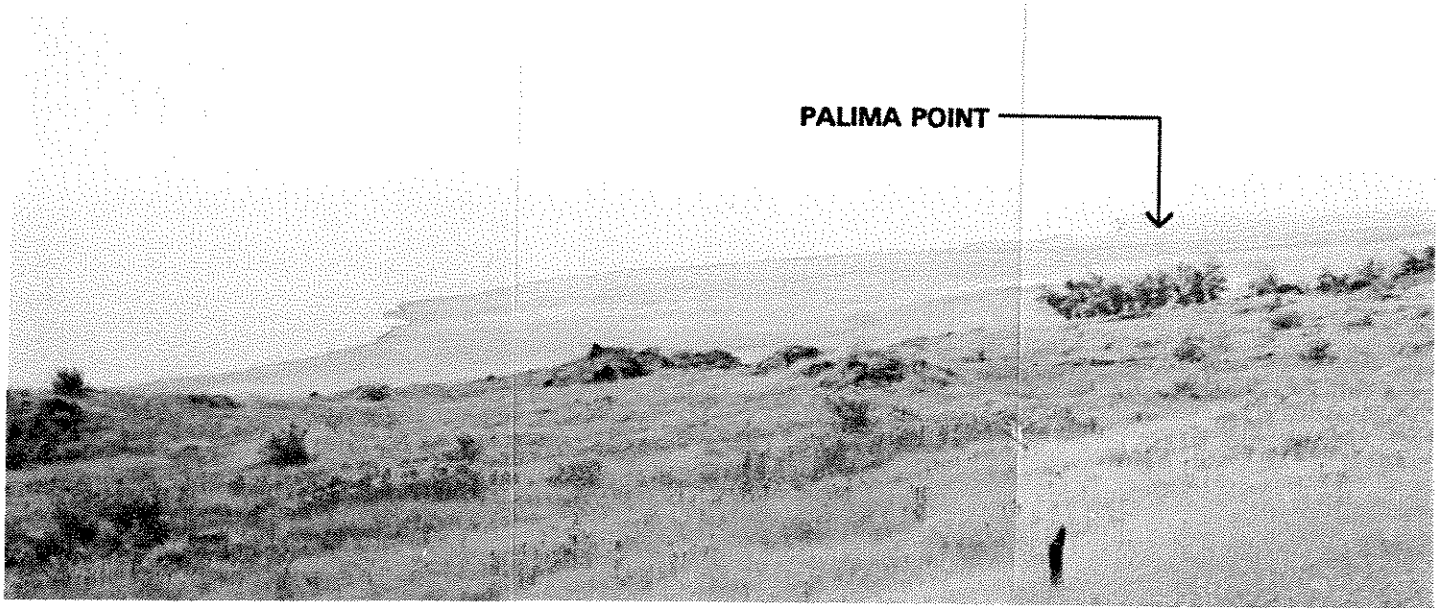
Figure VII-5.6 identifies view corridors in the vicinity of the site. These include views from locations adjacent to the southern Park boundary (A), from Pahala (B & C) and from Highway 11, south of the town (D). Visual impact from locations A through D are described below:

Hawaii Volcanoes National Park (HVNP). The proposed launch site will be visible from various locations within the southern wilderness area of the Park. Because many of these viewing areas are accessible only by hiking over long distances, the analysis was made from just south of the Park boundary, near Pu`u Ulaula (Location A). As shown in Figure VII-5.7, the entire facility is visible from that vantage point. The primary user group that would experience these views are those Park visitors who are willing to hike several miles in order to experience a remote, serene ambience and are expecting to see an undisturbed landscape. The introduction of Spaceport facilities into this viewshed could have a significant impact the users' wilderness experience.

Pahala. The highest level of visual impact will be from Pahala. The Technical Operations Area (Figure VII-5.8, as seen from Location B on Figure VII-5.6) will intrude onto the natural landscape. The main structure will be about 21,000 square feet in area by about 13 feet high. Tracking instrumentation and small fixed telemetry antennas will be mounted on the roof. A separate utility building will also be present in the area.

Portions of the Spaceport facility will be visible from Location C (Figure VII-5.9) and other areas with direct views to Palima Point. Residents will see two 175- to 225-foot-high mobile service towers along the coastline. The towers will be highly visible because the ocean will serve as a backdrop and the duration of the view will be continuous. Because the elements will be introduced into a landscape which is currently undisturbed by structures, the towers will intrude upon the middleground line form created by the shoreline. Visual impact will be high.

Along Highway 11. Near Pahala, the viewer is in an enclosed landscape surrounded by macadamia nut groves and windbreak trees 30 to 40 feet tall (Figure VII-5.10). The site is screened from view for about 3 miles, although at two points along this section of the highway, the facility is partially visible down the existing drainage gulches (Figure VII-5.6). South of Pahala, the landscape changes to a mixed forest characterized by a dense growth of monkeypod and other broadleaf canopy trees (Figure VII-5.11). This landscape screens most of the views of the



VIEW OF PALIMA POINT FROM HILINA PALI SHELTER, HAWAII VOLCANOES NATIONAL PARK

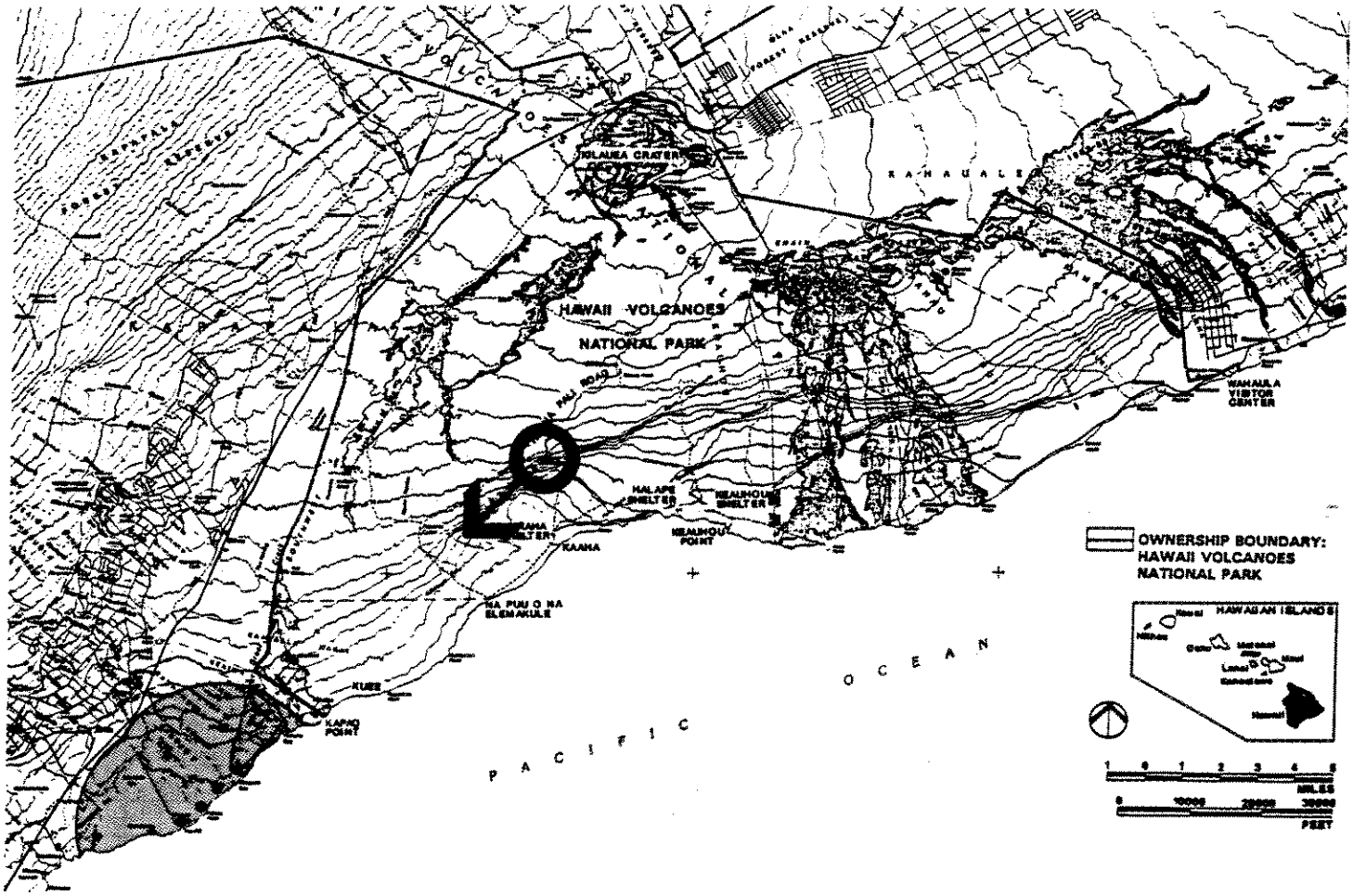
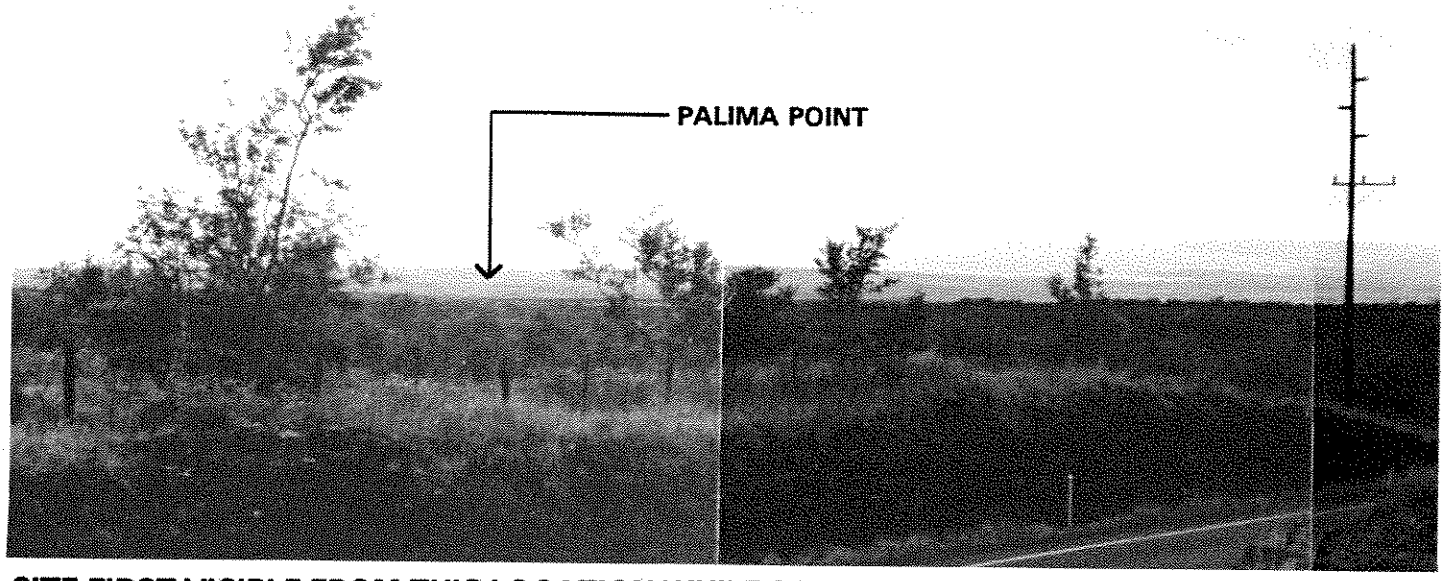


Figure VII-5.3
LONG RANGE
VIEW OF PALIMA POINT SITE FROM HILINA PALI



SITE FIRST VISIBLE FROM THIS LOCATION WHILE SOUTHBOUND ON HIGHWAY 11 AT 1500′ ELEVATION

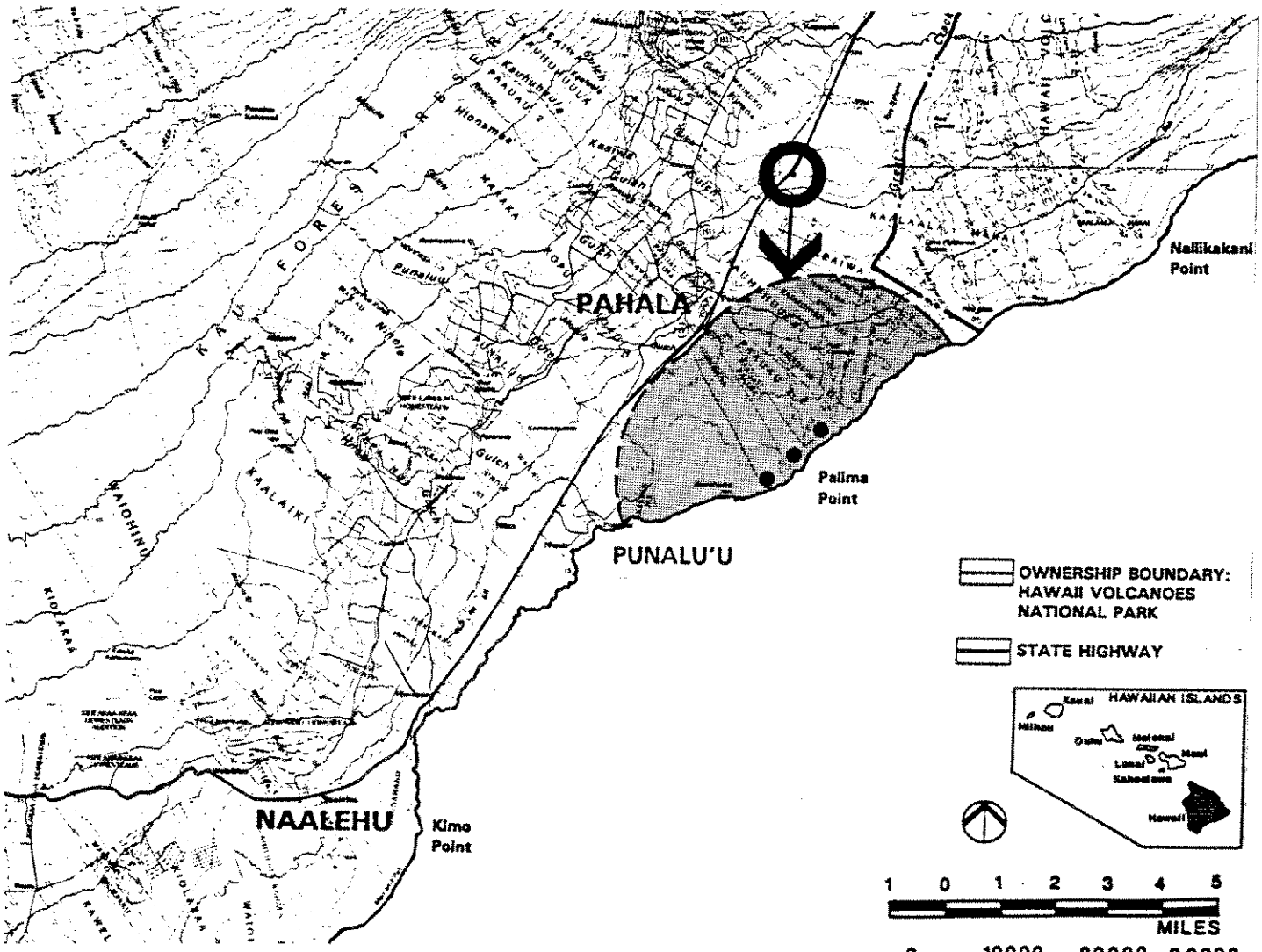
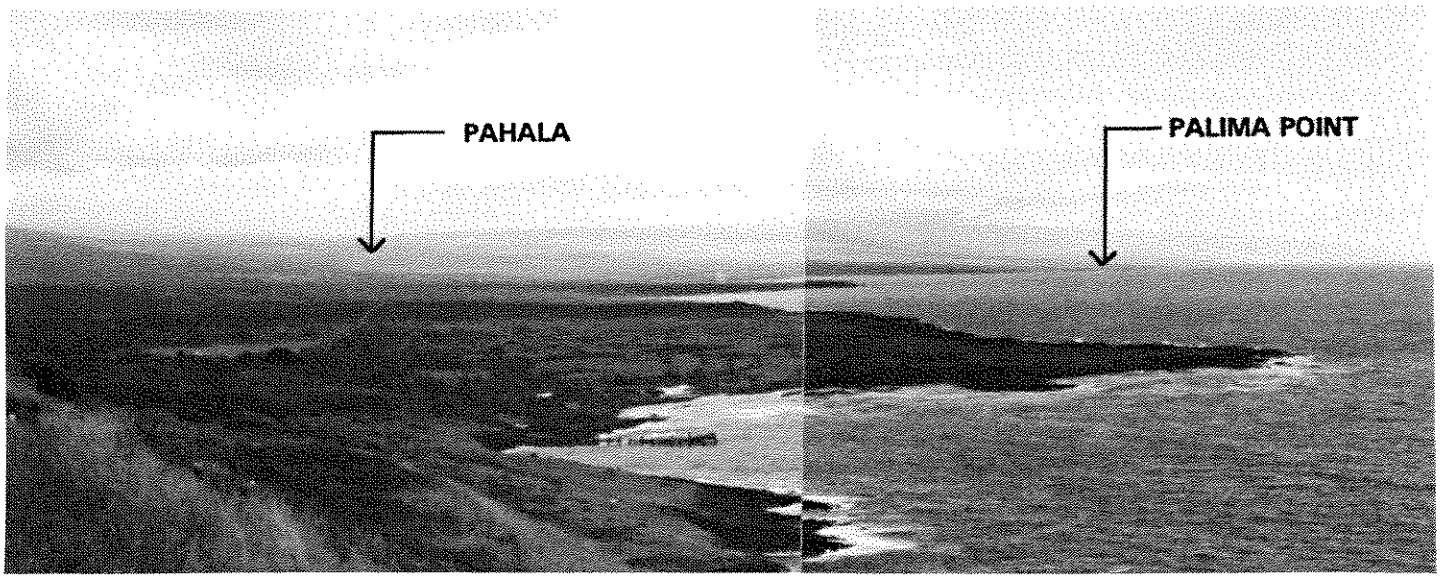


Figure VII-5.4

LONG RANGE VIEW OF PALIMA POINT SITE - SOUTHBOUND ON HIGHWAY 11



VIEW OF PALIMA POINT FROM PULL-OVER ALONG HIGHWAY ABOVE HONAUAPO BAY, ENTIRE SITE FIRST VISIBLE IF TRAVELING NORTH ON HIGHWAY 11

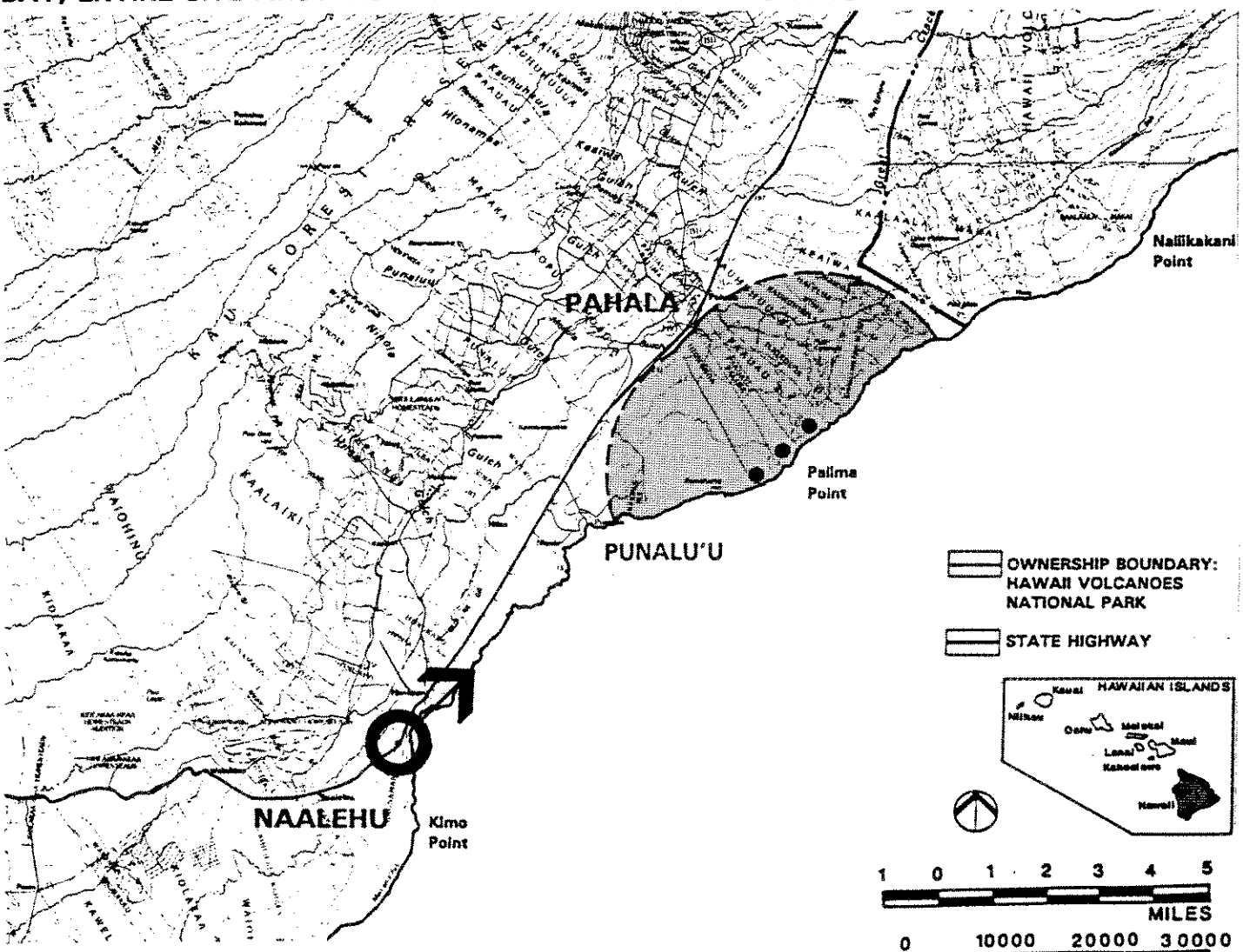


Figure VII-5.5

LONG RANGE VIEW OF PALIMA POINT SITE - NORTHBOUND ON HIGHWAY 11

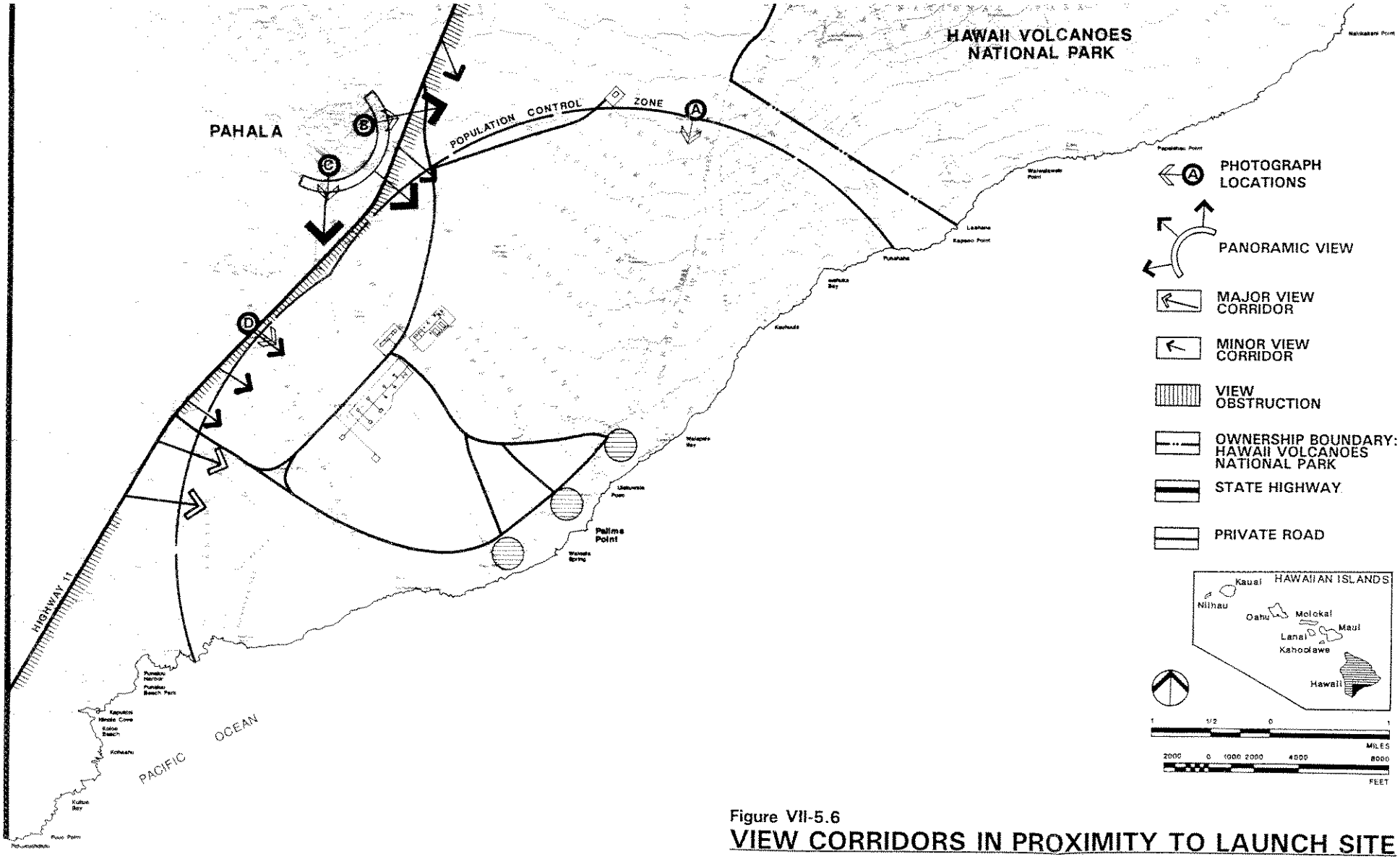


Figure VII-5.6

VIEW CORRIDORS IN PROXIMITY TO LAUNCH SITE

VIEW OF SITE FROM LOCATION NEAR HAWAII VOLCANOES NATIONAL PARK BOUNDARY

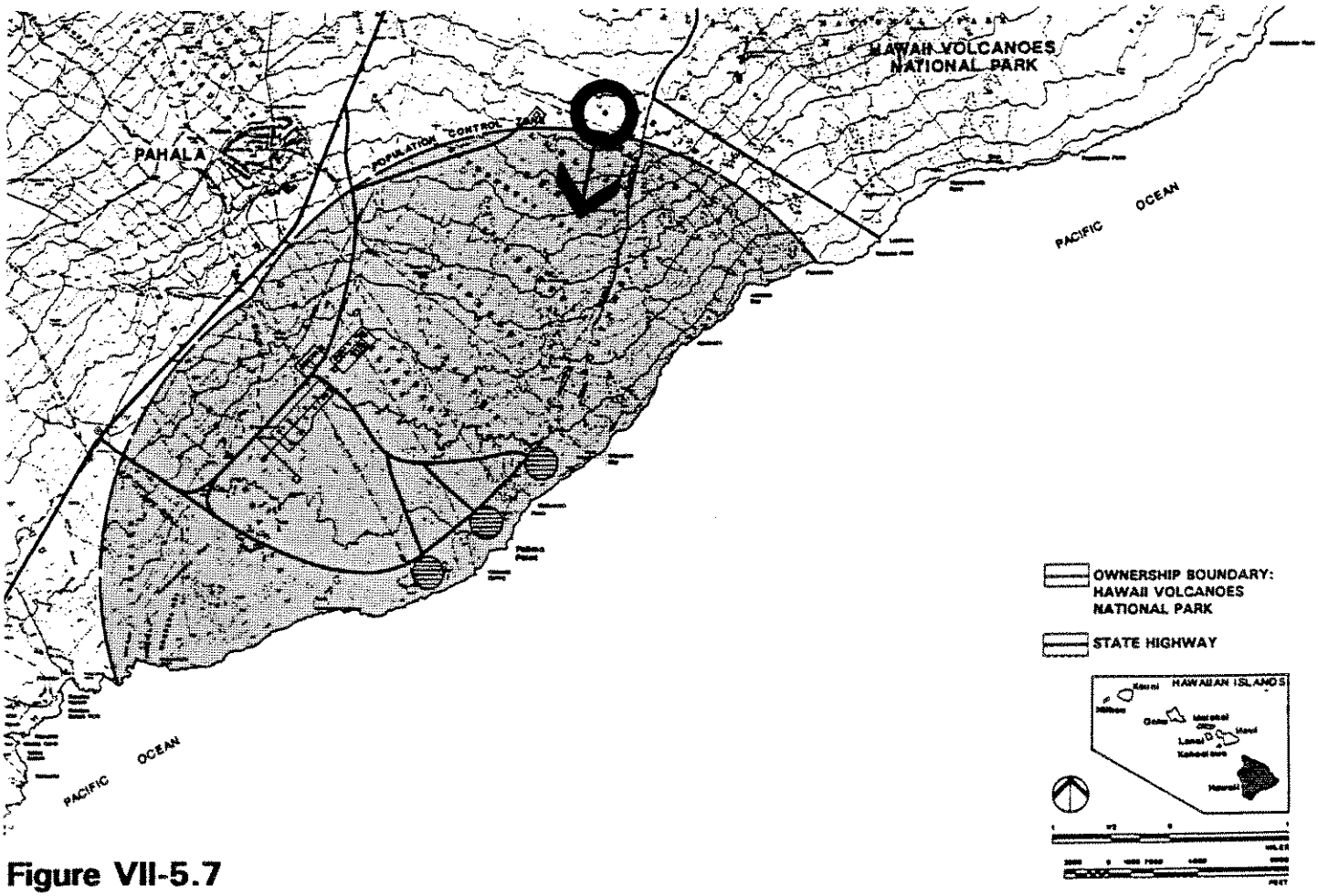
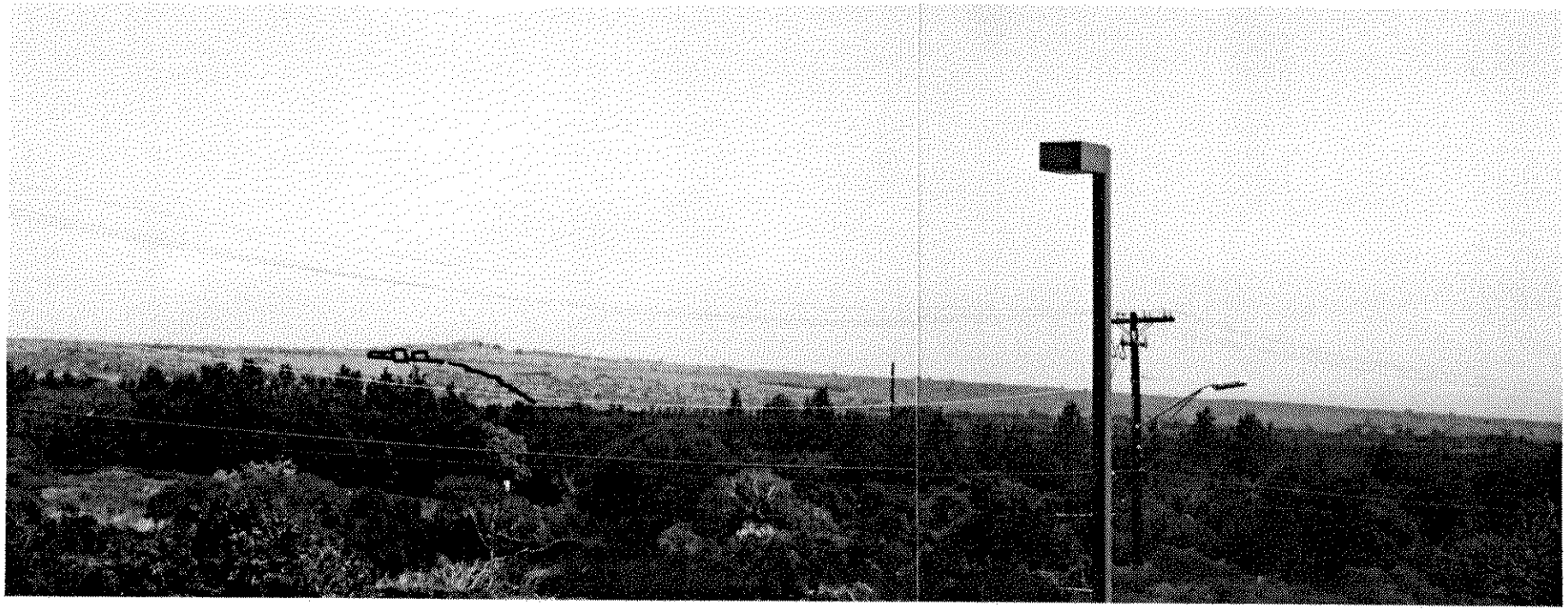


Figure VII-5.7

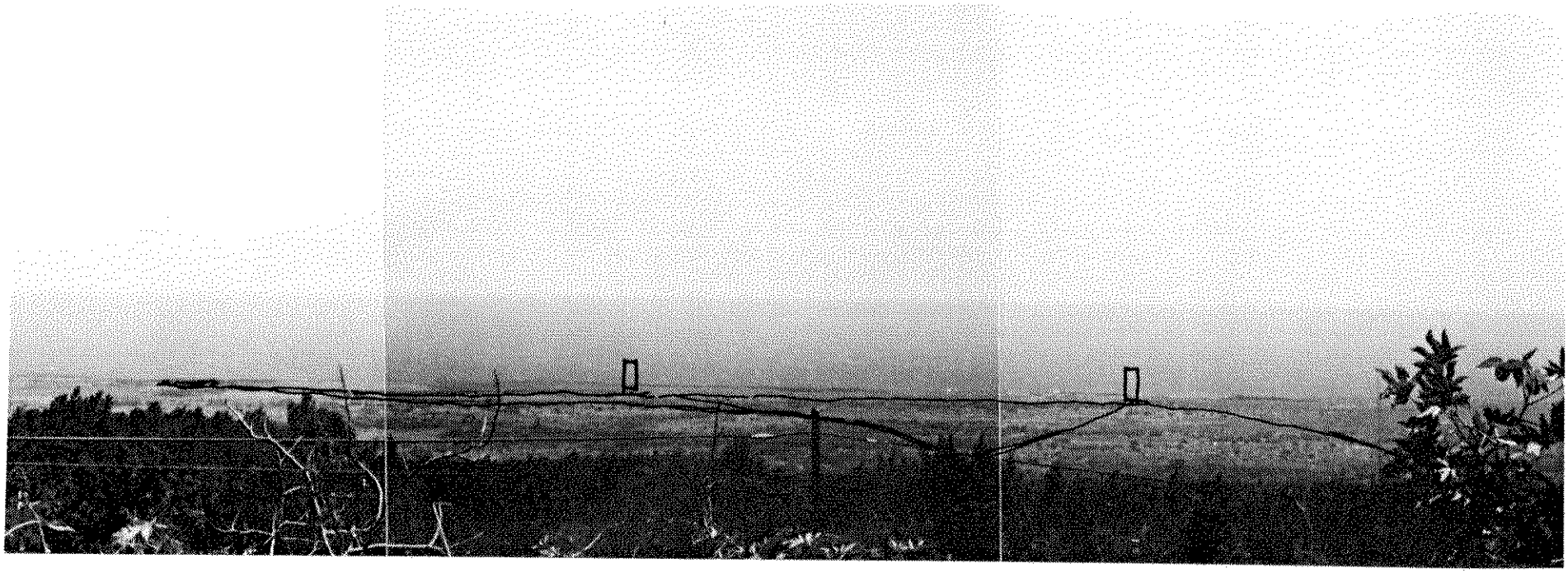
VISUAL IMPACT OF THE LAUNCH FACILITY FROM THE HAWAII VOLCANOES NATIONAL PARK BOUNDARY (LOCATION A)



VIEW OF TECHNICAL OPERATIONS FACILITY (RANGE INSTRUMENTATION) FROM PAHALA

Figure VII-5.8

VISUAL IMPACT OF THE LAUNCH FACILITY FROM PAHALA (LOCATION B)



VIEW OF SPACEPORT FROM PAHALA: LAUNCH PADS VISIBLE IN BACKGROUND, SUPPORT FACILITIES SCREENED BY TERRAIN AND VEGETATION

Figure VII-5.9

VISUAL IMPACT OF THE LAUNCH FACILITY FROM PAHALA (LOCATION C)

CHARACTER ALONG HIGHWAY 11 NEAR PAHALA: "ENCLOSED LANDSCAPE" VIEW SCREENED BY ORCHARDS

Figure VII-5.10
LANDSCAPE CHARACTER: ORCHARDS

CHARACTER ALONG HIGHWAY 11 SOUTH OF PAHALA: MIXED FOREST WITH OCCASIONAL VIEW CORRIDORS

Figure VII-5.11
LANDSCAPE CHARACTER: MIXED FOREST

site for about a mile. Although occasional glimpses of the site open up between the trees providing views down minor view corridors, the viewing duration for each corridor is brief.

As one travels south along the highway, the stand of monkeypod trees thins out and the landscape changes to an open pasture/shrubland (Figure VII-5.12). This area, which continues for about a mile, affords several major view corridors to the highly visible project site, as shown on Figure VII-5.13 from Location D. The impact will be the highest for northbound motorists as the view of the facilities will in front of the observer, and within the field of vision for a longer period of time. Farther south, near Punalu`u, there is little or no visual impact due to terrain shielding.

E. SUMMARY OF VISUAL IMPACTS

The evaluation of visual impact is very subjective and depends upon individual preferences. Although the use of colors that blend into the surrounding terrain, non-reflective roofs, and appropriate landscaping around launch-site buildings should serve to mitigate most visual impact, the launch-pad structures, radar, and communications dishes are not as amenable to design mitigation. It is assumed that the degree of negative reaction would relate to the degree of acceptance of the project by the viewer. It is expected that visitors to the wilderness areas of the Park will have the most negative reaction because their primary objective will be to have a wilderness experience.

CHARACTER ALONG HIGHWAY 11 NORTH OF PUNALU'U:
OPEN PASTURE / SHRUBLAND WITH MAJOR VIEW CORRIDORS

Figure VII-5.12
LANDSCAPE CHARACTER: PASTURE / SHRUBLAND

VIEW OF SPACEPORT FROM HIGHWAY 11: SUPPORT FACILITIES IN FOREGROUND, LAUNCH PADS IN BACKGROUND

Figure VII-5.13

VISUAL IMPACT OF THE LAUNCH FACILITY FROM LOCATION D