Forest Management Plan
Wao Kele o Puna

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Abbreviations

APO: Annual Plan of Operations

BMP: Best Management Practices

COH: County of Hawai‘i

FIMS: Forest Information Management System

FMP: Forest Management Plan

FMU: Forest Management Unit. The smallest land management area used in forest management; assigned using biological (flora/fauna) and practical (management intensity) factors. A “Forest Management Unit” is also called a “compartment.”

GIS: Geographic Information System. A spatially related database system and cartographic software that provides a visual representation of tabular data and allows analysis of cartographic information. Used extensively in natural resources management.

HCVF or HC: High Conservation Value Forest Management Class

IE: Invaded, Extensive Forest Management Class

IL: Invaded, Limited Forest Management Class

KHC: Kīpuka High Conservation Forest Management Class

QZ: Quarantine Forest Management Class

IPM: Integrated Pest Management

LV: Lava Forest Management Class

SWCD: Soil and Water Conservation District

TPA: Trees per Acre

T&E: Threatened and Endangered

EXECUTIVE SUMMARY

Wao Kele o Puna has significant environmental value as some of the last intact native Hawaiian lowland forest on Hawai‘i Island. The forest also has significant cultural value as a place where Tūtū Pele resides, and an important location to gather plants used in cultural practices. At the same time, however, Wao Kele o Puna faces a significant invasion of alien species and disease, which left unmanaged, will continue to accelerate the loss of this native forest ecosystem.

This forest management plan is a guide to Office of Hawaiian Affairs to be effective stewards of Wao Kele o Puna to perpetuate its ecosystem and cultural values and achieve the following goals:

1. Protect and assist the recovery in areas with higher concentrations of native plants.
2. Reduce the spread of alien invasive species within Wao Kele o Puna from areas with existing high coverage of invasive species.
3. Minimize further introduction of alien invasive species into the forest from elsewhere.
4. Improve access within the forest to better manage its resources and provide opportunities for surrounding communities to exercise their traditional practices

To characterize the existing forest, the forestry team performed field surveys of the area and put the data into GIS using categories of Forest Management Classes based on type of forest coverage. This system can produce maps identifying where the different types of forests are located including native species and invasive species. The areas categorized under each Forest Management Class are further divided into discrete Forest Management Units, each of which has its own unique number and associated database with all the forest management data for that location.

The plan identifies the threats and other factors affecting native forest coverage including invasive weeds, Rapid ‘Ōhi‘a Death and lava flows. The plan also notes that because of the lack of roads and the difficult terrain of earth cracks and lava flows, most of the Wao Kele o Puna forest is very difficult to access for forest management work and emergency purposes.

To protect against these threats and assist the recovery of areas with existing high coverage of native plants, this plan recommends:

1. Establish a Forest Information Management System (FIMS) to manage the resources and work at Wao Kele o Puna. This will allow the coordinated use of multiple databases necessary for tracking and characterizing native forest resources, alien invasive species, fire, and other threats affecting native forest coverage, restoration efforts, levels of use, and other parameters useful to manage the forest. The FIMS will incorporate all the forest resource data already in the GIS database used to characterize the forest.
2. Improve access to WKOP for effective forest stewardship and emergency response by

developing a simple network of service roads and trails. These roads & trails would follow certain guidelines for the route selection, design and construction to minimize negative impact on the native forest.

3. Control the spread of invasive species through phytosanitary protocols that would be required by anyone before entering or upon leaving the forest to prevent spread of invasive species. Because increased access means an increased risk to introduce alien invasive species.
4. Manage and allocate natural resource use by requiring some cultural protocol of everyone entering or leaving the forest, and requiring all users to participate in an administrative arrangement with the landowner such as a kapu system, permit system, kuleana, cooperative agreements or other stewardship arrangements with users and stakeholder groups.

Section 1 describes the forest resource management challenges, goals and objectives for Wao Kele o Puna. Section 2 describes the steps to establish a Forest Management Framework. Section 3 describes the threats and other factors affecting native forest coverage. Section 4 describes the recommended road access improvements. Section 5 describes the phytosanitary protocol recommended to control the spread of invasive species. Section 6 describes various possible administrative arrangements between the WKOP user and OHA, and also includes recommendations regarding the development and use of a cultural protocol by all WKOP users. Section 7 includes recommendations of specific management goals and implementation strategies for each Forest Management Class. Section 8 includes recommendations for an implementation strategy which identifies priority management activities.

In the development of the WKOP management plan, OHA formed the ʻAha Kūkā, an ad-hoc community advisory group of nine people from the various stakeholder groups including neighbors, cultural practitioners, environmental advocates, and others. The group meets every three weeks and discusses “hot topics” relevant to developing the management plan for WKOP. This consultative process has already been occurring in earlier OHA work on WKOP including the preparation of the ethnohistorical studies. The ʻAha Kūkā acts as a sounding board for OHA and Forest Solutions in the development of this management plan.

1. Resource Management Challenges, Goals, and Objectives

Wao Kele o Puna is the largest intact native lowland forest on the windward side of the Island of Hawai‘i, and has some of the last habitat of its type in the State. In addition to this significant ecosystem value, this forest is also culturally significant as a place where Tūtū Pele resides, and a location to gather plants used in cultural practices. At the same time, however, Wao Kele o Puna faces a significant invasion of alien species and fungus that left unmanaged will result in the loss of this native forest ecosystem. To be effective environmental and cultural stewards of this sacred land of Wao Kele o Puna, the Office of Hawaiian Affairs is faced with two important resource management challenges:

1. The forest is very large, at 25,700 acres, and has invasive species throughout in greater or lesser intensity. Some areas have been completely replaced by non-native species. Rapid ‘Ōhi‘a Death has added to this challenge by killing large numbers of canopy ‘ōhi‘a trees. Left unmanaged, the forest will continue to degrade and be overtaken by non-native species.
2. It is difficult to get around the forest of Wao Kele o Puna. It is bisected by large cracks and faults, and the existing road only extends 1.5 miles of the total 7 mile length and 6 mile width. Limited access has slowed human introduction of alien species. However, lack of roads also hinders effective forest management by making it difficult for forest managers to access areas for field work and emergency response.

The following management goals guide this forest management plan to perpetuate the ecosystem and cultural values of the Wao Kele o Puna forest by addressing the significant resource management challenges within the limitations of a finite budget:

1. Protect and assist the recovery of areas with existing high coverage of native plants.
2. Reduce the spread of alien invasive species within Wao Kele o Puna from areas with existing high coverage of invasive species.
3. Minimize further introduction of alien invasive species into the forest from elsewhere.

To protect Wao Kele o Puna forest against threats and assist the recovery of areas with existing high coverage of native plants, this plan recommends the following objectives:

1. Establish a forest management framework using a Forest Information Management System (FIMS) to manage the resources and work at Wao Kele o Puna. This will allow the coordinated use of multiple databases necessary for tracking and characterizing native forest resources, alien invasive species, fire, and other threats affecting native forest coverage, restoration efforts, levels of use, and other parameters useful to manage the forest. The FIMS will incorporate all the forest resource data already in the GIS database used to characterize the forest.
2. Improve access to WKOP for effective forest stewardship and emergency response by

developing a simple network of narrow service roads. These roads would follow certain guidelines for the route selection, design and construction to minimize negative impact on the native forest.

3. Control the spread of invasive species through phytosanitary protocols that would be required by anyone before entering or upon leaving the forest to prevent spread of invasive species. Because increased access means an increased risk to introduce alien invasive species.
4. Manage and allocate natural resource use by requiring some cultural protocol of everyone entering or leaving the forest, and requiring all users to participate in an administrative arrangement with the landowner such as a kapu system, permit system, kuleana, cooperative agreements or other stewardship arrangements with users and stakeholder groups.

The next section describes the forest management framework for Wao Kele o Puna, followed by a section which identifies the threats and other factors affecting native forest coverage. The subsequent sections contain specific recommendations to achieve the management objectives of improved access, invasive species control, and management of natural resource use. The next section includes specific management goals and implementation strategies for each Forest Management Class found at Wao Kele o Puna. The final section includes recommendations for an implementation strategy which identifies priority management activities.

2. Establish a Forest Management Framework for Wao Kele o Puna

A forest management framework is needed to make sense of a forest as diverse as Wao Kele o Puna. First, it is necessary to characterize the forest by Forest Management Class; then subdivide it into Forest Management Units, around which a forest management, budgeting, and communication framework is drawn up. These Forest Management Units are necessarily iterative: as more information becomes available on forest types, the boundaries need to be updated. Similarly, if a management action has modified a portion of a particular Forest Management Unit, it may need to be split to keep control of forest work over time.

To characterize the existing forest, the forestry team did field surveys of the area and put the data into a Geographic Information System (GIS) using a categorical framework of Forest Management Classes based on type of forest coverage. This GIS database system can produce maps identifying where the different types of forests are located. These maps show areas with high coverage of native plants to be protected and restored through direct management measures. The maps also show areas largely covered by invasive plants without the potential for recovery. Based on the unique management needs of that location, the foresters subdivided all the areas under each Forest Management Class into discrete Forest Management Units. Each Forest Management Unit (FMU) has its own unique number and associated database with all the forest management data for that location.

2.1. Forest Management Classes

Defining this mosaic of discrete Forest Management Classes which encompass the entire Wao Kele o Puna forest is essential to provide a simplified framework for management decisions and long term planning. Table 1 summarizes the different Forest Management Classes in WKOP showing its relative size and the percentage of native species cover. The forest classification system is based on the forest types described in the Invasive Species Plan modified with information collected for the Biological Assessment. While the Forest Management Classes are based on scientific data collection, their role is practical. With limited resources and time, only certain forest management actions will be feasible. It makes sense, therefore, to prioritize based on the largest possible impact using the least resources.

The forest is classified in two phases:

1. Broad level division into Forest Management Classes – in this case by forest quality
2. Detailed sub-division of Forest Management Classes into discrete Forest Management Units

Table 1: Native species cover and relative size of Forest Management Classes in Wao Kele o Puna

Forest Management Class	Abbreviation	Native cover	Acres	% forest area
High Conservation Value Forest	HC	75-100%	4,206	16%
Kīpuka High Conservation Forest	KHC	75-100%	153	0.6%
Invaded, Limited	IL	55-75%	5,883	23%
Invaded, Extensive	IE	30-55%	2,235	8.7%
Quarantine Zone	QZ	15-30%	6,881	27%
Kīpuka Quarantine Zone	KQZ	15-30%	57	0.2%
1977 Lava flow	LV	0-10%	2,891	11%
2015-16 Lava flow	LV	0-10%	3,396	13%
Infrastructure	INF	0%	5	0.02%
		Total (rounded)	25,700	

2.2. Forest Management Units

This forest management plan is being prepared at the larger forest level by initial surveys to identify Forest Classes throughout the forest. Figure 1 shows the distribution of Forest Management Classes at Wao Kele o Puna. The different areas of the same Forest Management Class are each labeled as Forest Management Units (FMUs) to help keep track of the specific resources and management measures taken in each FMU. Some of the initial FMUs like HC2 are large in size and will be subdivided later after the forest managers have worked on resource management activities in the field. FMUs are designated according to the expected management intensity. Areas where there is a higher intensity of management activity, such as a high conservation value forest, may result in a smaller area being designated as a FMU. This is mainly for practical purposes including communication (reporting), budgeting, and work flow control. FMUs are semi-static. Management actions completed within an FMU are easily tracked in a spatially related database system (GIS), allowing easy comparisons of activities across space and time in a unified system. As changes become necessary, FMU boundaries can be modified or split into smaller land management areas for practical purposes such as tracking species location, monitoring data from surveys, managing budgets, as well as tracking management activities. The overarching goal is to provide a data and spatial matrix in which management actions take place over time.

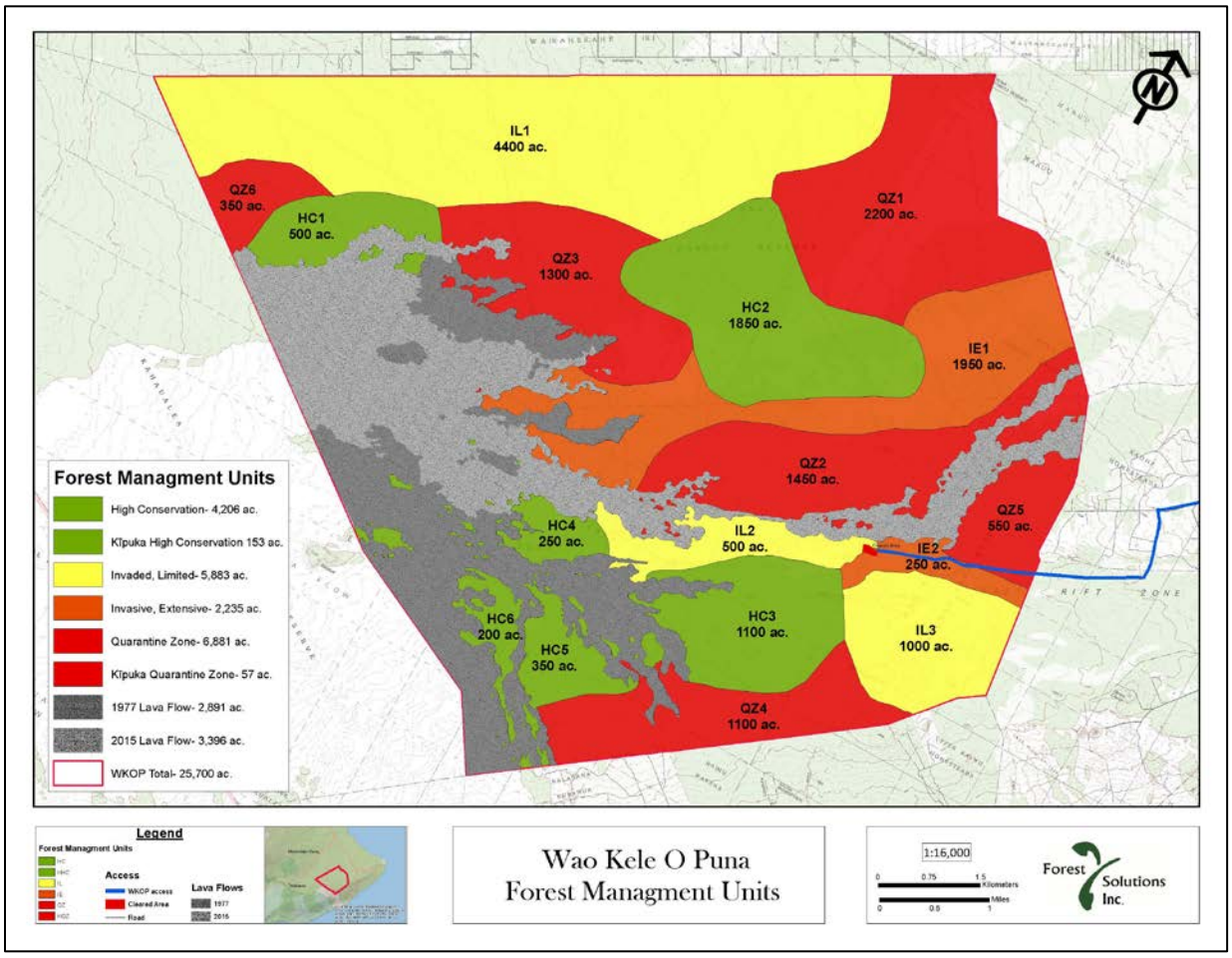

Figure 1: Wao Kele o Puna Forest Management Classes subdivided into Forest Management Units. A Forest Management Class represents a certain type of forest that is managed in a similar way across the ownership. The classes designated for WKOP are: HC- high conservation value forest; IL- invaded, limited; IE – invaded, extensive; QZ –quarantine; and recent lava flow. Forest Management Units are smaller subdivisions of one Forest Management Class.

2.3. Data management

The main benefit of using discrete Forest Management Units is the ability to keep track of activities that have occurred in the forest through georeferenced database. This "unified stand register" is made up of an initial Forest Management Unit (FMU) spatially related database using individual identification codes for each forest stand called "Unique IDentification numbers" or UIDs. Each FMU has its own UID, which is the central link between forest management databases and is separate from conventional naming procedures for specific forest areas. This initial FMU database is provided in the accompanying electronic submission[1].

This initial FMU database will be used to build a Forest Information Management System (FIMS), which

[1] This database is the attribute table for the FMU geodatabase, which forms part of the GIS repository that accompanies the Comprehensive Management Plan for WKOP.

allows managers to track a wide variety of spatially relevant information including:

- Resource data including baseline soils, flora, and fauna
- Forest type (i.e. high conservation, invaded limited, invaded extensive)
- Special management areas (SMA), such as cracks, pu‘us, rare plant communities)
- Management Activities including weed management and native plant restoration
- Budget & expenditures by stand or groups of stands
- Staff time by area
- Spatially oriented access agreements & permits – i.e. which group has the kuleana for a particular stand
- Research agreements
- Infrastructure maintenance, distances on road segments
- Climate information
- Neighbors & neighboring land use

A geo-referenced integrated database allows a forest manager to link weed control efforts, which are kept in a weed control database, with volunteer days, which are kept in a community engagement database. These activities might all occur in a particular forest management unit. A report created from such information would describe the weed control work and volunteer days spent within that particular forest management unit.

The UIDs are an artifact of spatially related databases and not of everyday forest management. They are a practical way to bridge disparate conventional names with the need for a consistent identifier to track work done within each forest stand. Figure 2 shows a basic Graphic User Interface for a generic Forest Information Management System used for large forest estate management. This basic FIMS framework would be customized for use at Wao Kele o Puna, where icons represent categories of information available for each FMU.

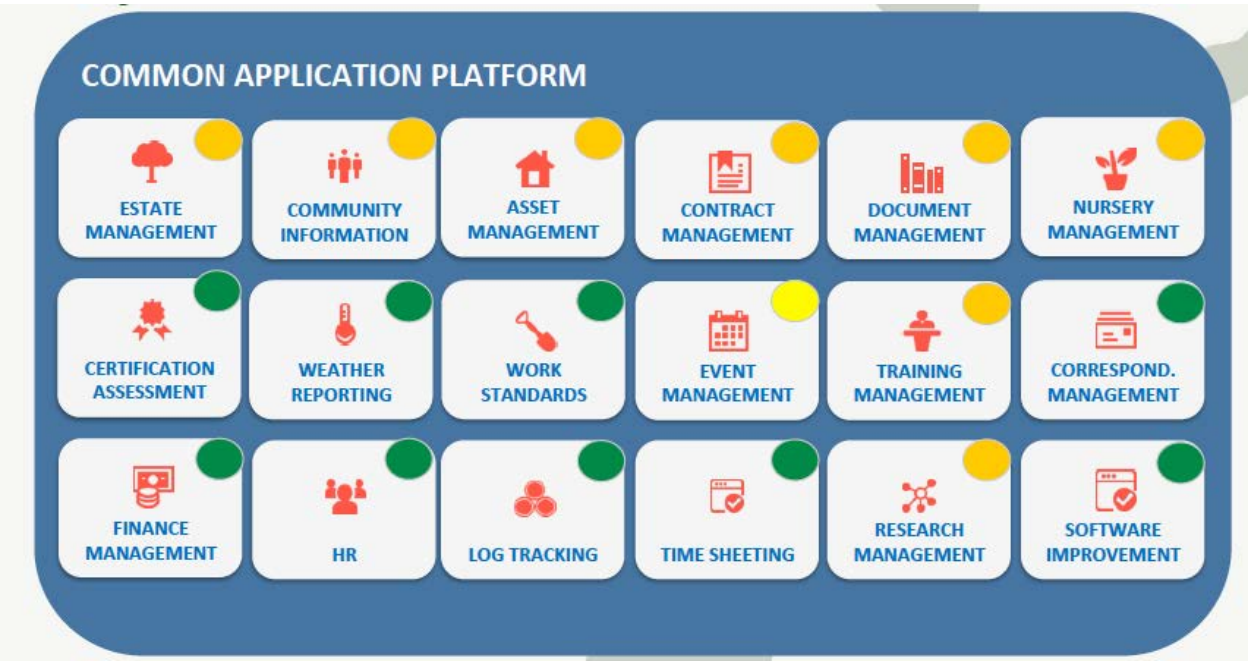

Figure 2: Basic Graphic User Interface for a generic Forest Information Management System (FIMS) showing categories of information available by Forest Management Unit (FMU) using its own Unique Identification number (UID).

3. Factors Affecting Native Forest Coverage

3.1. Weeds

Invasive species found in Wao Kele o Puna (WKOP) are among the most aggressive found in Hawai'i, including overstory species, albizia and strawberry guava, and understory species, clidemia, glory bush, and cane tibouchina (See Table 2).

While about 40% of WKOP consists of areas with high concentrations of native plants, nearly 60% of the WKOP forest has been colonized by invasive weeds. Areas with higher densities of invasive species are prevalent near the access road and makai portions of the forest, becoming less so in mauka areas near the Kahauale'a Natural Area Reserve. Lava areas are mostly devoid of vegetation, which makes them free of weeds by default. In the area below the geothermal papa, the extent of invasion has almost replaced the native forest in its entirety (See Quarantine Zone 4 (QZ4) in Figure 1), with only 18% combined native species cover remaining. There are, however, smaller areas where the extent of native plant cover is high and assisted recovery is possible and feasible. This management plan addresses the entire WKOP forest to protect and restore these "high quality" areas, prevent the spread of invasive species from areas with high concentration of these invasive species, and minimize the introduction of invasive species coming from outside the forest.

Table 2. Invasive species observed at WKOP during aerial and ground surveys, excerpt from the Invasive Species Management plan (2015)

Species		Threat Indicators			
Latin name	Common name	HPWRA	Risk Level	Seed (annual)	Shade Tolerant
Aleurites moluccana	kukui	12	High	1,000	Yes
Andropogon virginicus	broomsedge	20	High	500	No
Asclepias physocarpa	milkweed	8	Mod	2,000	No
Cecropia peltata	trumpet tree	9	High	2,500	No
Clidemia hirta	clidemia	ND	High	2,500	Yes
Falcataria moluccana	albizia	8	High	1,000	No
Melinis minutiflora	molasses grass	18	High	500	No
Musa acuminata	cavendish banana	-11	Low	---	No
Nephrolepis biserrata	fishtail fern	13	High	---	Yes
Phaius tankervilleae	swamp orchid	5	Low	100	Yes
Pluchea carolinensis	sourbush, cure-for-all	16	High	1,000	No
Psidium cattleianum	strawberry guava	18	High	3,000	Yes
Rubus niveus	Ceylon raspberry	19	High	500	Yes
Spathodea campanulata	African tulip tree	14	High	2,500	Yes
Tibouchina herbacea	cane tibouchina	24	High	2,500	No
Tibouchina urvilleana	glory bush	10	High	5,000	Yes

3.2. Rapid ʻŌhiʻa Death

The chronic threat from aggressive weeds has been joined in the last 5 years by a new threat to the forest, a fungal wilt *Ceratocystis fimbriata* that is commonly referred to as Rapid ʻŌhiʻa Death (ROD). As the name suggests, this disease quickly kills ʻōhiʻa trees by restricting water and nutrient flow through the bole (stem or trunk of a tree). The upper portion of the tree, devoid of water, dries up and perishes within weeks, providing its eponymous name.

Rapid ʻŌhiʻa Death was first detected in lower Puna, near the Leilani Estates subdivision in 2014. It has since spread to most of Hawaiʻi Island except Kohala. As of November 2016, it has been detected on approximately 50,000 acres[2] on the island (see Figure 3) .

[2] Press release for IUCN meeting, Honolulu 2016. Obtained from Rapid ʻŌhiʻa Death web page: http://www2.ctahr.hawaii.edu/forestry/disease/ohia_wilt.html | visited September 20, 2016.

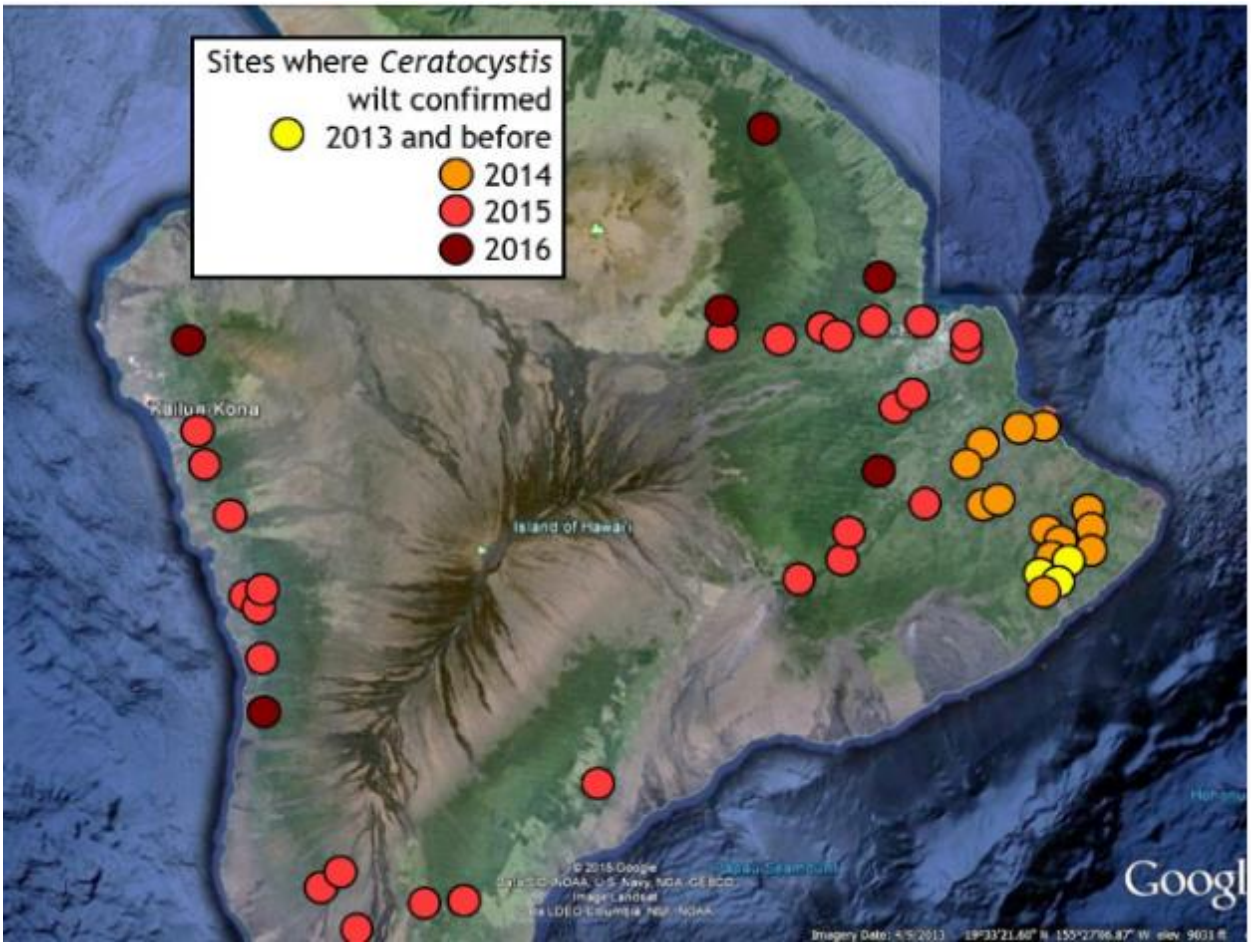

Figure 3. Confirmed ROD infected trees across Hawaii Island. Wao Kele o Puna has thousands of infected trees and is close to where the disease was first detected in the Leilani Estates subdivision. Source: University of Hawaii College of Tropical Agriculture and Human Resources.

It is likely that the entire WKOP forest is already infected with ROD to some degree. However, mortality related to ROD is limited to about 40% of the area (See Figure 3) as of the summer of 2015. The front line of the disease is moving quickly. Based on the speed of spread thus far and lack of physical or ecological barriers, it is sure to encompass the entirety of the forest within the next 10 years and likely to do so within the next 5 years. This means that the future of ʻōhiʻa in WKOP is uncertain at best. It also means that alternatives are needed to manage the forest in the face of potentially losing the most important canopy species. There are areas which potentially may never be infected by ROD. Identifying and protecting these areas will be very important to slow the spread of this disease.

As ʻōhiʻa stands decline, there will be an immediate replacement by weed species that are already in the sub-canopy, mostly strawberry guava, glory bush and in some areas, albizia. In areas that have significant hāpuʻu or uluhe understory, this species replacement will be delayed and may even be forestalled by taking specific management actions to limit the spread of invasive species in this sub-canopy. If these management measures are not taken, strawberry

guava will eventually emerge in hapu‘u or uluhe stands. This inevitability makes the future viability of a native forest in WKOP entirely dependent on the purposeful action of OHA and the community. Left alone, this forest will not improve with time; rather it will continue to lose native species and degenerate into a sizeable weed patch. Specific management measures recommended for each Forest Management Class are included in Section 7.

At the scale and intensity of this invasion, and provided that the causal agent is a fungus (*Ceratocystis fimbriata*), there is little to do at the forest level aside from the following:

1) Avoid the introduction of more pathogens, including more strains of the same disease; and

2) Prevent the spread from WKOP to other native forests in Hawai‘i;

This can only be accomplished with a strict phytosanitary approach that is both effective and practical, combined with a careful regimen of care and caution when entering WKOP. We recommend the inclusion of personal and vehicular sanitation procedures. This is discussed below in Section 5.

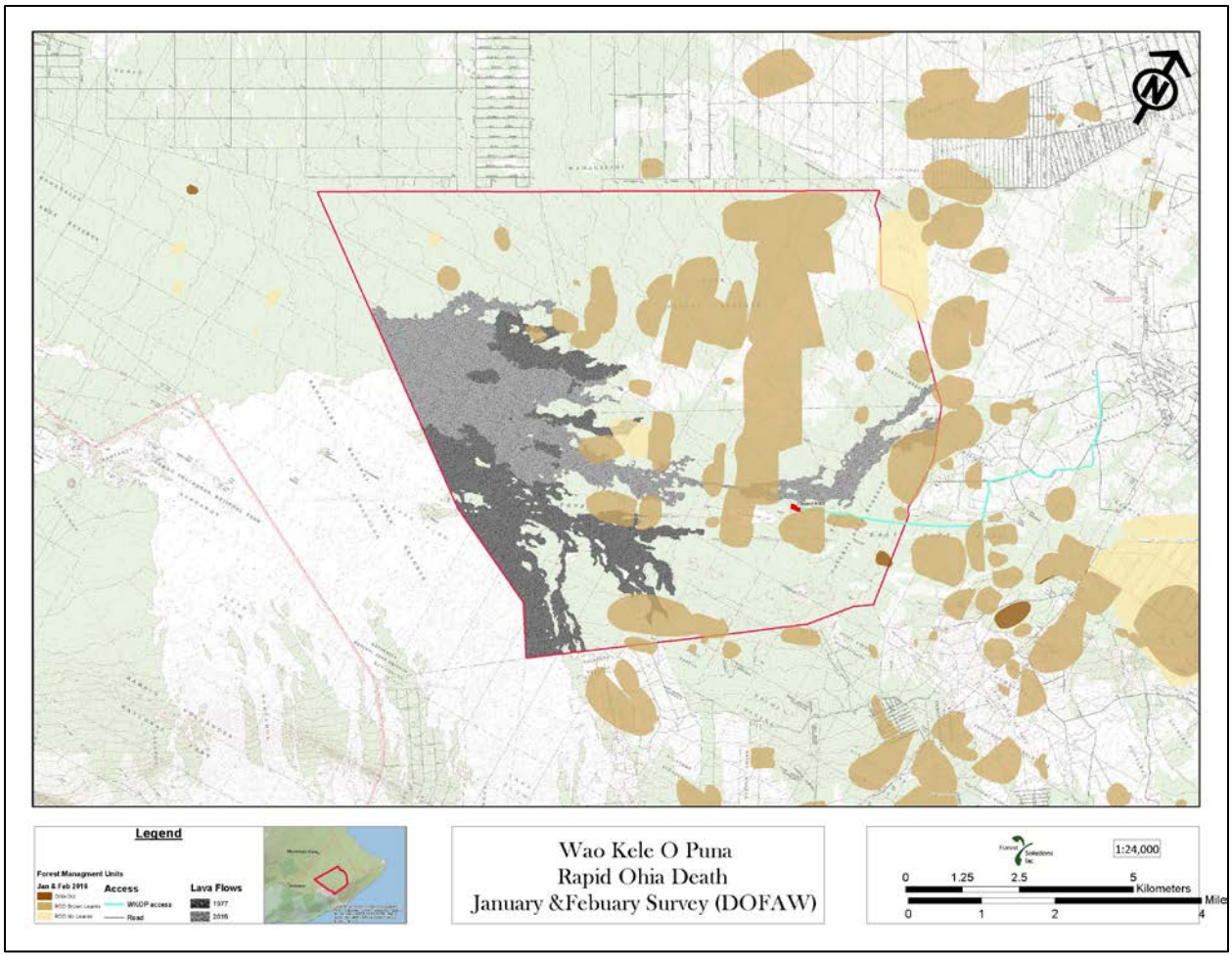

Figure 4: Rapid‘Ōhi‘a Death will have important consequences for forest management in Wao Kele o Puna in the coming decade as this species declines and is replaced within the forest.

3.3. Lava flows

Through lava flows and eruptions, Tūtū Pele can reshape the forest by physically covering a forest area, as well as igniting fires affecting forested areas adjacent to flows. Lava flows are also a regenerative force by building new land and restarting the plant colonization process for that area. The lava flow of 2014-16 that quickly traversed the forest and neared the village of Pāhoa is a salutary reminder of the high potential impacts of volcanic activity on the landscape this close to the home of Tūtū Pele. While the active flow has now shifted back toward the Royal Gardens Subdivision (roughly southeast), this can change at any time, as Wao Kele o Puna is situated makai of Puʻu ʻŌʻō vent. Steam is continuously emitted in various parts of the forest and young flows may occur frequently along the rift zone.

Figure 5. The land of Wao Kele o Puna is constantly being re-born, as successive lava flows cover the forest and the forest regenerates upon the new flow. This is one of several puʻu that have intact vegetation as a result of its relative elevation. Note the regenerating forest of ʻōhiʻa in the surrounding aʻa flow.

The eastern rift zone traverses the forest in an east-west direction, just south of the main access road. Portions of this rift zone have sporadically emitted molten rock and more frequently moved and/or emitted large amounts of steam and gasses. The puʻu located on the rift zone are evidence of past volcanic activity that is likely to re-occur.

Volcanic activity in the forest is not just a singular event, but is an ongoing yet sporadic condition that has and will continue to shape this land for the foreseeable future with profound implications to forest management. In recommending actions within the forest, it is with full awareness of what Tūtū Pele can bring and the ephemeral nature of any improvements that are installed in WKOP.

3.4. Limited access hinders effective forest stewardship

As discussed in other portions of this plan, access to and within Wao Kele o Puna is limited. So far, this general inaccessibility has kept the land forested and green (though not pristine or weed-free), limited the spread of weeds, and hindered potential land clearing on adjoining parcels. This inaccessibility, however, is today the largest hindrance to effective forest stewardship. The lack of access makes management tasks very expensive (by requiring air support) and increases the danger of any forest use by impeding quick and effective response to an emergency. Improving access to certain areas is crucial to conduct more active forest management.

4. Improve Access for Forest Stewardship Purposes

Legal access into Wao Kele o Puna (WKOP) is limited to a single 1.5-mile road that ends about 1/3 of the way into the forest at a 5-acre papa (a clearing previously used for geothermal development). This forest road is in good condition, having been designed for heavy trucks and regularly maintained by OHA and DLNR since OHA's purchase of the property. On either side of it, however, the forest is bisected by faults and cracks of various magnitudes (see Figure 4), as it is aligned with and built upon the East Rift Zone of Kīlauea. Vegetation obscures these cracks and faults from view, making foot travel from the road into the forest on either side very hazardous.

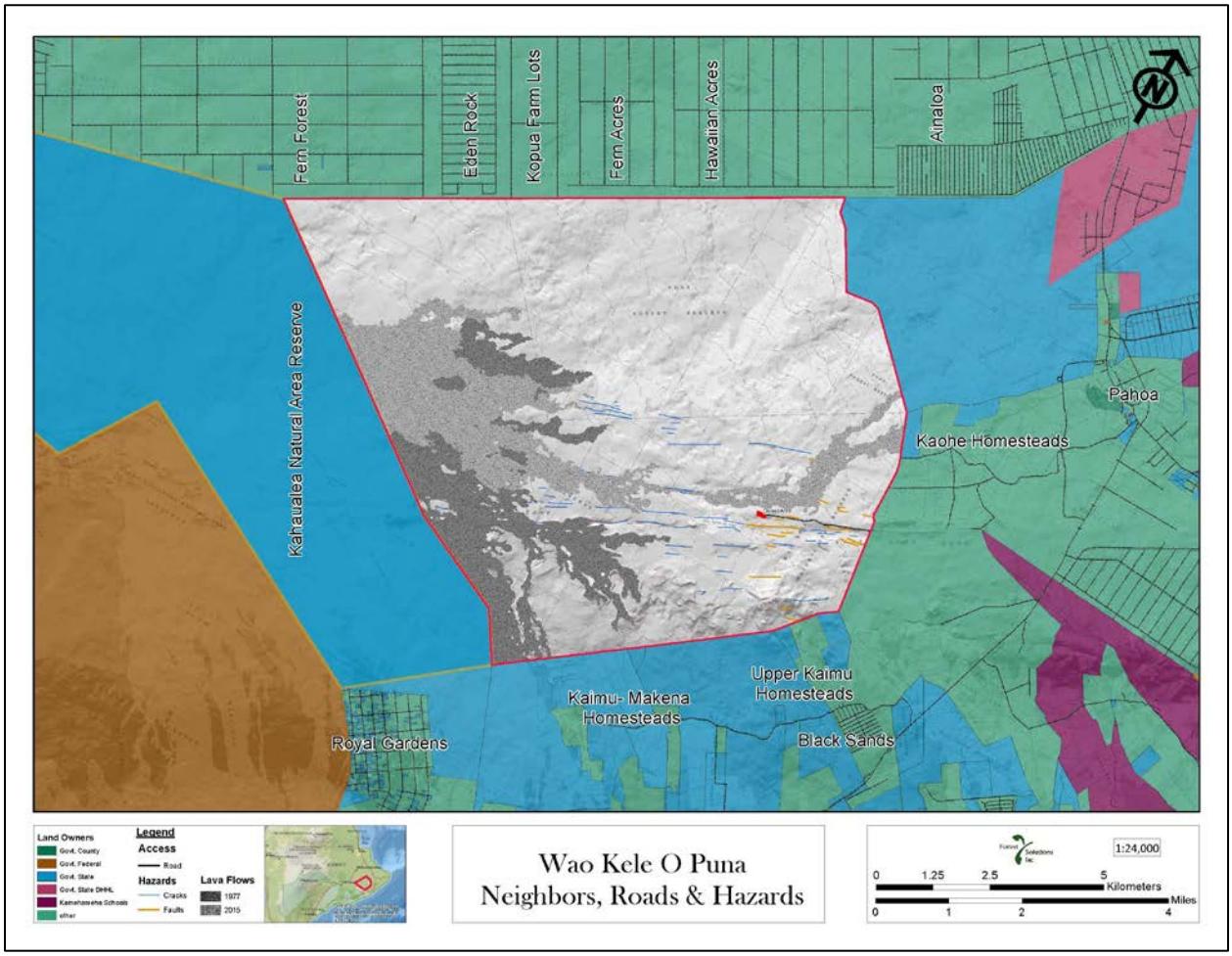

Figure 6. The only access to WKOP is a short, though well maintained road that is flanked by large cracks in the lava substrate.

The road itself is subject to occasional, usually small, collapses of the wearing surface due to movements in the cracks that lay beneath it. As expected, these cracks in the road may open up at any moment depending on the geological conditions of Kīlauea. Naturally, this adds another complication to emergency access, which could, therefore, be compromised in a large

earthquake or similar geologic event.

The rest of the forest is only accessible on foot, or via helicopter with prior permission from OHA for landing within the forest. There are, however, a number of roads and house lots in the area surrounding WKOP that touch the WKOP boundary (See Figure 4). These roads are private and there are no existing agreements for their use by OHA or the public as access ways into WKOP[3].

Figure 7. The existing 1.5 mile road is subject to cracks opening on the wear surface such as this one that appeared in 2015 just off the center. The crack is at least 30 feet deep (shoes added for scale). These cracks obviously limit access to the forest, and are a source of additional concern for evacuations during an emergency as they are unpredictable.

Once inside WKOP, traversing the forest is difficult and sometimes impossible due to a combination of thick vegetation (weeds and uluhe) and frequent ground cracks and holes (tree molds). The difficulty of moving around within the forest is exacerbated by the large distances that must be traversed within WKOP for effective management.

Travel time estimates for accessing different areas in WKOP can be determined using the average rate of travel that was achieved during the course of fieldwork for this plan. During fieldwork, the crew travelled about a mile per day. At this pace, a hike/bushwhack/crawl from the geothermal pad to the northwest property border, such as Hawaiian Acres subdivision or Eden Roc could take 4 to 6 days, depending on the size of the crew. A larger crew is faster since more people can be rotated into the lead person role of cutting the trail and pushing vegetation. Similarly, the route to the upper boundary of the forest (Kahaualea Natural Area Reserve) is over 5 miles, also representing a 3-5 day walk, somewhat facilitated by more recent lava flows, which in spite of being rough broken ground are at lease free of thick vegetation. At this pace, helicopter access is faster, safer, and more economical than the ground approach.

[3] Traditional and customary practitioners may have access rights to WKOP over private property. See Pele Defense Fund vs. the Estate of James Campbell, Deceased, et al., Civil No. 89-089 (Hilo), Declaratory Judgment/Injunction (enjoining Campbell Estate and its successors in interest to WKOP from excluding Hawaiian subsistence or cultural practitioners from entering developed portions of its property for reasonable access to the undeveloped portions).

4.1. The case for roads in Wao Kele o Puna

Managing Wao Kele o Puna effectively will require improved access. Simply put, the landowner is faced with the option of either spending money to develop a simple system of roads and trails, or spending money for helicopter access.

While an improved road system in WKOP will improve access for forest management purposes, it also can increase the risk of introducing invasive species. This plan recommends improving access to the forest through the development of several low-impact narrow roads and trails that connect the various portions of the forest. These roads would be developed using specific guiding principles to minimize any potential negative impacts on environmental and cultural resources. Naturally, the negative effects of the road and trail development will need to be ameliorated and the resultant access path managed to avoid later introduction of weed species. From a strictly ecological and practical perspective, the ability to access the forest and manage/restore it is superior to simply leaving the forest to fend for itself or trying to maintain it with air support.

From a social standpoint, one of the recurring themes of public and stakeholder comments is the need for community access to the forest. The current short road certainly provides access to *that* portion of the forest, yet falls far short of providing *meaningful* access to the rest of the forest. Having additional infrastructure improves community access to the rest of the forest, enhancing its social value to the people of Puna. This is particularly the case for kupuna, who are a fount of knowledge on traditional and customary practices, yet face difficulty moving around especially in a thick forest. What better solution than infrastructure to allow these and others with limited means of mobility the ability to visit Wao Kele o Puna. This is *meaningful access*.

4.2. Guiding Principles for Developing Roads and Trails

Roads are a necessity for the efficient and safe movement of resources and people within the forest. In order for forest management efforts to have a meaningful impact on weeds and other forest threats, road access will be needed. Similarly, considering the need to accommodate customary uses of the forest, roads and trails will allow people with different physical abilities to equally enjoy the forest, opening it for a broader group of practitioners, beneficiaries, and hunters. WKOP is an important place to participate in traditional Hawaiian cultural activities. Improved access would make this cultural experience available to more people.

Roads are not a panacea, however. The same access that facilitates management also facilitates introduction of diseases and weeds. Roads have traditionally been sources of new weed infestations in WKOP and other areas throughout Hawai‘i. Illegal dumping occurs in areas where access has been created into WKOP. Illegal commercial activities have also occurred in WKOP including a tour operation that entered WKOP from a neighboring property using ATVs

to approach the lava flow. Hunting is not currently a source of trouble, but it needs to be conducted in an orderly and fair framework that allows everyone to benefit.

Controlling access to and use of roads is critical to limit illegal dumping and the introduction of new weed or disease agents. To be effective limiting weed introductions, a multipronged approach to weed control is needed. In particular, the adherence to phytosanitary procedures is a key component to reducing this risk. Where serious weeds have been introduced in the past to native forests, phytosanitary procedures have either not been in place or ignored.

The following are recommended guiding principles for developing roads and trails to improve access into WKOP:

1) Build roads and trails with a reason in mind – why is access sought? Will this new road/trail benefit the forest and those who use it?
2) Keep roads and trails small, unobtrusive, and in conformity with natural features (i.e. not straight, this is not a subdivision).
3) Provide reliable access to High Conservation Value Forest areas of Wao Kele of Puna for forest management and community participation purposes.
4) Stay on lava flows to limit the collateral damage to native stands, particularly ʻōhiʻa.
5) Avoid special management areas – those that are ecologically, culturally or otherwise sensitive, such as High Conservation Value Forests and known archaeological sites.

4.3. Road Development Plan

Two road development options are readily apparent and are covered in the next two sections. The first, called the "independent road option," is to develop an infrastructure network based on the existing access easements within the forest. The second, called the "neighbor road option," assumes that some form of agreement can be crafted with the surrounding communities to provide access to WKOP through the neighboring subdivisions, homesteads, and pastoral leases. A third option is some combination of the two approaches, such as developing the independent road system within WKOP, and then connecting to individual neighbor roads after these connections have been negotiated with neighboring landowners.

4.3.1. Independent road option

This suggested alignment that is shown as solid black lines in Figure 5 provides access to the main portions of the forest via the existing main access road. The final layout of the roads will be based on terrain, topographic features, and other factors that will be discovered by field work, yet the layout proposed here has already taken into account known land features such as cracks and faults, known lava tubes and high conservation forest plant communities.

Road length under this plan is approximately 13.7 miles depending on the final alignment once the pre-building considerations (discussed below) are included.

The benefit of this approach is that it can be implemented somewhat faster as it does not depend on the ongoing consent of neighboring communities. The effect of this approach is that it concentrates the access for the entire forest on a single road. The upside of a single access point is ability to control entry into the WKOP forest. The downside is in the case of an emergency, there would be equally only one exit from the forest via vehicle. Considering the volcanism and hurricanes common to the area, this limitation is a serious consideration.

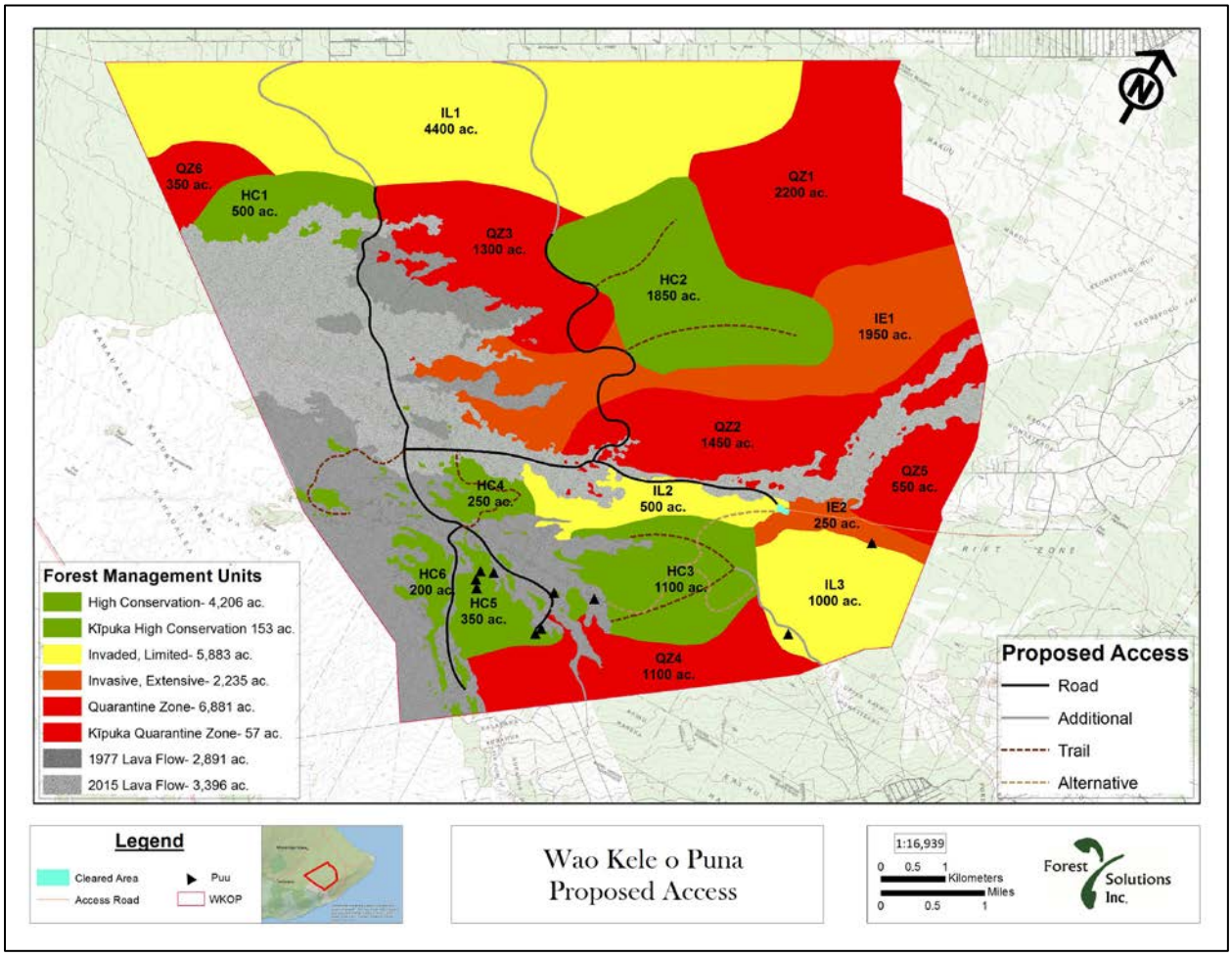

Figure 8. Suggested access layout for WKOP. Grey roads indicate access through neighboring properties, which would need to be negotiated. Layout of road and trails is intended to 1) provide reliable access to High Conservation Value Forest (HCVF)areas of the forest, 2) stay on lava flows as much as possible to reduce collateral damage to native forests and 3) make weed control more efficient.

Table 3. Proposed road access option lengths in miles

Access type	Independent	Neighbor rd
Existing road	1.5	1.5
Road	13.7	19.8
Trail	8.5	

4.3.2. Neighbor road option

The second option is to connect the internal WKOP roads to the neighbor's roads, shown in Figure 8 as several solid grey lines extending from the solid black lines of the internal roads to the borders of the WKOP forest. This "neighbor road option" would require consent and agreements with neighboring communities and likely sharing the cost of maintaining neighbor community roads.

This option adds 6.1 miles of roads to the 13.7 miles proposed as the "Independent Road Option" for a total of 19.8 miles of new road construction in WKOP.

The large benefit to this approach is that it provides several exit points from the forest in case of an emergency, particularly a lava flow or similar volcanic emergency. It also allows for more rational road development plan by capitalizing on other roads in the area. Finally, it also provides a level of access to the forest to the surrounding communities that they do not enjoy today, which will benefit the people of Puna. The downsides of this approach include the increased likelihood of noxious plant and disease introduction as well as the increased potential for illegal dumping and illegal commercial activity.

As more people use the forest, a result of its more open status, there may be an increase in negative impacts to the forest with indiscriminate clearing of native vegetation for trails. In other native forests of Hawai'i this has included painted/chopped blazes on native trees, aluminum cans left behind attached to vegetation among other impacts. Multiple access points also result in several access gates, which must be maintained and managed; all of which increases costs together with community access.

These options need to be vetted by OHA in the context of community involvement. The more use the forest has, the more intrinsic social value it creates, providing support for its ongoing maintenance and improvement.

4.4. Road Classification

4.4.1. Main Roads

Main roads are permanent roads that can carry weighted trucks and sustain frequent all weather use. There is only one such road in WKOP which is the current main access road. No further development of main roads is planned.

4.4.2. Secondary Roads

Secondary roads are permanent roads that can carry trucks with moderate weights and a high frequency of use in all weather. The main planned roads for WKOP are secondary roads. Base material can sustain weight and wear surface is wider to accommodate larger trucks.

4.4.3. Spur Roads

Spur roads can carry lightly loaded pickup trucks. These types of roads will have infrequent use by forest managers and users. Wear surface and base material are limited.

4.5. Road Objectives

There are three main objectives for building roads in WKOP:

1) Provide reliable access to the WKOP including areas designated High Conservation Value Forest.
2) Provide safe and economical transportation to serve the needs of forest management, protection, and use.
3) Minimize introduction of invasive weeds and pests by effective control at all access points, including facilities for all vehicles to carry out the required phytosanitary treatment protocols as they enter and leave WKOP, and restrictions on transport of any ʻōhiʻa.

4.6. Road Development Best Practices

Roads should be designed in locations according to the following:

1) A forester or road engineer should be responsible for the coordinated development of infrastructure including location of roads using GIS and data models such as Digital Elevation Models (DEM).
2) A forester or engineer must approve the road line prior to commencement of construction and after undergoing pre-construction assessment.
3) Roads should be located in areas of low side slopes to minimize side cutting.
4) Roads should be located on elevated areas wherever possible to minimize side cutting,

width of clearing, and drainage problems.

5) Roads should be located so that no earthworks or soil spill falls into sensitive habitats or other Special Management Zones.
6) Roads should be located on well-drained, stable soils with good load bearing capacity.
7) The number of crossings over cracks and faults should be minimized.
8) Cuts and fills should be balanced to minimize transport of road construction material.
9) Existing roads should be used wherever possible.

Figure 9. Road alignment should be follow well-drained, stable soil. In Wao Kele o Puna this means staying on recent, more elevated lava flows. In this road, most of the base material is derived on site with considerable savings.

10) Roads should follow the natural contour of the land.
11) Areas to avoid should be specified in the pre-construction assessment (including designation of areas under special management, such as endangered species habitat).
12) Areas that are steep and unstable should be specified and avoided where possible, faults and cracks should be avoided.
13) Minimize erosion by providing and maintaining good surface and side drainage during and after construction.
14) Reduce collateral damage to native forests by staying on the lava flows as much as possible, with proper honor and respect paid to Tūtū Pele with gratitude to her for building the foundation on which a road network can be built.
15) Minimize disturbance to any Special Management Zones like High Conservation Value Forest, rock walls, cracks, and endangered species habitat.

4.6.1. Typical road cross section

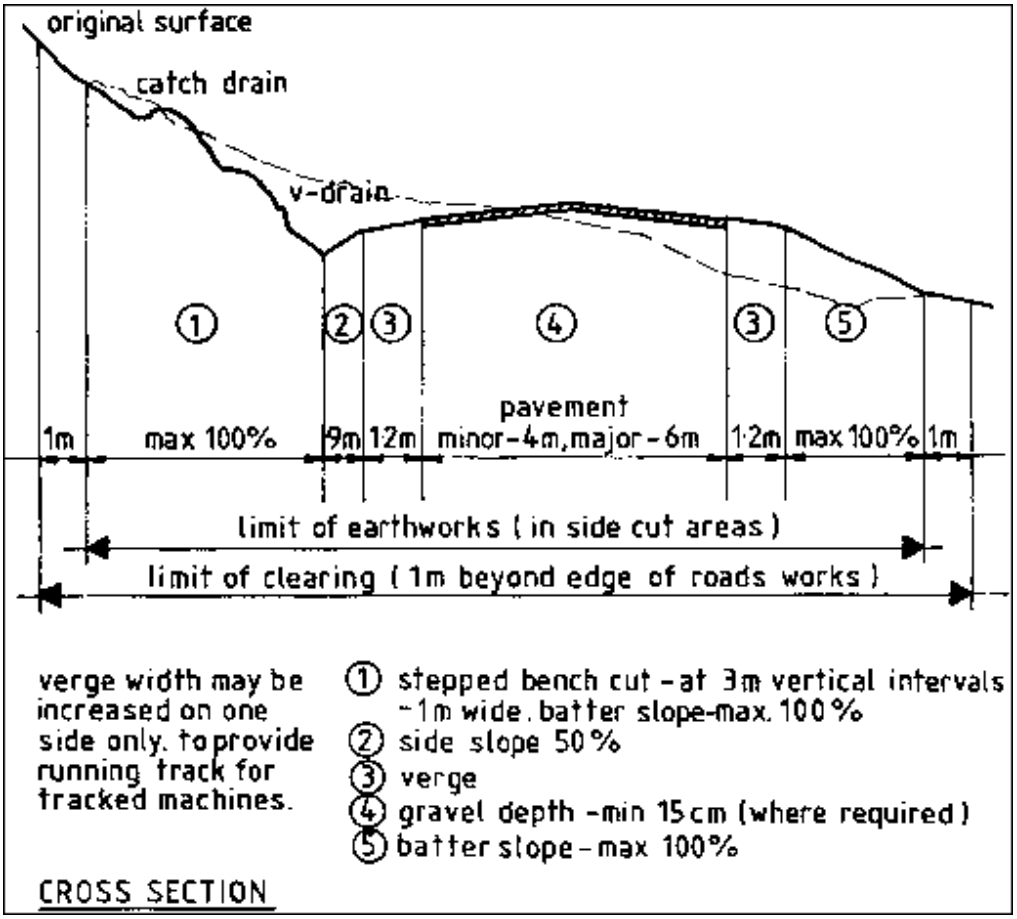

Figure 10. Example of ideal road layout. Wear surfaces and finished width will vary according to road type.

A typical road cross section for WKOP will have:

- Surface crown to deflect the high rainfall
- Gravel wear surface to provide traction in all weather and prevent rutting and erosion
- Side ditches to improve road drainage where appropriate
- Noninvasive shade tolerant grass species to stabilize the road cut after construction

4.7. Pre-construction Assessment

Roads are disruptive to the forest ecosystem and natural structures in the path of construction. It is critical to limit this impact by doing a pre-construction assessment prior to road construction.

The engineering of roads involves specifications in design, layout, construction, maintenance and rehabilitation. These specifications must be planned across the landscape in conjunction with other stages of forest activities. Pre-planning of any road system and construction will result in lower costs and less environmental, archaeological, and social disturbance than without effective planning. All roads must be constructed with accordance to the guidelines set forth in the Forestry Best Management Practices for the State of Hawai'i (DOFAW, 1996[4]).

Contours, digital elevation models (DEM), LIDAR, and other continuous and/or thematic maps should be used in the construction of all roads to avoid areas with sensitive native forest. Additional information such as easements, rights of way, and entry/exit points will also be delineated on maps when relevant. The following guidelines are to be used in road planning and engineering stages to minimize damage to the forest. These guidelines have been adapted from the Code of Practice for Forest Harvesting in Asia-Pacific (FAO, 1999[5]) with specific improvements for application to WKOP.

Figure 11. Mini-excavators, now widely available, are a good choice for trail development if manual options are not viable or not available. They can easily move around sensitive areas and do not cause extensive collateral damage. For Wao Kele o Puna, the use of steel tracks will be necessary due to rocky soils.

[4]Department of Land and Natural Resources Division of Forestry and Wildlife. 1996. Best Management Practices for Maintaining Water Quality in Hawaii. Available: http://dlnr.hawaii.gov/forestry/files/2013/02/Hawaii-BMP.pdf checked 21 Sep 2016.

[5]Food and Agriculture Organization of the United Nations (UN-FAO). 1999. Code of Practice for Forest Harvesting in Asia-Pacific. Available: ftp://ftp.fao.org/docrep/FAO/004/AC142e/ac142e00.pdf checked: 21 Sep 2016

Steps to be taken in any road construction:

1) Road mapping;
2) Drafting road standards of design;
3) Ground truth characterizing the proposed road route, including:
   a) Physical attributes (slope, cracks, etc);
   b) Environmental survey including threatened and endangered plants; and
   c) Archaeological and cultural survey;
4) Re-evaluation and adjustment planning (adjust road in response to survey findings);
5) Marking;
6) Building; and
7) Road rehabilitation and resting.

Table 4. Road and trail building standards appropriate to the expected light use in WKOP

Access type	Intended use	Track width (ft)	Cleared width	Aggregate	Aggregate Depth (in)	Max slope & distance
Main road (existing)	Light and heavy vehicles, no semi	15	20	Yes	10-12	12% < 50 ft
Minor road	Light vehicle only, 4wd, no trailer	8	12	Yes &/or corduroy[6]	6-8	20% < 75 ft
Trail	ATV or foot traffic	4 variable	5 variable	No or corduroy	N/A	40% any

[6] Corduroy road construction refers to the technique of building roads by placing numerous logs parallel to each other and perpendicular to the direction of travel.

Figure 12. Corduroy is widely used in wet locations as a replacement for costly aggregate, where anaerobic conditions prevent wood decay. It also allows the community to participate in building the road or trail. These examples are from Mexico (top left) and Volcano (top right, bottom right). The initial log layout is bound by either soil or sand to provide a smooth wear surface.

5. Establish Entry and Exit Sanitation Protocols

5.1. Cleansing of spirit and body: the entrance protocol

Before entering the forest, a cultural protocol is recommended as is customary in Hawaiian practice to honor and respect the land and spirits of the place. This is discussed below in the following section on managing and allocating resource use in the forest.

As it is important to cleanse one's mind and honor the land, it is equally important to clean one's body of any physical threats to the forest. The presence of invasive weed and pest species in forest areas adjacent to developments is a reminder of the importance of sanitation for the overall health of the forest. Greater access and activity within the forest increases the potential for introducing new weeds, diseases and pests. On the other hand, improved road access also provides the best means to contain existing weeds and eliminate new outbreaks as they occur. With these considerations in mind, sanitation methods to prevent the spread of forest threats will be discussed in this section. These methods were developed based on recommendations from the Hawaii Ant Lab and the DLNR protocol to reduce the spread of ROD.

5.2. Threat index

Not all modes of transportation or access to the forest are equally threatening (Table 4). Overall exposure is determined by the means and the frequency in which the exposure is encountered. We therefore propose a graduated response to the level of threat.

Most access to the forest is via light vehicle. As a result, most of the threat and concomitant effort to ameliorate the threat should be centered on vehicles. This is covered further in the next section.

Table 5 Relative threat of introducing harmful agents to a native forest in Hawai'i

Type	Relative impact	Agent introduced	Method
Foot	Low to very low	Seeds, fungi	Laces and treads
Car / light truck	**Low to medium**	**Seeds and fungi**	**Muddy wheel wells**
Animal: horse / pigs	Medium	Seeds and fungi	Stomach and hooves
ATV / UTV / Tractor	Medium	Seeds, fungi, sedge "nuts"	Mud clumps all over
Tracked machine: Bulldozer / Excavator	Very high	All + tubers (ginger),	large quantities in tracks

5.2.1. Heavy equipment cleaning – very important

While heavy equipment is not used frequently in the forest, each entry by a tracked machine has a disproportionate contribution to the spread of pathogens and weeds. Unfortunately, sanitation of heavy equipment is customarily neglected in Hawai'i. Given that the use is infrequent and that the threat is very high, it makes sense to take the highest level of precautions prior to allowing the entry to heavy equipment. This includes thorough hot water cleaning of all tracks and undercarriage, as well as sanitation of the operators' station. Supply and repair vehicles should also follow protocol appropriate for light vehicles.

5.3. Pre-entry sanitation kiosk

The best way to manage invasive species is to prevent their introduction in the first place. A pre-entry gathering area and cleanup kiosk is a simple way to encourage forest visitors to clean up their footwear and vehicles prior to entering the forest.

Regardless of the option selected below, additional vigilance is required in the area where cleanup occurs, as this is where soil, seeds, ants and other potential pathogens will be deposited when cleaning occurs. Since such a station will be located near the entrance(s) to the forest, this should not be overly onerous.

5.3.1. Minimal option

At a minimum, pre-entry cleanup should be a part of the forest entry greeting sign that is recommended elsewhere in this plan, and made a condition of access to the forest. Together with this sign, the following items should be available at all times:

- stiff brushes with short handles to clean footwear
- stiff brushes with longer handles to clean wheel wells on cars
- peanut butter and chopsticks or toothpicks to set up bait tests for little fire ants which are deployed on all vehicles upon arrival to detect if the vehicle carries little fire ants
- spray bottles with diluted rubbing alcohol to apply to footwear and wheel wells

The cost for the existence and continued maintenance of this system is minimal compared to the very large and very real cost for containment of invasive species once they are in the forest.

5.3.2. Improved option

A more robust option, that will prevent more injurious agents from entering the forest includes the items above but also includes a pressurized water system with mild detergent for vehicle wash-down. This system would be located within the locked gate at the entry to WKOP and will require:

- Small water tank (200 – 300 gallons)
- Small catchment surface (can be roof of interpretive sign)
- Solar panel for 12/24 VDC recharge

- High volume (3 gal/min or more) , medium pressure (50 psi +) water pump that runs on 12 or 24 VDC (See example: Shurflo model 4358-153-A09 in Figure 5)
- Plumbing and hose for pump
- Enclosure to keep everything safe under a lock and key
- Gravel area to catch the rinse water resulting from cleaning vehicles

This system will have a higher initial cost for installation and protection against vandalism and theft. The washdown system could be installed in a commercially available portable metal

Figure 13. Washdown kits designed for boats, such as this Shurflo model # 4358-153-A09, operate on 12 or 24 V DC. This is a practical option for a vehicle washdown station to provide a means for users to clean up before entering WKOP. Cost for such an installation is nominal, though it will require more maintenance than a passive system such as scrub brushes.

container that is temporarily secured to the ground. It will also require additional maintenance, but is again far less expensive than dealing with the pests/diseases once they invade the forest. The advent of reliable solar panels and wide availability of commercial 12 volt pumps make this an ideal solution for a remote location such as WKOP.

5.4. Threat containment/control

Once the threat is in the forest, containment and elimination are the two proactive management actions that should be taken. This requires two reinforcing principles to respond effectively:

- Early detection via monitoring; and
- Rapid and decisive action to remove or contain the threat.

To promote early detection and rapid action, contact information for the appropriate land managers should be provided at the pre-entry sanitation kiosk. In turn, managers need to quickly respond to and eliminate incipient invasive species before they have a foothold on the property.

Monitoring of new species, particularly weeds, should be a part of any access maintenance

procedures, whether these are in house or contracted out. Rather than relying on a long period between formal monitoring cycles, the emphasis should be on those who are in the field the most, including users of the forest, surrounding communities and those who maintain the infrastructure.

6. Resource Allocation

In order to maintain and promote the health of the forest and to avoid resource depletion, some level of control is needed over the gathering of forest materials for personal or group consumption. The object of this control is not to reduce access or in any way impact the ability to exercise traditional and customary practices, but to ensure sustainable resource availability for current and future generations.

This plan proposes a simple resource allocation or permit system that also includes a cultural component to promote the values of sustainable resource use for future generations and the responsibility of personal stewardship.

The intent is to create a permit system that is respectful of customary practices, easy to use, and provides an effective means to control access to forest resources. This permit system will be helpful to managers by providing feedback on what resources are most sought and, therefore, in need of management focus. Based on community feedback, we propose that these permits be granted free of charge, but with mutual responsibility for resource stewardship.

The following is a discussion of a cultural protocol to invite all users to practice when entering and leaving the Wao Kele o Puna forest. This simple protocol would help reinforce the kuleana responsibility shared by each user of the forest to comply with all phytosanitary protocols and restrictions on transport of plants from WKOP.

The subsequent sections include a discussion of various permitting systems and alternative administrative arrangements that could be considered for managing and allocating natural resources including different types of "kapu," a limited permit system, and community-based approaches. For more discussion of the permitting and access control measures, please see the Comprehensive Management Plan.

6.1. Cultural Protocol before entering and leaving Wao Kele o Puna forest

Establishing a specific cultural protocol that would be used by all who enter or leave the forest is a means of reminding all users of their kuleana responsibilities. One portion of entrance protocol is an oli or some other form of hoʻokupu (offering). The offering of an oli or other hoʻokupu before entering the forest serves to request permission to enter from the entities that dwell in the forest and is also to make your intentions in the forest known.

Another portion of entrance protocol includes clearing the mind, body, and spirit of any negativity or other issues that one may be carrying and opening one's self to be accepted by the forest.

The actual form of the oli should be determined by those cultural practitioners and ‘ohana from these lands, though the following chant is provided as an option:

Pule ‘Aina

Adapted from Hawaiian Antiquities by David Malo

E ke akua, he pule `ia e holoi ana i ka po’ino o ka ‘aina
A me ke pale a’e i pau ko ka ‘aina haumia
He pule `ia e ho’opau ana i nā hewa o ka ‘āina apau
I pau ke a’e, me ke kawau
I pau ke kulopia, a me ka peluluka
I pau a hulialana
A laila niho peku, ho ‘emu, huikala, malapakai,
Kamauli hou i ke akua.

Oh God.
This is a prayer to wash away all iniquity from the land,
To ward off and end the contamination of the land.
This is a prayer to end the mistakes done to all the land
So that the bitterness may be over.
The ground will be covered with greenery, leaves and vines,
And we may offer again our prayers of thanks to you for abundance.

6.2. Kapu system

One way to control the use of forest resources is to place a kapu, or ban on the collection or hunting of those resources to allow these to be replenished. This can be seasonal, based on resource levels, spatial (in a particular area of the forest), or a combination of more than one approach. We describe each in turn below:

6.2.1. Seasonal

Placing a seasonal restriction on resource use during a certain time of year is the simplest type of kapu. An example of a seasonal restriction is preventing the collection of plants when they are flowering or animals when they are breeding.

6.2.2. Based on resource level

Limiting resource use based on resource level is intuitive, yet difficult to implement because the manager must know what the population “ought to be” and what it currently is. Obtaining this information is difficult and expensive, particularly for more obscure resources. The testimony of forest users could be used to determine appropriate resource levels.

6.2.3. Spatial

There are areas of the forest where gathering is more appropriate than others, based on species and the overall environment. For example, it is recommended that gathering and hunting not take place in the vicinity of any Special Management Zones including High Conservation Value Forest, rock walls, cracks and any known habitat for threatened or endangered species, including plants.

6.3. Limited permit system

Under this approach, a limited number of permits are allowed for a given period of time or area. While this has similarities to the Kapu system, under a limited permit system, the number of permits can be adjusted at any time to attain the forest managers' objectives.

6.4. Enhancing WKOP through community groups

One way to promote native species and particularly those that are used for hula and lāʻau lapaʻau, as well as other resources is to plant and cultivate them within WKOP. This can be accomplished through cooperative projects with community groups. The list of plants appropriate for this purpose will be developed in consultation with the ʻAha Kūkā advisory group. Proposals for specific community projects will be considered on a case-by-case basis considering the proposed location and type of activity. OHA will review and decide on each community proposal in consultation with the forest management team.

6.4.1. Forest growing plots

Small kuleana ranging from 0.25 to 10 acres can be considered to be licensed to individuals or groups for their cultivation and use in their traditional practices. The locations for such gardens would, initially, be within the "Invaded, Extensive" or "Quarantine" forest area, with the potential to expand into other zones. This expansion will depend on the compatibility of the intended cultivation practice and the forest area intended for use.

The more intense use of these two weed-infested forest types will actually improve their species composition and ecological function by removing invasive weeds and planting native species.

We recommend that these kuleana be licensed based on a specific plot management plan for that area. OHA will consider the following factors related to each prospective licensee's proposed plan:

- How will the native forest benefit?
- What is the benefit to Hawaiian culture by way of protection, perpetuation and enhancement?
- What is the benefit to the greater community?
- How will existing native species be protected?
- Who will be responsible for its implementation?

- Will there be barriers for animals? How will these be constructed in a manner that is compatible with the forest?
- Does this person/group have the capacity to take this project on responsibly?
- What is the exit strategy if the project does not work out?

In addition, all the normal pre-activity reviews need to take place, including the following:

- Check for archaeological items
- Check for T&E species
- Make sure the area is appropriate for the intended use
- Check if area is at risk of lava flows – is it low lying and near historic flows?

The intent is to make the process as streamlined and simple as possible while providing some basic safeguards to protect all resources.

In return, that group needs to enjoy ready access to their plot for the collection and cultivation of their plants.

6.4.2. Considerations for kuleana

A less intense version of growing plots is to enrich the forest to better fulfill the needs of beneficiaries. This can take place in any forest type, though as a starting method it should be limited to “Invaded, Limited”, "Invaded, Extensive" or "Quarantine Zone" of forest until an understanding of the opportunities and limitations of this method are better understood.

While there are many resources that could be enriched in the forest, two examples of forest enrichment are provided for illustrative purposes:

1. Enhance maile production
   Maile is easy to propagate and grows best in a partially shaded environment. Through sensible reductions in non-native forest cover by removing some guava or albizia, enough light will reach the forest floor and lower canopy branches to provide ideal habitat for maile.
2. Increase production of tree fruits to provide high quality food for pigs for hunted for subsistence purposes
   An important community value for WKOP that surfaces repeatedly in the private and public consultations is the traditional use of the forest as an area to hunt pigs for sustenance. This practice can be enhanced by providing better food for the pigs in highly invaded portions of the forest, such as the “Quarantine Zone,”so that the harvested animals are healthier. These species include avocado (*Persea americana*), ulu (*Artocarpus altilis*), banana (Musa spp), kukui (*Aleurites moluccana*), and potentially, mango (*Mangifera indica*) and hala (*Pandanus tectorius*). Not every tree species will fruit

at the same time. So, a sequence of trees and their seasonal fruiting habits needs to be considered as part of this program.

Proposals for forest enrichment activities will be reviewed by OHA in consultation with the forest management team to determine if the proposed activity is consistent with the goals and objectives of the forest management plan.

7. Management Prescriptions for Each Forest Management Class

For simplicity, management prescriptions are offered on a forest management class level rather than in each forest management unit. Units in a particular class are assigned a pathway or overarching goal to achieve, and managed accordingly, regardless of whether they are contiguous. Details at the Forest Management Unit level are handled in an Annual Plan of Operations (APO) where activities in each stand are listed and budgeted for.

7.1. High Conservation Value Forest

This Forest Management Class accounts for over 16% of the forest area. Given the extent of invasion within the High Conservation Value Forest (HCVF), restoration of this Forest Management Class will be a top priority.

7.1.1. Goal

The goal is to keep the forest as native as possible and reduce the weed threat over time as budgets allow.

7.1.2. Weed strategy

The strategy is to clear out the weeds to maintain native forest cover and groundcover. The initial focus will be on kīpuka areas that are small and manageable and work toward less invaded central boggy area.

The priority is to start with high elevation kīpuka which are more likely to contain Threatened and Endangered (T&E) species. Of the high elevation kīpuka, start with those that are farther from Puʻu ʻŌʻō until there is a better Digital Elevation Model to determine which areas are unlikely to be inundated with lava in the near future.

7.1.3. Endangered plant species strategy

While endangered plants were not encountered during the surveys for the biological assessment, prior data notes their presence in WKOP prior to the recent lava flow. T&E plans could potentially still exist in WKOP, particularly in the high elevation kīpuka.

If encountered, the protection of endangered species should be the highest priority for vegetation management, including the exclusion of animals via small enclosures with a radius of 50 ft around the plant/population. Out-plantings of endangered plant species can be established to help restore these species.

7.2. Puʻu

There are many puʻu in WKOP along the rift zone, some more pronounced than others and several with existing native forests, albeit invaded by alien plants. See the black triangles in Figure 7 indicating the locations of several puʻu with largely intact native forest that present unique opportunities for restoring the native forests. The elevation of the puʻu would provide some protection against future lava flows. Some puʻu may have special cultural importance.

7.2.1. Goal

The goal is to restore native forest cover on those pu‘u with a largely intact native forest. In places where there are already plantings of banana, ti leaf and related plants, there should be discussion with the AK to determine if these plants should be kept and cultivated, or removed to restore it to native forest. Pu‘u, due to their elevation, may be culturally significant and should be approached with particular care and close consultation with the AK.

7.2.2. Weed strategy

The strategy is to control weeds and replace with native species. Weed control efforts would be started by removing habitat modifying species such as strawberry guava and glorybush (melastome). Species that are not critical weeds, such as thimbleberry and grasses, could be left in place during the initial effort. As the forest recovers, these non-native species can be replaced with shrubs and groundcovers, such as māmaki.

7.2.3. Access

All of the pu‘u are remote. Access roads and trails will be needed to realistically restore them.

7.3. Invaded, Limited

This Forest Management Class accounts for 23% of the forest area. Given the extent of invasion within the High Conservation Value Forest (HCVF) and the concomitant resources that restoring forests require, it is unlikely that there will be sufficient resources to significantly improve the ”Invaded, Limited” Forest Management Class within the 10 year span of this plan.

7.3.1. Overall goal

The overall goal in the “Invaded, Limited” Forest Management Class is to keep the forest in status quo until better options emerge. In the meantime, the plan is to gather information about particular areas of this forest type that might be improved through sustainable practices.

7.3.2. Weed strategy

The strategy is to keep weeds from moving around outside of the “Invaded, Limited” Forest Management Class. In particular, the emphasis will be to control outbreaks of new weeds and high risk weeds such as miconia and albizia. Otherwise, the strategy is to keep the “Invaded, Limited” Forest Management Class in current condition while the High Conservation Value Forest (HCVF) receives priority restoration work attention.

7.3.3. Subsistence practices

In this “Invaded, Limited” Forest Management Class, it is recommended that forest management efforts focus on working with community groups or individuals through one or more kuleana agreements to grow lā‘au lapa‘au plants and other resources gardens within accessible areas. This activity would require the removal of weeds within these designated areas. The resulting space can be used to cultivate native or other useful plants in symbiosis with the remaining native forest. The result is a forest that is healthier than the surrounding

invaded forest, though not entirely native. It will also produce the needed items for traditional practices that can then be harvested by the entities or individuals that planted and consistently cared for them.

7.4. Invaded, Extensive

This forest type accounts for just below 9% of the forest and presents extensive invasive weed cover. There are limited options in this "Invaded, Extensive" Forest Management Class due to the widespread distribution of this forest type combined with the extreme cost of any efforts that seek recovery of this forest into an intact lowland native forest.

7.4.1. Overall goal

Because of the significant challenges to restore these forest lands to a native forest, the overall goal is to keep the lands in the "Invaded, Extensive" Forest Management Class from getting worse, while using it for other community needs.

7.4.2. Weed strategy

The strategy is to control only the high impact invasive species such as miconia and albizia. Meanwhile, the plan is to allocate resources for management activities in High Conservation Value Forests (HCVF) where limited budgets will go farther to accomplish management goals.

7.4.3. Hunting area

This "Invaded, Extensive" Forest Management Class can be emphasized for hunting, potentially including the use of limited trails and other measures designed to make hunting more rewarding and safe. Work with hunters to create a sense of care for the forest by 1) not introducing new weed pests and 2) identifying areas within this zone that need more protection or enhancement, such as pockets of native forest, rare plants, or nesting sites for native birds.

7.5. Quarantine

This Forest Management Class accounts for over 27% of the WKOP forest. In the "Quarantine" Forest Management Class, invasive weeds have mostly replaced the native canopy, to such an extent that it is a native forest only in name. Really it is an invasive weed forest with a few, relict stands of native trees.

7.5.1. Overall goal

In the "Quarantine" Forest Management Class, the overall goal is to keep the worst species (miconia, albizia) from spreading out of this area. Meanwhile, it is realistic to conduct some limited experiments to test different methods to restore or rehabilitate this forest type.

7.5.2. Weed strategy

The strategy in the "Quarantine" Forest Management Class is to keep the weed infestation from getting worse, and only treat the highly invasive species like miconia and albizia.

7.5.3. Forest improvement

This highly damaged forest represents, perhaps, the best opportunity to experiment with a canopy replacement strategy using food bearing tree species. This will

1. Improve hunting success by providing healthier and more available animals; and
2. Provide sustenance food in case of supply disruptions to Hawai‘i.

It is important for the species to be non-invasive, competitive with the aggressive weeds, particularly guava, and provide some kind of secondary benefit, such as fruit or leaves that are useful. Trees in this category include ‘ulu, avocado, jackfruit, and possibly niu, though the latter does not provide shade needed to keep out weeds in the understory.

Native and non-native forests need not be absolute opposites, rather there is a continuum of forest types, many cultures in the Pacific utilize a combination of subsistence and native species in a mixed forest type that is more resilient than the original fully native forest.

7.6. Lava

Lava flows represent about 24% of the land in Wao Kele o Puna. The management objective on lava flows should be focused only to prevent new aggressive species that are colonizing the lava. Recognizing the cultural significance of the lava flows as physical manifestations of Tūtū Pele, this plan recommends that the ‘Aha Kūkā discuss utilizing lava flows as the location to site roads to reduce collateral damage to native forests and minimize loss of productive forest area. In this discussion with the ‘Aha Kūkā, it would be important to determine how to demonstrate the proper gratitude, honor and respect to Tūtū Pele for building the foundation for a road network to protect the forest.

7.6.1. Road alignment on lava rather than in the forest

Lava areas provide a better alignment for road surfaces. ‘A‘ā lava areas in particular make road construction cost considerably lower. There are several advantages to building roads on lava flows:

1. Drainage is excellent, reducing maintenance costs;
2. Weeds do not become established as easily and are easier to treat when they do;
3. Forest does not need to be cleared along the right of way;
4. It is easier to perform the pre-construction checks for archaeology and Threatened and Endangered species;
5. The lava flows are “defensible areas” that will not get over-run by a fire; and
6. The lava flows are generally higher than the surrounding land, meaning new lava flows will tend to run elsewhere.

8. Implementation Strategy

This management plan seeks to address all areas within WKOP, including those areas with high concentrations of native species and those areas that are dominated by non-native weed species. In areas with native forest, the emphasis is forest management measures to protect and restore native species by removing weed species and restoring native species. In areas that have been invaded with weeds, the emphasis is to contain the spread of the weed species and rehabilitate the forest into a healthier non-native forest using working partnerships with community members.

WKOP is very large, access is very challenging, and the invasion of weed species is widespread. To provide the technical capacity to keep track of each Forest Management Unit and the condition of the natural resources, forest management activities, and other important data, establishing a Forest Information Management System is a priority implementation step.

To protect and restore the native forest in WKOP in the most effective manner, the priority projects would focus on the High Conservation Value Forest areas that are of workable size and reasonably separate from human settlement. Based on these criteria, the recommended initial priority areas for resource allocation would be to support forest management efforts in two FMUs (HC4 and HC6) and the pu‘u areas.

To improve access to these priority areas for forest management work, the priority roads to build are to access HC4, HC6 and the pu‘u areas. Priority trails to develop would be to access HC4 and HC3 areas. The other interior roads to access HC1 and HC2 and the trail system in HC2 would be the second priority for construction. While the internal roads are being developed, efforts should be made to secure access from roads or parcels in neighborhoods adjacent to the WKOP border to connect to the internal road system.

To prevent further infestation of WKOP by invasive weeds, an important first step would be to install within the WKOP gated access a rinse station and signage to ensure compliance with phytosanitary protocols. The other important step is to contain the spread of invasive weeds into HCVF areas from those areas within WKOP that have a high concentration of weeds.

To ensure WKOP is used with respect, a priority would be to develop and utilize a cultural protocol in consultation with the ‘Aha Kūkā to enter and exit WKOP. This protocol would be incorporated in all license agreements or permits with users to access and utilize WKOP resources. To educate the broader community of users in WKOP, it will be important to work with the ‘Aha Kūkā to develop strategies to encourage that all forest users utilize the protocols.

To engage and manage community partnerships in forest management activities, a management priority would be to develop and implement a resource allocation system using kapu, a limited permit system and/or kuleana licenses. This would be developed in consultation with the ʻAha Kūkā.

In the following summary for each Forest Management Class, the percentage of WKOP land in that category is provided along with the priority management recommendations.

High Conservation Value Forest: (16%)

- Clear out the weeds to maintain native forest cover and groundcover.
- The initial focus will be on kīpuka areas that are small and manageable and work toward less invaded central boggy area.

Puʻu:

- Restore native forest cover on puʻu with largely intact native forest.
- Where there are already plantings of banana, ti leaf and related plants, discuss with the ʻAha Kūkā to determine if these plants should be kept and cultivated, or removed to restore it to native forest.
- Control weeds and replace with native species. Initial weed control efforts include removing habitat modifying species such as strawberry guava and glorybush (melastome).
- During the initial effort, leave in place those species that are not critical weeds, such as thimbleberry and grasses. As the forest recovers, these non-native species can be replaced with shrubs and groundcovers, such as māmaki.

Invaded, Limited: (23%)

- Keep weeds from moving around outside the area.
- Control outbreaks of new weeds and high risk weeds such as miconia and albizia.
- Establish kuleana agreements with community members to remove the weeds and grow lāʻau lapaʻau plants and other resources gardens within accessible areas.

Invaded Extensive: (<9%)

- Keep the weed infestation in these lands from getting worse, while using it for community needs.
- Control only the high impact invasive species such as miconia and albizia.
- Emphasize the use of the area for hunting by developing limited trails.
- Educate hunters to prevent the introduction of new weed pests.
- Identify areas that need more protection or enhancement, such as pockets of native forest, rare plants, or nesting sites for native birds.

Quarantine: (>27%)

- Keep the weed infestations from getting worse by only treating the highly invasive species like miconia and albizia, and preventing them from spreading out of this area.
- Conduct some limited experiments to test different methods to restore or rehabilitate this forest type.
- Experiment with a canopy replacement strategy using tree species such as ulu, avocado, jackfruit and niu.

Lava: (24%)

- Prevent new aggressive weed species that are colonizing the lava.
- Utilize lava flows as the preferred location to site roads to reduce collateral damage to native forests.
- Determine with the ʻAha Kūkā the most culturally appropriate manner to allow for building roads on the lava flow.