HAWAI'I VOLCANOES NATIONAL PARK

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FIRE MANAGEMENT PLAN 2005

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FIRE MANAGEMENT PLAN

2005

Prepared by: ____ Date: ____________________
Pacific Island Fire Management Officer

Reviewed by: ____ Date: ____________________
Chief of Resources Management

Approved by: ____ Date: ____________________
Superintendent

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I. INTRODUCTION

Purpose of Plan

The purpose of this plan is to develop and improve the park's fire management program to protect human life, property, and cultural resources and to maintain or restore natural resources. This Plan will facilitate the implementation of current National Fire Plan direction. Portions of the growing community of Volcano on the park's boundary are threatened by fire starting in the park; park resources are threatened by fire starting in the community. In addition, the acquisition of the 116,000 acre Kahuku Ranch in 2003 poses a new Wildland Urban Interface (WUI) issue with the adjacent community of Hawaiian Ocean View Estates.

The park has traditionally taken a very cautious approach with fires of natural origin, even at the risk of altering a natural process. All fires, regardless of origin, have been suppressed to prevent the spread of invasive plants and the loss of native plant communities. Approximately one-half of the fires started in the park are from lava flows. Lightning also has caused a few fires. Fire effects studies and prescribed burns in the coastal lowlands demonstrate that fire can enhance the spread of native pili grass (Tunison *et al*. 1994; Loh *et al*. 2003). There are fuel beds in the coastal lowlands, isolated *kïpuka* bordered by sparsely vegetated lava flows, that may benefit from allowing fires of natural origin to spread, without risk of fire spreading into adjacent environments where fire facilitates the spread of invasive species. There are also environments in the park, particularly in the alpine and subalpine, where the vegetation is sparse and the risk of fire spread is minimal. Fire effects studies have demonstrated that a number of native species in these environments respond favorably to fire and there are few invasive species in these environments.

Under the direction of Director's Order 18, parks are required to complete and review annually a park-specific Fire Management Plan (FMP). National Park Service Director's Order 18 states: "*each park with vegetation capable of carrying fire to prepare a fire management plan to guide a fire management program that is responsive to the park's natural and cultural resource objectives and to safety considerations for park visitor, employees, and developed facilities. Alternatives to be implemented will be described in detail in a draft Fire Management Plan. The Environmental Assessment developed in support of the fire management plan will consider effects on air quality, water quality, health and safety, and natural and cultural resource management objectives*."

The Federal Wildland Fire Management Policy and Program Review identifies the need for all federally owned lands with vegetation capable of supporting a fire to have an overall strategic Fire Management Plan and to review and amend on an annual basis as necessary.

An Environmental Assessment (EA) has been prepared to evaluate and provide public input to the wildland fire management program at Hawai`i Volcanoes National Park. The Environmental Assessment, required by the National Environmental Policy Act (NEPA), outlines the different alternatives that will be considered in revising the park's Fire Management Plan. It also characterizes the impacts of different alternatives on park visitors, surrounding communities, and cultural and natural resources in the park. A Finding of no Significant Impacts (FONSI) has been signed (Appendix A).

Collaboration

This plan formally documents the Hawaii Volcanoes National Park (HAVO) fire program and will help to achieve the goals and objectives described in HAVO's Resource Management Plan (RMP) (Appendix B) which is under the umbrella of the HAVO Master Plan. The RMP states: *Individual plans be developed for wilderness, fire and cave management…These individual action plans provide more detailed guidance in the operational implementation of resource programs.* The development of this plan and EA has been a collaborative interdisciplinary effort including; Park resource specialist, local cooperators and the general public.

II RELATIONSHIP TO LAND MANAGEMENT PLANNING/FIRE POLICY

Legislation establishing the National Park Service and Hawai`i Volcanoes National Park defines the broad purpose of the park.

The 1916 Organic Act (16 USC 1) establishing the National Park Service states that the purpose of the national parks is *"to conserve the scenery and the natural and historic objects and the wildlife therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations*."

Hawai`i Volcanoes National Park was established by an Act of Congress (Pub Law 95-635, 16 U.S.C. Sec. 1132) on August 1, 1916. This act states that the Park *"shall be perpetually dedicated and set apart as a public park or pleasuring ground for the benefit and enjoyment of he people of the United States…*" The park's enabling legislation also provides for the *"preservation from injury of all timber, birds, mineral deposits, and natural curiosities or wonders within said park, and their retention in their natural conditions as nearly as possible. . . the Secretary of the Interior shall make and publish such general rules and regulations as he may deem necessary and proper for the management and care of the park and for the protection of property therein, especially for the preservation from injury or spoilation of all timber, natural curiosities, or wonderful objects within said park.*" The park enabling legislation does not provide specific guidance for resource or fire management.

The Park Master Plan (1975) states more specifically that the "purpose of Hawai'i Volcanoes National Park is to conserve volcanic features, endemic Hawaiian ecosystems, Hawaiian cultural and archeological remains, and inherent scenic views." The 2001-2005 Strategic Plan for Hawai`i Volcanoes National Park defines the purpose of the Park in more detail as follows:

- *To protect, study, and monitor volcanic landscapes and processes.*
- *To protect, study, and restore native Hawaiian ecosystems and species, many of which are rare or endangered.*
- *Top protect, preserve, and study cultural resources including landscapes, features, archeological or historical structures and features and museum objects.*
- *To provide a nurturing environment for the preservation and practice of traditional native Hawaiian culture*
- *To provide opportunities for public education, enjoyment, and safe access to the Park and its resources.*

The FMP provides specific details for the fire program that most efficiently meets fire management direction. The FMP does not make decisions. Rather, it provides the operational parameters needed to implement the RMP. The FMP tiers to the HAVO RMP (Appendix H) approved in 1975 and is in compliance with the National Environmental Policy Act.

In addition, the Federal Wildland Fire Management Policy and Program Review (USDA/USDI 1995 and 2001) recommends that: *Fire, as a critical, natural process will be integrated into land and resource management plans and activities on a landscape scale, across agency boundaries and will be based upon best available science. All use of fire for resource management requires a formal prescription. Management actions taken on wildland fires will be consistent with approved Fire Management Plans.*

III WILDLAND FIRE MANAGEMENT

A. General Management Considerations

Fire management goals, strategies, and potential impacts need to be evaluated in the context of park purpose. Park purpose is based on the enabling legislation that created Hawai`i Volcanoes National Park and other federal laws that affect management of the park. On-the-ground guidance for implementing these laws is provided by National Park Service Management Policies (2001) and Hawai`i Volcanoes National Park resource management goals and strategies. HAVO will follow the core principles described in the 10-year Comprehensive Strategy of the interagency National Fire Plan:

Collaboration*:* Hawaii Volcanoes National Park will continue to strengthen its partnerships with local, state, and federal cooperators on and adjacent to the unit. HAVO will continue to provide assistance and direction to local fire departments and fire safe councils by reviewing grant and Rural Fire Assistance applications and pursuing approval of such grants for the purpose of reducing fuel loading in and adjacent to their communities and providing protection for their communities. HAVO will continue to develop agreements and operating plans to facilitate mutual cooperation in detection, prevention, training and suppression activities.

Priority Setting*:* HAVO, as directed by the National Fire Plan and the Resource Management Plan, will continue to prioritize fuel treatment and restoration projects. By utilizing satellite imagery, wildland fire risk and hazard analysis and vegetation mapping the park will engage in priority setting for treatments and suppression activities in an interdisciplinary forum. The National Fire Danger Rating System (NFDRS) utilizes fire weather and fire history to produce fire danger indices (Energy Release Component) to assist managers in assessing risk and conducting fire business. Communities at risk will be the priority for both suppression actions and hazardous fuels treatments followed by special ecological areas identified in an interdisciplinary process. Further prioritization will take place in the relative weighting of Fire Management Units (FMU) within the Fire Program Analysis (FPA) scheduled for implementation in 2006.

Accountability*:* Hawaii Volcanoes National Park will maintain, establish and employ cost effective measures, standards, reporting processes and budget information in implementation plans, FIREPRO (National Park Service wildland fire disciplines planning and budgeting program), FPA (2006), National Fire Plan Operations Reporting System (NFPORS), Wildland Fire Situation Analysis (WFSA) and Wildland Fire Implementation Plans (WFIP).

B. Wildland Fire Management Goals and Objectives

The goals for fire management in Hawaii Volcanoes National Park are consistent with those outlined in the Resource Management Plan. They tier from and are closely aligned with both regional and national direction. The following are fire management goals that will guide fire management actions throughout the park:

- Every fire management activity is undertaken with firefighter and public safety as the primary consideration.
- Protect and restore the park's ecological, cultural, and social values.
- Fire management programs and activities are aligned to fully compliment one another in support of an ecological approach to resource management
- Wildland fires are managed using the full range of wildland and prescribed fire options in order to protect, enhance and restore resources within and adjacent to the park
- Fire managers collaborate with park workforce, other federal, state and local land management agencies, air regulators, affected private landowners and the public in order to coordinate fire management activities that may impact private lands or public health.

The following objectives have been developed to specify actions and tasks to facilitate the achievement of Fire Management Goals.

1. Minimize and mitigate exposure of hazards to fire fighters and provide a safe work environment.
    - Prepare and review a complete Job Hazard Analysis (JHA) for all work practices that have potential hazards.
    - Utilize the Risk Management Process identified in the NWCG Incident Response Pocket Guide (IRPG) to ensure critical factors and risks associated with fireline operations are considered during decision making.
    - Utilize work/rest guidelines outlined in the Interagency Standards for Fire and Aviation Operations to mitigate fatigue on all incidents.
    - Provide all firefighters with proper personal protective equipment and appropriate level Safety Officers for all incidents.
2. Manage all unplanned wildland fires appropriately.
    - Manage all wildland fires, regardless of ignition source, using strategies and tactics commensurate with protection of human health, safety, and natural and cultural resource values, as described in this document.
    - Develop and maintain staff expertise in all aspects of fire management.
    - Utilize existing interagency wildland planning procedures, analyze risk and complexities for all ignitions in order to determine those ignitions which can be successfully managed for the benefit of ecological and life/safety values and those that should be suppressed. Conduct this analysis in an interdisciplinary fashion.

3. Plan and implement appropriate treatments to reduce the threat to values from unwanted wildland fire and to restore or maintain ecological values.

- Annually, analyze fire hazards, values, and risks so that projects are designed within Fire Management Units and consistent with FMU management strategies.
- Use GIS and other accepted science to plan treatments. Ecological, life/safety, infrastructure, and cultural resources values will be analyzed and updated through feedback from monitoring and research advances within and outside of the park.

4. Monitor and understand the consequences of fire management activities.
   - Monitor and evaluate the effects of fire and fuels management activities on park natural and cultural resources with particular attention to vegetation, water, wildlife, air, and cultural resources.
   - Evaluate monitoring information to refine the management activities and objectives, and prescription range values as appropriate.
   - Understand public attitudes and political concerns through personal contacts, social science research, public information officer, and other avenues. Incorporate this information into management decisions as appropriate.

C. Wildland Fire Management Options

The Hawaii Volcanoes National Park wildland fire policy is to conduct wildland fire actions in a timely, effective and efficient manner with the highest regard for firefighter and public safety. Every wildland fire requires an appropriate management response based on management direction. Wildland and prescribed fire are used whenever appropriate as tools to achieve resource management objectives. All fires not ignited by managers for specific purposes are considered wildland fires.

Wildland Fire Suppression

Initial suppression action will be taken to minimize cost and damages and to prevent the escape of any wildland fire. The full range of fire suppression strategies is available for use in most of the park. The intensity of response may range from aggressive suppression action to monitoring with minimal on-the-ground actions. Guidelines for determining specific strategies are described in the following sections of this document. All human caused fires will receive a suppression response commensurate with values-to-be-protected, firefighter and public safety, and cost efficiency.

Wildland Fire Use

A naturally ignited wildland fire may be managed to accomplish resource management goals. Those FMU’s where wildland fire use may be appropriate are discussed in the FMU descriptions. In the event a natural ignition is considered a candidate for wildland fire use, there are several aspects of the wildland fire use program which must be addressed and are discussed in section IV of this document and in detail in Reference Manual 18, chapter 9.

Prescribed Fire

Prescribed fires are classified as those ignited by managers to accomplish resource management objectives. In general, prescribed fire may be used for three main objectives; 1) wildland fire hazard reduction, 2) reintroduction of fire as an ecological process, and 3) other resource benefits. Prescribed fires are intentionally ignited under predetermined environmental parameters to accomplish various resource management objectives. All prescription parameters, actions, and measurable objectives are stated in a project burn plan, approved by the Superintendent prior to ignition. Prescribed fire may be used in support of ecosystem management to maintain and/or restore plant communities, cycle nutrients, reduce or remove exotic plants, and for a variety of other resource management objectives.

Non-Fire Applications

Non-fire applications, including mechanical treatments, hand treatments, and chemical applications can be used to meet hazardous fuel treatments or restoration goals Although costs can be considerably more, it is generally more successful and greater control of risk factors can be achieved.

D. Descriptions of Wildland Fire Management Strategies by Fire Management Units

There are seven Fire Management Units in HAVO. Each Fire Management Unit has distinct climate, fuels, fire potential, fire history, fire impacts, resources at risk, and fire management objectives (see Figure 2 FMU map).

Alpine and Aeolian Fire Management Unit, (FMU-1).

Geography and Climate. The park's alpine FMU extends from approximately 8,500 foot elevation to the summit of Mauna Loa at 13,677 foot elevation. Lying above the inversion layer, the climate is cool and dry. The annual rainfall is 20-28 inches. One or two light snows, typically melting within a few days, occur in the winter. The mean air temperature is 43-48 degrees Fahrenheit with frequent nightly frost in the winter months. The alpine zone is found on the Mauna Loa Strip and in the Kahuku acquisition. Much of the Kahuku acquisition is in the alpine zone.

Vegetation, Fuels, and Fire Potential. There is essentially no fire potential or resources at risk from fire in the alpine FMU. Fuels and vegetation are sparse and low, consisting of small patches of stunted native shrubs, mostly pükiawe (*Leptecophylla tameiameiae*) and ‘ohelo (*Vaccinium reticulatum*). Grasses, sedges, lichens, and mosses comprise the rest of the plant life. Most of the alpine zone consists of nearly barren lava flows.

Fire History. No fires have been documented in the alpine zone.

Management strategies. Limited allowance of naturally-ignited fires in isolated kïpukas will provide opportunities for fire effects studies.

Subalpine Fire Management Unit, (FMU-2).

Geography and Climate. The subalpine FMU in Hawai'i Volcanoes National Park lies mauka of the forests on Mauna Loa and extends from approximately 6,500 foot elevation to 8,500 foot elevation or higher. The average annual temperature ranges from 40 to 50 degrees Fahrenheit, with occasional winter frost. On the Mauna Loa Strip, rain fall averages are from 30-40 inches per year. Summers are dry and most precipitation is in the winter. Additional precipitation is provided by fog-drip from trees and shrubs resulting from low-lying clouds. The climate of the Kahuku subalpine environment is decidedly more moist, with nearly daily cloud cover and light precipitation on the southeast slope *mauka* of the Ka'ü and Kapapala Forest Reserves. Dry periods without little or no rain can occur any time of year, resulting in a year-round fire season.

Vegetation, Fuels, and Fire Potential. Most of the subalpine fire environment in the park lies in the Kahuku acquisition. On the Mauna Loa Strip, much of the subalpine vegetation is concentrated in two major kïpuka on older pähoehoe lava flows. Vegetation on the extensive, younger 'a'a flows consists of scattered and very scattered native 'öhi'a (*Metrosideros polymorpha*) trees and native shrubs. Vegetation on the older pähoehoe is 'öhi'a/ mämane (*Sophora chrysophylla*) woodland with an understory of open native shrubs and grasses. The most abundant native shrubs are 'öhelo, pükiawe, and 'a'ali'i (*Dodonaea viscosa*). The most abundant grass is the native bunch grass *Deschampsia nubigena*. Vegetation is similar in Kahuku acquisition but more depauperate in species diversity because of four decades of browsing by mouflon sheep.

The potential for large or intense fires in the subalpine is low. Patches of vegetation with closely spaced shrubs and grasses are small and discontinuous. Vegetation is sparse and low growing, with low fuel loadings. Young lava flows dissect subalpine fuel beds. Fire potential may increase in the subalpine in the Kahuku acquisition with the removal of mouflon sheep by park control efforts. Once mouflon sheep are controlled, native vegetation will recover, including pükiawe and ohelo, as well as native hair grass. Invasive grasses, such as velvet grass and sweet vernal grass, may increase in abundance and increase fire potential. However, the climate of the Kahuku acquisition is subject to more frequent clouds, fog, and moisture than the Mauna Loa Strip. This may decrease fire potential.

Fire History. No fires have been documented in the subalpine zone on the Mauna Loa Strip; fire history of the Kahuku acquisition is unknown. Charcoal layers are present in the subalpine of the Mauna Loa Strip. These may reflect a period of more continuous vegetation prior to soil and vegetation loss due to cattle and feral goats.

Fire Effects. The effects of fire in the subalpine FMU are not known because of the absence of recent fire in the park in this ecological zone. The response of the most common plants in the subalpine can be expected to be similar to their response in the montane seasonal zone. The scattered 'öhi'a trees will be readily top killed but some may resprout. 'A'ali'i and 'öhelo, two common shrubs, will regenerate well after fire, as will native hairgrass. The other common shrub, pükiawe, will recovery poorly after fire. Mämane and koa, found in the lower part of the subalpine on the Mauna Loa Strip, will resprout or become established by seed after fire. The most abundant invasive grasses, velvet grass and sweet vernal grass, may increase in abundance after fire.

Management strategies. Limited allowance of naturally-ignited fires in isolated kïpukas will provide opportunities for fire effects studies.

Resources at Risk. The subalpine, on the whole is remarkable for the high proportion of native plants and animals that make up the biotic community and the paucity of alien species. The subalpine environment lies above the mosquito breeding habitat. Therefore, avian diseases transmitted by mosquitoes are not important limiting factors for the relatively abundant native bird life, including ‘Apapane (*Hemiatone sanguinea*), ‘Amakihi *(Hemignathus virens*), ‘I’iwi (*Vestiaria coccinea*), and ‘Oma’o (*Myadestes obscurus*). Feral goats, pigs, and mouflon sheep have been eradicated from the Mauna Loa Strip subalpine. These species will be removed from the Kahuku subalpine. Removal will promote the recovery of native vegetation and increase plant and animal biodiversity. Alien plant invaders are relatively unimportant in the subalpine, although scattered patches of invasive grasses such as velvet grass and sweet vernal grass are present. Threatened and endangered plant species include laukahi kuahiwi (*Plantago hawaiensis*), Mauna Loa silversword (*Argyroxiphium kauense*), *Asplenium fragile*, and Hawaiian catchfly (*Silene hawaiiensis*). Species of special concern include the rare plant Hawaiian strawberry (*Fragaria chiloensis* ssp. *sandwicensis*), yellow eyed grass (*Sisyrinchium acre*), and heau (*Exocarpos menziesii*). Fire sensitivity of these rare plant species has not been determined.

Mesic/Wet Forest Fire Management Unit (FMU-3)

This fire environment includes all of the wet forest and most of the mesic forest of the park. Mesic and wet forest grade into each other along the sharp rain fall gradients that characterize the park. Mesic and wet forest also share many of the same species, fuels, and responses to fire. For these reasons, they are considered as one fire environment.

<u>Wet forest</u>

Geography and Climate. There are approximately 30,000 acres of tropical wet or rain forest in the park; it is much more widespread than mesic forest in the mesic/wet forest fire environment. Almost all wet forest is found on the eastern edge of the park receiving nearly daily trade wind rains, areas with approximately 90-140 or more inches per year. Wet forests are found in four locations: on the eastern rim of the summit caldera of Kïlauea volcano; along the East Rift zone of Kïlauea above approximately 2,300 foot elevation; in a 10,000 acre disjunct part of the park east of the community of Volcano, the ‘Öla’a Forest; and on the eastern edge of the pastures in Kahuku between 3,000 and 5,000 foot elevation.

Vegetation, Fuels, and Fire Potential. There are two major plant associations in the wet forest, one dominated by tree fern and one dominated by uluhe fern. The former association is a multi-layered forest dominated by ‘öhi’a and tree ferns. In many areas of Kïlauea summit and the East Rift, ‘öhi’a forms closed stands on the relatively young substrates of these volcanically active areas, with a subcanopy of other native trees and tree ferns. Tree fern wet forest is best developed on the older, deep ash soils of ‘Öla’a Forest and some areas of the East Rift, particularly on older flows near Näpau Crater. Most of the wet forest in ‘Öla’a is dominated by a dense canopy of tree fern, often co-mingled or slightly overtopped by open stands of native trees. ‘Öhi’a formed a nearly continuous overstory until a dieback in the late 1960s and early 1970s and now persists as scattered trees or occasional open stands. A high diversity of native ferns, often along with native shrubs and herbaceous plants form a dense ground cover understory. Feral pigs have been removed from well over half of the park’s wet forests and recovery of understory ferns, tree ferns, native shrubs, and native tree seedlings is taking place.

The other wet forest community relevant to fire management is dominated by uluhe fern, found at the summit of Kïlauea and along the East Rift. Uluhe is a dense matted fern that forms a natural ladder fuel 3-20 feet tall, clambering over trees and shrubs. Because the thick mat suppresses all vegetation, native and alien, uluhe wet forest is less diverse than tree fern wet forest. Uluhe is characteristic of early successional communities on younger lava flows in the East Rift. It has also become more abundant on the East Rift southwest of Pu'u 'Ö'ö in recent years because it colonizes tephra deposits laid down in the 1983-1986 fountaining eruptions. It is the dominant fuel in the upper East Rift. Uluhe is also abundant in older forest stands which have gone through a cycle of 'öhi'a dieback and recovery.

The lower fronds of uluhe fern retain dead foliage and a mat of fallen fronds form a continuous litter layer. Because the tree canopy is typically sparse, the understory and litter layer can dry out after a couple of weeks of little or no rain. Most uluhe fires have occurred after rainless periods of several weeks when uluhe litter dries out. However, during the Kupukupu Fire of 2002 on the East Rift a large fire occurred under very windy conditions after just a week long drying trend following a rainy spring. In 2003, the Luhi Fire spread in uluhe during a period of extremely low relative humidity, following a wet spring, with low to moderate wind conditions.

Fire History. Until recently, lava caused fires have not been observed to carry into tree fern wet forest, even under drought conditions. Fire flanked over 50 yards into dense tree fern stands in the 2003 Luhi Fire on the East Rift, under record low humidity conditions, before dying out. Fire spread in continuous abundant litter of dead tree fern fronds and 'öhi'a. No fires have been documented in tree fern wet forest in 'Öla'a or Kïlauea summit.

On the East Rift, the first large fire documented in uluhe was the Valentines Day Fire of 1996 which burned 600 acres, carried by uluhe and sword fern. Subsequent lava-ignited large fires occurred in 2002 (Kupukupu Fire) and in 2003 (Luhi Fire).

Because of these fires, a new fuel type has developed on the East Rift in burned areas. The bottom portion of the fuel bed was wet when the flaming front passed through. This left a 6 inch to two feet deep duff and litter layer capable of reburning one or more times. Because uluhe takes several years to recover, this litter fuel type is expected to persist in the wet forest for the near term.

Fire effects. Plant recovery after fire in uluhe varies by site. Uluhe, along with other native wet forest species, has been observed to recover to near preburn cover and abundance 10-15 years after fire (Tunison et al. 2001). Although alien grasses initially invade burned uluhe dominated forest, native grasses, sedges, and shrubs then get established, and uluhe recovers beginning two to three years after fire. Many native woody plants resprout, including tree ferns and 'öhi'a. Others become established from seed. In other burned uluhe areas, aggressive alien plants invade immediate after fire and recovery of native plant species does not occur.

Management strategy. All fires are suppressed to limit disturbance and invasion by alien species. Fire effects studies are underway to increase knowledge of fire effects in this environment.

Resources at Risk. Late successional tree fern wet forest is species-rich. Most of the biological diversity in the wet forest is located in the ground cover layer, rather than in the canopies as in continental wet forests. Fern species account for much of the plant diversity. In ‘Ola’a, a third of the vascular plant species are ferns and fern allies. Although not rich in bird life, the native birds ‘Apapane and ‘Öma’o can be very abundant, especially where the ‘öhi’a canopy is dense. Insect life is rich in the wet forest. Significant species include Happyface Spider, two species of predaceous caterpillars, and a number of picture wing *Drosophila*. Threatened, endangered, candidate species, as well as species of special concern, include the plants hi’awale, ‘öhäwai, kihi, ‘anunu, ‘akü, ‘ohe, *Phyllostegia floribunda*, ‘awapuhi a kanaloa, and koli’i. Ongoing field surveys to inventory biological resources are ongoing in Kahuku have identified additional endangered, threatened and rare species (Table 1).

<u>Mesic Forest</u>

Geography and Climate. Mesic forests are found primarily east of Chain of Craters Road and west of wet forests; makai of wet forest in the southeaster section of the park; and in Kahuku mauka of the Ka’ü and Kapapala Forest Reserves.   Mesic forests are found from approximately 60-90 inches of rain per year.

Vegetation, Fuels, and Fire Potential. Mesic forests are dominated by closed to open stands of ‘öhi’a. The understory vegetation and fuels are highly variable. In Kahuku, mesic forest has an understory of tree ferns and native trees or native shrubs. East of Chain of Craters Road, the understory is similar but many areas are occupied by dense stands of introduced faya tree or uluhe fern The understory of mesic forest in the lower East Rift of Kïlauea is dominated by continuous swards of introduced swordfern that range 4-6 ft in height.

Fire History. Only the mesic forest stands in the lower East Rift have had a recent history of fire. Fire spread readily in older swordfern understory under windy conditions. Fire in a swordfern area consumes both green and dead fronds but leaves a thick litter and duff layer capable of burning immediately in subsequent fires.

Fire Effects.   Swordfern vegetatively recovers very rapidly after fire, much more rapidly than native species. ‘Öhi’a appears to be regenerating in swordfern but many mesic forest trees, shrubs, and herbaceous understory elements are missing.   Introduced faya tree and strawberry guava vegetatively recovers very rapidly after fire.

Management strategy. All fires are suppressed to limit disturbance and invasion by alien species. Restoration strategies using direct seeding and outplanting into recent wildfires are being tested. Fire effects studies are underway to increase knowledge of fire effects in this environment.

Resources at Risk. Past wildfire and browsing by feral ungulates removed much of the diversity in mesic forest on Kïlauea. Species of Concern remaining in the area include trees, Päpala ke pau and Ohe mauka, and the endangered Hawaiian Hawk. Diversity of native plants and forest birds is much higher in the mesic environment of Kahuku. Ongoing field surveys to inventory biological resources are ongoing in Kahuku have identified additional endangered, threatened and rare species (Table 1).

Montane Seasonal Fire Management Unit (FMU-4)

Geography, Climate, and Geology. Most of the montane seasonal fire environment in the park lies on the lower slopes of Mauna Loa Strip mauka of mid-elevation seasonal woodland at 4,000 foot elevation and makai of the subalpine fire environment zone at 6,700 foot elevation. In Kahuku, the area between 5,000-6,000 foot elevation on the southwest facing slope between Manukä and Kipahoehoe Natural Area Reserves can also be characterized as montane seasonal.

The montane seasonal zone of the Mauna Loa Strip has a summer-dry climate with rain fall declining from 60 inches per year at 4,000 foot elevation to 40 inches per year at 6,000 foot elevation. The montane seasonal in Kahuku is summer-wet. Mean annual temperatures are 50-60 degrees Fahrenheit with occasional winter frost at higher elevations. Frequent afternoon cloud build up and low-lying fog are characteristic of the montane seasonal forests in Kahuku.

Vegetation, Fuels, and Fire Potential. Most of the montane seasonal environment is densely vegetated on 750-4,000 year old lava flows, although several massive, late prehistoric or historic ‘a’ä flows penetrate the montane seasonal. Soil development is greatest in the lower portion of the zone at Kïpuka Kï and Kïpuka Puaulu between 4,000 and 4,400 foot elevation. These greater than 10,000 year old kïpuka have layers of ash soil up to 20 foot deep originating from the nearby Kïlauea summit. Most soils above 5,000 foot elevation are shallow and discontinuous ash deposits over weathered pähoehoe.

The vegetation of the zone varies considerably with soil depth and substrate age. The most diverse and well-developed forests of the montane seasonal are in Kïpuka Kï and Kïpuka Puaulu on the lower east end of the Mauna Loa Strip (4,000-4,400 ft elevation). These islands of old soil support a rare mänele/koa/’öhi’a forest community including many threatened, endangered, candidate or species of concern including hau kuahiwi, koki’o, alani, ‘aiea, hölei, ‘anunu, kilioe, ‘äkala, manele, and kauila. Kïpuka Puaulu is the most biologically rich site in the park.

Vegetation in the montane seasonal in Kahuku is dominated by closed stands of ‘öhi’a forest with a native shrub, fern, and mixed native-alien grass understory capable of carrying fire. Small stands of koa with invasive grass understory occur in the ‘öhi’a forest stands. A fire carried through one of these koa- ‘öhi’a stands in 1993. Native ‘öhi’a regenerated well from crown sprouts; koa did not recover because of mouflon sheep browsing; alien grasses became abundant.

On the Mauna Loa Strip, koa dominates the forests upslope on weathered pähoehoe above Kïpuka Kï. Below 5,000 foot elevation, the understory of these forests are dominated by alien pasture grasses, a legacy of 150 years of cattle grazing. Koa forest understory above 5,000 foot elevation is comprised of native shrubs pükiawe and ‘a’ali’i, sedges and, a mixture of alien meadowrice grass and native grasses.

Koa stands have rapidly expanded by root suckering into grasslands and shrublands on Mauna Loa since the mid-1970s when ungulates were removed from the area. Koa seedlings and suckers are highly palatable to cattle and feral goats. Cattle grazing was terminated in 1948 but the remaining stray cattle and feral goats were not removed from Mauna Loa until the mid 1970s.

Small stands of shrubland and grassland persist on sites with shallow soils. The shrublands are dominated by native shrubs pükiawe and ‘a’ali’i, with a continuous understory of mixed alien and native grasses at lower elevations and native bunchgrass above 5,000 foot elevation. Grasslands are generally small and are dominated by alien grasses at lower elevation and native bunch grasses at upper elevation.

‘A’ä flows are much more sparsely vegetated than older pähoehoe flows. In a number of places are open to sparse ‘öhi’a woodlands with a sparse native shrub understory. In other areas, very scattered native shrubs may occur. Grass is never abundant.

On the Mauna Loa Strip, fuels are continuous in the forests, woodlands, shrublands, and grasslands on older pähoehoe. Vegetation below 5,000 foot elevation is particularly dense and grass fuel loadings are high in all plant communities. The Mauna Loa Strip lies above the temperature inversion and is not subject to daily trade wind showers. Although summers tend to be drier than other seasons, extended dry periods can occur throughout the year. Curing and green up of the grass fuels can take place several times in a year and is timed to rain fall patterns that vary from year to year.   Therefore, the Mauna Loa Strip montane seasonal zone has essentially a year-round fire season.

In Kahuku, forests and woodlands have been subjected to four decades of browsing by mouflon sheep and understory vegetation is relatively sparse. These factors suggest that fire potential of the montane seasonal FMU in Kahuku is lower than that of the Mauna Loa Strip. Removal of the sheep in the near future may increase fuel loadings of grasses and woody vegetation. The fire potential of the montane seasonal in Kahuku may increase.

Fire History. There were a number of small, human-caused ignitions in the 1920-40s while the Mauna Loa Strip was leased for cattle ranching. There was a 2,000 acre fire in 1975 in koa forest, shrublands, and grasslands. In spite of abundant fuels on the Mauna Loa Strip, there have been no fires since then. Part of this may be due to vigorous fire prevention, closing the Mauna Loa Road in very high and extreme fire danger. In addition, the infrequent lava flows from Mauna Loa have been well distant from the park.   Continued cattle ranching have reduced grass fuel loadings and human access in lands adjoining the Park.   Fire history of Kahuku is not known in detail. A wildfire starting in ranchlands below penetrated a stand of ‘öhi’a and koa in 1993.

Unlike many other environments in the park, fire may have played an important role in the evolution of the montane seasonal ecosystems (Mueller-Dombois 1981). This is suggested by the fact that there are continuous fine fuels in the form of native grasses and shrubs and that many of the dominant plant species, including koa, ‘a’ali’i, and native grasses recover rapidly from fire by resprouting or seed. On the other hand, the montane seasonal communities are at a highly dynamic stage of development. The suite of species on the Mauna Loa Strip that responded positively to release from herbivores may share characteristics common to fire-adapted species.

Fire Effects. On the Mauna Loa Strip, the major impact of fire in koa forest with invasive grass understory is to alter the stand structure of koa forest, replacing older, larger diameter trees with small stems.   Koa resprouts readily from root suckers after fire to reestablish the forest overstory within a decade. The potential nesting and foraging habitat for rare forest birds declines with the loss of larger, old growth koa. Younger trees, provide excellent habitat to Elepaio and the endangered ‘Akiapola’au. Alien meadowrice grass, the dominant understory component, rapidly recovers. Shrublands and grasslands change only subtly in composition after fire, with a shift in cover from less fire-tolerant pükiawe to the more fire-tolerant ‘a’ali’i, with no net increase in alien species cover, including alien grasses.

These observations about fire in the montane seasonal environment are based on succession following the only fire to occur on the Mauna Loa Strip in the last 30 years (Hauss unpubl.). New alien species have since become established in the park and vicinity since that fire and others have increased in abundance. These newly arrived species may affect succession after future fires. Historical fire is not known from the unique, species-rich Kïpuka Kï and Kïpuka Puaulu. The fire tolerance of the many woody species in these kïpuka, including the numerous rare species, is not known.

There was a large fire in Kahuku in ‘öhi’a/koa forest in 1993. Recovery of koa and other species has been inhibited by browsing of mouflon sheep. ‘Öhi’a and naio, plants ignored by sheep, are recovering rapidly after fire by resprouting.

Management strategies. The current strategy is to exclude fire. This area is still recovering from past decades of ungulate browsing. Fire would reduce stand structure of koa and habitat quality for some birds. Although some species share characteristics common to fire-adapted species, there is insufficient evidence to indicate that communities are fire-dependent.

Resources at Risk. The greatest diversity and concentration of rare plants in the Park is in mänele/koa/’öhi’a forest in Kïpuka Kï and Kïpuka Puaulu. These include many threatened, endangered plant species , candidate or species of concern including hau kuahiwi, koki’o, alani, ‘aiea, hölei, ‘anunu, kilioe, ‘äkala, manele, ‘a’e , ‘olona and kauila. Kipanapona, an endangered Hawaiian mint, is present at higher elevations on the Mauna Loa strip. Ongoing field surveys to inventory biological resources are ongoing in Kahuku have identified additional endangered, threatened and rare species (Table 1).

The montane seasonal fire environment (as well as the lower portions of the subalpine) supports the greatest densities of native birds of any of the park’s major ecological zones. The widespread ‘Apapane and ‘Amakihi are particularly abundant. ‘I’iwi and ‘Elepaio also occur in high numbers. The montane seasonal environment provides habitat for three endangered bird species lost from the Mauna Loa Strip area of the park in the last half century: ‘Akiapölä’äu, Hawai’i creeper, and ‘Äkepa. The recovery of woodlands and forest on Mauna Loa following the removal of cattle and goats may eventually provide suitable habitat to support these species, either through natural migration or deliberate translocation. In Kahuku, all three species were observed in the montane seasonal fire environment above the Kau Forest Reserve.

The uplands are notable for many endemic insect species such as the two native butterflies of Hawai’i, the Kamehameha butterfly and the Blackburn butterfly and a broad diversity of native long horned beetles. Kïpuka Kï and Kïpuka Puaulu are habitat for many native insect species, including two species of the large, picture wing *Drosophila* flies endemic largely to these sites: *Drosophila engrochracea* and *Drosophila mimica* which require soapberry bark and fruit to carry out their life cycles.

Mid-elevation Seasonal Fire Management Unit, (FMU-5).

Geography, Climate, and Geology. The mid-elevation seasonal woodland zone is the area of the park above Hïlina, Poliokeawe, and Hölei Pali and below, west, and south of Kïlauea Caldera. The upper elevation is approximately 4,000 foot and the lower elevation varies from 1,000 to 2,000 feet. The mid-elevation seasonal zone is in the leeward part of the park sheltered from daily trade-wind rains. Rain fall varies from 20-60 inches per year, and there is typically a distinct summer dry period. Dry periods on the island can result in pronounced drought in lower portions of the mid-elevation seasonal zone.

Vegetation, Fuels, and Fire Potential. Vegetation of the mid-elevation seasonal environment varies with substrate and rain fall. On younger flows or deep cinder with little ash soil development, vegetation typically consists of sparse native shrubs, primarily pükiawe and ‘a’ali’i, and scattered, short-statured ‘öhi’a. Fire potential of these communities is very low. Flows with deeper ash support dry ‘öhi’a woodland. Undisturbed, this community is characterized by open stands of ‘öhi’a and native shrubs, and a sparse ground layer of native sedge, lichens, and mosses. However, this plant community is one of the most disturbed and altered in the park. The understory, invaded by alien grasses in the 1960s, is now dominated by beardgrass, broomsedge, and molasses grass. These alien grasses form a nearly continuous matrix between the open layer of native shrubs. The majority of dry ‘öhi’a woodlands have burned in the last 30 years, further degrading this community to savannas of scattered ‘öhi’a with scattered native shrubs and abundant alien grass. Other areas have been invaded by the alien faya tree which has become a co-dominant with ‘öhi’a in some areas and displaced ‘öhi’a in other areas. In portions of the dry ‘öhi’a woodland along Hïlina Pali Road, the two-spotted leafhopper has caused an extensive dieback of both faya tree and öhi’a.

The mid-elevation seasonal environment in Kahuku also supports dry ‘öhi’a woodland degraded by invasive grasses, including beardgrass, broomsedge, and barbwire grass. The invasive shrub Christmasberry is also invading these woodland stands. ‘Öhi’a is slowly reestablishing in fallow pastures. Dry ‘öhi’a woodland in Kahuku occurs in the dry, western portion of the pasture zone in abandoned pastures.

Fire History. Fire has been most prevalent in the park in the mid-elevation seasonal environment. Following the invasion of broomsedge and beardgrass in the mid 1960s, and molasses grass in the 1980s, the area burned per year increased almost 2,000 fold and the number of fires increased nearly 10-fold (Tunison et. al. 1995). Nearly two-thirds of the burnable area of the mid-elevation seasonal environment burned in the last 40 years.

Fire Effects. Fire has been highly destructive to native ecosytems in the mid-elevation seasonal environment. Fire greatly reduces native woody vegetation, especially the community dominants, ‘öhi’a and pükiawe. On average, 55% of the ‘öhi’a are killed by fire (D’Antonio 2000). Some surviving trees protected partially from fire were on pähoehoe tumuli with little alien grass fuel. More typically, aerial portions of the trees were killed and surviving individuals recovered by crown or epicormic sprouts (Parman and Wampler 1976, Tunison et al. 1995). ‘Öhi’a seedlings do not become established to replace ‘öhi’a trees killed by fire. In fact, ‘öhi’a seedlings were not found in any recently burned seasonally dry woodlands (Tunison et al. 1995). The loss of mature ‘öhi’a and failure of ‘öhi’a to recruit from seed resulted in the conversion of open canopied woodlands to savannas characterized by scattered to very scattered trees.

Three of the four native shrub species common in the mid-elevation seasonal before fire were sharply reduced in cover and density following fire, and show little sign of recovery, even 17 years after fire (Hughes et al. 1991, Tunison et al. 1995). The aerial portions of all four shrubs are readily killed by fire, although resprouting occasionally took place under low fire intensity conditions (Tunison et al. 1995). Native shrub cover, as a whole, is reduced nearly two orders of magnitude. Pükiawe, the dominant shrub before fire. is nearly absent in most burned areas; it declined 10-fold in cover and 3-fold in density after fire. Although mature plants of the common shrub, ‘a’ali’i, were killed by fire, this native shrub species generally recovered to pre-fire abundance. Recruitment from seed was substantial (Hughes et al. 1991). Recruitment into larger size classes occurred through dense grass cover, and densities of large plants were similar in older burns to densities in unburned areas (D’Antonio et al. 2000). Although sample sizes were very small, the small native tree mämane resprouted nearly invariably from the root crown, even after severe fires (Tunison et al. 1995).

Alien grass cover increases on average by one-third after fire (D’Antonio et al. 2000, Tunison et al. 1995). Alien grass biomass increases 2-3-fold after fire, increasing fuel loadings. Molasses grass cover increases the most in burned sites in which it was present prior to fire.

The rapid reestablishment and long-term persistence of alien grasses inhibit shrub colonization and growth (Hughes and Vitousek 1993). This was particularly true in sites in which molasses grass was present (D’Antonio et al. 2000); native shrub cover was lowest in these sites. The vigorous response of this mat-forming species creates a formidable environment for native species regeneration. The native shrub ‘a’ali’i persists in burned areas because of its rapid germination and growth.

The invasion of broomsedge and beardgrass into the seasonally dry woodland has established an alien grass/fire cycle (Hughes et al. 1991, D’Antonio and Vitousek 1992, Freifelder et al. 1998. Grass invasion of seasonally dry woodlands promotes fire in a previously fire-independent ecosystem and alters the disturbance regime of this ecosystem. After fire, grasses out-compete native woody plants and increase in cover and fuel loading (Hughes et al 1991, D’Antonio et al. 2000). Burned sites are then predisposed to more severe future fire compared to adjacent unburned woodlands because of increased fuel loadings and, more importantly, because wind speeds are substantially greater in the more open post-fire savannas (Freifelder 1998).

*Management Strategie***s.** Prescribed fire has proven to be a useful tool in experimental rehabilitation of fire-damaged dry ‘öhi’a woodlands conducted between 1993-2000 (Loh unpubl.). Four small, prescribed burns have been conducted since 1993 to test methods for establishing fire-tolerant native plant species to burned areas in the mid-elevation seasonal environments. The species targeted for restoration are tolerant of fire, recovering rapidly from seed and/or resprouts. Many of these species were formerly more abundant, but populations were depleted by past browsing from feral goats. Goats were removed from the park in the 1970’s, but natural recovery of species was poor because of insufficient seeds in the soil. Prescribed fire accompanied by direct seeding and outplanting results in successful establishment of fire-tolerant species. Prescribed fire temporarily removes the alien grass mats and allows establishment of seedlings from artificial seeding of the area. Grasses eventually recover, but seedlings are able to survive and grow to attain reproductive maturity. Past restoration with fire-tolerant species is limited to small experimental prescribe burns in isolated kipukas and following the occurrence of natural wildfires (Loh et al. 2003, Loh et al. in prep.). Under these conditions, areas with the greatest need or highest potential for native plant restoration were not necessarily included. Under this proposed Fire management Plan, the haphazard approach to long-term restoration of the landscape would be avoided by incorporating the planned use of prescribe fire.

Alternatives to prescribe fire for removing grasses are investigated that include mechanical and chemical treatments. These treatments are used to temporarily knockdown grasses followed by outplanting and direct seeding of native plants. No follow-up treatments are used. However the cost of mechanical and chemical treatments severely limits the scale at which restoration can be accomplished (e.g. landscape level restoration).

Resources at Risk. Alien birds dominate the avifauna of the mid-elevation seasonal zone, including Japanese white-eyes, nutmeg mannikins, and a number of species of introduced game birds. The native, malaria-resistant ‘Amakihi persists in the dry ‘öhi’a woodlands. Native invertebrate life is still rich in the mid-elevation woodlands, included long-horned woodborers and yellow faced bees. A number of rare native plants persist in unburned areas or protected kïpuka. These include ‘akoko, hoawa, kauila, kolea, ko’oko’olau, hulumoa, naupaka kuahiwi, and the endangered ‘öhai.

Coastal Lowland Fire Management Unit, (FMU-6).

Geography and Climate. The coastal lowland fire environment lies below the mid-elevation seasonal environment. It includes the coastal strand along the immediate shoreline and the coastal plain makai of the large fault scarps or pali, usually located one to several miles away from the shoreline, and woodland communities on the face of the pali.

The coastal lowland environment is typically warm and dry. Rainfall varies from about 60 inches per year in the eastern park boundary to less than 20 inches in the west. Summer drought conditions characterize the area.

Vegetation, Fuels, and Fire Potential. The combination of dry conditions and relative young substrates limits the development of vegetation. A narrow band of coastal strand vegetation is found in a number of areas along the immediate shoreline. Vegetation varies from naupaka dominated scrub to sparse salt-tolerant herbs. The endangered grass *Ischaemum byrone*, the endangered loulu palm, and the species of concern, *Portulaca villosa* grows in a number of locations where outplanted. The endangered shrub ‘öhai grows in some coastal strand sites. Fire is generally not a major concern in the coastal strand, except for the upper fringe of the strand in some areas. Where grass fuels are present, they tend to be low growing and scattered.

The coastal plains of the park are now largely dominated by grasses. The wetter, eastern coastal lowlands have the remains of a coastal shrubland, modified by fire. Prior to fire this community was dominated by tall ‘akia shrubs, along with other native shrubs including ‘a’ali’i and ‘ülei. Alien broomsedge and beardgrass, along with native pili grass, formed a matrix between the shrubs and permitted wildfires to spread. Most of the ‘äkia shrublands burned in the Pu’u ‘Ö’ö eruptions that started in 1983. Small pockets persist. However, most of the ‘äkia shrubland has been converted to low open shrubland with scattered ‘a’ali’i and ‘ülei, broomsedge, beardgrass, and pili grass between the shrubs.

The western portion of the coastal lowlands are dominated by alien grasslands with patches of alien shrubs. The dominant grasses are alien Natal redtop, thatching grass, molasses grass, beardgrass, and broomsedge. Native pili grass is an important component of the grasslands in some areas. Wildfire has become relatively frequent in the coastal lowlands in the last 30 years. Feral goats were removed in the early 1970's. Without grazing pressure, the grass species above replaced low growing grasses that were adapted to grazing pressure.

The coastal lowlands also contain small scattered stands of dry and mesic forests on the faces of the pali. Younger flows are dominated by open stands of 'öhi'a. The short native tree lama with an understory of the shrub alahe'e replaces 'öhi'a on older flows. A number of threatened, endangered, candidate species include kauila, hala pepe, 'ahakea, and 'ohe makai. Lama forest in the park have been greatly reduced in the last 30 years by lava flows so that just a few patches remain. Although grassy fuels are common only in the smaller lama forest patches, fire may carry in alien sword fern and lantana during extreme fire conditions. Lama recovers poorly after fire.

Fire History. Fire was a very rare event in the coastal lowlands of the park prior to early 1970's . Broomsedge and beardgrass invaded the eastern coastal lowlands in the early 1960's. Wildland fire occurred in the early 1970-1990's ignited by lava flows. Feral goats were removed in the early 1970s from the central coastal lowlands. Tall, perennial, fire-promoting grasses quickly replaced annual and short perennial grasses. The removal of goats has also allowed the recovery of native pili grass in some areas of the coastal lowlands. As a result of the increased grass abundance, fires have occurred in the central coastal lowlands in the last 30 years.

Fire Effects. The impact of fire varied between the two major vegetation types in the coastal lowland environment (Tunison et al. 1994). In the shrublands in the eastern coastal lowlands, a matrix of broomsedge and beardgrass filled in the gaps in open shrubland and carried the wildfires that have occurred. Even though the fire-intolerant native shrub 'akia was nearly eliminated by fire, other native shrubs, including 'a'ali'i and 'uhaloa recovered rapidly from seed and the native shrub 'ülei recovered by resprouting. There was a net increase in native plant cover because of a positive response of native pili grass to fire. In the central coastal lowlands, fire had little long-term effect on the composition of alien grasslands because the recovery to pre-fire composition and abundance was rapid. Fire also enhanced the cover of native pili grass in pili-Natal redtop communities.

Fire in the coastal lowlands was not as damaging to native ecosystems as it was in the seasonally dry woodland, even though alien, fire-promoting grasses had invaded this ecosystem (D'Antonio et al. 2000). Part of this favorable response can be attributed to the presence of shrub species that recover by resprouting or became established from seed. However, the favorable response is also partly due to the persistence of native pili grass that survived cattle, feral goats, and the spread of tropical and subtropical alien grasses after goat control. Pili is a fire-stimulated species and has a history of responding to fire in the lowlands. It was probably an important historical component of the coastal lowlands, and Polynesians used fire in the coastal areas to stimulate pili.

Management Strategies. Between 1995-2002, four prescribed burns have been conducted to evaluate the efficacy of using prescribed burns to restore pili grasslands. Once dominate on the dry lowland slopes of the Hawaiian islands, pili grasslands are much reduced and are mixed or replaced by introduced grasses and woody species on the island of Hawai'i. Two small prescribed burns conducted in mixed pili-alien grasslands show that pili abundance can increase relative to alien grasses present in the area, but results vary according to the alien species present (Loh unpubl.). A series of prescribed burns are currently underway to 1) determine whether pili grasslands can be maintained or expanded through the use of prescribed burns, 2) determine whether fire severity of subsequent fires is reduced by periodic burning, and 3) test the response of selected lowland native species to frequent fires.

Expanded use of prescribe fire, and allowance of natural fire in isolated kipukas will provide more opportunities for fire effects studies, development of restoration strategies, and allow for the expansion of management of pili grass to the landscape level.

Limited manual and chemical treatments are currently in place to prevent the widespread establishment of fountain grass. Outside the park, fountain grass has increased fuel loads and consequently fire frequency and intensity in areas it invades. Fires carried by fountain grass have caused considerable damage to native lowland dry ecosystems and threatened urban areas on the west side of Hawaii island. In HAVO, fountain grass poses a unique problem because of the plants ability to thrive in harsh environments such as barren lava flows, poor soils, and xeric conditions not favorable to other alien grasses.

A systematic control program for fountain grass has been in place since the mid-1980s. Fountain grass occurs across 21,000 hectares in HAVO between sea level and 1,200 m elevation (Tunison et al 1994). Fortunately, it is distributed at very low densities for over 90% of its range. HAVO has made an intensive effort to control satellite populations. This program has been successful in preventing expansion into new areas and reducing densities of core populations. Chemical control is used to initially knock down populations followed by manual retreatment to prevent re-establishment from seed until the seed bank is depleted.

Resources at Risk. Small patches of dry and mesic lama forest contain a number of rare, threatened, and endangered plant species (Kauila, Halapepe, Ohe). The endangered grass Ischaemum byrone, the endangered loulu palm and öhai, and the species of concern, Portulaca villosa grow in the coastal strand. The endangered nene goose is observed in the eastern portion of the coastal lowlands.

Kahuku Pasture Fire Management Unit, (FMU-7).

Geography and Climate. The acquisition of Kahuku Ranch has brought a new fire environment into the park. There are approximately 7,200 acres of pasture extending from 2,500 foot elevation to 5,000 foot elevation on the south slope of Mauna Loa. The area extends east to mesic forest (60-80 inches of rain per year) and west to seasonally dry ‘öhi’a woodlands (40-60 inches of rain per year).

Vegetation, Fuels, and Fire Potential. Most of the pastures have an open canopy of ‘öhi’a or ‘öhi’a-koa which has an understory of pasture grasses, predominantly Kikuyugrass. Small kïpukas of diverse mesic forest are scattered on the east end of the pasture. Grazing has prevented the invasion of alien shrubs and tall-grasses found commonly in fallow, cleared land outside the park. Cattle grazing will continue until 2009 under a Special Use Permit to prevent the invasion of weedy grass and shrub species into the pastures and surrounding forest. Grazing may continue on a smaller scale after that and eventually be phased out as the park reforests some pastures and allow others to naturally recover.

With intensive grazing, the risk of fire is low to moderate because fuel loadings of grasses are relatively low and dead grass biomass is not allowed to accumulate. Pastures, including those dominated by Kikuyugrass, are not invulnerable to fire. Grazed pastures are capable of carrying fire, as evident by the Six Tanks Fire of 1975. This fire started in Keauhou Ranch in pasture lands. It swept through the park and burned into Kapapala Ranch. The main fuel in the ranch lands was Kikuyu grass. Fire potential in the Kuhuku pastures is probably greater at lower elevations and to the west where rainfall is lower. Nearly daily rains affect the pastures to the east and at higher elevations.

Fire potential will increase in the pastures with the phasing out of cattle grazing. Abandoned pastures on the drier, western side of the pasture zone are being invaded by fire-promoting grasses including beardgrass, broomsedge, and barbwire grass, as well as the invasive shrub Christmasberry. If left unmanaged, fuel loads may increase and eventually resemble areas in the mid-elevation seasonal FMU where fire has been most prevalent in the park.

The park will actively restore pastures to mixed koa and ‘öhi’a forests on the moister, eastern side of the pasture zone. Following cessation of cattle grazing, conversion from pasture to native forest will be accomplished through a combination of natural recovery and active restoration. Active restoration will include herbicidal removal of alien grasses to allow native woody plants to become established supplemented by native plant reintroduction in selected areas. Conversion of pastures to forests through natural recovery and active reforestation will reduce fire potential in the long term by eliminating grass fuels. However, in the early stages of recovery and restoration, there will be dense stands of young trees in a grassy matrix, a fuel type with high fire potential.

Fire History. The fire history of the grazing areas is not known.

Fire Effects. The response of some of the more common plants can be expected to be similar to their response in nearby mid-elevation seasonal and montane seasonal FMU's. ‘Öhi’a trees will be readily top killed but some may resprout. Koa will resprout or become established by seed after fire. Alien grasses will rapidly re-establish, particularly on the drier west end where fire-adapted beardgrass and broomsedge are invading pastures.

Management strategies. The current strategy is to suppress all fires. Removal of cattle, and wild mouflon and goats is expected to results in recovery of some native species, but also the spread of invasive grasses and christmasberry. Mechanical and chemical treatment to limit the spread of invasive grasses and christmasberry, that can increase fire potential, are currently being tested.

Resources at Risk. Numerous kïpuka of native mesic forest are located on the east end of the pasture. These kïpukas serve as important seed sources for pasture reforestation. Kïpukas also have the potential to contain rare, threatened and endangered species. An endangered Cyanea stictophylla was found inside a pit crater, and several rare plant species (e.g. ohe mauka, hame, lono), the endangered Nene and ‘I’o have been observed in the pasture. Ongoing field surveys to inventory biological resources are ongoing in Kahuku may result in additional endangered, threatened and rare species discoveries (Table 1).

Threatened and Endangered Species and Important Rare Species

The flora and fauna of Hawai’i Volcanoes National Park contains a high proportion of endangered, threatened, and species of Special Concern. There are 31 threatened and endangered plant species, or

7% of the Park's native flowering plants and ferns (Table 1). There are over 70 species of special concern. These include seven candidate endangered species, 25 Species of Concern, five former Species of Concern, and approximately 40 species deemed rare in the park by park Botanists. Threatened and endangered species, as well as species of special concern, comprise one-quarter of the park's native flora of vascular plants.

Ten resident animals are threatened or endangered species (Table 1). These include 'Öpe'ape'a (Hawaiian Hoary Bat), Nënë (Hawaiian goose), 'Io (Hawaiian Hawk), 'Ua'u (Hawaiian Petrel), 'A'o (Newell's Shearwater), Picture-wing fly, 'Äkepa, 'Akiapöläu, Hawai'i Creeper, and Honuea (Hawksbill Turtle). One additional forest bird species, the O'u, was last sighted in 'Ola'a wet forest in the 1980's and is possibly extinct. Five of these species have habitat in fire-prone areas of the park. In addition, there are four candidate or proposed endangered animal species in the park.

Ongoing field surveys to inventory biological resources are ongoing in Kahuku may result in additional endangered, threatened and rare species discoveries.

FIRE BEHAVIOR

Fire behavior varies greatly in HAVO.

The alpine and sub-alpine zones (FMU 1 & 2) have very low fire potential because of the lack of continuously arranged fine fuels.

The fire potential of the Mesic and Wet Forests (FMU-3) are generally low because of the high frequency of rainfall. Tree fern dominated wet forest carries fire only under extreme drought. Uluhe-dominated rainforest fires can be strictly wind-driven but more often occur after short dry periods. Fire intensities of tree fern dominated wet forest may be extreme because of the high loadings of 1000-hour fuels. Fire potential may increase following wildfire, because of the removal of stand structure, that allows greater wind penetration and curing of fine fuels, and unburn litter and duff that have a high reburn potential.

The fire potential of the montane seasonal zone (FMU-4) is apparently intermediate probably because of green-up periods. However, fire history of the montane seasonal indicates the potential for infrequent, large, and intense fires.

The fire potential of grassy sections of the Mid-elevation Seasonal Woodland (FMU-5) and coastal lowlands zones (FMU-6) is high. In addition, there are extensive areas in these zones without natural fuel breaks.

Fire frequency is low in HAVO but the potential for large fires with extreme fire behavior is great. Fire behavior does not conform to established mainland fuel models, and research is continuing to see if customized fuel modeling will work in Hawaii.

HISTORIC ROLE OF FIRE

Determining the historic role of fire in the park before recent decades is limited by the lack of precise tools to determine fire history in the Hawaiian environment. Dendrological analysis is not applicable in Hawaii because of its tropical climate and lack of annual ring formation in trees. Fire scar chronologies therefore cannot be developed.

Natural fire occurred. Geologists attempting to date lava flows have found and dated charcoal fragments in locations away from lava flows. This distribution suggest the occurrence of wildfires, probably of volcanic origin. Fragments and charcoal layers have been found at Kilauea summit (Don Swanson, personal communication) and Mauna Loa Strip (Jack Lockwood, personal communication). However, a reliable and detailed fire history cannot be constructed from these findings.

Dated charcoal fragments found in sediment cores in Hawaiian bogs also indicate that natural fire occurred in some Hawaiian ecosystems. Although it is not possible currently to develop a detailed fire history from these cores, general patterns of fire history can be inferred. Pollen records from these cores indicate a climate alternating between wet and dry periods over the last 40,000 years (Burney et al. 1995, Hotchkiss unpubl.). Higher concentrations of charcoal are present in strata dominated by ‘öhi’a and grass pollen and lower charcoal concentrations are found in strata dominated by pollen for wet forest species. A marked increase in charcoal sediments indicate an increase in fire since European contact 200 years ago.

Polynesian Fire History. Fire history of the park before 1924 is partly understood for at least one ecosystem. The coastal lowlands were deliberately burned starting with Polynesian occupation nearly a millenium ago. Anthropogenic burning by prehistoric Polynesians is thought to be responsible for the deforestation of the coastal lowlands of Hawaii (Kirch 1982). Polynesians burned to clear forest for swidden agriculture and to stimulate the growth and abundance of pili grass, used as thatching material, and other desirable plants. A detailed analysis of historic accounts in the Hilo area of Hawaii Island indicate that there was a broad belt of cleared land up to 1,500 foot elevation (McEldowney 1979). Although a similar historical analysis has not specifically been done for HAVO, Polynesian burning practices certainly modified the coastal lowlands of HAVO below 500 foot elevation and may have also affected lower portions of the dry ‘öhi’a woodlands upland up to 1,500 foot elevation. In any case, anthropogenic burning would have had little effect on the evolutionary and ecological role of fire and the evolution of plants in Hawaii because Polynesians arrived less than 2,000 years ago.

Documented Park Fire History. Detailed park records dating back to 1924 document the recent history of fire in Hawaii Volcanoes National Park. Fire frequency and size have increased dramatically starting in the late 1960s (Loh et al. unpubl.). From 1924 to 1963, there were 35 fires or 0.9 fires per year on average (Table 1). These fires burned 215 acres or 6.1 acres per fire on average. Most of these small, infrequent fires were concentrated in visitor use areas along the rim of Kilauea Caldera, in pastures leased to cattle ranchers on the slopes of Mauna Loa, and in the vicinity of Civilian Conservation Corps camps or work projects. From 1964-1995, there were 97 fires or slightly more than three fires per year. These fires burned approximately 34,450 acres or an average of 355 acres per fire.

The approximately 3-fold increase in fire frequency and nearly 60-fold increase in fire size from 1967-1995 followed the introduction and spread of alien fire-promoting grasses starting in the 1960s. Two tall bunchgrasses, beardgrass from topical America and broomsedge from the SE United States, invaded and spread very rapidly in many plant communities below 4,000 foot elevation in the park, particularly into dry ‘öhi’a woodland, but also into coastal scrub and grasslands and disturbed gaps in wet forest. Beardgrass and broomsedge were not found in systematic botanical survey of the park lowlands in 1959 (Stone 1959). By 1966, they were characterized as dominant species of many vegetation types in the park (Mueller-Dombois and Fosberg 1974). In dry ‘ ‘öhi’a woodland they now form approximately 30% of the understory biomass and 65-80% of the understory cover woodland (D’Antonio et al. 1998, D’Antonio and Vitousek 1992). The invasions of broomsedge and beardgrass may have been facilitated by high densities of feral goats (*Capra hircus*) which suppressed potentially competitive native woody vegetation.

Fire-promoting grasses also spread rapidly in the coastal grasslands during the early 1970s following the control of feral goats. The coastal grasslands and scrub were an anthropogenic landscape created by Hawaiian agricultural practices (Kirch 1982), cattle grazing, and two hundred years of feral goat browsing (Williams 1990). Grasslands prior to goat control were dominated by short-statured annual grasses such as the alien love grass (*Eragrostis tenella*) or mat-forming stoloniferous grasses such as the alien Bermuda grass (*Cynodon dactylon*) (Mueller-Dombois and Spatz 1975). An effective goat control program was begun in 1970. Within two years following the exclusion of goats, short-statured grasses were replaced by tall, introduced, fire-enhancing perennial grasses including thatching grass (*Hyparrhenia rufa*), molasses grass, and Natal redtop (*Melinis repens*), as well as by the perennial native pili grass (*Heteropogon contortus*) (Mueller-Dombois 1980). Thatching grass continued to expand in the coastal grasslands in the 1980s and 1990s (Loh et al. unpubl.).

In the dry ‘öhi’a woodlands, park vegetation maps and fire records indicate that broomsedge and beard grass invaded an ecosystem with little previous history of fire. Prior to invasion, the dry ‘öhi’a woodland was apparently dominated by an open to closed cover of native shrubs and a discontinuous groundcover of lichens, bryophytes, and sedges (Cuddihy and Stone 1990, Mueller-Dombois and Fosberg 1974). Native grasses were unlikely to have been an important component of this ecosystem. The only native grass present in the seasonally dry woodland, a native love grass *(Eragrostis variabilis*), is uncommon. Following the invasion of broomsedge and beardgrass in the 1960s, removal of feral goats in the 1970s may have also contributed to the spread of molasses grass (*Melinis minutiflora*) in the dry ‘öhi’a woodland.

The invasion and spread of fire-promoting grasses in the dry ‘öhi’a woodlands and coastal ecosystems coincided with an era of renewed volcanic activity that started during the late 1970s and continues to the present. The Mauna Ulu eruption lasted from 1969-1974. The Pu’u ‘O’o eruptions started in 1983 and continues today. Visitation also increased since the 1960s. Visitor use was approximately 300,000 visitors per year in 1950, 1,400,000 visitors per year in 1972 (National Park Service), and 2,500,000 visitors per year today (National Park Service 2000).

Although it is not possible to strictly separate the increased potential for ignitions lava flows and humans from the impact of invading fire-enhancing grasses, the fire record is clear that most of the fire activity in the park since the late 1960s occurred in the two ecosystems of the park invaded by fire-promoting grasses. The first fire in the park in the newly arrived broomsedge and beardgrass fuels occurred in 1969 (Garrett Smathers personal communication). From 1965-1995, 81% of the area burned and 90% of the fires in the park were in the seasonally dry woodland and coastal grasslands/scrub (Tunison et al. unpubl.). Prior to 1965 just five small fires burned in the dry ‘öhi’a woodland; only one fire was recorded for the coastal grasslands/scrub (Tunison et al. unpubl.).

A new fire regime has developed along the East Rift Zone of Kilauea since the mid-1990s. Prior to 1996, the East Rift wet forest and mesic forest had little history of fire. Portions of the drier, western margins of mesic forest burned during the Mauna Ulu flows of 1969-1974 (Warshauer 1974). However, despite nearly continuous eruptive activity from Pu'u 'O'o since 1983, there was little fire spread caused by lava-ignitions until the mid-1990s. At least eight fires on the East Rift of Kilauea, burning approximately 11,600 acres or about 1,450 acres per fire, occurred between 1996-2003. These fires occurred when lava flows moved west, putting the ignition source in contact with sulfur dioxide killed forest, uluhe fern (*Dicranopteris linearis*) dominated wet forest, and mesic forest with dense alien sword fern (*Nephrolepis multiflora*). The first large fire in these fuels types was the Valentine's Day Fire in 1996, spreading over 600 acres. The 3,800 acre Kupukupu Fire, the 1,800 acre Panau Iki Fire, and the 4,900 acre Luhi fire spread in uluhe wet forest and 'öhi'a/swordfern mesic forest (as well as grass and brush fuel types) in 2002 and 2003, during high wind or very low relative humidity events. More large fires can be expected to occur because of continued lava flow activity, the prevalence of thick deposits of lightly burned duff and litter layers that have a high reburn potential, and the more open forest canopy caused by sulfur dioxide dieback and damage by previous wildfire.

ECOLOGICAL ROLE OF FIRE

Plant succession after wildfire has been studied most systematically in the dry 'öhi'a woodlands where most park acres burned from the mid-1960s to the mid-1990s (Tunison et al. 1995). The impact of fire has also been evaluated in a few sites in the coastal lowlands (Tunison et al. 1994), uluhe (*Dicranopteris linearis*)-dominated wet forest (Loh et al. unpubl.), and montane mesic forest and shrublands (Haunss et al. unpubl.).

Dry 'öhi'a Woodland

The dry 'öhi'a woodland is located in the leeward area of the park from approximately 1,000-3,900 foot elevation, and is part of the Submontane Seasonal Fire Management Unit. In the seasonally dry 'öhi'a woodland, precipitation averages 40-60 inches per year, with most rainfall between November and April. Soils, derived from volcanic ash, are generally shallow and patchy over young pahoehoe flows less than 1,000 years old. Prior to fire, woodlands are dominated by open stands of 'öhi'a with an understory of native shrubs, the most common of which are pükiawe (*Leptecophylla tameiameiae*), 'a'ali'i (*Dodonaea viscosa*), 'ulei (*Osteomeles anthyllidifolia*), and 'akia (*Wikstroemia phillyreifolia*). Alien grasses form a nearly continuous matrix between and within the open shrubs. Typically beardgrass (*Schzycharium condesatum*) is the dominant grass in unburned dry 'öhi'a woodland, with molasses grass and broomsedge (*Andropogon virginicus*) as minor components. Molasses grass (*Melinis minutiflora*) was present in the park early in the twentieth century but was largely confined to roadsides, possibly because of feral goat browsing. It spread into dry 'öhi'a woodland in the 1970s and 1980s, apparently after goats were controlled (Loh et al. unpubl.). Molasses grass seed is widespread in the soil in the unburned woodland. The dominance of beardgrass in the unburned woodland is likely due to the fact that it became established on site prior to the spread of molasses grass.

Plant succession after fire was studied in 14 sites in the dry 'öhi'a woodland, with reported sampling periods after fire ranging from 4-17 years (Hughes et al. 1991, Tunison et al. 1995). Fire greatly reduced native woody vegetation partially by reducing the community dominants, ‘öhi’a and pükiawe. On average, 55% of the ‘öhi’a, the dominant tree species in the pre-fire community were killed by fire. Surviving trees were partially protected from fire on pahoehoe tumuli with little alien grass fuel. More typically, aerial portions of the trees were killed and surviving individuals recovered by crown or epicormic sprouts (Parman and Wampler 1976, Tunison et al. 1995). ‘Öhi’a mortality was positively related to fire severity, with height of char on the bole the best predictor of mortality (D Antonio et al. 2000). On average, 60% of ‘öhi’a in high severity sites and 29% in low intensity sites were killed. ‘Öhi’a is a very slow growing species. Crown sprouts, by far the most common method of recovery, were only 3-5 meters tall with narrow crowns, even after 17 years. ‘Öhi’a seedlings rarely become established (Tunison et al. 1995). Regeneration from seedlings was evident in only one burn located on the wet end of the ‘öhi’a woodland ecosystem (Loh unpubl.). The loss of mature ‘öhi’a and failure of ‘öhi’a to recover from seed resulted in the conversion of open canopied woodlands to savannas characterized by scattered to very scattered trees (Hughes et al. 1991, Freifelder et al. 1998).

Three of the four native shrubs common in the seasonally dry woodland before fire were sharply reduced in cover and density following fire, and show little sign of recovery, even 17 years after fire (Hughes et al. 1991, Tunison et al. 1995). The aerial portions of all four shrubs were readily killed by fire, although resprouting occasionally took place under low fire intensity conditions (Tunison et al. 1995). Native shrub cover as a whole was reduced nearly two orders of magnitude. Pükiawe, the dominant shrub before fire was nearly absent in most burned areas, declined 10-fold in cover and 3-fold in density after fire. Although some seedlings were observed, no seedlings of pükiawe recruited successfully to larger size classes in any burned site (D’Antonio et al. in press). Although mature plants of the common shrub, ‘a’ali’i, were killed by fire, this native shrub species generally recovered to pre-fire abundance. Recruitment from seed was substantial (Hughes et al. 1991), recruitment into larger size classes occurred even through dense grass cover, and cover of large plants were similar in older burns to unburned areas (D’Antonio et al. in press). Although sample sizes were very small, the small native tree mämane (*Sophora chrysophylla*) resprouted nearly invariably from the root crown, even after severe fires (Tunison et al. 1995, Loh unpubl.).

Alien grass cover increased on average 33% after fire (D’Antonio et al. 2000). Also, alien grass biomass increased 2-3-fold after fire, increasing fuel loading (Tunison et al. 1995). Molasses grass had the greatest increases in cover in burned sites in which it was present prior to fire. Fire disrupts the priority effect of beardgrass and molasses grass effectively out-competes beardgrass in burned sites for both light and nutrients (D’Antonio et al. in press).

The rapid reestablishment and long-term persistence of alien grasses inhibit shrub colonization and growth (Hughes and Vitousek 1993). This is particularly true in sites in which molasses grass was present (D Antonio et al. 2000); native shrub cover was lowest in these sites. The vigorous response of this mat-forming species creates a formidable environment for native species regeneration. Low light levels under alien grasses in burned areas, rather than lack of soil moisture or nutrients, were responsible for the lack of recruitment of native shrubs (Hughes and Vitousek 1993). The native shrub ‘a’ali’i persists in burned areas because of its rapid germination, growth, and tolerance of the low light levels beneath a grass canopy.

Grass/Fire Cycle

The main fire-enhancing grasses that invaded and/or spread in the 1960s and 1970s--broomsedge, beardgrass, thatching grass (*Hyparrhenia rufa*), and molasses grass--have characteristics that facilitate fire spread and rapid recovery after fire. Broomsedge, beardgrass, and thatching grass are tall perennial bunchgrasses. Molasses grass is a rhizomatous, mat-forming grass. All maintain high dead-to-live biomass ratios throughout most of the year. Consequently, these grasses provide a high standing biomass of dead material. Broomsedge and molasses grass have higher surface-to-area volume, loadings, and fuel depth estimates than the corresponding parameter of standard grass models (Fujioka and Fujii 1980). Molasses grass fuels in HAVO have been measured as high as 7 tons per acres (Wright et al. 2002). In addition, molasses grass leaves are coated with a resinous material and may have a high heat content. All four grasses appear to have high moistures of extinction and can carry fire at high relative humidity, even as high as 80-90% (Tunison, unpubl.). All recover after fire by resprouting or seedling recruitment and grow with increased vigor following fire (Tunison et al. 1995, Hughes et al. 1991, D'Antonio et al. in press). Fountain grass (*Pennisetum setaceum*) is another tall perennial, fire-enhancing bunchgrass that has invaded dry forest or shrublands and even relatively bare lava flows and created fire problems in other areas of Hawai'i Island (Takeuchi 1991, Shaw et al. 1995). This species is now effectively controlled in Hawai'i Volcanoes National Park and does not currently affect the fire regime of the park.

The invasion of broomsedge and beardgrass into the dry 'öhi'a woodland has established an alien grass/fire cycle (Hughes et al. 1991, D'Antonio and Vitousek 1992, Freifelder et al. 1998), a process facilitated by the fire-promoting and post-fire colonizing characteristics of these grasses. Grass invasion of dry 'öhi'a woodlands promotes fire in a previously fire-independent ecosystem and alters the disturbance regime of this ecosystem. After fire, grasses out-compete native woody plants and increase in cover and fuel loading (Hughes et al 1991, D'Antonio et al. in press). Burned sites are then predisposed to more severe future fire compared to adjacent unburned woodlands because of increased fuel loading and, more importantly, because wind speeds are substantially greater in the more open and homogeneous post-fire savannas (Freifelder 1998). Contrary to expectations, temperature is higher and relative humidity is lower in the unburned woodland. The open canopied woodlands (40% tree cover (Hughes et al. 1991)) apparently serve as a windbreak but do not shade the understory sufficiently to reduce near-ground temperatures as much as tall, dense mats of molasses grass do in burned areas.

Changes in Nitrogen

Nitrogen changes after fire have been extensively studied in the dry 'öhi'a woodland. The most detailed studies compared four related sites: an unburned woodland, a 17 year old burn, a recent burn, and a twice burned site (Hughes et al. 1991, Hughes and Vitousek 1993, Mack et al. in press). Pool sizes of available N were significantly increased (Hughes and Vitousek 1993) in all burned sites compared to the unburned woodland within one year after the fire. Pool sizes were greatest in the young burn but were less in the twice burned and old burn sites, indicating a decline over time after fire and with successive fires. However, rates of N fixation were greater in the unburned woodland (Ley and D'Antonio 1998) than in the burned sites. N fixation occurs asymbiotically on 'öhi'a leaf litter and wood debris and in the soil organic horizon. These substrates are largely absent from the burned sites, except for unconsumed wood debris. The decrease in N fixation in burned sites indicates that ecosystem-level rates of N accretion are decreased by fire and that N lost during volatilization due to fire is not likely to be replenished very rapidly by N fixation.

The dramatic change in N cycling associated with fire is the result of the loss of native species after fire (Mack et al. in press). Comparing just the 2X burned and the UB sites, these investigators found that rates of mineralization on an annual basis are higher in the TB. They also found that the potential for uptake of the mineralized N by vegetation on microorganisms was significantly lower in the TB sites. Thus, the potential for N loss from the system is great. This is due to reduced annual NPP by the vegetation in the burned sites as a result of the loss of 'öhi'a and other native woody species.

Coastal Lowlands

The impact of fire varied between the two major vegetation types in the coastal lowland environment, shrublands in the east and largely alien grasslands in the central and western parts of the coastal lowlands below 1,000 foot elevation. In the shrublands, a matrix of broomsedge and beardgrass filled in the gaps in open shrubland and carried the wildfires that have occurred there. Even though the fire-intolerant native shrub 'akia was nearly eliminated by fire, other native shrubs, including 'a'ali'i and 'uhaloa (*Waltheria americana*) recovered rapidly from seed and the native shrub 'ulei recovered by resprouting. There was a net increase in native plant cover because of a positive response of native pili grass to fire. In the central coastal lowlands, fire had little long-term effect on the composition of alien grasslands, with rapid recovery to pre-fire composition and abundance (Tunison et al. 1994). However, fire enhanced the cover of native pili grass in pili-Natal redtop (*Melinis repens*) communities.

Fire in the coastal lowlands was not as damaging to native ecosystems as it was in the dry 'öhi'a woodland, even though alien, fire-promoting grasses had invaded this ecosystem (D'Antonio et al. 2000). Part of this favorable response can be attributed to the presence of native shrub species that responded favorably to fire by resprouting or seeding. The favorable response is also partly due to the persistence of native pili grass that survived cattle, feral goats, and the spread of tropical and subtropical alien grasses after goat control. Pili is a fire-stimulated species, and has a history of responding to fire in the lowlands. It was apparently an important historical component of the coastal lowlands, and Polynesians used fire in the coastal areas to stimulate pili.

Mesic and Wet Forest.

The current understanding of plant succession after wildfire in uluhe wet forest is based on studies conducted in small fires immediately outside the park in the Volcano community. Fire in wet forest was uncommon until 1996. In the oldest study site, alien broomsedge, foxtail (*Setaria gracillis*), and Himalayan raspberry (*Rubus ellipticus*) invaded and dominated the post-fire community in the first two years after fire (Loh and Tunison unpubl.). Early successional native plants also invade immediately after fire. These include the sedge 'uki (*Machaerina* spp.), the grass 'ohe (*Isachne distichophylla*), and the shrub naupaka (*Scaevola chamissoniana*). In this site, uluhe again dominated the understory of the wet forest by 11 years. Tree ferns, shrubs, and 'öhi'a resprouted in varying degrees. 'Öhi'a also successfully established from seed. In other study sites, aggressive alien plants may prevent native forest recovery. Invasive kahili ginger (*Hedychium gardnerianum*) and bamboo (*Phyllostachys nigra*), present before fire, quickly resprouted and increased cover abundance after fire (Loh unpubl.). Both species become dominant in native forest they invade.

The rapid, post-fire recovery of native vegetation in some uluhe stands contrasts with the poor recovery in dry 'öhi'a woodland. Several reasons may be offered for this difference. Wet forest, with dense canopy cover, was not invaded by fire-promoting grasses before fire. Much of the heat generated from fire in the uluhe occurs high in the canopy, leaving the lower litter and duff layers lightly scorched or unaffected. Thus, the root crowns of native trees, soil seed bank, and uluhe rhizomes are potentially not affected by fire. The litter and duff mat may protect the burned site from weed colonization. Although broomsedge invaded burned areas in ‘öhi’a/uluhe, it did not create the dense mats of inhibiting grass that molasses grass creates. Instead, uluhe was able to regenerate vegetatively and suppress alien grasses that initially dominated the post-fire environment. Although uluhe clearly suppresses other native plants, many native species are able to germinate, grow, and reproduce under uluhe or in gaps in the uluhe mat. A favorable plant environment and consistent rainfall may account for why the only burn observed in the park with ‘öhi’a seedling recruitment was in the wet forest.

There were three large fires in uluhe-dominated wet forest on the East Rift in 1996, 2002, and 2003. Monitoring has been established in the two more recent fires to determine the response of uluhe dominated communities in this environment along gradients of tree fern and uluhe abundance and the number of times burned. Reburns tend to reduce the duff and litter layers, scorch resprouting trees, potentially affect the soil seed bank and uluhe rhizomes, and reduce the natural organic mulch inhibiting weed colonization.

Only the mesic forest stands in the lower East Rift Zone have had a recent history of fire. Fire spread readily in invasive sword fern understory under windy conditions. Fire in a sword fern area consumes both green and dead fronds but leaves a thick litter and duff layer capable of burning immediately in subsequent fires. Invasive sword fern vegetatively recovers very rapidly after fire, much more rapidly than native species. ‘Öhi’a appears to be regenerating in sword fern but many mesic forest trees, shrubs, and herbaceous understory elements are missing. Introduced faya tree and strawberry guava vegetatively recovers very rapidly after fire.

Montane Seasonal Communities

Fire is also uncommon in the montane seasonal environment (Parman 1976, Loh et al. unpubl.), in spite of the abundance of fine fuels, characteristic summer drought, and an annual rain fall equivalent to the dry ‘öhi’a woodlands. Fire may have been an important component in some portions of the montane seasonal ecosystem (Mueller-Dombois 1981). This is inferred from the fact that native shrubs and grasses form a nearly continuous fine fuel bed, and many native species recover rapidly from fire. Only one fire has occurred here in the last 28 years, originating in pasture land outside the park and spreading through stands of koa (*Acacia koa*) forest, native shrublands with a significant admixture of native and alien grasses, and occasional small grasslands dominated by native or alien grass.

On the Mauna Loa Strip, the major impact of fire in koa forest with invasive grass understory is to alter the stand structure of koa forest, replacing older, larger diameter trees with small stems. Koa resprouts readily from root suckers after fire to reestablish the forest overstory within a decade. Alien meadowrice grass, the dominant understory component, rapidly recovers. Shrublands and grasslands change only subtly in composition after fire, with a shift in cover from less fire-tolerant pükiawe to the more fire-tolerant ‘a’ali’i, with no net increase in alien species cover, including alien grasses. These observations about fire are based on studies of single fire in 1975. New alien species have become established in the park and vicinity since the fire and others have increased in abundance. These might affect succession after fire in the future.

FUEL CHARACTERISTICS

HAVO fuel types are now being classified and mapped. Fire behavior has not been documented or even observed in many fuels; therefore, the following classification is provisional

A large number of Park fires have occurred in fire-adapted alien grasses, particularly in bush beardgrass, broomsedge, and molasses grass (Tunison and Leialoha, unpubl.). More recently large fires have carried in native uluhe fern and invasive swordfern in the East Rift of Kïlauea. Occasional fires occur in native shrubs, small trees, and native bunchgrasses on Mauna Loa. Presumably all native vegetation types can burn under extreme conditions, even tree fern dominated rainforest.

Alien Grasses

Common features of alien grass fuels below 4,000-ft elevation are these:

1. They are bunchgrasses or matted perennials that accumulate copious litter and have considerable dead attached foliage. The percentage of live material is usually 10-20% throughout most of the year. In periods of prolonged rain, the percent of live foliage may reach as high as 40-50% in molasses grass, bush beardgrass, and broomsedge, and even higher in broomsedge in wet forest and Natal redtop and thatching grass in the coastal lowlands.

2. They are highly fire-tolerant. Most of these grasses occur in fire-type vegetation in their natural ranges. All resprout vigorously after fire, broomsedge and bush beardgrass within 2-3 days. Molasses grass, bush beardgrass, thatching grass, and broomsedge also establish from seed after fire (Tunison et al., unpubl. (b)). Fountain grass is stimulated to flower three months after fire.

3. They have high moistures of extinction. Most species will carry fire at dead fuel moistures as high as 20-25% and relative humidities as high as 85-90%. They are adapted to burn in the relative high tropical humidities, and carry fire under essentially all conditions except sustained rain or when free water is present. Most of the grasses originate in seasonal tropical, subtropical, or warm and humid temperate areas where they can burn under high relative humidities. The live foliage of molasses grass has a resin, which seems to increase its heat content.

4. Fuel loadings of alien grasses appear to be increasing in many sites. Fuel loadings increased dramatically in the sub montane seasonal zone with the spread of broomsedge and bush beardgrass in the 1960's and in the coastal lowlands with the removal of goats in the 1970's. Fuel loadings are continuing to increase. Thatching grass and molasses grass are expanding and intensifying in the Park, replacing grasses with lower fuel loadings. Thatching grass has spread in the central coastal lowlands and is now expanding into the western and eastern coastal lowlands and into the lower sub montane seasonal. Molasses grass appears to be spreading throughout the sub montane seasonal, vigorously invading the lower sub montane seasonal and upper coastal lowlands. Fountain grass occurs in the southwestern coastal lowlands and along roads below 4,000-ft elevation. Densities are now low because of a control program. Without control, fountain grass would become a major fuel in the park below 8,500-ft elevation (Tunison, in press).

5. The cover of alien grass increases in most mid-elevation seasonal and wet forest sites after fire. Also, molasses grass, which has higher fuel loadings than bush beardgrass and broomsedge, replaces these species after fire. Fuel loadings may decrease after fire in some mid-elevation seasonal and coastal lowland sites when redtop replaces broomsedge and bush beardgrass. It is not known if

broomsedge and bush beardgrass are intensifying in areas they dominate. Fire intensity is probably increasing because fuel loads are increasing, although other fuel characteristics may affect fire intensity.

6. A year-round fire season characterizes fuel types dominated by alien grasses. The year-round fire season results from the accumulation of litter, the high percentage of dead attached foliage, the shortness and incompleteness of green-up, frequent non-rainy periods, and the lack of soil to hold moisture.

Even though alien grass fuels below 4,000-ft elevation are available throughout the year, long periods of rain or droughts can affect fire behavior and ignition potential. Protracted rainy periods may increase the live/dead and significantly reduce rates of spread, fire intensity, and likelihood of fire starts. Long dry periods reduce the live fuel moisture, percentage of live foliage, increase fire intensity and rates of spread, and increase the likelihood of fire starts. Localized droughts in HA VO can result in localized severe drying of fuels. Shorter periods of drying are required in summer when day length and solar radiation are somewhat greater and chances of major storms are minimal.

7. Fine dead fuel moistures can drop very rapidly in alien grass fuels. Most of the alien grasses are concentrated in leeward environments. Tradewind rains are most frequent in the late afternoon, night or early morning, with mid-day clearing. The paucity of soil, [. sparseness of overstory, and strong winds also expedite drying. Fire danger ratings can therefore climb rapidly following even heavy or prolonged rain. Very high and extreme fire danger can follow lengthy wet spells with two to three days of dry weather.

8. Dead fuel moisture and wind usually control fire behavior of these fuels. Slope is not, a factor in most fuel beds, and the percentage of live foliage and live fuel moisture is I relatively constant except after prolonged rainy periods.

Alien grasses are also the primary fuels from 4,000-5,000 ft elevation. The most abundant species are meadow ricegrass and *Paspalum* grass. These species accumulate litter and retain dead foliage, but probably not to the extent of broomsedge, bush beardgrass, and molasses grass. Both species can re-sprout after fire. A notable difference is that meadow ricegrass and *Paspalum* green up significantly, generally during winter and spring. They are generally dry in summer and fall and can certainly carry fire. The capacity of these fuels to carry fire during dry periods in winter and spring is not known. In some areas, sufficient dead attached foliage and litter underlying green foliage may permit fire to be carried during dry periods.

The following provides a more detailed description of alien grass fuel types by species. This is not meant to be a comprehensive description of all alien grass species but a summary of the current knowledge.

Mixed Broomsedge. This fuel type is dominated by a mixture of broomsedge and bush beardgrass with an admixture of native pili, native redtop, and molasses grass with scattered native and alien shrubs. Mixed broomsedge is the dominant fuel type in the coastal lowlands in the eastern part of the Park and an important constituent of the mid-elevation seasonal zone, particularly in areas with shallow soils and little tree cover. Height of fuels is 2-4 feet tall. Live grass fuel loadings average 3-4 tons/ac and can be as high as 5 tons/ac in some areas. Biomass of litter ranges between 2-3 tons/ac (Wright et al. 2002).

The fire behavior of this fuel type is probably better understood than any other type. A customized fuel model has been developed, but has been verified only for mid-range fuel moisture and wind speeds. The range of predicted fire behavior conditions is described in detail in Tunison and Leialoha (unpubl. (b)). After prolonged rain, the percent of live foliage may reach 40%, decreasing fire intensity and rate of spread considerably. Torching and spotting are generally not a problem in mixed broomsedge. However, shrubs and trees, particularly ‘öhi’a and christmasberry may torch and cause spotting with higher fire intensity.

Bush Beardgrass. This fuel type is dominated by bush beardgrass 3-5 feet tall, with broomsedge and molasses grass as minor components. Native shrubs are usually abundant and probably contribute to fire intensity. This fuel type is found primarily under dry ' ‘öhi’a 'a woodlands and forest in the mid-elevation seasonal zone. Fire behavior in this fuel type has not been documented. From sampling in one site, live grass fuel loadings averaged 2.7 tons/ac, and biomass o*f* grass litter was 2 tons/ac (Wright et al. 2002).

Mixed Molasses Grass. This fuel type is a mosaic of patches of molasses grass intermixed with bush beardgrass and broomsedge. The molasses grass patches are usually more extensive, and bush beardgrass is usually more abundant than broomsedge. Thatching grass is an important component near the coastal pali. Shrubs and ‘öhi’a are usually scattered. Mixed molasses grass occurs in the mid-elevation seasonal zone above the coastal pali, and replaces other fuel types in this zone after fire. Grass mats vary between 2-4 ft in height. In one site where grasses were only 2 ft tall, fuel loading of live grasses was 7 tons/ac, and litter was 3.4 tons/ac (Wright et al. 2002). This fuel type supports the most intense fires in the mid-elevation seasonal zone and possibly the Park. The mosaic pattern of the two components of this fuel type lends them to predicting fire behavior using the two-fuel model approach.

Thatching grass. This fuel type is dominated by thatching grass, with molasses grass important at upper elevations and Natal redtop important at lower elevations. This fuel type is found primarily in the central coastal lowlands between Keauhou and Kamo'oali'i, but is expanding in HAVO as the range of thatching grass increases. Fire behavior has not been documented in this fuel type. Intense fire behavior is expected because of high fuel loadings and great depth of the fuel bed.

Pili/Natal Redtop. This fuel type is found in the coastal lowlands in sites with shallow soils. Natal redtop is more often the dominant grass with pili more abundant in recently burned areas at lower elevations. Grasses are < 2 ft tall. Fuel loadings (< 1.5 tons/acre live grass fuel loads, 0.5-2 tons/acre litter) are sparse and continuity is marginal for the spread of fire. Fire behavior has not been documented but is expected to be of low intensity with low rates of spread. Pili grass and Natal redtop are the dominant components, and fire behavior probably depends on which is dominant. Pili grass is probably a much more fire-prone species because it tends to accumulate more litter and does not green up as rapidly or as thoroughly as Natal red top.

Montane Tall Grass. This fuel type is found in openings, woodlands, and sparse brush fields between 4,000 ft and 4,800-ft elevation on Mauna Loa. It is dominated largely by a mixture of alien grasses (Paspalum, velvet, sweet vernal grass) 2-5 ft tall. Native bunchgrasses, 'emo-loa and *Deschampsia* contribute to fuel loadings. Fire frequency is relatively low, the only recent fire being the Six Tanks Fire (1975). High intensity fire behavior is possible because of high fuel loadings of grass, litter, and shrubs.

Montane Alien Short Grass. This fuel type also occurs on Mauna Loa from 4,000 ft-5, 000-ft elevation. It occurs in the understory of koa, koa- 'öhi'a, and koa-soapberry stands, and is dominated by meadow ricegrass or kikuyu grass (<2 ft tall). It integrates with Montane Tall Grass in open forests. Grass fuel loadings are lower, tree litter significantly contributes to the litter layer; and greenup periods are probably longer than in Montane Tall Grass. Fire intensities are probably lower than Tall Mauna Loa Grass. The Broomsedge Fire (2000) flanked 50 m across meadowrice grass under koa forest. Fire crept slowly through the grass and upper litter layer but did not penetrate the duff.

Deschampsia Grass. This fuel type occurs above 4,800-ft elevation on Mauna Loa. It is dominated by mountain pili and *Deschampsia,* with an admixture of alien velvet grass and sweet vernal grass between these native bunchgrasses. Grasses are 1-3 ft tall. Open to scattered native shrubs is common in this fuel type. Fire potential is low during rainy seasons because of green-up and paucity of litter. Velvet grass, a minor component of the fuel type, which grows between bunchgrasses, as well as some robust *Deschampsia,* appears to retain dead foliage in rainy seasons. Fire may therefore carry in some areas during short dry periods while fuels are otherwise green. Native shrubs probably contribute to fire intensity but not fire spread over large areas. Fire has not been observed in this fuel type.

Brush. This fuel type occurs primarily above 4,000-ft elevation on Mauna Loa and in some areas in the coastal lowland. Shrubs form closed or nearly closed stands (3-5 ft tall) with perennial grasses forming an understory in all except the densest stands. Above 4,000 ft elevation, shrubs are primarily native 'a'li'i and pükiawe. Lower elevation (<1,500 ft elevation) brush is dominated by alien shrubs, lantana, christmasberry, and koa haole. Fire frequency has been low in this fuel type. Fire behavior may be very intense with high rates of spread. The 1975 Six Tanks Fire on Mauna Loa apparently carried in the crowns of dense stands of shrubs.

Timber Litter. This fuel type occurs in a number of disparate plant communities below 6,500 ft elevation, all dominated by closed forest with a leaf litter ground cover. The most important plant communities include some 'öhi'a forest with or without a tree fern understory, mesic forest, and koa/'a'ali'i in the montane seasonal zone. Fire has not been observed in this fuel type. Fire intensities and rates of spread are expected to be low because fire is carried by leaf litter. Fire probably will not carry under the normal range of relative humidities in HAVO in this fuel type.

Swordfern. The alien swordfern fuel bed consists of dense swards of swordfern under a closed to open 'öhi'a canopy. Few other understory species persist in dense 'öhi'a/sword fern mesic forest. With little subcanopy, wind can penetrate readily into even closed 'oh'ia/swordfern stands. The height of the ferns varies from one to six feet in open forest and is typically three to six feet in closed forest. Dead stipes persist on sword fern and provide enough heat to involve green fronds. In one site, live fuel loads of sword fern were 5.4 tons/acre, and litter was 5 tons/acre. Live fuel moistures were measured at over 300% during the 1992 Napau Fire that occurred during an extended drought. The heat content of swordfern is not known.

Fire carried during extreme drought in open swordfern/grass swards and under open 'öhi'a forest in the 1992 Napau Fire. The fire died out when it backed upslope into closed forest or uluhe stands. A small head fire carried through swordfern under windy conditions through several acres in open forest in the Sandalwood Fire in 1994. In 2002 and 2003, large fires carried through swordfern under closed canopy forest under windy conditions. Fires consumed both green and dead fronds but left a thick litter and duff layer (6-12 inches deep) capable of burning immediately in subsequent fires.

Swordfern appears to be a “go/no go” fuel that carries fire only under very windy conditions when humidities were relatively low for their environment (50-60%), after a drying trend of one to several days. Protracted dry periods were not necessary for fire spread. Although the wind threshold for fire spread was not quantified, when these conditions were reached, fire tended to spread rapidly as wind-driven head fires.

Uluhe. Uluhe is a tropical fern that forms dense mats 2-10 feet thick in some wet and mesic forest areas. Uluhe grows higher when it climbs trees, thereby forming a laddered fuel bed. Uluhe retains copious amounts of dead attached fronds near the ground level, and accumulates a blanket of litter on the ground. In drier or ungulate-disturbed areas, alien grasses and swordfern may be important components of the uluhe fuel type.

Fires have occurred in uluhe during extreme wind, low relative humidities and following extended dry periods when uluhe litter dries beneath its dense canopy of live fronds.

In the absence of wind, a prolonged dry period is required for fuels to cure and support fire spread. Several fires occurred in the community of Volcano in 1985, 1992, and 1998 and on the East Rift in 1992 following extended dry periods. These fires crept in the frond litter on the ground or near the base of the plants and torched up through the laddered uluhe fuels growing between and on trees. Under windy conditions (Luhi Fire 2003, Kupkupu Fire 2002), fires carried in the upper portion of the fuel bed above the wet litter fuels, and dramatic crown fires occurred.

There is a strong reburn potential in uluhe fuels. In the Kupkupu and Luhi Fires, reburning occurred in the unburned tangled mass of uluhe stipes and fronds, mixed with ‘öhi’a leaf litter. The litter and duff layer ranged between 6 inches to two foot, with 4 foot pockets, and reburning occurred one or more times. These fires burned with less than one foot flame lengths, with torching to three feet in fluffy jackpots of uluhe litter. They crept slowly at about one foot per minute with the wind and much slower backing into the wind. Reburning was ignited by heat retained by ‘öhi’a. ‘Öhi’a is a very dense hardwood. Heat was held in ‘öhi’a snags, logs, and cigar ends for up to two months. Reburning occurred after two to three days of dry weather.

Tree Fern. This common wet forest vegetation type is the least fire-prone of all HAVO fuel types. This fuel type receives nearly daily rain, fuels are well- shaded, fuel moistures are high, and herbaceous component is green. Fires may be possible only under extreme drought. Fire flanked over 50 yards into dense tree fern stands in the 2003 Luhi Fire on the East Rift, under record low humidity conditions, before dying out. Fire spread in continuous abundant litter of dead tree fern fronds and ‘öhi’a. Fire intensities of tree fern dominated wet forest may be extreme because of the high loadings of 1000-hour fuels. Fire potential may increase following wildfire, because of the removal of stand structure, that allows greater wind penetration and curing of fine fuels, and unburn litter and duff that have a high reburn potential.

FIRE REGIME ALTERATION

There is disagreement among vegetation ecologists in Hawaii about the evoloutionary and ecological role of fire in Hawaii. Mueller-Domboisn (1981) felt that natural fire was not a significant ecological or evolutionary factor in Hawaii prior to the introduction of alien vegetation (Mueller-Dombois 1981). Fires may have occasionally burned under favorable combinations of lava flows, drought, and fuels. Mueller-Dombois cited the infrequency of lighting and lightning caused fires, the temporal and spatial localization of volcanic ignition sources, and the paucity of fine fuels in native plant communities. The apparently ability of some native plants to recover after fire may be generalized adaptations to disturbance in a volcanic landscape. The natural HAVO fife regime can probably be characterized as fire-independent. In a fire-independent fire regime, fire is an infrequent perturbation from which vegetation eventually recovers rather than a regular or frequent disturbance that becomes a significant ecological or evolutionary factor.

Mueller-Dombois indicated that fire may have been an ecological factor in the montane seasonal environment (Mueller-Dombois 1981). In this environment, native grasses and shrubs form continuous fuel beds. The diversity and abundance of endemic grasses here implies that this life form was at a competitive advantage in this environment, and the dominant bunchgrasses regenerate well after fire. The fire-tolerant bracken fern is common, and native koa has a remarkable capacity to produce root sprouts following fire.

Vogl (1969) outlines several lines of evidence for considering fire to have beene a significant evolutionary and ecological force in Hawaii. He states that lightning is nearly as frequent in Hawaii as many mainland areas, and many fires have been documented to have started by lava flows. He points out that dry conditions prevail in leeward areas and wet, windward areas are prone to drought. . He describes a number of native fine fuels , including native grasses and ferns. Finally, he describes adaptations of native plants to disturbance and fire.

The role of invasive species in fire confounds understanding the natural role of fire in Hawaiian ecosystems. In many cases, fire is carried by invasive plants, particularly grasses. Invasive species often respond favorably after fire and compete with recoverying native plant species. The degree to which this happens varies by ecosystem. The worst case scenario is in the mid elevation seasonal woodlands. Fire is carried by invasive broomsedge, beardgrass, and molasses grass. These species recover rapidly after fire, suppressing native species recovery.

Climate at Hawaii Volcanoes National Park

Hawaii Volcanoes National Park (HAVO) is situated in the sub-tropical climate of the Hawaiian Islands, in between 19 and 22 degrees north latitude. Elevation of the park reaches from sea level up to the top of Mauna Loa at 13,679ft, which helps contribute to great variations within the parks' climate conditions. The climate of the Hawaiian islands and HAVO is affected primarily by the following 4 factors: latitude, ocean setting, and position in the global wind pattern and presence of local mountains. (Blumenstock et al. 1972)

Seasons

There are only 2 main seasons at HAVO distinguished more by general weather patterns than by any drastic differences in weather. The summer season, generally from May through September (5 months), experiences warmer temperatures with the sun being directly above, drier weather and reliable NE winds. The winter season, from October through April (7 months), tends to be cooler, rainier, more wind variation, and the sun is slightly lower in the sky. Length of daylight therefore, also changes little throughout the year with a variation of only 2 hours 34 minutes from winter to summer (Juvik et al. 1998).

Temperature

Temperature at HAVO varies reliably due to elevational gradients, which cause temperature to cool as elevation increases (adiabatic lapse rate 3.6 degrees per 1000ft). Diurnal temperature differences are greater than seasonal differences for the same area. (Blumenstock et al. 1972). Summer and winter temperatures do not vary greatly for one chosen area throughout the year. Coastal temperatures in the summer range from the 80’s to 90’s in the daytime to 70’s at night, and in the winter from 70’s to 80’s and 60’s at night. The 4000 ft. Volcano area temperatures ranges in the summer from 70’s to 80’s in the day to the 50’s at night, and in the winter from the 60’s to 70’s during the day to 40’s, 30’s and occasionally freezing at night. At 9000 ft. temperature ranges from 75 to 40 in summer, and 50’s to near freezing or below in winter. The upper slopes within Mauna Loa lie above the thermo-regulating cloud cover, thereby experiencing wide swings in temperature from day to night.

Rainfall

HAVO is greatly affected by orographic rainfall**,** when moisture-laden clouds off the ocean meet the high Hawaiian mountains causing them to cool and release precipitation (Ziegler 2002). One of the greatest variabilities throughout the park is the amount of rainfall different areas receive. Not only are there elevational differences, but also microclimatic variation, and inversional changes. Below the 4,000ft elevation a distinct east-west rainfall gradient is evident. At all 8 rain gauges evaluated, the wettest month of the year is November and the driest month of the year is June.

At HAVO the areas with the most rainfall tend to be in the Volcano area near the 4000-ft zone, with an average rainfall of 105 inches per year. Raingauges within the park between the 3000 ft and 20 ft level have much less variation in precipitation throughout the year. An exception is the Ainhou rain gauge at 3200ft, which receives an average of about 20 inches more rainfall annually, perhaps due to topography influencing micro-climatic conditions. The areas within HAVO which tends to receive the least amount of rain are the high elevation flanks of Mauna Loa, which average 20 inches annually, and the western flanks of the park’s Kau desert area. Drought can occur within all areas of the park, and is most severe when winter rain fail to fall. Localized drought appears to occur more commonly on Mauna Loa, the Kau Desert and the Hilina Pali area more than in other areas. Typical of most tropical areas, annual rainfall is relatively constant, but occasionally very dry and very wet years may occur. (Fig. 1, HAVO Raingauge Monthly Average Precipitation).

Inversion
On many Hawaiian island mountains there is a moisture discontinuity between 4000 and 8000 ft, called the Trade Wind Inversion, which prevails 50-70% of the time. This causes elevations below the inversion to be more humid and cool, and conditions within and above the gradient to be drier and warmer (Blumenstock et al.1972, & Ziegler et al. 2002). The Mauna Loa rainguage, at 6700' and the Keamoku rainguage at 5600' receive over 50 inches less precipitation annually than the Headquarters raingauge at 3900'. This is partly attributed to the inversion found between 5000' and 7000'on Mauna Loa.

Relative Humidities

Higher mountain areas on Mauna Loa tend to have low relative humidity values and can often be below 40%. These lower humidites are characteristic of the zone above the inversion layer. Much of the rest of the park can have relative humidities that are much higher especially when compared to typical RH's in the western U.S. It is not uncommon to have relative humidites in the 60 to 80% range throughout the year. In June, the driest month of the year throughout the park, at 1300 hours, relative humidities are often between 65 to 40 percent, with less than $1/4^{th}$ of days being under 40 percent. At HAVO the trigger point for an observable increase in fire behavior is 50% relative humidity, combined with winds.

Trade Winds

Due to the location of the Hawaiian Islands in the global wind pattern, the island as well as HAVO, are predominately affected by the Trade Wind system. This occurs due to a large high-pressure system semi-permanently positioned northeast of the islands, called the North Pacific High. As winds issue from this system in a clockwise direction, they arrive at the Hawaiian Islands from the Northeast, hence the Trade winds are northeast winds. The North Pacific High is stronger in the summer months, therefore summer winds on the Hawaiian Islands and at HAVO are strong and very consistent from the NE. 80% of summer days experience the trade winds, versus 50 to 80 % of winter days. In the winter trade winds are less predictable, as the North Pacific High shifts its position further to the south and generally weakens. This produces lighter and more variable winds in the winter, however winter is also a time the park can occasionally experience very strong winds. (Ziegler 2002)

At HAVO incoming trade winds are shunted in a variety of directions due to mountains, valleys and open slopes. Wind speeds at HAVO are strongest above the coastal pali (cliffs/ridges) and in coastal grasslands where there are few barriers to the wind flow. Winds are also able to flow freely across extensive lava flows. In theses areas consistent 15 to 20 mph trade winds are common. Eye level winds within rainforest tree canopy are often much less than winds in the unobstructed areas. Diurnal winds are noticeable when trade winds have weakened, causing upslope winds during the day and downslope winds at night.

Thunderstorms

Thunder and lightening storms may occur throughout the Hawaiian islands accompanying Kona storms, localized storms, tropical storms and cold fronts (Ziegler 2002). Thunderstorms can occur both in the summer and winter months yet at a much less frequent rate as their mainland counterparts. These intense storms are usually localized. They often come with intense rainfall. Throughout the islands this type of storm may occur only 5 to 10 times a year.

Cold Front Storms

A variety of different types of storms may occur at HAVO. **Cold front storms** can occur on average 5 times a winter, and are associated with heavy rains, gusty cool winds mainly from the NNW, and cooler temperatures. Snow may be deposited at the top of Mauna Loa during these storms (Ziegler 2002).

Kona Storms

Kona storms also occur mostly in the winter when trade winds subside and winds come from any direction other than the typical NE of the Trade Winds. These Kona winds bring with them moist, southerly winds and rain that is more widespread and prolonged than cold front storms. Rains may last from several hours to over a week and may produce extreme amounts of rain (Ziegler 2002). Without the influence of trade winds, the action of light south winds often create hazy and vogy conditions within areas of the park that usually experience good air quality, such as Volcano.

Hurricanes, Tropical Storms

Other storm systems affecting HAVO, are hurricanes, which occur very rarely, and tropical storms, which are more frequent. Tropical storms will pass sufficiently close to Hawaii almost every year and affect the weather at HAVO at different levels. Hurricanes and tropical storms are not limited to the winter and can occur from July through December (Juvik et al. 1998).

IV. Wildland Fire Management Program Components

A. Wildland Fire Suppression

Safety:

Firefighting is an inherently dangerous occupation and requires the active involvement of all personnel to exercise due caution and participate in safety awareness. Prevention of injury is the overriding consideration during all operations. At no time will the protection of resources be placed before the safety of fire management personnel. The Fire Management Officer at HAVO outlines safety policy in general discussion in the Wildand Fire Operation Guide. This document advocates that all operations be carried out in accordance with safety practices as set by Reference Manuals 18, 58, and 60, the Fireline handbook (NWCG 410-1), and the Incident Response Pocket Guide (NWCG 1077).

HAVO has some very unique safety considerations and hazards associated with fire operations near active and inactive lava flows. A Standard Operating Procedure (SOP) (Appendix C) has been developed to supplement the Wildland Fire Operation Guide that deals specifically with the hazards of lava flows. This SOP is specifically intended to protect firefighter health while working on wildland incidents near active volcanic flows. Lave flows produce toxic gasses and particulate matter and a phenomenon known as VOG (volcanic gas) and LAZE (lava haze). This SOP outlines procedures for airway protection and/or disengagement. Further work and research will be necessary along with monitoring of emissions during the next fire associated with lave flows. The Fire Management staff is developing a briefing package to better inform incoming resources of the hazards associated with lava flows and other hazards unique to HAVO including cracks, lave tubes, and heat related considerations.

Wildland firefighters must meet minimum physical standards for their assigned incident position as defined in the Wildland Qualifications Subsystem Guide (NWCG 410-1). Physical fitness/work capacity testing will be completed to commensurate with line qualifications. In addition, all line personnel on active lave flows will be fit-tested for respirators.

Fire Prevention/Education Activities:

Fire prevention includes all activities designed to reduce the number and severity of human-caused wildfires that occur in the Park. The objective of the program will be to minimize preventable fires and reduce hazard buy a variety of fuels management programs.

Prevention activities for HAVO will consist of prevention signing, prevention messages through interpreters and staff and prevention patrols during periods of very high fire danger. Prevention messages will be tailored for the public and specific to time of year.

An important component of the prevention program is the periodic closure of park roads and visitor fire use during period of prolonged drought and/or extreme burning indexes. Due to the rapidly changing fire conditions within the park, upon approval of this plan, the Superintendent delegates the authority to temporarily close park roads to the Fire Management Officer. When the status of park roads are changed the Fire Management Officer (FMO) will give a written notification to the Superintendent, Pacific Island Dispatch, all Division Chiefs, and the front desk.

Fire prevention and fire status will be discussed at the monthly all Park meeting as needed.

When requested, the Park will participate in fire prevention and safety presentations at local schools so that the general public is aware of the importance of fire prevention.

During periods of Extreme Fire Danger, the general public and park visitors will be informed of conditions through press releases, interpretive media and, if necessary, the posting of signs at park entrances the visitor center, and the campground.

The public will be reminded of the 36 CFR regulations regarding the use of fireworks within the park. Fire personnel will post “Fireworks Prohibited” signs strategically throughout park prior to appropriate holidays. Patrols will be alert to fireworks use.

A concerted effort will be made to make the public aware of fire concerns at the park including fire prevention messages, fire danger indices when they are high or extreme and the presence of on-going fires. Fire management messages will be introduced into interpretive programs where appropriate. The Park Information Officer (PIO) is responsible for all press releases, and for providing the local media with fire prevention concerns during periods of Extreme Fire danger. Media access to fire scenes will be facilitated when it is safe to do so. When interest is warranted, the PIO will be designated as the contact person for all information requests. The PIO works for the Incident Commander on all wildland fire incidents and will not release any information without the IC’s approval.

Annual Fire Training:
Annual training will consist of administering the Work Capacity Test (WCT) and the mandatory annual fire fighter safety refresher training to commensurate with the Wildland and Prescribed Fire Qualifications System Guide (NFES 310-1). Red Cards will be issued annually beginning in June of each year. The FMO will be responsible for:

- Maintaining an updated list of all qualified firefighters within the Pacific Islands, and distribute the list to appropriate personnel.
- Assuring fire physical exams as per standards in RM-18, Fire Management Guidelines.
- Administration of the WCT to fire personnel and militia annually, as per standards in RM-18.
- Updating and submitting fire qualifications and maintain mobilization contacts with the Regional Office or designated Geographic Area Coordination Center.
- The inventory of fire equipment, ordering needed supplies and updating equipment list. Includes both fire cache and personal equipment. The park will maintain a cache to outfit 100 firefighters and provide annual refresher training.
- Reviewing and revising the "Step-Up Plan" as needed.
- Checking the established Regional procedure for utilizing suppression and emergency preparedness accounts.
- Assuring engines are maintained in a state of "readiness" throughout the year.
- Evaluating individual performance of park fire management staff through a formal readiness review and submit findings to the Regional Office.
- Reviewing and revising FMP as needed.

Fire Season

Hawaii has the potential to experience drought conditions throughout the year and has historically had large fires in every month fairly evenly distributed.

Step-up Plan and Emergency Preparedness Operation

It is neither reasonable not prudent to program funds annually for the worst possible fire season. Emergency preparedness plans therefore need to be formulated to deal with years with extreme fire seasons or periods of extreme fire danger within "normal" fire seasons. Step-up plans should incorporate specific measures to be taken to provide adequate resources to meet elevated fire danger. Emergency preparedness funds are available to accomplish approved step-up plan activities when the park is in staffing class 4 or 5. (RM 18, Chapter 7, Page 6)

The step-up plan is designed to direct incremental preparedness actions in response to increasing fire danger. Those actions are delineated by "staffing classes". The step-up plan addresses five staffing classes (1-low, 2-moderate, 3-high, 4-very high, and 5-extreme). Preparedness activities are currently based on the National Fire Danger Rating System (NFDRS) utilizing burning index and energy release component as an indicator and incorporating historical weather data. Fuel models L, T. and G were chosen as they best represent fire danger conditions within HAVO. Dailey observations are taken and archived from the following weather stations with the park. ERC with fuel model G at stations 496006 or 496009 shall be the index utilized in determining daily staffing levels. Elevation of the park reaches from sea level up to the top of Mauna Loa at 13,679ft, which helps contribute to great variations within the parks' climate conditions. Therefore, either of the above station indices may be used for determining staffing classes. Kealakomo may also be used when it meets NWCG standards.

Station Name	**Station ID**	**Elevation**	**Fuel Model**
Keaumo	496006	5560 ft.	L, T, and G
Pali2	496009	2780 ft.	L, T, and G
Kealakomo	496016	600 ft.	L and G

Staffing Class 1 and 2

Fires present a low to moderate level of control difficulty. Fires occurring at these levels are typically controlled with existing initial attack resources. Initial attack resources may consist of a "wet patrol" unit staffed with one type V incident commander. Normal tour of duty will apply.

Staffing Class 3

Fire may present a moderate to difficult level of control difficulty. Fuels are dryer and/or winds is a major factor in control operations. Initial attack resources shall work normal tour of duty including holidays and will consist of a minimum of two fire fighters on wildland fire engine, including one type IV incident commander. Cooperating agencies and aircraft may be ordered upon detection of a wildfire. Red-carded militia may be mobilized to assist in operations.
If high visitation period is determined to pose exceptional human-caused risk of wildland fire or active lava flows pose threats to wildlands, move to staffing class 4.

Staffing Class 4

Fires may present a high level of difficulty to control. Initial attack forces will likely require reinforcements and extended attack may be necessary. Suppression resources may be required to work extended shifts throughout the burning period and their sixth day. Emergency preparedness funds may be accessed in order to staff two wildland fire engines and water tender with two firefighters per apparatus, including one type IV incident commander. Crews will maintain a five-minute get away standard and aircraft and cooperating agencies will be requested upon report of any wildland fire. Move up resources shall be ordered or made available as soon as possible. Aerial reconnaissance may be order if lightning has occurred recently or active lave flows pose a threat to wildlands. If in combination with other risk factors, closures and restrictions may be imposed.

Staffing Class 5

All Staffing Class 4 actions will apply with further action described below.
If FMO or delegated Type III IC are committed off-island, a Type III incident commander will be identified to respond in the event of an extended attack incident. Road closures and restrictions may be imposed including the use of equipment by park staff. FMO will have periodic discussions with cooperating agencies regarding mutual aid and available resources. If cooperating agencies request assistance, Park will maintain initial attack capabilities within the park of one wildland engine staffed with two firefighters including one type IV incident commander or immediately order cover engine.

Other Circumstances Warranting Expenditures of Emergency Funds

The Fire Management Officer may authorize the expenditure of emergency funds for unusual park events that may increase the potential for wildland fire. Examples of such events may be: three-day weekends or other events that pose exceptional human-caused risk of wildfire, surface lave flows within the park, or unusual weather phenomena.

Initial Attack

Suppression actions upon initial response to an incident may range from aggressive suppression to a combination of strategies to achieve confinement. Management actions taken on wildland fires must be cost effective, consider firefighter and public safety, benefits, values to be protected, and consistent with natural and cultural resource objectives. It is agency policy to use the Incident Command System (ICS) to manage all incidents, and to have an operational briefing for all fire personnel on any type of incident. All fires, regardless of size, will have an IC – a single individual responsible to the agency administrator for all incident command level functions and activities. ICs and/or agency administrators have the authority to supercede cultural, natural resource considerations and constraints to provide for the safety of firefighters, other personnel, and the public.

The Incident Commander with the assistance of a Resource Advisor will identify any special ecological areas, cultural and historic sites, and any other natural resource concerns. The IC will make every effort to mitigate negative impacts on these resources without jeopardizing safety. Strategy and tactics will incorporate Minimum Impact Tactics (MIT) (Appendix D) whenever possible.

Extended Attack

When an incident escapes initial attack and extends beyond one operational period a Type III organization will be put in place in accordance with guidelines found in the Interagency Standards for Fire and Fire Aviation Operations (Red Book). A Type III IC will not serve concurrently as a single resource boss. Extended attack action requires a Wildland Fire Situation Analysis (WFSA) to guide the re-evaluation of suppression strategies and appropriate level of Incident Management. The WFSA is a decision process that employs a systematic and reasonable approach to determine the most appropriate management strategy for a particular situation. The Superintendent shall approve the WFSA and any revisions. (Appendix E)

The transfer of authority for suppression actions of a fire is done through the execution of a written limited delegation of authority from the Superintendent to the IC. This procedure facilitates the transition between incident management levels. (Appendix F)

Air Quality and Visibility

The federal 1963 Clean Air Act stipulates that federal land managers have an affirmative responsibility to protect a park's air quality related values (including visibility, plants, animals, soils, water quality, cultural resources, and visitor health) from adverse air pollution impacts. The Park is designated as a federal "Class I" airshed. This places the most stringent constraints on construction and operation of pollution-emitting facilities in the park's vicinity. Air quality would be affected in the short-term during any type of ignition event. Close coordination with Hawaii State Department of Health is essential to a successful fire management program. The FMO will be responsible for any necessary permits and keeping the Health Department informed of all prescribed and wildland fire activity.

Prescribed fire will be conducted only when conditions for smoke dispersal are favorable. This requirement will be written into prescribed fire plans as an element of the prescription. Park visitors will be informed about planned prescribed fires and the possibility of seeing smoke, as well as the objectives of the burn.

Aviation Management

It is the policy of Hawaii Volcanoes National Park to limit the use of aircraft to activities involving life or health-threatening emergencies, the administration and/or protection of resources, research, and for individually approved special purpose missions. Hawaii Volcanoes National Park aviation activities will be performed in accordance with applicable Federal Aviation Administration regulations, Reference Manual 60 policies, and the Interagency Helicopter Operations Guide (IHOG) to ensure a safe, economical, and efficient program. Deviations from established policy are permitted only where specific waiver procedures are identified. All aviation activities shall be accomplished with minimum impact on park resources and visitors. The responsibility for management of air operations within Hawaii Volcanoes National Park is delegated to the Chief Ranger. The Chief Ranger will perform as or designate a Park Aviation Manager. All aircraft use will be guided by an approved Aviation Management Plan (Appendix G) approved by the Superintendent.

The Aviation Management Plan is designed to help manage the aviation program at Hawaii Volcanoes National Park. This plan addresses NPS use and other government agency aircraft. The Aviation Management Plan and Appendices will be reviewed and updated as needed.

The Aviation Manager will maintain a list of approved helicopter pilots by company and an aircraft rental agreement source list as approved by the Aviation Management Directorate (AMD) formerly known as the Office of Aircraft Service (OAS).

B. Wildland Fire Use

A naturally ignited wildland fire may be managed to accomplish resource management goals. Those FMUs (FMU-1(alpine), 2(subalpine), 6(coastal lowland))where wildland fire use may be appropriate are discussed in the FMU descriptions. In the event a natural ignition is considered a candidate for wildland fire use, there are several aspects of the wildland fire use program which must be addressed and are discussed in section IV of this document and in detail in Reference Manual 18, chapter 9. In all cases, a Wildland Fire Implementation Plan (WFIP) will be completed. (Appendix H)

Wildfires occurring in those FMU's identified as appropriate will be assessed on a case-by-case basis to determine the management response and implementation procedures. No human caused ignitions will be managed for resource benefit. Affected air quality districts will need to be notified if a fire is being managed for fire use and a smoke management plan prepared and sent to the air quality district.

The Superintendent must assign a qualified Fire Use Manager (FUMA) for each wildland fire for resource benefit. For fires going into Stage II or beyond, consideration will be given to ordering a Fire Use Team. When a Team is ordered priority will be given to assigning Park personnel in trainee positions, especially Fire Use Managers.

C. Prescribed Fire

Prescribed fires are classified as those ignited by managers to accomplish resource management objectives. In general, prescribed fire may be used for three main objectives; 1) wildland fire hazard reduction, 2) reintroduction of fire as an ecological process, and 3) other resource benefits. Prescribed fires are intentionally ignited under predetermined environmental parameters to accomplish various resource management objectives. All prescription parameters, actions, and measurable objectives are stated in a project burn plan, approved by the Superintendent prior to ignition. Prescribed fire may be used in support of ecosystem management to maintain and/or restore plant communities, cycle nutrients, reduce or remove exotic plants, and for a variety of other resource management objectives.

Burn plans will be completed using the standard format found in Reference Manual 18, chapter 10. In addition, all burn bosses will maintain a burn project folder that will contain the following documentation:

- Approved Burn Plan
- Go, no-go checklist
- Approved smoke management plan
- All maps
- Weather forecasts
- Notification check lists
- Press releases
- Fire occurrence (DI-1202)
- Post fire analysis
- Incident action plan

D. Non-Fire Fuel Applications

Non-fire applications, including mechanical treatments, hand treatments, and chemical applications can be used to meet hazardous fuel treatments or restoration goals Although costs can be considerably more, it is generally more successful and greater control of risk factors can be achieved. These treatments must be NEPA compliant.

E. Emergency Rehabilitation and Restoration

Emergency rehabilitation is an extension of emergency actions directly related to managing an unplanned wildland fire. It is not designed to fund all future actions related to the effects of a fire, including long term monitoring, research of fire effects on sensitive species and ecosystems, or long term actions to control or eradicate invasive non-native species. Rather, it should be viewed as short-term funding authority available to mitigate immediate threats until the park can secure additional funding to address long-term needs.

Emergency rehabilitation plans and funding requests must be submitted to regional offices within five calendar days following control of a wildfire. Plans should follow the standard format as outlined in the draft DOI Burned Area Emergency Rehabilitation Handbook, and will identify the cost of initial damage assessments and mitigation actions, and estimate the scope of follow-up phases of work expected to result from initial assessments.

The Park will continue to utilize the least intrusive and least resource damaging methods to manage wildland fire, and the least intrusive emergency rehabilitation actions required to mitigate actual or potential damage caused by wildland fire. It is generally inappropriate to undertake emergency rehabilitation or expend funds on wildland fires managed for resource benefits or prescribed fires.

V: Organizational and Budget

Description of Organization and Responsibilities

The current Fire Management organization includes six permanent-full-time employees. Two permanent full time employees, the Fire Management Officer and Fire Management Program Assistant work under the direction of the Superintendent. The Fire Ecologist works under the direction of the Chief of Resource Management. These employees receive all of their funding through FirePro and are expected to spend a minimum of 80% of their time working on fire related projects. The Fire Management organization is currently being evaluated to consider protection needs for the newly acquired Kahuku Ranch.

Park Superintendent: The Park Superintendent is responsible to the Regional Director for the safe and efficient implementation of fire management activities within their unit, including cooperative activities with other agencies or landowners in accordance with delegations of authorities. The Park

Superintendent or principle acting will meet the required elements outlined in the Management Performance Requirements for Fire Operations, including:

- Takes necessary and prudent actions to ensure firefighter and public safety
- Ensures use of fire funds is in compliance with Department and Agency policies
- Ensures an approved burn plan is followed for each prescribed fire project, including follow-up monitoring and documentation to ensure management objectives are met.
- Ensures that a Wildland Fire Situation Analysis (WFSA) is completed and approved on all fires that escape initial attack.
- Provides incident management objectives, written delegations of authority, and Agency Administrator briefings to Incident Management Teams.
- Reviews Prescribed Fire Plans and recommends or approves the plans depending upon the delegated authority. Ensures that the Prescribed Fire Plan has been reviewed and recommended by a qualified technical reviewer who was not involved in the plan preparation.

Fire Management Officer: The Fire Management Officer is responsible and accountable for providing leadership for fire and fire aviation management programs at the local level. The FMO determines program requirements to implement land use decisions through the Fire Management Plan to meet land management objectives. The FMO negotiates interagency agreements and represents the Agency Administrator on local interagency fire and fire aviation groups and:

- Has immediate responsibility for overseeing all aspects of the fire management program.
- Translates science and research into policy and fire management practices.
- Develops short and long-range plans for network parks' wildland fire management programs.
- Establish liaison with cooperating agencies and coordinate and maintain cooperative agreements.
- Prepares and/or revises annually, cooperative agreements concerning wildfire management, prescribed fire, smoke management, and cross-agency fiscal matters.
- Formulates and directs the budget accountability program for preparedness, hazard fuels operations, emergency fire accounts and approves all FirePro expenditures.
- Responds to regional and national office information requests.
- Maintain fire weather/fire records and FirePro data.
- Coordinate Pacific Island fire training and equipment acquisition.
- Maintain Pacific Island crew lists and equipment records.
- Maintain Weather Information Management System (WIMS) and SACS data input.
- Coordinate annual review of this plan. (Appendix I)
- Perform administrative duties, i.e., approving work hours, completing fire reports for command period, maintaining property accountability, providing or obtaining medical treatment and evaluating performance of subordinates.
- Ensure fire reports (DI-1202) are properly prepared and submitted to the Pacific West Regional Office and/or entered into SACS.
- Maintain qualification and training records.

FirePro Funding

FirePro continues to be the funding mechanism for Fire Preparedness, Leadership and Training at the park level. The Fire Management Officer is responsible for the development of an annual operating budget for the fire management program. Budget development occurs in SACS, with the FirePro component of SACS only available during certain times of the year. Fire Program Analysis (FPA) is schedule to be the new interagency economic model in FY-07.

Hazardous Fuels, Wildland-Urban Interface projects and Community Assistance programs, including Rural Fire Assistance, are currently funded based on inputs to the National Fire Program Operations System (NFPORS). The schedule for inputs into NFPORS for project funding does not coincide with the FirePro schedule. The Regional Wildland Fire Specialist provides an annual call letter for inputs. Access to NFPORS is password protected. The FMO, FPMA and Fuels Technician currently have access to the program.

Emergency fire suppression funds will be requested through the Regional Office as needed. A blanket E-11, Emergency Preparedness account is established on the Park at the beginning of each fiscal year. This account can be accessed based on direction in the approved Specific Staffing and Action Guide and Step-up Plan. The FMO and FPMA are responsible for tracking all expenditure associated with this account and will maintain a file that verifies the fire danger condition or specific event that authorized the expenditure of E-11 funds.

VI. Monitoring and Evaluation

This monitoring plan (Appendix J) is intended to address only those communities where prescribe fire (FMU-5, FMU-6)and/or wildland fire use (FMU-1, FMU-2, FMU-6) is used to restore native plant communities and/or reduce hazardous fuels. These projects are largely concentrated in the Seasonal Submontane (FMU-5) and Coastal Lowland (FMU-6) Fire Management Units of the Kilauea Region of Hawaii Volcanoes National Park. These are units where alien grasses and wildfire have heavily impacted native plant communities. The remaining FMU's will not be addressed in this document since these communities will not be treated in the near future. Once park staff has created prescribe fire/fuel reduction/restoration management strategies for these communities, separate monitoring plans will be created.

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