Kohala Mountain Watershed Management Plan

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Kohala Mountain Watershed Management Plan

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EXECUTIVE SUMMARY

On the island of Hawai‘i, Kohala Mountain, crowned in native cloud forest, lies perpendicular to the prevailing trade winds, favoring frequent cloud formation and abundant rainfall vital to North Hawai‘i. These forested areas of Kohala Mountain are vital for recharge of North Hawai‘i’s groundwater aquifers and a supply of dependable surface water for its streams.

As described in Chapter I, the Kohala Watershed Partnership (KWP) brings together major landowners on Kohala Mountain to protect the water resources and watershed functions of the forested watershed. Efforts to protect vital watershed values began to coalesce when a group of government and private landowners signed a Memorandum of Understanding (MOU) in August 2003, officially forming the Kohala Watershed Partnership. By signing this MOU, partners committed to work collaboratively to protect the Kohala Mountain Watershed, despite differences in priorities, mandates and constituencies. These partners include: Parker Ranch; Kahuā Ranch; Ponoholo Ranch; Kamehameha Schools; Queen Emma Foundation; Surety Kohala Corporation; Laupahoehoe Nui, LLC; Hawai‘i Department of Land and Natural Resources; and Department of Hawaiian Home Lands. The Hawai‘i County Department of Water Supply and The Nature Conservancy have joined in this effort as (non-landowner) “associate” partners, because of their experience in and commitment to effective watershed conservation.

The primary goal of the Kohala Watershed Partnership is to show improvements in water and environmental quality by enabling comprehensive and sustainable watershed management projects that address the threats to the watershed, while maintaining its integrity and protecting its economic, socio-cultural, and ecological resources. This management plan describes the watershed resources and associated values, identifies the threats to those resources, and directs the activities of the KWP toward their protection. This plan sets management goals, identifies information needs, and prescribes monitoring activities to measure effectiveness and success. The area addressed by this plan includes approximately 68,000 Acres (Ac) of forest and grass lands on the windward and leeward slopes of the Kohala Volcano.

Chapter II of the management plan describes the resources, uses, and current conditions of the Kohala Watershed, including physical characteristics, hydrology and water use, biological resources, and socio-cultural resources. Kohala Mountain provides approximately 6% (154 million gallons per day) of the sustainable yield of water for Hawai‘i Island, though potential production is far greater. Hawai‘i County Department of Water Supply (DWS) relies on the streams and groundwater of Kohala Mountain for its primary source of domestic drinking water for residents of North Kohala, South Kohala, and parts of Hāmākua. The Hawai‘i Department of Agriculture’s Waimea Irrigation Water System, the Kohala Ditch System, and the Lower Hāmākua Ditch Irrigation System depend on surface water from Kohala Mountain to provide agricultural irrigation water to farms. Private ranches, such as Parker Ranch, Ponoholo Ranch, and Kahuā Ranch also rely on the waters of Kohala. The taro farmers in Waipi‘o Valley also depend on a reliable source of water from the watershed.

The Kohala watershed management area (WMA) is also rich in biological resources, unique ecosystems, and rare and endangered plant and animal species. Upper leeward Kohala slopes support particularly diverse Montane moist forests and bog ecosystems that harbor

many rare flora. The WMA and Kohala vicinity contain over three dozen federally-listed plant species. These rare plants vary in habitat from dry to wet, windward coastal sea cliffs to the montane bogs of the summit region, over to the remnant dry forest still extant in the pastures and gulches of leeward Kohala. There are many small streams that drain from the Kohala summit, most of which harbor native aquatic insects, fishes, crustaceans, and mollusks. Native animal species within the watershed include birds, the hoary bat, snails, and arthropods – many of which are found no where else on earth but in Hawai'i.

The watershed is also rich in cultural history, and the area historically supported a relatively large population of Hawaiians. The early Hawaiians practiced wetland agriculture, particularly taro, in the valleys, and the lower windward slopes were terraced for farming. On the leeward side of Kohala Mountain, the Hawaiians terraced and farmed the land in dryland agriculture, carrying water to these drier lands in *auwai* (irrigation ditch or canal). The 1793 introduction of cattle to the Hawaiian Islands and the sandalwood trade in the early 1800s changed the natural landscape forever, and many of the leeward areas of Kohala Mountain were converted to cattle ranching. Sugar plantations were established in North Kohala and Hāmākua during the second half of the 19th century, relying heavily on the water of Kohala Mountain.

Chapter III of the management plan describes the watershed values of Kohala Mountain. These are characteristics or functions of a watershed that have social, economic and/or ecological benefits. The water resources of Kohala Mountain are valued for their domestic and agricultural uses in the lands of Waimea, Hāmākua, and North Kohala. Kohala Mountain is valued for the watershed functions of its forest, including ensuring sustainable water, reduced rates of water loss via evaporation and transpiration, contributions of organic matter, carbon storage, and soil-holding capacity which prevents erosion. Kohala Mountain contains numerous and diverse ecosystems and many rare and endangered plant and animal species, many of which are found nowhere else in the world. Kohala Mountain's forests help purify the air, regulate climate, regenerate soil fertility, and feed coastal reefs and nearshore fisheries. Species within the forest and streams provide economic, recreational, and socio-cultural benefits as well. The inter-relationship between the land and the people who inhabit it, nourished through daily practice of their culture, has forged a strong bond of Hawaiian culture to the Hawaiian landscape. The watershed is also valued for public access and outdoor recreation, and provides a tremendous opportunity to educate adults and children alike about the unique ecosystems and biodiversity of Hawai'i.

Chapter IV explains the threats to the Kohala watershed. Today, the primary threats to the watershed of Kohala Mountain are from alien plants and animals and their effects, including some feral and domestic cattle, and other factors such as wildfire and climate change. The problem of alien species invasion in native habitats is a well-documented management problem in Hawai'i's natural areas, and this chapter describes the invasive plant species which threaten the resources of Kohala Mountain. Feral ungulates also do considerable damage to the forested watershed, which evolved without the pressures associated with hooved animals. Smaller non-native animals and alien aquatic species also have the potential to become serious pests in the Kohala watershed. Human activities in the watershed, most of which are done with good intentions, can also have a negative impact on the watershed. This chapter also describes the threats arising from aquatic pollutants, wildfire, and climate change.

Chapter V outlines a management program to protect and conserve the resources of the Kohala Mountain watershed. This management program was developed in a series of

planning meetings held by the Kohala Watershed Partnership, drawing from previous information and planning efforts, and with input from landowners, resource managers, and community members. This chapter identifies objectives related to the protection of water resources and watershed functions and the management of threats to these resources. Because the watershed of Kohala Mountain supports unique plant and animal communities that have value to society, this chapter also includes recommendations related to the protection of biodiversity. Recognizing that a management program cannot be effectively implemented without sufficient infrastructure and personnel, recommendations addressing the administration of the program are incorporated. Finally, the chapter addresses compatible public use of the watershed.

Outlined in this chapter are objectives and recommended actions to implement the primary goal and another six major goals over a 20 year period. Under each management goal, there will be one or more objectives, each followed by a brief description of current management activities. Each objective will identify specific management actions to achieve the objective.

This proposed management program reflects the ideas and watershed management goals of the Kohala Watershed Partnership. Recommended actions have not been finalized or prioritized at this time. The Kohala Watershed Partnership believes it is important to get further community input on the plan before the management program is finalized.

Opportunities for additional public input will occur during the environmental review process (Chapter 343, HRS). During this process, the KWP will engage in an outreach effort to gather feedback on the management plan and public input on the action priorities. Various forums will be used to solicit public input, including workshops and community meetings. This input will be incorporated into the draft watershed management plan and Draft Environmental Assessment (EA). These documents will then be available for further review and comment during a 30-day public comment period. Following this public comment period, the management plan and EA will be finalized and submitted to the Board of Land and Natural Resources with the Conservation District Use Application (CDUA) for proposed actions within the Conservation District.

The proposed management goals and objectives are delineated below.

Management Goal 1: Protect Water Resources.

Objective 1a: Maintain a structurally-complex vegetative cover that promotes infiltration and groundwater recharge and minimizes erosion.

Objective 1b: Protect, enhance, and manage high yield watershed areas to maintain water quantity and quality.

Objective 1c: Monitor the quality and integrity of ground water, surface waters, and aquatic environments.

Objective 1d: Develop a thorough understanding of the nature of groundwater resources affected by Kohala Mountain.

Objective 1e: Support appropriate water development to meet the needs of future demand.

Management Goal 2: Prevent New Introductions and Effectively Control Existing Invasive Plant Species.

Objective 2a: Prevent the introduction of new potentially-invasive plant species.

Objective 2b: Manage the spread of incipient and well-established weed pests.
Objective 2c: Conduct monitoring and research to determine efficacy of control measures and to identify occurrences and distribution of other new species.

Management Goal 3: Control Non-Native Animal Populations within Designated Areas.
Objective 3a: Remove feral cattle from the watershed management area.
Objective 3b: Implement pig control to minimize loss of watershed vegetation cover, watershed soil erosion, and human health risks associated with animal-borne diseases.
Objective 3c: Slow the rate of introduction and manage established alien aquatic species.
Objective 3d: Reduce the impacts of rats and other small mammals and promote control of other non-native animals as appropriate.

Management Goal 4: Protect Unique Biological Communities and Rare Species.
Objective 4a: Protect unique plant and animal communities within the WMA.
Objective 4b: Control priority invasive aquatic species in windward streams within the WMA.

Management Goal 5: Prevent and Minimize Wildfire.
Objective 5a: Protect the watershed management area from the threat of wildfire.

Management Goal 6: Manage Access for Compatible Public Use.
Objective 6a: Support continued public hunting on DLNR-managed lands, where compatible with the conservation of water and related watershed values.
Objective 6b: Establish and maintain suitable hiking access trails where the activity is compatible with conservation of water and related watershed values.
Objective 6c: Permit public access to and over private property only with explicit permission of private property owner or representative.
Objective 6d: Ensure that cultural practices, and archaeological and other cultural sites within the WMA are identified, protected, and enhanced.
Objective 6e: Generate community awareness and support of watershed values and management activities on Kohala Mountain.

Management Goal 7: Provide Effective Administrative Coordination and Infrastructure.
Objective 7a: Provide and maintain the appropriate infrastructure and administration to allow for effective watershed management.

The management plan proposes to fence approximately 10,500 acres of the Kohala Mountain watershed management area. The protected areas include both public (7,445 acres) and private lands encompassing approximately 3,065 acres. Management Goal 1 includes measures to protect forest areas comprising the significant portion of the watershed in which groundwater infiltration is occurring. The plan recommends fencing four areas totaling approximately 6,600 acres in order to maintain high yield watersheds. These areas coincide with the areas proposed for fencing in the Kohala Forest Management Group's Action Plan Outline of Projects, for which there was broad agreement amongst participants which included community members, landowners, and resource managers. Management Goal 4 includes management actions to protect a total of approximately 3,910 acres harboring significant native plant and animal communities and ecosystems. These areas would be fenced and managed to protect these important biological communities.

Chapter VI of the management plan provides management program indicators that may be used to gauge the success of the various management actions. Chapter VII is the bibliography. Appendices make up the last part of the management plan. Appendix A is a list of animals and vascular plants of the Kohala Mountain watershed. Appendix B lists selected Hawai‘i statutes and rules that pertain to the management of the Kohala watershed. Appendix C consists of summaries of statements and recommendations made in earlier efforts that related to watershed management on the Island of Hawai‘i. Finally, Appendix D provides detailed descriptions of each biodiversity conservation unit proposed under Management Goal 4.

Kohala Mountain Watershed Management Plan

I. INTRODUCTION

Olelo no`eau in praise of Kohala:

O Kohala nui, o Kohala iki, o Kohala loko, o Kohala waho, o Kohala makani ʻĀpaʻapaʻa, o Pili o Kalāhikiola, o Na-puʻu-haele-lua. ʻOia hoʻi! ʻOia la! O nā ʻokina iho la ʻia o ka ʻāina haʻaheo i ke kāhili a ka makani ʻĀpaʻapaʻa e hoʻolaʻau mai ana me he ipo ala ka nē hone i ka poli o ke aloha –

Large Kohala, little Kohala, inner Kohala, outer Kohala, Kohala of the *ʻĀpaʻapaʻa* wind, of Pili and Kalāhikiola, the two traveling hills. Indeed! They are the combined sub-districts of this proud land brushed by the *ʻĀpaʻapaʻa* wind, maturing like a love nestled fondly in the bosom of love (*Ka Hoku o Hawaiʻi*, March 22, 1917).

On the island of Hawaiʻi, Kohala Mountain, crowned in native cloud forest, lies perpendicular to the prevailing trade winds, favoring frequent cloud formation and abundant rainfall vital to North Hawaiʻi. These forested areas of Kohala Mountain are vital for recharge of North Hawaiʻi's groundwater aquifers and a supply of dependable surface water for its streams.

The critical role played by Hawaiʻi's forests in supporting water has long been recognized. In 1902 U.S. Forester E.M. Griffith wrote, "Forest protection means not only increasing the rainfall, but more important still, conserving the water supply. The future welfare and agricultural prosperity of the Hawaiian Islands depends upon the preservation of the forest." In 1924, C.S. Judd, Superintendent of Forestry in Hawaiʻi, wrote eloquently "Probably in no other section of the world is the relation between a satisfactory forest cover on the mountains and supply of water for domestic and agricultural uses better or more ably demonstrated...." The forested watershed of Kohala Mountain has evolved into an efficient system to capture and store water. Again, C.S. Judd articulated it so well:

> The happy combination of small trees, bushes, ferns, vines and other forms of ground cover keep the soil porous and allow the water to percolate more easily into the underground channels. The foliage of the trees breaks the force of rain and prevents the impacting of the soil by rain drops. A considerable portion of the precipitation is let down to the ground slowly by this three-storied cover of trees, bushes, and floor plants and in this manner the rain, falling on a well-forested area, is held back and instead of rushing down to the sea rapidly in the form of destructive floods, is fed gradually to the springs and streams and to the underground artesian basins where it is held for use over a much longer interval....(1924)

The Kohala Watershed Partnership (KWP) brings together major landowners on Kohala Mountain to protect the water resources, watershed functions, and the natural and cultural resources of the forested watershed. Efforts to protect vital watershed values began to coalesce when a group of government and private landowners signed a Memorandum of Understanding (MOU) in August 2003, officially forming the Kohala Watershed Partnership.

By signing this MOU, partners committed to work collaboratively to protect the Kohala Mountain watershed, despite differences in priorities, mandates, and constituencies. These partners include:

- Parker Ranch
- Kahuā Ranch
- Ponoholo Ranch
- Kamehameha Schools
- Queen Emma Foundation
- Surety Kohala Corporation
- Laupahoehoe Nui, LLC
- Hawai‘i Department of Land and Natural Resources
- Department of Hawaiian Home Lands

The Hawai‘i County Department of Water Supply and The Nature Conservancy have joined in this effort as (non-landowner) “associate” partners, because of their experience in and commitment to effective watershed conservation. The MOU is the basis for the primary goal of the KWP, which is to show improvements in water and environmental quality by enabling comprehensive and sustainable watershed management projects that address the threats to the watershed, while maintaining its integrity and protecting its economic, sociocultural, and ecological resources.

The Kohala Watershed Partnership agreement marks the eighth out of nine watershed partnership that has been formed across the State. Other partnerships include East Maui (1991), ‘Ōla‘a-Kīlauea (1994), West Maui (1998), East Moloka‘i (1999), Ko‘olau Mountains on O‘ahu (1999), Lanai (2001), Kaua‘i (2003), and South Maui (2003). Watershed partnerships are voluntary alliances of public and private landowners committed to the common value of protecting large areas of forested watersheds and associated conservation values. By bringing public and private landowners together around a shared interest, such as watershed protection, these partnerships enable landowners to work together to manage threats that occur across common land ownership boundaries, pool limited resources to achieve conservation goals, and promote collaboration in protecting vital resources across large landscapes.

This management plan describes the watershed resources and associated values, identifies the threats to those resources, and directs the activities of the KWP toward their protection. This plan sets specific management goals, identifies information needs, and prescribes monitoring activities to measure effectiveness and success.

II. DESCRIPTION AND CURRENT CONDITION OF KOHALA WATERSHED

Isabella Bird, explorer in the 1870s, on her first trip to Waipi'o Valley and the Falls of Waipi'o:

With great difficulty and many bruises, [I] got up the river to its exit from the basin, and there, being unable to climb the rocks on either side, stood up to my throat in the still tepid water till the scene became real to me…No words can paint the majesty of the surroundings, the caverned, precipitous walls of rock coming down in one black plunge from the blue sky above to the dark abyss of water below, the sullen shuddering sound with which pieces of rock came hurtling down among the trees, the thin tinkle of the water as it falls, the full rush of the river, the feathery growth of ferns, gigantic below, but so diminished by the height above, as only to show their presence by the green tinge upon the rocks, while in addition to the gloom produced [Bird 1964:93] by the stupendous height of the cliffs, there is a cool, green darkness of dense forest, and mighty trees of strange tropical forms glass themselves in the black mirror of the basin… [Bird 1964:93]

The area addressed by this plan includes approximately 68,000 Acres (Ac) of forest and grass lands on the windward and leeward slopes of the Kohala Volcano. The boundary of the Watershed Management Area (WMA) follows State Hwy 250 (Kohala Mountain Road) from ʻŌuli Gulch at milepost 1.5 as it climbs northwest to mile 11, where it then climbs northward over Kohala Mountain's northwest shoulder to drop northeastward toward the Pololū Valley estuary. The WMA follows the windward coastline, bends up Waipiʻo Valley, and climbs to encompass the Puʻukapu section of the Kohala Watershed. The Southern boundary then follows the southern Forest Reserve boundary westward and continues to meet ʻŌuli Gulch at the Hwy 250 crossing (Figure 1).

The extinct Kohala volcano is approximately 700,000 years old, making it the oldest of Hawaiʻi island's five shield volcanoes (Ziegler 2002). It rises to a height of 5,480 ft. above sea level at the northern tip of the island. The outstanding features of Kohala's tropical climate are its mild year-round temperature, its persistent northeasterly tradewinds, and its regular pattern of orographic cloud formation and precipitation. As rising moist air cools, it drops moisture in the form of rain. The cooled clouds continue to drop moisture as rain and intercepted fog and become drier as they flow over the mountains to the leeward side. Fog water that is intercepted by vegetation and drips to the ground (fog drip) is a consistent characteristic of the windward Kohala Mountain slopes above 2,500 ft.

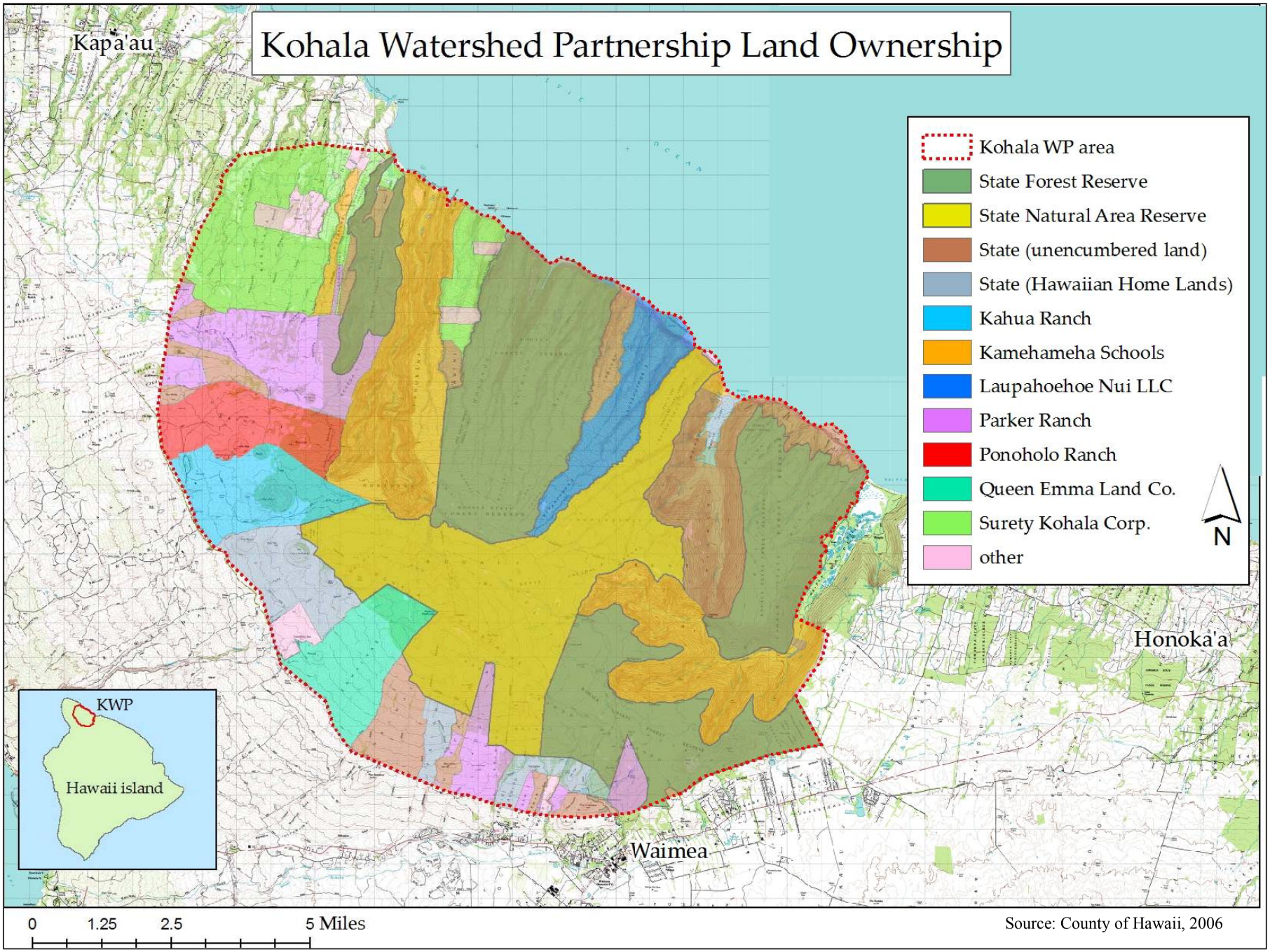

Figure 1. Land Ownership in the Kohala Watershed Management Area

A. Physical Characteristics

Kohala Mountain's elongated northwest to southeast shape was formed by thousands of basaltic lava flows that erupted from two main rift zones and possibly a caldera that may have existed but was later buried by younger lava flows. Eruptions on Kohala volcano were fed by magma rising through fissures toward the rift zones and central caldera. Magma that did not reach the surface may have cooled within the fissures, forming vertical sheets of low-permeability rock (Oki 2002). The northeastern slope of the volcano has experienced a major slope failure that resulted in a reentrant of the shoreline 12 miles long and extending one mile inland. Pololū and Waipi'o valleys formed along these faults (USGS 1995). The exposed volcanics of the WMA fall into two main classes: Hawi volcanics and Pololū volcanics. Pololū volcanics occur within the windward valley areas affected by the slope failure. They are comprised of tholeiitic, transitional, and alkalic basalts dated about 700, 400, and 250 thousand years old, respectively. Hawi volcanics consist of postshield-stage Hawai'ite, maugerite, benmoreite, and trachyte. Lava flows originated from numerous vents, marked by cinder cones and lava domes, near the rift zones of the volcano. Most of these lava flows are *a`a* lava, average 40-ft. in thickness, and few reached the coast. The composite thickness of the layered flows of Hawi volcanics may be as great as 500-ft. near the summit. The slope of the flows range from 3 to 12 degrees except where they flowed into deeply eroded valleys. Soils are generally a few inches to 3 feet thick and commonly rocky in dry areas.

Kohala's summit region is characterized by cinder cones, lava domes, and abrupt slip faults (Wolfe and Morris 1996). Topography throughout the rest of the WMA is highly varied and ranges from very steep valley walls and sea cliffs, to shallow valleys and narrow drainage gullies and broad rolling pastures. The lower windward slopes are deeply dissected, and major drainage patterns are well established. The mountain is moderately dissected in the upper reaches and along the upper leeward slopes.

Soils of the mountain are primarily inceptisols. The Amalu soils series dominates the WMA and covers nearly all of the slopes along the windward side, except for the Rough Broken Lands, also in the Amalu series, that comprise the valley walls. The upper western windward slopes are Silty Clay Loams in the Kahuā, Palapalai, and Manahaa series, and leeward soils are Silty Loams in the Palapalai and Maile series.

B. Hydrology and Water Use

Average annual rainfall on Kohala Mountain ranges from about 40 inches along the leeward section of the Kohala Mountain Road at 3,500-ft. to over 160 inches near the 3,500-ft. elevation in the wet forest between Waipi'o and Honokāne valleys on the windward side (Figure 2). As rising moist air cools, it forms clouds that drop moisture in the form of rain, as dictated by topography and wind direction (Juvik and Juvik 1998). The cooled clouds continue to drop moisture in the form of rain and intercepted fog and become drier as they flow over the mountains to the leeward side. Fog water that is intercepted by vegetation (fog drip) is a consistent characteristic of the windward Kohala mountain slopes above 3,000-ft.

A distinctive feature of Kohala's hydrology is that a significant proportion of its total precipitation comes from water intercepted from the clouds passing through the vegetation high on the mountain. The distinguishing hydrologic feature of montane cloud forests is their contribution of fog moisture to the hydrology of the forest ecosystem. Recent studies in tropical cloud forests have found that the water intercepted by vegetation typically ranges between 10% and 25% of rainfall, or more, and comprises a larger proportion (up to one-third)

of the total precipitation during dry periods (Juvik and Nullett 1995; Bruijnzeel 2000; Bruijnzeel and Hamilton 2000; Bubb 2004; and Scholl *et al.* 2004). Scholl and colleagues working in East Maui used stable isotopes to trace cloud forests fog water through the hydrologic cycle. They found that water from fog comprised a very small proportion of soil moisture (comprised mostly of rainfall from large storm events), but made up much of ʻŌhiʻa (*Metrosideros polymorpha*) tree sap. Fog drip contributes significantly to stream flow. Overall, they found that cloud water interception adds significantly to rainfall. Cloud water interception at dry and wet cloud forest sites there was equivalent to 10.6 and 42.3 inches per year, respectively (Scholl *et al.* 2004). Together, rainfall and fog drip may total near 200 inches per year across Kohala's broad windward summit region. Cloud forests are mountain forests defined and limited by the persistent presence of clouds and mists and so, in addition to rainfall, capture water droplets that condense on the vegetation.

The precipitation either runs off, evaporates or is transpired by vegetation, recharges the groundwater system, or is stored in the soil. The porous and permeable structure of the mountain geology favors the storage and transport of subsurface water from the mountainous interior parts of the WMA to the coastal areas where it is discharged. Fresh groundwater that is not withdrawn from wells and tunnels discharges naturally from the aquifer at subaerial and submarine springs and seeps. Fresh groundwater in Kohala Mountain occurs as either a freshwater-lens system in the dike-free lava flows or as a dike-impounded system (Oki 2002).

Numerous dikes penetrating through Kohala's sheets of basaltic flows form dike complexes that store water at high elevations. The boundary between the dike-impounded system and the freshwater-lens system generally corresponds with the seaward extent of mapped volcanic vents represented by cinder cones and lava domes. Water enters the dike-impounded system mainly by infiltration of some part of rainfall and fog drip. Natural discharges from these stores occur via high-level springs and streams and groundwater flow to the down-gradient freshwater-lens system (Oki 2002).

Estimated average annual recharge in the Hawi Hydrologic Study Area, an area of 55 square miles bounded on the southwest by the crest of Kohala Mountain and on the east by Pololū Valley and on the north by the coast, is 37.5 million gallons per day (mgd), which represents 18% of the average annual rainfall (Oki 2002). This recharge rate varies across the study area, but is highest in the upland southeastern portion of the study area. Average annual recharge from the direct infiltration of rainfall in the study area was estimated at 55%.

Kohala Mountain provides approximately 6% (154 mgd) of the sustainable yield for Hawaiʻi island (2,431 mgd) (Figure 2). Water budgets for the island of Hawaiʻi indicate that the rainfall is dispersed as 44% evapotranspiration, 25% runoff, and 31% groundwater recharge (Armstrong *et al.* 1983).

Soil moisture-holding capacity[1], measured in inches of available water capacity per inch of soil, is higher in forested areas. In the Hawi Hydrologic Study Area, soil moisture storage capacity was computed from soil type and root depth. Root depths were estimated to be higher in ʻŌhiʻa forest (30 in) than in pasture (22 in) and lowest on steep slopes and in gulches (12 in) (Oki 2002). Using these estimates, the soil moisture-holding capacity of the WMA should be

[1] Soil-moisture storage capacity is estimated by superimposing vegetation information (root depths) on the soils information (available water capacity).

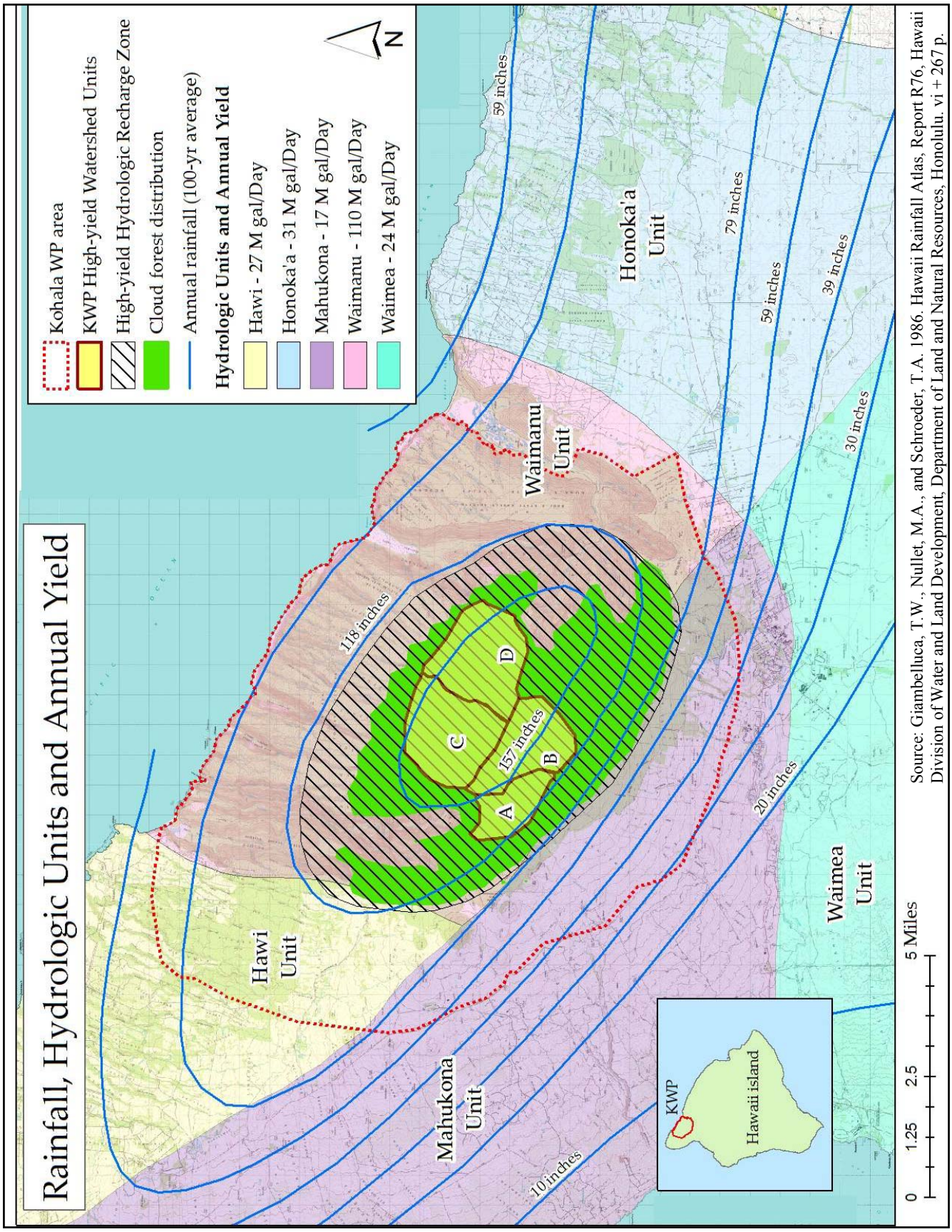

Figure 2. Rainfall, Hydrologic Units and Annual Yield in Kohala Watersheds

high due to the vast, structurally-diverse native forest dominated by ʻŌhiʻa (*Metrosideros polymorpha*), the abundance of organic material produced and cycled within the forest, and the frequently deep soils.

Similar studies have not yet been completed for the other two Kohala Mountain hydrologic units, Waimanu and Māhu-kona. However, an assessment of groundwater conditions was conducted for the districts of North and South Kona and South Kohala from 1991 to 2002 (Bauer 2003). This State Commission on Water Resource Management study provided baseline data to support and inform planning decisions related to development and well-drilling for that region. Implementation of additional studies will be important to the further understanding of Kohala's complex hydrology.

The Kohala Watershed Management Area has numerous perennial streams or rivers that flow from summit regions to the ocean (Table 1 and Figure 3). Table 1 lists the majority of these streams; however, given the many small waterways, the list is likely incomplete. Additionally, local observations indicate there may be a need to reassess the streams in Table 1 for stream class. Many of the streams flow from non-agricultural forested lands to the ocean; others flow through agricultural lands intermittently and during flood events. Some are perennial in the upper reaches and intermittent at lower elevations. Intermittent streams on the leeward side of Kohala Mountain appear to flow less now than they did in the past. Based on anecdotal information obtained through interviews with *kamaʻaina* residents from the region, streamflow may be reduced today from even half a century ago. Some believe that the flow regime is now more flashy in nature. While the causes of a drying local climate are not precisely known, there appears to be a drying trend.

All but four streams in the WMA meet State water quality standards. The federal Clean Water Act requires states to prepare and submit biennial lists of waterbodies not expected to meet state water quality standards. This list is referred to as the Section 303(d) List of Impaired Waters. Hawaiʻi Department of Health's (DOH) 2004 303(d) List includes 70 streams and 174 coastal stations around the State. Of these, the Kohala WMA has four streams: Aamakao, Niulili, Waikama, and Wailoa/Waipiʻo. In its 2004 303(d) List, DOH reported that Wailoa/Waipiʻo Stream, not listed in 2002, exceeded the wet season Nitrite/Nitrate standard by a factor of 2. Waikama Stream, however, previously listed for exceedance of the wet season turbidity standard, showed no exceedance for the wet season in 2004, but exceeded the dry season turbidity standard. Aamakao and Niulili also both exceeded dry season turbidity standards.

DOH identifies these four streams, as well as Pololū, as needing additional monitoring (Koch *et al.* 2004). There are no coastal stations that lie adjacent to the WMA; however, Pelekane Bay, adjacent to Kawaihae Harbor on the leeward side of Kohala, is on the 303(d) List as an impaired coastal water body in exceedance of turbidity standards.

Table 1. Major Streams Emanating from the Kohala Watershed Management Area.

Ref. No.	Stream	CWA 303(d) classification	Pollutant	Stream class†	Land Use Code**	Aspect
1 *	Aamakao	Impaired	Turbidity	Perennial	A, C	Windward
2 *	Niulii	Impaired	Turbidity	Perennial	C	Windward
3 *	Waikama	Impaired	Turbidity	Perennial	C	Windward
4 *	Pololu	--		Perennial	C	Windward
5 *	Honokane Nui East	--		Perennial	C	Windward
6.	Honokane Nui West	--		Perennial	C	Windward
7. *	Honokane Iki East	--		Perennial	C	Windward
8.	Honokane Iki West	--		Perennial	C	Windward
9.	Opaeloa	--		Perennial	C	Windward
10.	Waipahi	--		Intermittent	C	Windward
11. *	Honokea	--		Perennial	C	Windward
12.	Kailikaula	--		Intermittent	C	Windward
13. *	Honopue	--		Perennial	C	Windward
14.	Kolealiilii	--		Perennial	C	Windward
15.	Paohia	--		Perennial	C	Windward
16. *	Ohiahuea	--		Perennial	C	Windward
17. *	Nakooko	--		Perennial	C	Windward
18.	Kamoloumi	--		Perennial	C	Windward
19.	Waiapuka	--		Intermittent	C	Windward
20. *	Waikaloa	--		Perennial	C	Windward
21.	Waimaile	--		Intermittent	C	Windward
22.	Kukui	--		Intermittent	C	Windward
23.	Paopao	--		Intermittent	C	Windward
24.	Waiaalala	--		Perennial	C	Windward
25. *	Punalulu	--		Perennial	C	Windward
26. *	Kaimu	--		Perennial	C	Windward
27.	Pa`e	--		Intermittent	C	Windward
28.	Waimanu	--		Perennial	C	Windward
29.	Wai`ilikahi	--		Perennial	C	Windward
30.	Waihilau	--		Perennial	C	Windward
31.	Kakaauki	--		Perennial	C	Windward
32.	Pukoa	--		Perennial	C	Windward
33.	Manuwaikaalio	--		Perennial	C	Windward
34.	Haweleau	--		Intermittent	C	Windward
35.	Papala	--		Intermittent	C	Windward
36.	Naluea	--		Intermittent	C	Windward
37.	Kahoopu'u	--		Intermittent	C	Windward
38. *	Waipahoehoe	--		Intermittent	C	Windward
39. *	Wailoa/Waipi'o	Impaired	Nitrite/Nitrate	Perennial	C	Windward
40.	Waima	--		Perennial	C	Windward
41.	Koiawe	--		Perennial	C	Windward
42.	Alakahi	--		Perennial	C	Windward
43.	Kawainui	--		Perennial	C	Windward
44. *	Lanimaumau	--		Intermittent	A	Leeward
45. *	Waikoloa	--		Perennial	C	Leeward
46. *	Kohakohau	--		Perennial	no data	Leeward

Ref. No.	Stream	CWA 303(d) classification	Pollutant	Stream class	Land Use Code**	Aspect
47. *	Haleaha Gulch	--		Intermittent	no data	Leeward
48. *	Waiaka Gulch	--		Intermittent	no data	Leeward
49.	Ouli	--		Intermittent	no data	Leeward
50.	Mamaewa	--		Intermittent	no data	Leeward
51.	Pauahi	--		Intermittent	no data	Leeward
52.	Umipoho	--		Intermittent	no data	Leeward
53.	Waiakamali	--		Intermittent	no data	Leeward
54. *	Luahine	--		Intermittent	no data	Leeward
55. *	Keawewai	--		Perennial	no data	Leeward
56. *	Kilohana	--		Intermittent	no data	Leeward
57.	Waipahoehoe	--		Intermittent	no data	Leeward
58. *	Keanahalululu	--		Intermittent	no data	Leeward

* Source: Perennial streams n83 GIS data files from Statewide GIS website (DLNR 2004).
† Stream classes may need revision.
** Land Use Code: A=Agriculture, C=Conservation.

For years, the presence of an extensive *ʻauwai* (irrigation channel system), has given rise to the possibility that large portions of the Waimea plains were irrigated and cultivated in ancient times. In fact an important legal case on the water rights of Parker Ranch in the early 1900s led to the production of a detailed map of the *ʻauwai* system on the *kula* of Waikōloa Nui, Waikōloa Iki, Lālāmilo and Puʻukapu (Kanakanui et al., 1914; Reg. Map No. 2576), which depicts flow of water to, and through many of the *kuleana ʻāina* (fee simple land interests) awarded to native tenants in the region (Maly and Maly 2004).

Extensive agricultural ditch systems built in the early part of the last century capture surface water and distribute it to agricultural lands and storage reservoirs throughout the northern portion of the island (Figure 3). Originally developed to support an extensive sugar cane industry, the Upper and Lower Hāmākua Ditches, Kohala Ditch, and Kehena Ditch now supply water for ranching, farming and other uses. Streams throughout the WMA have been diverted, mostly for agricultural uses. The County Department of Water Supply also diverts surface water in the WMA for domestic consumption.

Hawaiʻi County Department of Water Supply (DWS) relies on the streams of Kohala Mountain for its primary source of water. The DWS system draws its water from diversions on Waikoloa and Kohakohau streams. Raw water from the streams is stored in 4 reservoirs with a total capacity of over 150 million gallons (MG) and is treated in the DWS filtration plant. This system provides about 2.0 mgd to users in Waimea and as far east as Paauilo and west to the Waiemi subdivision on Kawaihae Road. These communities are some of the few in the State still relying on surface water for domestic consumption. During periods of prolonged dry weather or high water usage, the treatment plant cannot process sufficient surface water sources to meet demand; as a result, DWS has developed a deep well in Waimea to supplement surface water sources with groundwater. Residents in North Kohala depend almost entirely on groundwater for their water supply (approximately 700,000 gallons per day).

DWS is currently updating its water use and development plan, scheduled for completion in 2006. With the existing DWS filtration plant at capacity, stricter Environmental Protection Agency (EPA) standards for surface water used for domestic consumption, and rapid growth

within the North and South Kohala regions taxing water supplies, the county will likely develop more groundwater resources in the very near future to meet the growing demand. Groundwater is also more reliable during periods of dry weather. As one component of the hydrology of Kohala Mountain, the groundwater aquifer also relies on captured rainfall and the watershed functions of the forested watershed. There is a need for greater research on the total hydrology and recharge capacity of Kohala Mountain, as well as the connection between Kohala Mountain hydrology and perched groundwater in the Waimea Plains.

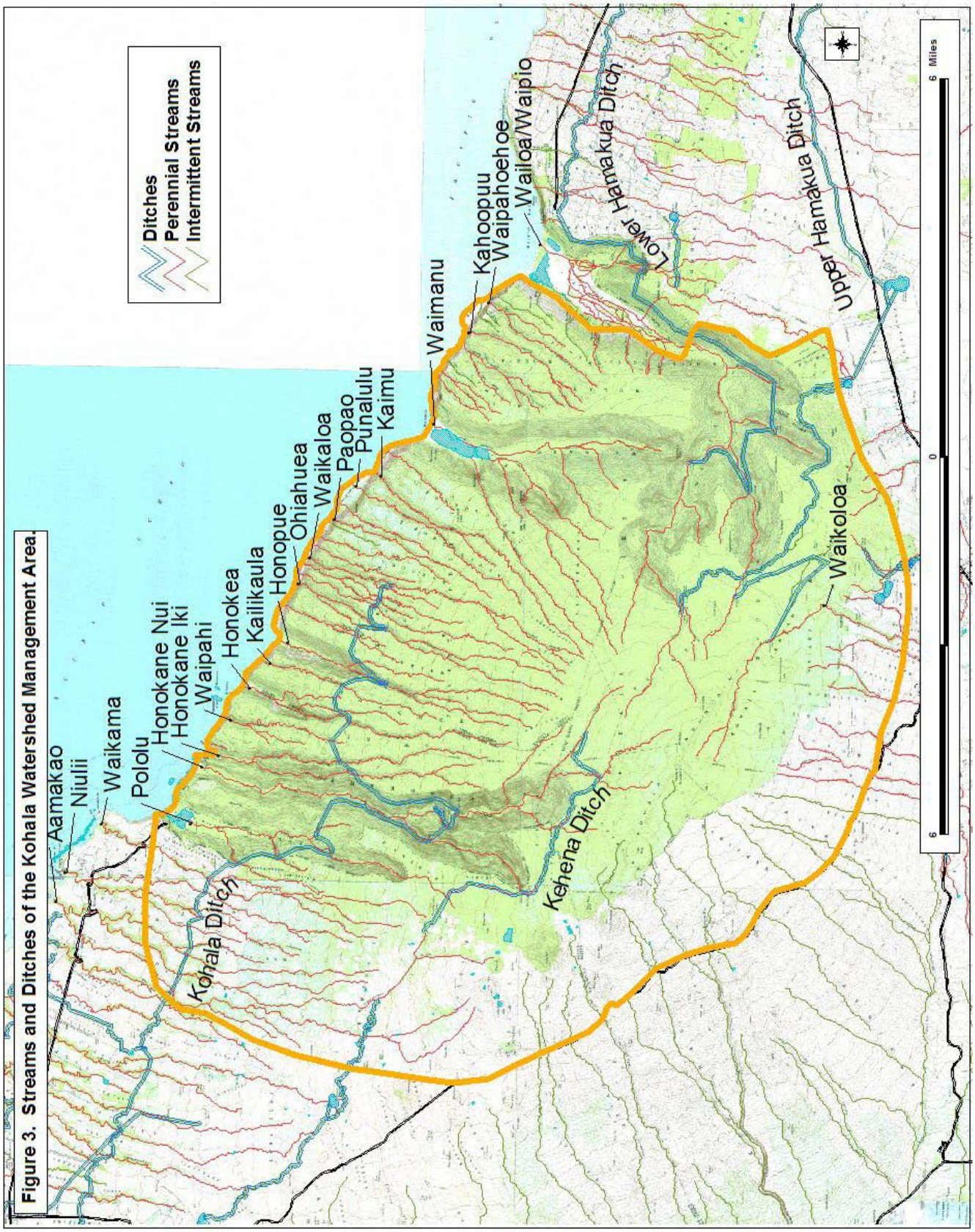

Figure 3. Streams and Ditches of the Kohala Watershed Management Area.

The Hawai‘i Department of Agriculture’s (HDOA) Waimea Irrigation Water System provides agricultural irrigation water to farms in Pu‘ukapu and Lalamilo (Figure 4). Surface water diverted from Kohala Mountain streams flows through the Upper Hāmākua Ditch to the system’s 60 MG Waimea Reservoir and 100 MG Pu’u Pulehu Reservoir (HDOA 2003). Pu‘u Pulehu Reservoir water can be transferred to the Waimea Reservoir via a booster pump and connecting pipeline. The water is then distributed by pipelines from Waimea Reservoir to farm lots in Pu‘ukapu and Lalamilo. In 2003, the system had 117 water service accounts drawing over 330 MG annually (0.906 mgd) on 587 acres of farmland (HDOA 2003). Improvements to the system have been planned to better water conveyance efficiency of the existing system; to add storage capacity; and to expand service to provide livestock drinking water (Waimea-Paauilo Watershed Plan).

The Lower Hāmākua Ditch Irrigation System, also operated by HDOA, diverts the headwaters of four streams (Kawainui, Alakahi, Koiawe, and Waima) in Waipi‘o Valley at the 1,000-ft. elevation (Figure 5). The Waima intake is currently inactive (HDOA 2003). The gravity flow system extends approximately 14 miles to Paauilo Reservoir, the last of five reservoirs scattered along the ditch system. According to HDOA (2003), the Department of Agriculture is still in the process of locating all the buried pipelines that distribute the water laterally from the system. For this reason, the system is not fully metered at this time. In September 1999, the USDA Natural Resources Conservation Service (NRCS) prepared a Lower Hāmākua Ditch Watershed Plan under Public Law 83-566 (Watershed and Flood Prevention Act) that assesses needs and recommends improvements to the ditch system including among other things: flume replacement and repair; ditch lining repair and sediment removal; additional reservoir construction; lateral pipelines; screening and filtration; water meters; and improved intakes. State and Federal monies are funding these improvements, and approximately $20 million have been spent since 2001. One recommendation, the construction of a bypass transmission tunnel behind Hakalaoa Falls in order to restore the waterfall into Waipi‘o Valley, has been completed. Historically, the Lower Hāmākua Ditch system maintained a relatively consistent flow of 30-40 mgd; it is difficult to estimate current usage since the HDOA is still working on maintenance and improvements to the system in order to assure reliable water.

A portion of the Kehena Ditch, abandoned by the sugar plantation in the late 1960s because of its unreliable and inconsistent flow, is still used today, drawing water from Opaeloa Stream. Kahuā and Ponoholo ranches continue to draw water via pipeline from the upper portion of the Ditch for domestic and agricultural uses, drawing on average between 250,000-500,000 gallons per day. They supplement this ditch water with water from the forested Pu’u Pili. Water is stored in several existing reservoirs. New and larger reservoirs are needed to ensure adequate and consistent supplies during drought times.

Parker Ranch continues to use a water system developed in 1902 to extend water to the Waimea-Waikoloa Plains. The system’s supply of approximately 300,000 gallons per day comes from high level intakes in Waikoloa, Kohakohau, Alakahi, and Haunani streams on Kohala Mountain. An extensive system of distribution lines deliver livestock water to Parker Ranch’s widely-spread pasture lands in the Waimea area. Parker Ranch also draws water from streams at Keawewai, Kohakohau, and ‘Ōuli, as well as from portions of the former Kehena Ditch, to fill reservoirs from which water is distributed to tanks and cattle troughs throughout leeward Kohala.

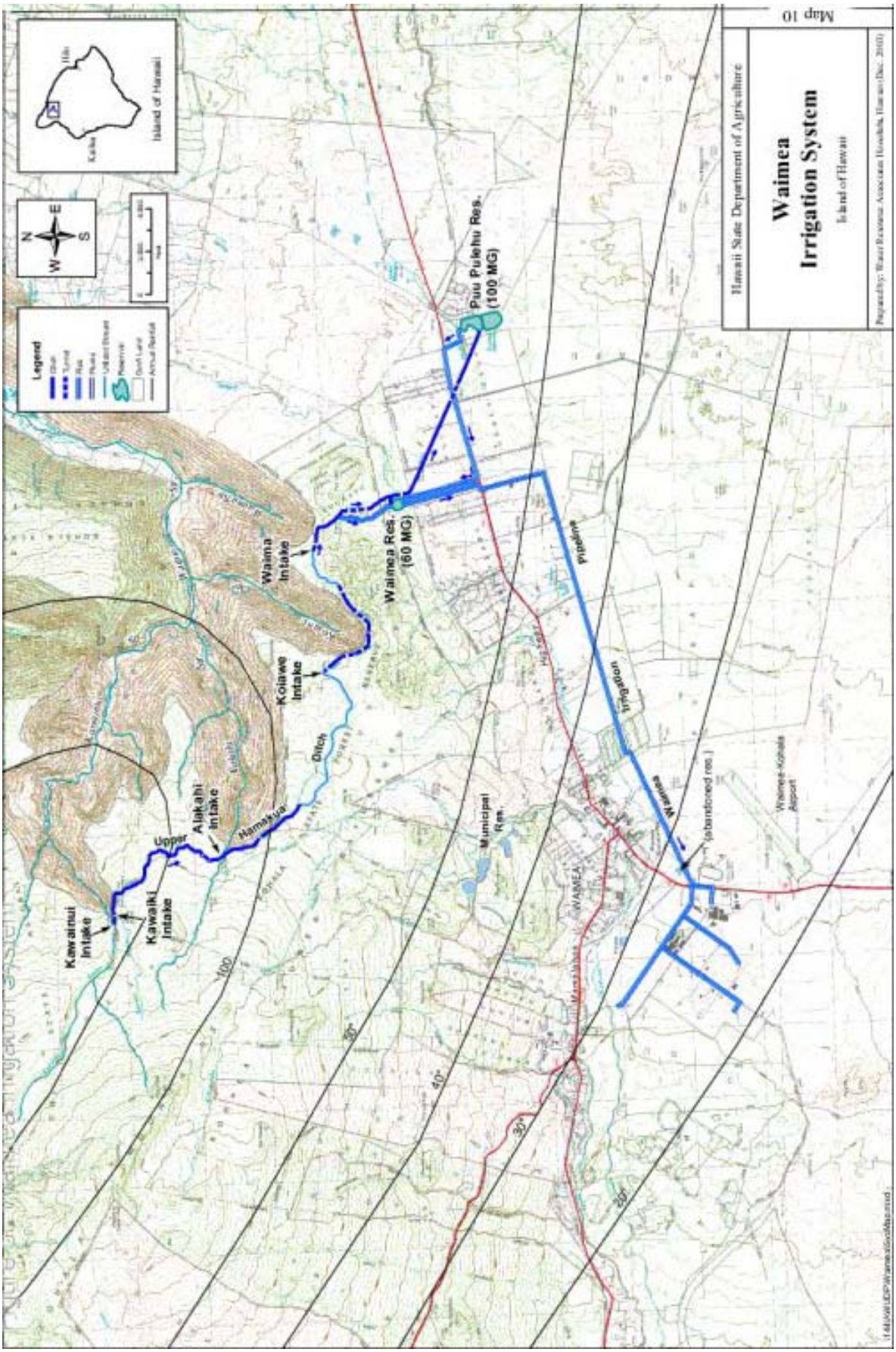

Figure 4: Waimea Irrigation System (taken from HDOA 2003)

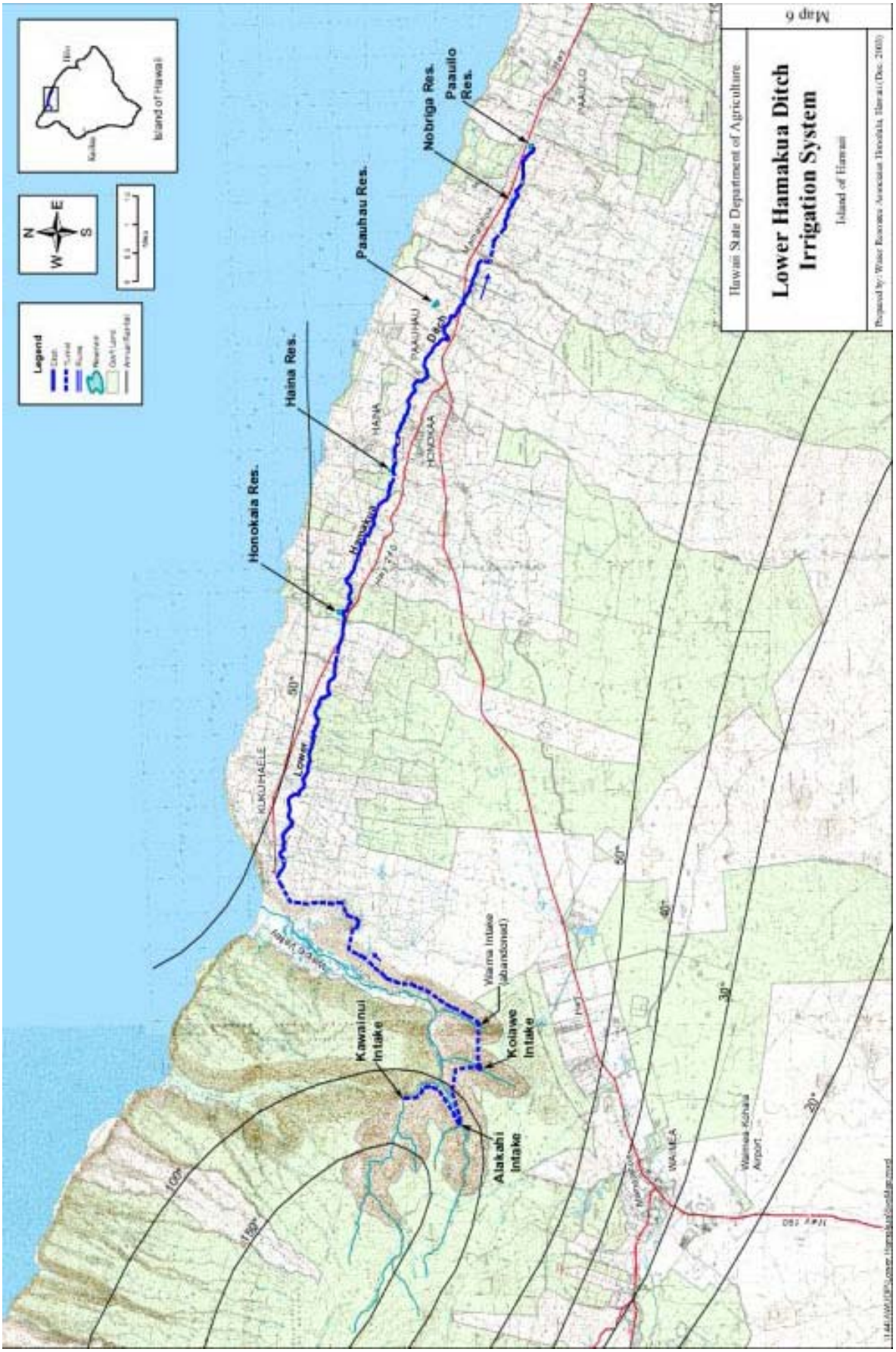

Figure 5: Lower Hāmākua Ditch Irrigation System (taken from HDOA 2003)

The Kohala Ditch, initially developed in the early 1900s by the Kohala Ditch Company to provide water to the Kohala sugar plantations, is currently owned by Surety Kohala Corporation and produces roughly 12-14 mgd during normal flows and is used by a myriad of small private entities for irrigation, hydroelectric power, aquaculture, and livestock water. At this time, the ditch water comes primarily from Honokāne Nui. As demand for the ditch water increases, Surety Kohala Corporation may restore other sections of the ditch system currently in disrepair. The table below summarizes current water usage from Kohala Mountain.

Table 2. Current Water Usage.

Water User	Type of Use	Ave. Amount (mgd)
Dept. of Water Supply	domestic	2.7
Waimea Irrigation System	agricultural	0.906
Lower Hāmākua Ditch Irrigation System	agricultural	30-40 historically ??? current
Kehena Ditch (Ponoholo, Kahua, Parker ranches)	agricultural and domestic	0.25 - 0.50
Parker Ranch	agricultural	0.3+
Kohala Ditch	agricultural, industrial	12 - 14
Waipiʻo Valley taro farmers	agricultural	30 - 50

Drought conditions have affected the Hawaiian Islands throughout history. These events often reduce crop yields, diminish livestock herds, desiccate streams, irrigation ditches and reservoirs, deplete groundwater supplies, and lead to forest and brush fires. Periods of drought invariably give rise to water crises, sometimes requiring imposition of emergency conservation measures. The users of the water resources of Kohala Mountain have been particularly susceptible to drought conditions in the past, and the Hawaiʻi Drought Plan identifies this region as an area vulnerable to drought impact. Severe droughts over the past century that have affected North Hawaiʻi or Kohala occurred in 1901, 1908, 1912, 1953, 1962, 1965, 1971, 1977-78, 1980-81, 1983-85, 1996, 1998-1999, and 2000-2002 (DLNR-CWRM website). According to DLNR-CWRM (2004) the "drought of 1998 to 2003 has wreaked havoc on the farmers and ranchers of Hawaiʻi, especially those on the southeastern end of the State." The most severe events of the past 15 years have been associated with the El Nino phenomenon.

The Commission on Water Resource Management (CWRM) recently updated the Hawaiʻi Drought Plan (DLNR-CWRM 2004) to "serve as a 'framework' through which State and local entities can work together to proactively implement mitigation measures and appropriate response actions during periods of drought. Effective coordination of these activities can help reduce and minimize the effects upon the people and natural resources of Hawaiʻi."

Flooding can be equally disastrous to the communities on and surrounding Kohala Mountain. While flooding is a natural process that has occurred throughout time, it has been accentuated in modern history by human habitation and development. Periodically, pressure systems destabilize normal weather patterns around North Hawaiʻi and result in the development of heavy showers and thunderstorms. This, combined with the flashy nature of Kohala streams, can cause flash flooding. A storm on March 14, 2004, washed out a portion of Kohala Mountain Road, cutting off traffic on this road for two months. This same storm caused major flooding in and around Waimea, closing all roads into town and damaging the town's major water supply lines. Several weeks later, another storm caused a portion of the road through

Kapa`au to wash out. Waipi‘o Valley is also particularly susceptible to flooding, and floods over the years have caused significant economic damage.

C. Biological Resources

In Hawaiian culture, natural and cultural resources are one and the same. Native traditions describe the formation (literally the birth) of the Hawaiian Islands and the presence of life on, and around them, in the context of genealogical accounts. All forms of the natural environment, from the skies and mountain peaks, to the watered valleys and lava plains, and to the shore line and ocean depths are believed to be embodiments of Hawaiian gods and deities (Maly and Maly 2004).

1. Ecosystems

Prior to the arrival of humans, Hawaiian life forms evolved in complete isolation for as many as 70 million years. Because the Hawaiian archipelago was never connected to a continent, colonization of the land masses had to occur across 2,000 miles of open ocean by way of wind, storm-driven birds, or floating. Successful colonizations occurred on the average of once every 35,000 years. From approximately 2,000 colonizing ancestors (405 plants, 350 insects, 23 snails, 20 land birds, and numerous fungi, liverworts, mosses and lichens) evolved approximately 8,500 to 12,500 species: plants (1,128), insects (6,000-10,000), land snails (1,200), land birds (115); and numerous fungi, liverworts, mosses and lichens (Loope 1998). As a result, Hawai‘i’s percentage of endemic species[2] is very high.

Kohala Mountain forests, bogs, and streams support over 155 native species of vertebrates, crustaceans, mollusks, and plants. Fungi, liverworts, mosses and lichens further contribute to its biological diversity. The complexity and diversity of its ecosystems are significant in comparison to other volcanoes on the island.

Pacific-wide biomes represented on Kohala include coastal strand, lowland tropical rain forest, montane rain forest, cloud forest, montane bogs, and mesophytic (moist) forest – all ecological zones determined primarily by macroclimate. Azonal ecosystems, those dictated by adaptive factors, are represented by windward coastline vegetation, bogs, aquatic ecosystems, and cliff environments (Mueller-Dombois and Fosberg 1998).

The **coastal strand vegetation** is characterized by salt-tolerant plants, many of which have indigenous distributions beyond Hawai‘i. Inland from there up to 2,500-ft. lies the **Lowland Wet Forest**. This type occurs only on the windward side of the WMA. Above 2,500-ft., the **Montane Wet Forest** covers the windward slopes and a **Diverse Mesic Forest** covers the leeward side above pasture lands. Smaller patches of other plant communities within these major vegetation types include **Montane Wet Bogs**, **Lowland and Montane Shrub and Grasslands**, and **Wet and Dry Cliffs** (DLNR 1989; Gagne and Cuddihy 1990).

Cloud forests in Hawai‘i are represented on most of the major islands. Cloud forests make up only 2.5% of the total area of the world’s tropical forests. The frequent presence of clouds and the additional input of water from intercepted fog significantly influence the hydrology, support

[2] Endemic species are species found only in Hawai‘i and nowhere else in the world.

ecosystems of distinctive floristic and structural form, and contain a disproportionately large number of the world's endemic and threatened species (Stadtmuller 1987; Scholl *et al.* 2004).

Older cloud forests possess an abundance of epiphytic plants, such as mosses and ferns that grow on the trunks and branches of trees. In cloud forests, up to a quarter of all plant species may be epiphytes[3] (Foster 2001). The epiphytes capture water directly from the fogs and clouds and provide a variety of microhabitats for invertebrates, amphibians and their predators (Benzing 1998). Water storage in epiphytes has been calculated as ranging from 3,000 liters per hectare (Richardson *et al.* 2000) up to 50,000 liters/ha (Sugden 1981). Up to half the total input of nitrates and other ions and nutrients to the forest can come from water stripped from clouds by epiphytes (Benzing 1998).

Occurring as open patches within the montane cloud forest are wet bogs, a community dominated by grasses or sedges, with few woody plants. Kohala mountain support a large bog-cloud forest mosaic across the gently sloping upper windward slopes. It is believed that bogs develop on poorly drained areas where clay soil formation impedes drainage, causing accumulation of perched water on top of the clay, thereby drowning out root systems of woody plants. Hawai'i Island bogs are characterized primarily by sedges, sphagnum moss, and low-stature 'ōhi'a of varying density (Gagne and Cuddihy 1990). Two specific rare bog communities known from Kohala Mountain are the **Mixed Grass and Sedge Montane Bog** and the **'Ōhi'a Mixed Montane Bog**, located adjacent to one another at approximately 3,700-feet in the eastern section of the Pu'u O 'Umi Natural Area Reserve (NAR).

Other unique plant communities from windward Kohala include the *Carex alligata* **Montane Wet Grasslands** and the **Mixed Fern/Shrub Montane Wet Cliffs**, where the steep slopes and cliffs are covered by fern and shrub communities. Three distinct types of 'ōhi'a-dominated forest cover the majority of the WMA: **'Ōhi'a-Olapa Montane Wet Forest** comprises the majority of the 'ōhi'a-dominated forests; **'Ōhi'a Mixed Shrub Montane Wet Forest** usually occupies the best drained areas on the ridge tops; and a broad expanse of **'Ōhi'a-Uluhe Montane Wet Forest** covers the north slopes, ridgetops, and areas recovering from disturbance. Vegetation within the WMA varies across the topographically-complex landscape.

Perennial and intermittent streams comprise another important ecosystem on Kohala Mountain. Hawai'i's streams are generally short (less than 10 miles in length), with numerous waterfalls giving the streams steep profiles. Streamflow typically tracks rainfall patterns. The isolation of the Hawaiian archipelago has resulted in high levels of endemism in the aquatic species: at least 5 native species of fishes (4 endemic, 1 indigenous[4]), 2 species of crustaceans (all endemic), 3 species of mollusks and many species of native arthropods (all endemic).

An important factor that may contribute to the success of long-term conservation of Kohala Mountain's unique ecosystems is the simple fact that they occur on Hawai'i Island. The Island of Hawai'i has an area of more than 4,028 square miles (10,000 sq. km) comprising 63% of the total area of the State, and two high peaks over 13,600 ft (4,146 m). As such, Hawai'i Island possesses by far the most acreage of contiguous native-dominated forest within the State

[3] Epiphytes are plants physically growing on other plants.
[4] Indigenous species are native to Hawai'i but also found elsewhere.

(Juvik and Juvik 1998). Given the rising number and rates of alien species invasions, and other habitat-altering factors such as wildfire and habitat encroachment occurring throughout the State, the large contiguous forests of the island of Hawai‘i may hold the best promise for long-term conservation of Hawaiian ecosystems.

Unfortunately, the isolating factors that have contributed so much to the uniqueness of Hawai‘i’s ecosystems also have made them particularly vulnerable to the effects of many alien species. Many major groups of organisms common on continents, such as land-dwelling mammals, coniferous trees, and ants, never made it to Hawai‘i prior to human arrival. As a result, there was no need for Hawai‘i’s native species to develop traits that favored resistance to pressures such as predation, feeding of rodents, and effects of hoofed animals. In addition, the effects of human activities such as burning, logging, cattle grazing, crop agriculture, development, and wildfire on habitats drove out most lowland species. It is estimated that 170 species of native birds, snails, and insects have disappeared within the last 200 years (Cuddihy and Stone 1990; HBS 2004).

Large-scale extinctions of terrestrial mollusk, arthropod, and bird faunas throughout the Pacific are attributed primarily to the spread of rats that accompanied Polynesian dispersal. In Hawai‘i, rats have had particularly devastating effects on snails, birds, and arthropods (Atkinson 1977).

Extreme reductions in the numbers of sea and forest birds are believed to have affected ecosystems and their inhabitants. Seabirds, waterbirds, and forest birds contributed an enormous amount of organic waste to terrestrial ecosystems (Loope 1998). The contributions were mainly in the form of guano, but also lost eggs, dead birds, spilled food, and molted feathers (Loope 1998). The nitrogen and phosphorus-rich guano deposits would have enriched soils and likely affected vegetation and ecological community structure.

Notable is the relative isolation of Kohala Mountain’s forests from those of adjacent Mauna Kea. The ecologic gap between the two mountains was formerly forested, allowing an exchange of genetic material between the two volcanoes.

The range in habitats and species is also reflected in native Hawaiian mele, which reflect the types of species found and the condition of habitats in these areas (Maly and Maly, 2004):

He lā manu ka kēia o Waipiʻo,	This is a day that the birds gather at Waipiʻo
Ke wili nei i ka lehua,	Encircling the *lehua*,
Ke piʻi nei ka ʻōpae kalaʻole,	The clawless shrimps (inexpert competitors) rise up,
Ka hinana pākanaka o Wailoa,	As do the tame *hinana* shellfish of Wailoa,
E hoʻokomo ana i ke ao a ka ua,	The rain clouds enter the valley,
He lā ua kēia kūʻululū nei,	It is indeed to be a cold rainy day,
Kūʻululū ka manu ua ʻōpili,	The birds are chilled, numbed by the rain (filled with anxiety),
ʻŌpili i ka ua hoʻokina lēhei pā,	Numbed in the rain which blemishes, and passes over walls,
He pā mauka, he pā makai,	Striking the uplands, striking the lowlands,
Pōʻai a puni a koe koena,	Encircling all who remain,
I hoʻokoe ʻia na Ka-Miki,	All [the competitors] who remain for Ka-Miki
No ka uhu haehae ʻupena o nā pali,	Who is like the *uhu* fish of the cliff which tears at the net
No ka iʻa nahu kananā o ka hulaʻana,	Who is like the fierce biting fish [shark] of the *hulaʻana* (swimming trails).
Ka ʻalaʻihi kala loa e pau ʻai	The *ʻalaʻihi kala loa* [*Holocentrus*] fish which
nā lima i ka ʻekeʻeke!	consumes [pierces] hands in the fisherman's bag (one who should not be trifled with)!

2. Species Biodiversity

There are over 15,000 native organisms known from Hawaiʻi, but the number is rising as paleo-ecological research discovers extinct species new to science (Olson and Olson 1991; Steadman 1995; Burney *et al.* 2001). Biological diversity (biodiversity) can be defined on a range of scales from genetic to ecosystem. To use species as the measure of biodiversity, Kohala Mountain's total biodiversity is represented in the total of the sum of the species, their interactions, ecological functions, and ecological processes performed.

Biodiversity is important for ultimately providing ecological services that are of value to society. Based on a broad review of scientific evidence, a panel of well-respected evolutionary ecologists determined with certainty that, "1) Ecosystem services are essential to civilization; 2)They operate on such a grand scale and in such intricate and little-explored ways that most could not be replaced by technology; 3) Human activities are already impairing the flow of ecosystem services on a large scale, a trend that is deleterious to the welfare of all" (Daily *et al.* 1997). They were also confident, again based on scientific information, that: "human activities may cause deterioration of ecological services whose value, in the long term, dwarfs the short-term economic benefits society gains from those activities" (Daily *et al.* 1997). They

further stated that the functioning of many ecosystems relied on very large numbers of species and populations that are required to sustain ecosystem services.

Native Birds

The Kohala WMA provides a diversity of bird habitats that support over a dozen species of sea birds, 4 forest birds, 2 waterbirds, and a hawk. Native waterbirds (Anatidae) of Hawai‘i were the largest animals in the Hawaiian ecosystems. There were more than 12 species in this group, including now extinct giant flightless geese and ducks. Numerous pressures pushed these species to extinction, and, today, the Hawaiian Duck or Koloa maoli (*Anas wyvilliana*) and Hawaiian Goose or Nēnē (*Branta sandvicensis*) are the only members of the family remaining within the main islands of the Hawaiian archipelago. The third extant species from this group is the Laysan Duck (*Anas laysanensis*), which is now known to have once been distributed widely within the islands. Individual ducks from the Laysan population were recently trans-located from Laysan to Midway Atoll in a recovery effort that is off to a successful start.

In addition to being our State bird, the Hawaiian Goose or Nēnē (*Branta sandvicensis*) is considered the eighth most endangered waterfowl species in the world. There are approximately 1,220 individuals in Hawai‘i, of which 620 occur on the Island of Hawai‘i. In addition, there is a captive-bred population of 55 on Moloka‘i. Nēnē were once widespread throughout the islands, but suffered drastic decline due to human hunting, predation by mongoose and feral cats, and other human-induced stresses, until limiting factors started to be addressed and a captive propagation program was initiated by the State of Hawai‘i in 1949 (USFWS 2004). Nēnē use Kohala Mountain occasionally.

The Koloa maoli, an endangered species, inhabits wetlands, ponds, and streams of the WMA. The Koloa maoli was once a widespread species that inhabited coastal marshes of all the main islands except the dry islands, but today it is found only in upland ponds and along mountain streams. It had been reduced to 500 individuals on Kaua‘i and 30 on O‘ahu by the mid-1900s (Schwartz and Schwartz 1949). Its decline has been due to the loss of wetland habitat, hunting, predation by introduced animals (*e.g.*, rats, dogs, cats), and other factors. Furthermore, hybridization of Koloa maoli with feral populations of the closely related mallard (*A. platyrhynchos)* threaten to genetically alter the species (Engilis and Pratt 1993).

A Koloa maoli restoration program was initiated in 1962 by the World Wildlife Fund and the State. By 1979, 350 Hawaiian ducks had been released on O‘ahu and Hawai‘i as part of the program. Recent estimated populations are 2,000 Koloa maoli on Kaua‘i-Ni‘ihau, 300 on O‘ahu, 25 on Maui, and 200 on the Island of Hawai‘i (Engilis 1998). The Hawaiian Duck was listed as an endangered species in 1967 under the Federal Endangered Species Act. The Hawaiian Waterbirds Recovery Plan was completed in 1978, revised in 1985, and is currently being revised and updated again based on a 1999 draft plan. Kohala ponds and streams are probably the most important habitat for these birds on Hawai‘i Island.

The Hawaiian Hawk or ‘Io (*Buteo solitarius*) is widespread on the island of Hawai‘i. Fossil bones recovered on Moloka‘i and Kaua‘i indicate that it may have once been distributed throughout the main islands (Olson and Olson 1982; Burney *et al.* 2001). Its population size is estimated to be between 1,320 and 1,594 hawks, and its distribution essentially follows that of native forests (Klavitter 2000). The ‘Io’s preferred nesting trees are large ‘ōhi‘a. While the ‘Io once fed mainly on forest birds, its diet now consists mainly of introduced rodents (Klavitter

2001). It is not known precisely what proportion of the hawk's population is distributed on Kohala Mountain.

Hawai'i's other endemic raptor is the Hawaiian Owl or Pueo (*Asio flammenus sandwichensis*). Owls inhabit dry forests and rainforests, but are most often seen hunting in leeward pastures. Active during the day and evening hours, the primary diet of the Pueo is rodents. Before rodents arrived, pueo is believed to have fed on the small Hawaiian rail (*Porzana* sp.), a flightless bird that is now extinct.

The 'Auku'u or black-crowned night heron (*Nycticorax nycticorax*), also inhabits wetlands, ponds, and streams within the WMA. Black-crowned night herons are found by marshes at night and by day they roost communally. Night herons are distributed almost worldwide, including North America, South America, South Europe, Africa, South Asia, Falkland Islands, and Hawai'i. In the Hawaiian Islands, the 'Auku'u can be found in all coastal wetlands. The diet of the Black-crowned night heron depends on what is available, and may include algae, fishes, leeches, earthworms, insects, crayfish, squid, amphibians, small rodents, plant materials, and garbage. They have been seen taking baby ducklings and other baby water birds.

Seabirds such as the Newell Shearwater, Hawaiian Petrel, and the migratory Kolea or Pacific Golden Plover (*Pluvialis fulva*) also occur within the WMA. The Newell Shearwater or 'A'o (*Puffinus newelli*) is federally-listed as "Threatened." Records of sightings and calls suggest that 'A'o colonies exist within the Hāmākua and Kohala forests but that these colonies are very dispersed and probably contain very few individuals (Kepler *et al.* 1979). `A`o nest in burrows in steep mountainous terrain between 500 and 2,300-ft. elevation, usually in association with uluhe. Because the birds are active at night and nest in dense rain forest on steep slopes, nesting sites are difficult to locate (USFWS 1983).

The Hawaiian Petrel or 'Ua'u (*Petrodromus sandwichensis*) occurs throughout the North Pacific and migrates between the west coast of California and Hawai'i every year. Once perhaps the most abundant bird in the islands, the petrel has around five populations in Hawai'i totaling between 400-600 individuals (Scott 1986; Harrison 1990; Engilis and Pratt 1993). They nest in burrows 3-6+ ft. deep in steep mountainous terrain between 500 and 2,300 ft. elevation from March through November each year. As with the 'A'o, their burrows are used repeatedly as they return from year to year (USFWS 1983). 'U'au suffered serious declines in both the prehistoric and historic periods. Traditional hunting and predation by the Polynesian rat, dogs, and pigs eliminated 'ua'u populations in the lowlands prior to Western contact. Since then, predation by feral cats, mongooses, dogs, pigs, and all three species of rat now present in Hawai'i, combined with large-scale habitat loss, hunting, and degradation by humans and introduced hoofed mammals, have further reduced the species. Fledglings making their initial flight to the sea can also be disoriented by urban lighting and fly into utility lines and other obstacles. Once grounded, they are vulnerable to predation and being struck by automobiles.

The forest birds 'elepaio (*Chasiempis sandwichensis)*, 'amakihi (*Hemignathus virens*), 'apapane (*Himatione sanguinea*), and 'i'iwi (*Vestiaria coccinea*) are most abundant in closed-canopy forests of 'ōhi'a and 'ōlapa (both the 'apapane and 'i'iwi, along with the now extinct 'ō'ū and 'ō'ō, have been historically documented and linked in Kohala with native Hawaiian use).

On Kohala Mountain, the majority of these native birds are found above the 4,000-ft. elevation, above the range of mosquitoes which can transmit avian diseases. Introduced bird species also pose a threat to native species through competition for food and other resources or as potential vectors for avian diseases and parasites. The Hawai‘i Forest Bird Survey, conducted from 1976-1981, established the status of several of these species (Scott *et al.* 1996).

Extinct Birds

The rate of extinction within Hawai‘i's endemic birds is by far the highest in the United States and is approached worldwide only within a few other isolated island groups. At the time of Captain Cook's visit in 1778 about 93 species and subspecies of native birds were breeding in Hawai‘i. In the ensuing two centuries, at least 23 of these have gone extinct (A.O.U. 1983) and another 13 are imperiled. George Munro (1944) reported observing the Drepanid ula-ai-hawani (*Ciridops anna*) along the "Kahua Ditch Trail" on Kohala Mountain. The species reportedly fed on seeds of the hawane palm (*Pritchardia* sp.). He also reported that the mamo (*Drepanis pacifica*) was known to frequent the interior of the forest area, where ‘akialoa (*Hemingnathus procerus*) and the ‘Oma‘o or Hawaiian thrush (*Myadestes obscura*) were also observed (Munro 1944). Recent discoveries of the bones of prehistorically-vanished species now reveal a vast array of former birds that became extinct long before Captain Cook arrived. Extinct flightless bird species reported from Pu‘u Wa‘awa‘a, such as the flightless Hawaiian goose (*Nesochen sandvicensis*), flightless rails (*Porzana* sp.), a slender-billed crow (*Corvus* sp.), the Kioea (*Chaetoptila angustipluma*), the long-billed akialoa (*Hemingnathus* sp.), and the Hawai‘i ‘o‘o likely also inhabited Kohala Mountain (Giffin 1993). Ancient DNA extracted from an array of fossil duck bones from Hawai‘i revealed that the Laysan duck (*Anas laysanensis*) was once very widespread, from near-coastal areas well into the forests at 5,900-ft. elevation (Cooper *et al.* 1996).

Native Bat

The Hawaiian hoary bat or ‘Ope‘ape‘a (*Lasiurus cinereus semotus*) is the only extant land mammal native to the Hawaiian archipelago. It was listed as endangered in 1970 due to apparent population declines and a lack of knowledge concerning its distribution, abundance, and habitat needs (USFWS 1998). However, recent research indicates that the bat may be more widely distributed than previously believed, use both native and non-native habitats, and move seasonally between regions of the island (Menard 2001). Menard found patterns of annual migration up and down slope and that males persisted in upland areas during most of the year. However, her research did not include the Kohala region. Bats are frequently seen along the windward Kohala coast, especially between Waipi‘o and Waimanu valleys. Data on the food preferences of the species indicate that ‘ope‘ape‘a consume a broad range of insects, including many beetles (Whittaker and Tomich 1983).

Native Snails

One of the most highly diversified groups of animals in Hawai‘i are the native land snails (Cowie *et al.* 1995). The greatest known concentration of tree snails ever recorded in the islands occurred on the Waimea Plains in 1903, where approximately 75,000 *Partulina confusa* were seen in an area of one-half square mile on 150 olopua (*Nestegis sandwicensis*) trees (Pilsbry and Cooke 1912-1914). But the land snails suffered dramatic declines resulting from rat predation, habitat destruction, and overcollecting (Hadfield 1986; Hadfield *et al.* 1993; Hadway and Hadfield 1999). Particularly rare are members of the arboreal Achitinellidae family. The Island of Hawai‘i once supported dozens of species in the family (Hadfield and

Miller 1989); however, today only a single population of one species of the family are known from the island (Hadway and Hadfield 1999). In 1992, researchers found *Partulina physa*, previously not recorded since 1946, on forested leeward slopes on Kohala Mountain. Other snails observed within the WMA include succinids and minute tornatellinids (DLNR 1989; Hadway and Hadfield 1998). A comprehensive mollusk inventory for Kohala Mountain has not been made. Appendix A includes a preliminary list of snail species found on Kohala Mountain.

Native Arthropods

Hawai'i's native terrestrial arthropods are most noted for their large number of unknown species and extremely high rate of endemism (99%) (HBS 2004). Generally, Hawai'i's native arthropod fauna includes insects, arachnids, crustaceans, and myripods. Kohala's native arthropod fauna is particularly rich and supports many rare species (Appendix A).

Native Aquatic Species

Kohala streams also support a unique and diverse fauna. Dozens of freshwater streams entering the ocean along the windward coastline support a relatively intact and diverse native stream fauna. The fishes consist of two closely related families, *Gobiidae* and *Eleotridae*, usually referred to as *o'opu* or gobies. In fact, the goby fish is featured in a native Hawaiian story of the testing of two brothers where in a contest, one of the required items was an 'o'opu 'ai lehua (lehua blossom eating goby fish) known from Hi'ilawe in Waipi'o. According to DLNR's Division of Aquatic Resources, the gobies "are particularly adapted to the rocky, steep, flashy-flow nature of Hawaiian streams" (DLNR-DAR website). The native crustaceans include the 'opae kuahiwi or mountain opae (*Atyoida bisulcata) and* opae 'oeha'a **(***Macrobrachium grandimanus).* There are three endemic species of river *opihi* (limpets), the most common of which is the hihiwai (*Neritina granosa*). Most native Hawaiian stream animals share a unique life cycle pattern called amphidromy[5]; this life cycle underscores the importance of maintaining natural stream flows.

There are many small streams that drain from the Kohala summit, most of which harbor native aquatic insects, fishes, crustaceans, and mollusks. Currently, there is inadequate data pertaining to the ecological condition of Kohala's streams, but the general opinion among biologists is that they are relatively intact compared to those of Hāmākua and other islands (Okamura 2003). A baseline condition needs to be established and a monitoring program developed that uses biological and physical criteria to characterize various biotic and environmental features (Englund and Arakaki 2004; Englund *et al.* 2003; Kido and Smith 1997).

Members of Laupahoehoe Nui, LLC partnered with the University of Hawai'i's Hawai'i Stream Research Center to collect baseline biological and physical information for windward streams between Waimanu and Honopue, including every stream from Kaimū to Ohiahuea. They found all of the native stream fishes present.

[5]In an amphidromous life cycle, the species lays its eggs in the stream. The larvae migrate downstream and are swept out to sea. In the post-larval stage, the juveniles return to their freshwater habitat, migrating upstream and often climbing numerous waterfalls.

Invasive aquatic species are those that are non-native and are likely to cause economic or environmental harm, or harm to human health (Shluker 2003). Mexican minnows are among Hawai'i's most ecologically-disruptive invasive aquatic species that have become established in north Kohala Mountain streams but have not yet made it into the Kohala Ditch. They compete with native algae eaters and could prey on baby o'opu; however, they cannot climb waterfalls, limiting their access to low gradient channels. Tahitian prawns (*Lar sp.*) are also disruptive and have the capability to climb waterfalls. Crayfish (*Procambarus clarkii*) are also considered very disruptive, and Talapia (*Oreochromis mozambicas, O. zellei, and other Oreochromis* species), which compete for food, are well-established throughout Kohala streams. In addition, the Chinese catfish (*Clarius fuscus*) is migrating toward interior Kohala from Waipi'o and the Saltwater tilapia (*Sarotherodon sp.*) from the North Kohala side; however, neither is yet documented within the WMA. A list of native and exotic stream animals is included in Appendix A.

Native Plants

Hawai'i is recognized for its high levels of endemism. Approximately 12,000 – 13,000 species of native flowering plants are recorded for Hawai'i, 95% of which are endemic to Hawai'i. The 12,000 or so endemic species evolved from approximately 270 successful plant colonizing species. Approximately 32 Hawaiian genera (16%) are endemic (Wagner 1985). Hawai'i's unique native flora has formed the fabric in which Hawai'i's biological and cultural heritage is woven.

Like other groups of terrestrial organisms, Hawai'i's native flora has suffered the effects of centuries of change. Approximately 10% of Hawai'i's native plants are extinct and roughly 50% are threatened or endangered. Many of these species that meet criteria for formal federal/state listing as Threatened or Endangered have escaped designation due to administrative limitations. But rare species that are not formally recognized remain important components in ecosystems. An evaluation of plant taxa that were candidates for federal listing in 1985, conducted by island, found mesophytic forests and low-elevation rain forests of Hawai'i Island to be the most degraded ecological zones, harboring 20% and 25% of candidate taxa, respectively. In contrast, they found Montane rain forests to harbor 10% of taxa (Wagner 1985). Upper leeward Kohala slopes support particularly diverse Montane moist forests that may harbor a greater percentage of the island's rare flora than indicated by the study.

The WMA and Kohala vicinity contain over three dozen federally-listed plant species. These rare plants vary in habitat from dry to wet, windward coastal sea cliffs to the montane bogs of the summit region, over to the remnant dry forest still extant in the pastures and gulches of leeward Kohala.

Although portions of the WMA have been surveyed for rare plants, large expanses have not been thoroughly searched, and specific threats to many of these species are unknown. For this reason, this plan addresses all rare species that may need management attention to control threats to survival and stabilize their populations. Management actions are proposed to protect known rare and endangered plant communities and to address threats to native plants generally; other actions to protect high-yield watershed areas, such as fencing and ungulate control, will also benefit rare plant species. A list of rare plant species is included in Appendix A.

One of Kohala's most conspicuous rare plants is the *Trematalobelia grandiflora*. The name referring to its unusually large flower, *T. grandiflora* is a member of a 4-species endemic genus. It occurs in wet, windswept cliffs and in wet forests and low, boggy wet forests, on Kohala Mountain, in the saddle between Mauna Kea and Mauna Loa, and in and around Hawai'i Volcanoes National Park. The 3-13-ft. tall Lobeliad shrubs bear 5-10 flower branches 1-2 ft. long, each branch forming a raceme of 1-2 in. curved corollas white to pink to rose, or sometimes rose-streaked. Other notable rare plants from Kohala include the stately loulu fan palm, *Pritchardia lanigera*, and another endangered Lobeliad ōhāwai, *Clermontia drepanomorpha*, both of which occur only on Kohala Mountain.

The ohawai is a kinolau of Uli, a goddess of sorcery, for whom an area in Kohala is thought to be named.

Hole Waimea i ka ihe a ka makani,	Waimea is stripped by the winds,
Hao mai na 'ale a ke kīpu'upu'u.	The buffeting waves of the *kīpu'upu'u*.
He lā'au kala'ihi ia na ke anu,	The forest is hardened in the cold,
'O'o i ka nahele o Māhiki.	Matured in the forests of Māhiki.
Ku aku la i ka malanai a ke Kīpu'upu'u.	Rising and spreading out before the *kīpu'upu'u*.
Holu ka maka o ka ōhāwai o Uli,	The centers of the *ōhāwai* (*lobelia*) blossoms of Uli sway,
Niniau 'eha i ka pua o ke koai'e,	The *koai'e* blossoms droop in pain,
'Eha i ke anu ka nahele o Waikā…	The forest of Waikā is pained by the cold…

(cf. Roberts, 1967; Maly, translator)

Extinct Native Species

Recent paleological research documents ecological and climatic change that has occurred over the past 10,000 years. Periods of dry and wet climate caused fluctuations in composition of vegetation and relative proportions of major groups of species, such as ferns and woody plants (Burney *et al.* 1995). But also notable were more recent changes in species coinciding with the arrival of humans. It is well-established from pollen and fossil bird studies that recent extinctions are the result of human activities. Forest clearing on many islands is signaled in changing pollen spectra from sediment cores, with tree taxa rapidly giving way to ferns and grasses; also characteristic are sharp increases in microscopic charcoal influxes, indicating human-induced burning, in most cases probably associated with shifting cultivation. On some islands, forest clearance led to increased erosion rates, along with alluviation of valley bottoms or along coastal plains. The exploitation of natural resources is particularly evident in the zooarchaeological assemblages from early settlement sites, which are characterized by high numbers of land and seabirds, many of them representing now extinct or extirpated species (Steadman 1995, Kirsch 2004). The effects of rats are believed to have played a large role in those extinctions. Extinctions of the past few hundred years include the ula-ai-hawani last seen on Kohala Mountain, the mamo (*Drepanis pacifica*), the akialoa (*Hemingnathus procerus*), and the 'Oma'o (Munro 1944). Also extinct are the flightless Hawaiian goose, flightless rails, a slender-billed crow, the Kioea, the long-billed akialoa, and the Hawai'i 'o'o (Giffin 1993). The Laysan duck and the tree snail *Partulina physa* are examples of two

important Hawaiian species that are close to extinction, but could possible by recovered through intensive habitat management.

D. Socio-cultural Resources

1. Land Ownership, Land Use Zones, and Land Management History

Land Ownership

There are 8 major landowners holding properties of more than 500 acres within the Kohala Mountain Watershed Management Area. These landowners, as well as the acreage of their holdings, are listed in Table 3. These landowners are all members of the KWP. Land ownership is spread across the landscape between public and private landowners, with approximately 56% of the WMA publicly-owned. This distribution of land ownership provides many opportunities for public-private partnerships to implement management projects in the watershed.

Table 3: Total Acreage of Parcels that occur within the WMA.

Major Owner	WMA Acres	Proportion
Govt. State DLNR	34,862	52%
Kamehameha Schools	9,088	14%
Surety Kohala Corporation	5,072	8%
Parker Ranch	4,408	7%
Govt. State DHHL	2,949	4%
Laupahoehoe Nui, LLC	2,261	3%
Kahua Ranch	2,346	4%
Queen Emma Land Company	2,261	3%
Ponoholo Ranch	2,196	3%
Other under 500 Ac	1,325	2%
Grand Total	66,768	100%

Special Management Areas and Land Use Zones

The Hawai‘i Coastal Zone Management (CZM) Act, Chapter 205A, HRS, requires counties to issue use permits for development in coastal areas falling within designated Special Management Areas (SMAs), to ensure that the development is consistent with the objectives and policies of the Hawai‘i CZM Program. While in most places the SMA encompasses coastal lands extending not less than 100 yards inland from the shoreline, along the windward Kohala coast the SMA boundary extends several miles inland to cover areas in which coastal resources are likely to be directly affected by development activities (Figure 6).

State zoning regulations dictate the kinds of uses and projects that are acceptable in any given area. Chapter 205 of the Hawai‘i Revised Statutes (HRS) grants power to the Land Use Commission to zone all lands in the State into four districts: Agriculture, Conservation, Urban, and Rural. The State has jurisdiction for areas designated Conservation District, while the county has jurisdiction over the other three districts. The County of Hawaii revised its zoning in 2007 to match the State zoning, with all State Conservation districts now encompassed by the

county Conservation zone. Figure 6 delineates the State and County land use districts on Kohala Mountain. Approximately 30% of the WMA is designated “Agricultural” while most other lands (71%) are designated as Conservation District (Table 4).

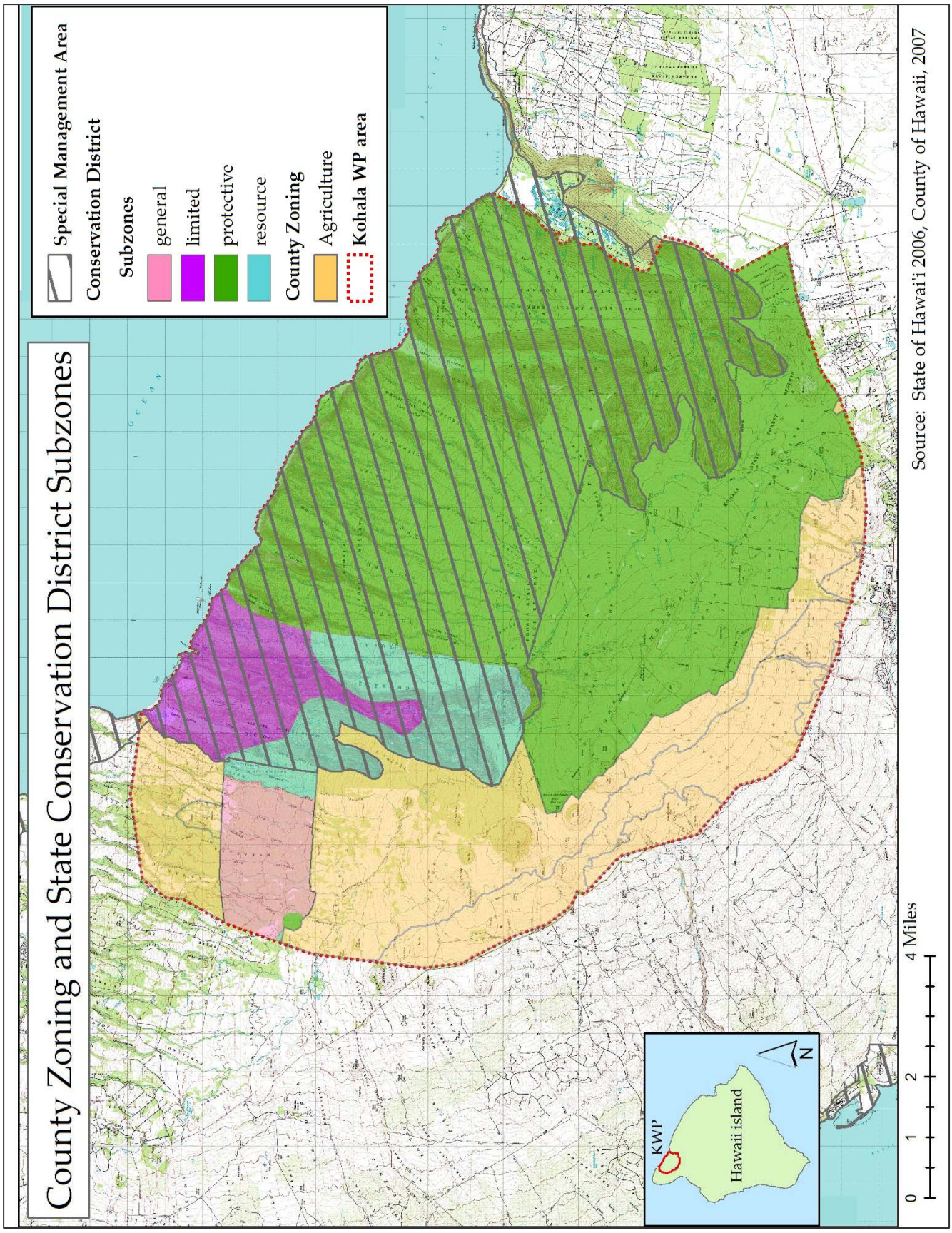

Figure 6. State Conservation District Subzones, Special Management Area and County of Hawaii Zoning

The Conservation District is subdivided into five subzones: Protective, Limited, Resource, General, and Special. Chapter 13-5 of the Hawai'i Administrative Rules (HAR) defines the objectives and types of activities allowed for each subzone. Most of the Conservation District land (79%) within the Kohala Mountain WMA falls within the Protective subzone (38,689 Ac), the most environmentally-sensitive of the Conservation District subzones. The protective subzone encompasses lands and waters necessary to protect watersheds, water sources, and water supplies, as well as natural ecosystems, and significant historic, archeological or geological features. The other subzones included on Kohala Mountain are: Limited (3,473 Ac), where natural conditions suggest constraints on human activities; Resource (4,521 Ac), areas to be managed to ensure sustained use of the natural resources; and General (2,100 Ac), designated open space where specific conservation uses may not be defined but where urban use would be premature. Prior to any use of land in the Conservation District, a Conservation District Use Application (CDUA) must be submitted to and approved by the Board of Land and Natural Resources.

Historic and Current Land Management

In ancient Hawai'i, the traditional system of land and water tenure and management centered on the *ahupua'a*, a wedge of land that extended from the mountains to the ocean and often followed natural watershed divisions. Land and water resources were under the control of the *ali'i* (chief), providing an efficient means of constructing land and water infrastructure. This infrastructure consisted of a highly advanced system of irrigation ditches that would carry water from mountain streams into *lo'i* (irrigated terraces). Native Hawaiians drew their water supplies from fresh water springs, lakes, streams, and shallow wells (Handy and Handy 1972).

The early Hawaiians engaged in subsistence living. During these times, Hawaiians inhabited most of the windward valleys of Kohala Mountain. Though remote, these *ahupua'a* provided the water, ocean, and soil essential to the Hawaiian settlers who relied on farming and fishing (Schweitzer and Gomes 2003). Wetland agriculture, particularly taro, was practiced in the valleys, and the lower windward slopes were terraced for farming. At the height of pre-contact Hawai'i, the larger valleys of Waipi'o, Waimanu, and Pololū supported large populations of Hawaiians. On the leeward side of Kohala Mountain, the Hawaiians terraced and farmed the land in dryland agriculture, carrying water to these drier lands in *auwai* (irrigation ditch or canal), as evidenced by the remnants of extensive rock work still visible today (Vitousek *et al.* 2004). This area is known as the Kohala Field System.

The 1793 introduction of cattle to the Hawaiian Islands changed the natural landscape forever. Kamehameha I declared a *kapu* on cattle shortly after their introduction, and they were allowed to roam free and unharmed, damaging the natural environment and becoming a public nuisance. When whaling vessels began to visit the islands regularly, their demand for beef prompted the establishment of ranches. These ranches included large tracts of native forests, which were gradually destroyed by cattle that were eating and trampling the plants, gradually converting forested lands into open rangelands. Free reign of cattle resulted in what Griffiths, a professor from O'ahu College (1902), called the "total destruction of all the undergrowth and trees on the lower slopes" to a point where the "remaining forests [were] confined to the upper slopes and the more inaccessible canyons."

In the early 1800s (circa 1810-1829), tens-of-thousands of pounds of sandalwood (*Santalum paniculatum* or *iliahi*) were harvested from the leeward slopes of Kohala Mountain and shipped

out of Kawaihae (Maly and Maly 2004). Nearly all of the sandalwood was harvested, leaving only a network of well-used trails that undoubtedly helped spread exotic plants throughout former sandalwood areas. Forest trees were also harvested for firewood. It was also during the 1800s, following Western contact, that new diseases decimated native Hawaiian populations.

Sugar plantations were established in North Kohala and Hāmākua during the second half of the 19th century, and recruitment by plantations drew Hawaiians away from their traditional lifestyles. It took a million gallons of water on average to produce one ton of sugar (Wilcox 1996). Each plantation needed a reliable source of water, especially during dry spells. In spite of an ongoing search for new sources of irrigation water, supplies were soon stretched to their limits. These water users recognized that unmanaged ungulates and timber harvests were threatening the health and integrity of the forested watershed on which their water supply depended (Maly and Maly 2004). Concern for watershed protection arose in response. On September 19, 1876, King Kalakaua signed into law an Act for the Protection and Preservation of Woods and Forests, authorizing the Minister of the Interior to set apart and protect from "damage by trespass of animals or otherwise, such woods and forest lands, the property of government... best suited for the protection of water resources."

In the early 1900s, the Territory of Hawai'i initiated plans to protect Hawai'i's forests by designating select areas as forest reserves. Act 44, the Forest Reserve Act, was passed by the Territorial Legislature in April 1903. This legislation created Hawai'i's forest reserve system, the largest public-private partnership in the history of the islands. In the 1904 annual report to the Governor, the Division of Forestry noted "[n]owhere in the Territory is there more pressing need for forest reservation than in this district [Kohala], for on the forest area of the Kohala Mountain depends the chief water supply of the north end of the island. To insure its permanence this forest ought to be reserved at once." In a 1908 report to the Board of Agriculture and Forestry, the Superintendent of Forestry wrote: "The Kohala Mountain Forest Reserve is created as a protection forest to assist in the conservation of water on the Kohala Mountain.... Within the limits of the proposed forest reserve the Kohala Mountain is clothed with a dense mass of indigenous vegetation - a cover that for its effect on runoff and for holding back moisture after it once reaches the ground cannot be surpassed." In 1913, the Territory designated 29,627 acres of Kohala Mountain as forest reserve.

Meanwhile, demand for water by the plantations and ranches continued to increase, and these businesses "sought to develop a means of transporting the water greater distances to increase the productivity of marginal lands" (Maly and Maly 2004). The perennial streams in the eastern valleys of Kohala were sought for their abundance of water, and systems of ditches, tunnels, flumes, and dams were built to carry water from these sources to areas of Kohala and Hāmākua (see Figure 3 for map of ditches.).

The Honokāne section of the Kohala Ditch was completed in 1906, while the Awini section was finished in 1907 (Wilcox 1996). The Kohala ditch delivered to the Kohala plantations an average of 26 mgd of water from streams as far east as Waikaloa Stream, "upon completion, meandering often through solid rock, the Ditch measured 22½ miles, with sixteen miles of ... tunnels..., six miles of open ditch, and 29 flumes.... Along its way, the ditch tapped into thirty-six intakes and ran close to forty miles of mule trails, three miles of foot trails, dams, contributory tunnels, and twelve bridges" (Schweitzer and Gomes 2003).

The Hāmākua Ditch Company, which later became the Hawaiian Irrigation Co., was formed in 1904 to provide water to the sugar plantations on the Hāmākua coast. The Upper Hāmākua Ditch was completed in 1907, while the Lower Ditch was finished in 1910. Because of more favorable rainfall, the plantations on the Hāmākua coast did not depend as much on irrigation as others; consequently, water from the Upper and Lower Hāmākua Ditches was used primarily at the mills and for fluming (Wilcox 1996). The water sources for the Upper Hāmākua Ditch were the Kawainui, Alakahi, and Koiawe tributaries of Wailoa stream, which runs through Waipiʻo valley. The Upper Hāmākua Ditch averaged about 8 mgd, but was leaky and required significant maintenance; it was returned to the Territory of Hawaiʻi in 1948 (HDOA 2003). The Lower Hāmākua Ditch tapped into these same water sources, but at lower elevations. The Lower Ditch had an overall length of 24.75 miles (Wilcox 1996). It was extended to Paauhau in 1912 and Paauilo in 1918, and had an average flow of 30 mgd.

The last of the sugar plantations in Kohala closed in the mid 1970s, while Hāmākua Sugar Co., the final consolidation of the Hāmākua sugar plantations, filed for bankruptcy in 1993. As noted earlier, the Kohala Ditch is currently owned by Surety Kohala Corporation and produces roughly 12-14 mgd during normal flows. The Hawaiʻi Department of Agriculture (HDOA) took over the Lower Hāmākua Ditch system as a result of the closure of Hāmākua Sugar Company and is in the process of converting the ditch system from large-scale sugar cane irrigation to small scale diversified crop farming operations (HDOA 2003). HDOA also took over the Upper Hāmākua Ditch for use as part of its Waimea Irrigation System.

The Kehena Ditch, established to distribute water to Kohala's homesteads and ranches, was completed in 1914. It was not, however, a success. Despite a maximum design capacity of 54 mgd, it provided only 1 mgd on an irregular basis. "Rain and run-off seeped straight into the absorbent ground, captured water was too seasonal, and storage water disappeared from reservoirs" (Schweitzer and Gomes 2003). The lower section of the Kehena Ditch was abandoned in the late 1960s. Kahuā and Ponoholo ranches continue to draw water from the upper portion of the Ditch.

Parker Ranch developed its first pipeline from Kohala Mountain above Waimea in 1902 to extend water to the Waimea-Waikoloa Plains as far as Waikiʻi. Parker Ranch currently operates an extensive system of distribution lines to provide livestock water for its widely-spread pasture lands in the Waimea area.

Kalo (taro) farmers in Waipiʻo Valley also rely on the surface waters of Kohala Mountain. Kalo is currently grown on approximately 150 acres on the floor of Waipiʻo Valley. Consistent water is essential to this wetland agriculture. Kalo growers are vulnerable to major changes in water levels, either from drought, diversions, or flooding, as well as water-borne diseases and alien species.

Current Water scarcity and conflicts in water allocation triggered the establishment of watershed protection laws. In 1987, the State Water Code was adopted by the Hawaiʻi Legislature; this statute, Chapter 174C HRS, was amended in 2004. The State, in its stewardship capacity, has management responsibility for all water resources of the State through the Commission on Water Resource Management (CWRM) – also known as the Water Commission. According to HRS §174C-2(c):

> The state water code shall be liberally interpreted to obtain maximum beneficial use of the waters of the State for purposes such as domestic uses, aquaculture uses, irrigation and other agricultural uses, power development, and commercial and industrial uses. However, adequate provision shall be made for the protection of traditional and customary Hawaiian rights, the protection and procreation of fish and wildlife, the maintenance of proper ecological balance and scenic beauty, and the preservation and enhancement of waters of the State for municipal uses, public recreation, public water supply, agriculture, and navigation. Such objectives are declared to be in the public interest.

The Water Commission sets policies and approves water allocations for all water users. Existing uses established prior to 1987 are grandfathered in, provided the existing use is reasonable and beneficial (§174C-50, HRS). The Water Code also requires CWRM to establish and administer a statewide in-stream use protection program, including flow standards on a stream-by-stream basis whenever necessary to protect the public interest (§174C-71, HRS).

In its regulation of water resources, the Commission delegates to the county boards of water supply the authority to allocate the use of water for municipal purposes. The counties are also tasked with adopting water use and development plans, setting forth the allocation of water to land use in that county (§174C-31, HRS).

The State Department of Health (DOH) is assigned primary responsibility for protecting the water quality of Hawai‘i’s water resources under Chapter 342D, HRS. DOH is responsible for developing state water quality standards (including aquatic life use standards), identifying Clean Water Act Section 303(d) impaired waters that do not meet state water quality standards, and preparing Total Maximum Daily Loads (TMDLs) for these impaired waters. Chapter 11-54, HAR, classifies inland and marine waters for purposes of applying the water quality standards. Streams are designated as class 1a (most pristine), 1b or 2, with specific protected uses identified for each class. Likewise, elevated wetlands (bogs) and low wetlands are classified as 1a, 1b or 2.

The 1986 Amendments to the U.S. EPA Safe Drinking Water Act established a nationwide wellhead program to protect groundwater resources used for public water systems from contaminants that may adversely affect the health of humans. This was codified under State statute in Chapter 340E, HRS, Safe Drinking Water, and implemented by the Department of Health.

As noted earlier, the Territory of Hawai‘i established the Kohala Forest Reserve in 1913. DLNR-DOFAW regulates activities in the forest reserves under Chapter 13-104, HAR. These rules prohibit taking of any plant or animal life, except by permit; disturbing of any natural or historic feature; introduction of plants and animals; dumping and littering; and fires. Bird and mammal hunting is permitted by persons with valid Hawai‘i hunting licenses in designated public hunting areas following guidelines set forth in Chapter 122, HAR, Exhibits 1 and 2, and Chapter 123, HAR, Exhibits 11 and 12. Approximately 30,000 acres of public hunting areas are located on Kohala Mountain, within designated Units B (forest reserve), D (restricted watershed) and K (Pu‘u O ‘Umi NAR) (Figure 7). Hunting for pigs in units B and K is permitted year-round on a daily basis, while pig hunting in unit D is limited to weekends and State holidays. Bird hunting is permitted in units B, D, and K during designated hunting seasons.

The Puʻu O ʻUmi Natural Area Reserve (NAR) was established by Executive Order in 1986. This area of 10,142 acres, formerly part of the State forest reserve, is managed by DLNR to protect unique natural resources of Kohala Mountain. The NAR protects the headwaters of Kaiwainui, Alakahi, Honokāne Nui, and Kohakohau streams, all of which are tapped in their lower reaches for domestic and agricultural uses. The Reserve also protects rare native ecosystems and biological resources. According to Chapter 13-209, HAR, allowed activities in the NAR include hiking, nature study, bedroll camping, and hunting pursuant to the hunting rules. Puʻu O ʻUmi NAR is designated public hunting area Unit K, which allows persons with valid Hawaiʻi hunting licenses to hunt daily and year-round for game mammals and on weekends and holidays during the open hunting season for game birds.

The 10,175-acre Kohala Restricted Watershed (Hunting Unit D) was established in 1980 (and contracted in size in 1986 with the establishment of Puʻu O ʻUmi NAR) within the Kohala Forest Reserve to protect a watershed where public supplies are vulnerable to contamination by public access (see Figure 7). Under Chapter 13-105, HAR, all persons are prohibited from entering the 4,834-acre Kohala Restricted Watershed, except by permit from DLNR for official duties, research and scientific pursuits, recreational and educational purposes, and collection of plants for personal use. Public hunting in Unit D is permitted under Chapters 122 and 123, HAR; persons with a valid Hawaiʻi hunting license may hunt on weekends and holidays year-round for game mammals and on weekends and holidays during the open hunting season for game birds.

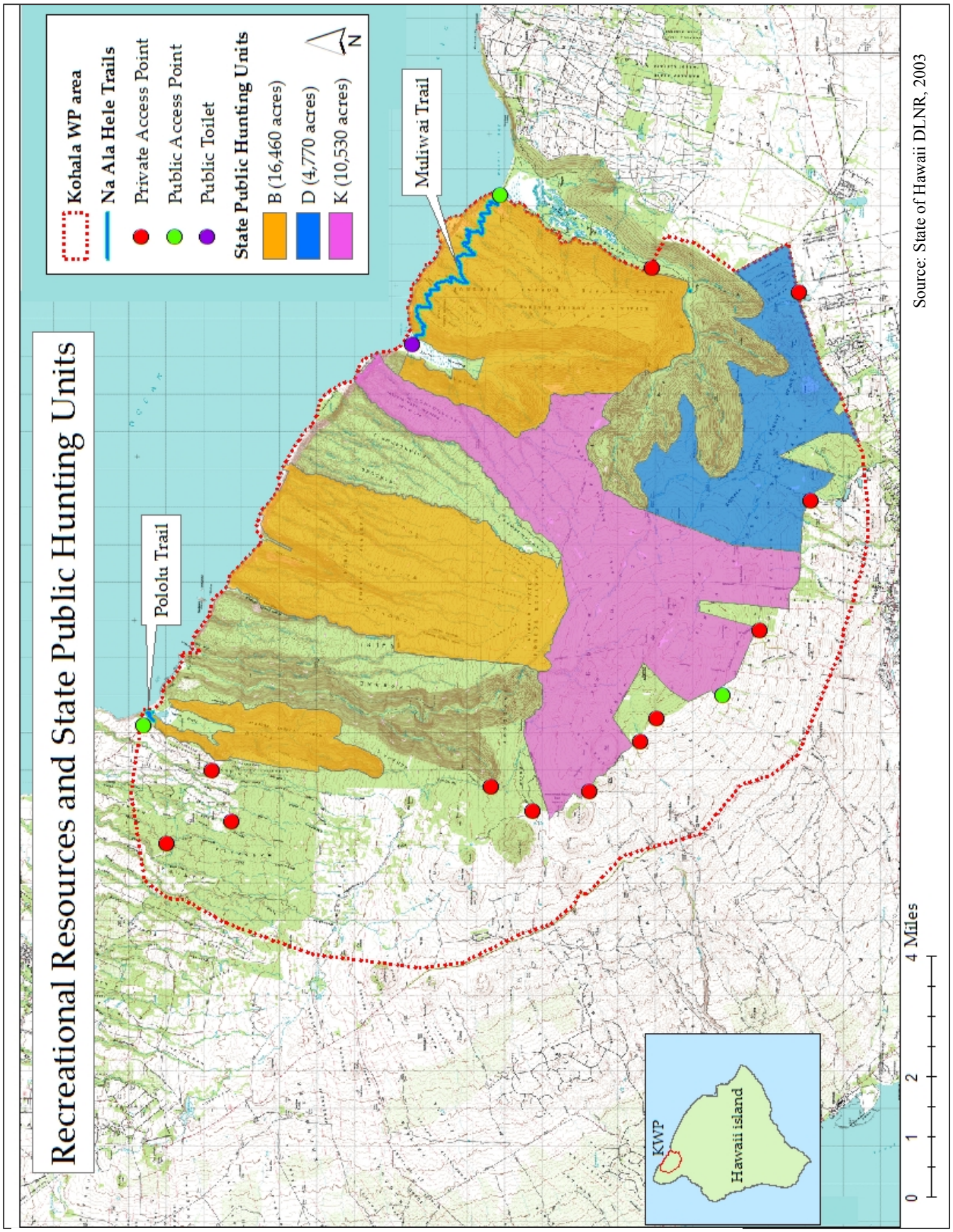

Figure 7. Trails, State Hunting Units, and Access Points

2. Population and Local Communities

Currently, there are few residents who live full-time within the WMA boundaries. However, there are major communities that surround the more remote watershed area. While these communities may not be official members in the Partnership, it is important to gain an understanding of the neighboring communities and involve them in outreach and education efforts.

The town of Waimea is the largest neighboring community, with a population of over 7,000 residents. Kapa‘au and Hawi in North Kohala have populations of 1,159 and 938 respectively (County of Hawai‘i 2000). To the east, in the district of Hāmākua, Honokaa is the largest community, with a population of over 2,200 residents. Neighboring Kukuihaele has a population of 317 residents. While located at a greater distance from the watershed area, Paauilo, population 571, is included in this description because of its reliance on water from Kohala Mountain.

A common factor among all these communities is their reliance on the water resources of Kohala Mountain - whether surface water, groundwater, or spring water - for their domestic and agricultural water supplies. The proximity of these population centers to the Kohala watershed also means that these are the people who are most likely to use the watershed area for hunting, hiking, and gathering of plants for personal and cultural uses.

3. Cultural Resources and Traditional Practices

Kohala Mountain is rich in cultural history. The native traditions and historical accounts associated with the Kohala-Hāmākua mountain lands span many centuries, from Hawaiian antiquity to the later period following western contact. Many narratives found in Maly and Maly (2004) describe customs and practices of the native people who resided on these lands, walked the trails, and who were sustained by the wealth of the mountain lands, the kula (plain and plateau lands), and the adjacent marine fisheries.

The most detailed descriptions of the Kohala-Hāmākua mountain lands, including documentation of traditional and customary rights, are those found in the Kingdom collections, documenting the history of land tenure, and defining the boundaries of ahupua‘a in the Kohala-Hāmākua Districts. Detailed oral testimonies from elder native tenants were taken in court proceedings of the mid to late 1800s, and document the occurrence of traditional and customary practices, and nature of the resources within given ahupua‘a. In those records, we learn of the traditional knowledge and occurrence of native practices in the lands which today are a part of the Kohala Watershed Partnership Area.

In native traditions and beliefs, Hawaiians shared spiritual and familial relationships with the natural resources around them. Each aspect of nature from the stars in the heavens, to the winds, clouds, rains, growth of the forests and life therein, and everything on the land and in the ocean, was believed to be alive. Indeed, every form of nature was a body-form of some god or lesser deity. As an example, in this context, and in association with lands which are now included in a part of the landscape of the Watershed Management Area, we find the goddess Hina-ulu-‘ōhi‘a (Hina, goddess whose form is in the groves of ‘ōhi‘a); and Pō-kāhi (the darkened place), a god of the mountain mists (the tradition of Lau-ka-‘ie‘ie), are deified parts

of the landscape. Such body forms and attributes in the Hawaiian mind are "*kino lau*," the myriad body-forms of the gods and creative forces of nature that gave Hawaiians life.

In the Hawaiian mind, care for each aspect of nature, the *kino lau* of the elder forms of life, was a way of life. This concept is expressed by Hawaiian *kūpuna* (elders) through the present day, and is passed on in many native families. When discussing the relationship of native families with the lands and resources around them, it is not uncommon to hear *kūpuna* express the thought — *"E mālama i ka ʻāina, a e mālama hoʻi ka ʻāina iā ʻoe! E mālama i ke kai, a e mālama hoʻi ke kai iā ʻoe!"* (Care for the land, and the land will care for you! Care for the sea, and the sea will care for you!). This concept is one that is centuries old and is rooted in the spirituality of the Hawaiian people. Importantly, the converse is that when one fails to care for, or damages nature—the *kino lau*—around them, they are in-turn punished. This is expressed in many traditional sayings, one being, *"Hana ʻino ka lima, ʻai ʻino ka waha!"* (When the hands do dirty-defiling work, the mouth eats dirty-defiled food!). In this cultural context, anything which damages the native nature of the land, forests, ocean, and *kino lau* therein, damages the integrity of the whole.

In the traditional context, we find that the mountain landscape, its native species, and the intangible components therein, are a part of a sacred Hawaiian landscape. Thus, the landscape itself is a highly valued cultural property. Its protection, and the continued exercise of traditional and customary practices, in a traditional and customary manner, are mandated by native custom, and State and Federal Laws (as those establishing the Kohala-Hāmākua Forest Reserves and Puʻu O ʻUmi Natural Area Reserve; and the Endangered Species Act).

In this discussion, protection does not mean the exclusion, or extinguishing of traditional and customary practices, it simply means that such practices are done in a manner consistent with cultural subsistence, where each form of native life is treasured and protected. *Kūpuna* express this thought in the words, *"Hoʻohana aku, a hoʻōla aku!"* (Use it, and let it live!).

Existing literature provides detailed information on this history. Maly and Maly (2004) provide readers access to primary documentation on native traditions, customs, and practices associated with the Kohala-Hāmākua mountain lands. The traditional system of land and water tenure and management centered on the *ahupuaʻa*, where each chief acted as a steward of the land and granted the *makaainana* (general populace) living in the *ahupuaʻa* use of the land's bounty for their livelihood. Headmen (*konohiki*) facilitated day to day operations with the assistance of specialists (*luna*). The *ahupuaʻa* formed a self-contained economic and social unit that effectively integrated the uses of its resources from dispersed ecological zones. Everyone living throughout the *ahupuaʻa* had access to all types of products and everyone was entitled to a share of what they produced from the soil or took from the sea. Wetland agriculture, particularly taro, occurred in the valley streams; terraced agriculture on the slopes produced dryland foods, such as sweet potatoes and dryland taro. Food animals were kept within villages and not allowed to escape into the forest. In the forests, Hawaiians would gather building materials and fuel; sources of cordage; adornment for display of rank; water; birds; herbs and medicines; and craft materials. The review in Maly and Maly (2004) of more than 60,000 native Hawaiian land documents dating from 1846 to 1910 revealed many references to *puaʻa* (pigs), but nearly every reference was in the context of them being near-home and as being cared for (raised), not hunted. In the same review of the native Hawaiian land documents, and a large collection of writings from native authors (e.g., D. Malo, 1951; J.P. Ii, 1959, S.M. Kamakau 1961, 1964 & 1976), every reference to traditional collection or

"hunting" (a word seldom used in the historical records), was in the context of native birds—those used either for food or from which feathers were collected for royal ornaments and symbolic dress.

Maly and Maly (2004) also provide a historical overview of the land and activities of people in the region from the early 1900s through the present day. Schweitzer and Gomes (2003) offer a history of North Kohala, beginning in ancient times and describing some more modern cultural resources stemming from the multi-culturalism of the plantation era. Wilcox (1996) includes information on the history of the plantation ditches and irrigation companies on the island of Hawai'i.

The Hawaiian culture nearly lost much of its rich history of cultural traditions and practices over the past 150 years. However, the ancient practice of *hula*, Hawaiian storytelling through dance, has remained strong on the Island of Hawai'i, now globally recognized as home of the world hula championship Merrie Monarch Festival. The forests of Kohala Mountain serve as an important source of materials used in *hula* and other aspects of Hawaiian culture. Today, modern-day practitioners continue to gather plants for medicinal and religious purposes, for lei making and adornment in *hula*, and for other crafts.

In addition, the Kohala region is a stronghold for the modern Hawaiian cultural revival. Modern legends of Hawaiian culture, such as the late slack-key guitar virtuoso Gabby Pahunui and living legend and storyteller Kindy Sproat, hail from the Kohala region.

4. Compatible Public Use

The landscape of the forested watershed of Kohala Mountain is wet, steep, and rugged. The nature of this landscape - muddy bogs, dense vegetation, numerous gulches and steep cliffs - naturally limits access to a certain extent. A more limiting factor, perhaps, is the fact that much of the perimeter of the WMA is encircled by private lands. Historically, these two factors, as well as the control of traditional access and use of resources by landlords and chiefs, have resulted in limited access to the area. Such limited access reflected the high value of the watershed both as mountain and water resources. Nevertheless, the relatively small amount of public access into the watershed area generally occurs along the fringes of the forest reserve; few people venture into the interior of the mountain, which is dangerous terrain for the unprepared visitor.

Trails, with both positive and negative attributes, are important to the management of the watershed. From a management perspective, trails provide points of ingress to more easily and safely conduct activities such as surveys, ungulate control, search-and-rescue efforts, and fire management. Trails also represent avenues to experience cultural and historical features, as well as conduits for economic, ecotourism, and recreational opportunities. Trails also tend to serve as animal corridors, areas where ungulates will most likely travel and be found. Hikers or animals using the trails contribute to the spread of weeds. Overuse of trails can lead to soil compaction and increased water runoff or loss of stabilizing vegetation and soil erosion.

Few trails on Kohala Mountain are maintained, marked, or open to the public; in fact, many occur on private land or require crossing over private property for access. There are two

public trails promoted by the Na Ala Hele Program[6] on Kohala Mountain (Figure 7). The difficult Muliwai Trail links the remote Waimanu Valley with Waipiʻo Valley. This 9-mile trail on the high plateau between the two valleys crosses numerous gulches and descends steeply into Waimanu Valley. Camping is allowed in Waimanu Valley with a permit from DLNR's Division of Forestry and Wildlife. The 0.25 mile Pololū Trail descends in switchbacks down into Pololū Valley and is an attainable hike for residents and tourists. Until recently, a popular hiking trail in the WMA was the trail from the end of White Road in Waimea to overlook the back of Waipiʻo Valley. Though it was promoted by some guidebooks as a public trail, this ditch trail has no legal public access and requires hikers to leave their cars along White Road, where there is insufficient parking, and trespass across leased Department of Hawaiian Homelands property to gain access to the trail. Additionally, the trail has become dangerous due to collapsed sections that were the result of the earthquake of October 2006. Hikers also enter the forest reserve above the reservoirs in Waimea, normally traversing Parker Ranch lands without permission.

Much of the access into the watershed is unmonitored. The only data that exist for public use of the Kohala Mountain region are hunting harvest records submitted by licensed hunters. Trails within the WMA often intersect or lead to hunting areas. Many of the trails in the WMA were established in order to maintain the ditch systems and other water diversions, and access gauging stations on streams within the watershed. Other trails are used by government personnel and researchers to access transect sites, conduct biological and hydrological surveys, and perform weed control.

There is broad and growing interest in environmental research and management in Hawaiʻi. A growing proportion of visitors are interested in seeing wild places and learning about ongoing environmental management projects, such as watershed conservation. The Kokeʻe Resource Conservation Program on Kauaʻi administered by the Kokeʻe Natural History Museum, and the volunteer tree-planting program at Hakalau Forest National Wildlife Refuge are both demonstrating the broad national and international interest visitors have in pitching in with time, money, and effort to help protect and restore Hawaiʻi's unique ecosystems. At this time, there is limited access into the WMA for educational purposes. However, there is interest in facilitating such access, provided it can occur in a controlled and safe manner, as outlined in the management section of this plan.

5. Infrastructure and Facilities

There are few facilities and little infrastructure within the Kohala Mountain watershed. There are eight camping sites, with composting toilets, in Waimanu Valley; camping is allowed with a permit from DLNR. There is vehicular access across some State lands to the edge of the forest reserve, from which hunters and hikers must continue on foot. Private ranch roads lead to the forest reserve at several locations, and access through these private lands requires landowner permission. Much of the perimeter of the forest reserve on the leeward side of the mountain has been fenced to exclude neighboring cattle. The County Department of Water Supply maintains a road above the Waimea reservoirs to its intake on Kohakohau Stream.

[6] Na Ala Hele, administered by DLNR's Division of Forestry and Wildlife, was established in 1988 under Chapter 198D, HRS, in response to public concern about the increasing loss of public access to trails and the threat to historic trails from development pressure.

Three and three-quarter miles of fences have been built, encompassing approximately 140 acres, to protect sensitive natural bog habitat within the Pu‘u O ‘Umi NAR; these exclosures comprise < 1% of the total acreage of the WMA. Helicopter landing zones have been constructed throughout the watershed to improve access into remote areas for management and search-and-rescue missions. A management shelter (Mauga Cabin) has been constructed to facilitate DLNR’s overnight work trips. Some landowners also maintain historic cabins within the watershed.

III. WATERSHED VALUES

Characteristics or functions of a watershed that have social, economic and/or ecological benefits are defined as watershed values. The broad watershed values described in this chapter were compiled through a literature search and interviews with various stakeholders on Kohala Mountain, and built upon past efforts including the Natural Area Working Group, Kona/Kohala Natural Resource Area Workshop, Kohala Forest Management Group, and Waimea Water Roundtable. Summaries of each of these land and water management planning efforts are provided in Appendix C.

A. Water Resources

Historical accounts recount waterfalls, lakes, and streams that were harnessed to provide for native Hawaiian agricultural fields, small towns, and ranches. Today, much of the water of the Kohala watershed is captured and delivered for similar domestic and agricultural uses in the lands of Waimea, Hāmākua, and North Kohala. Existing water resource facilities include the Kohala Ditch; Kehena Ditch; Lower Hāmākua Ditch Irrigation System; Waimea Irrigation System; DWS stream intakes, pipelines and reservoirs; Parker Ranch water capture, storage and transport system; and the water systems of other private landowners. Although the agricultural demand for surface water is not as great as it once was, there is a growing demand for domestic water within all of the municipalities surrounding the mountain. Society's demand for water is expected to grow as the North and South Kohala and Hāmākua districts continue to grow over the coming decades. Hawai'i County DWS is currently investigating the feasibility of shifting supplies for domestic water from surface water to groundwater through the establishment of additional withdrawal stations. These proposed changes will be enumerated in the updated County water use and development plan currently under development.

The water that rains and drips down into streams and the groundwater aquifer flows mostly unnoticed. As a society, we take this most precious resource for granted and fail to recognize its importance in sustaining us. Nonetheless, we use it daily for consumption, agriculture, and development. It is essential for economic, social, and cultural sustenance, and we cannot live without it. Surface water resources also have instream values, sustaining unique aquatic ecosystems and supporting Hawaiian cultural farming practices.

B. Watershed Functions of Forest

Most notable of the services provided by Kohala Mountain is the abundance of fresh clean water. Lush forests provide the ability to ensure sustainable water, even when rainfall patterns are intermittent. Like all mountain forests, Kohala's forests have an important role in stabilizing water quality and maintaining sustainable natural flow patterns of the streams and rivers originating from them. But, tropical montane cloud forests such as that of Kohala Mountain also have the unique additional value of capturing water from the condensation from clouds and fog. This 'stripping' of wind-blown fog by the vegetation becomes especially important during the non-rainy season and in areas with low rainfall but frequent cloud cover. Water originating from cloud forests is also increased because water loss from vegetation wetted by rain or fog is reduced. This results in streamflows from cloud forest areas that are greater and

more dependable in dry periods (Bubb 2004). Kohala's cloud forest encompasses approximately 10,000 to 20,000 acres (Figure 2).

Forests and cloud forests reduce rates of water loss via evaporation and transpiration and maintain high water storage capacity. Water loss from evaporation is moderated by a multi-layered forest canopy structure and persistence of clouds. A functional forest keeps sunlight from reaching the ground and heating up the surface. Ground cover such as leaf litter, moss, ferns, and other plants, and foliar cover also help to create pockets of moist air that reduce the pull of water from the soil surface by the hot, dry daytime air. Rates of transpiration of water vapor into the atmosphere by plants is also moderated by dense vegetation cover and the humid air in the cloud forest. Forests also contribute and recycle organic matter, further increasing the absorptive sponge-like quality of the soil. The forests of the Kohala Mountain watershed support an abundance of dense and multi-storied canopy of woody plants that serve to store carbon. Sphagnum and peat environments that are abundant within forest and bog communities of the watershed are considered to represent a relatively high proportion of world carbon stores.

The watershed is also an open space free from development and use of fossil fuels, a value becoming increasingly scarce in today's world. Furthermore, the rich and diverse beauty of the landforms of Kohala, combined with its unique climate, vegetation, and wildlife, provide aesthetic values that, while may be hard to quantify, are of great value to visitors and local residents alike. Indeed, for native Hawaiians, the landscape itself is a highly valued cultural property and considered sacred (Maly and Maly 2004).

The forest also acts as a soil anchor, a function critical to protect nearshore waters from sedimentation. Shallow-rooted plants such as ferns and forbs help hold surface organic matter that is used as nutrients, and deep-rooted woody plants hold deeper layers of soil and bedrock. The multi-layered canopy of the Kohala forests shelters the ground surface from the frequent heavy rains that might otherwise wash away its organic matter and mineral soils, thereby protecting nearshore waters from sedimentation. The forest also acts as a filter to clean and to cycle organic matter and nutrients through the vegetation, soils, and streams, and helps deliver a consistent and dependable source of artesian and surface water.

C. Native Species and Ecosystems

Kohala Mountain contains numerous and diverse ecosystems and many rare and endangered plant and animal species, many of which are found nowhere else in the world (see Section II.C. Biological Resources for more information). Kohala Mountain's unique climatic and ecological setting supports a wide array of biomes, numerous highly-endemic, and in some cases rare, biological communities that occur as a contiguous forested landscape. Kohala's ecosystems are relatively intact, compared to the rest of the State, and support some of the most intact stream ecosystems in Hawai'i, an array of montane bogs interspersed within tropical montane cloud forest, and diverse montane mesic forest. Conservation of remaining hotspots of biodiversity (locations that harbor clusters of rare species and unique biological communities), such as in the Kohala Mountains, is important to conserve Hawai'i's dwindling biological heritage. Kohala's forested watershed also plays an important role in conservation of biodiversity at the regional and global scales as natural environments decline world-wide.

Kohala Mountain's forests help purify the air, regulate climate, regenerate soil fertility, and feed coastal reefs and nearshore fisheries. Species within the forest and streams provide economic, recreational, and socio-cultural benefits as well. Although the value of these services are not typically quantified, economic research evaluating the value of ecosystem services such as these estimates their value in the hundreds of millions to several billions of dollars (Pearce and Moran 1994).

D. Cultural Resources

Native Hawaiians resided in the valleys and on the slopes of Kohala Mountain at the time of European arrival. Many *ahupua'a* that at one time supported large agricultural and subsistence populations are included within the WMA. The traditional *ahupua'a* system of land and water management in old Hawai'i was centered around the natural watershed divisions. The native Hawaiians lived within the means of what the *ahupua'a* resources could sustain. Wetland agriculture, particularly taro, was practiced in the valleys, and the lower windward slopes and broad areas of leeward Kohala were terraced for farming. The Hawaiians gathered materials from the forest primarily for building, adornment, medicine, crafts, and sustenance.

Some of these cultural practices continue today. *Hula halau* and others may harvest plant materials for the making of lei and adornment for dance and other rituals. Hawaiian healers collect herbs and plants for medicines. The prominent natural features of Kohala Mountain continue to have importance today in Hawaiian myth and culture. Indeed, a mele from 1894 reflects this traditional viewpoint (Maly and Maly 2004):

E-o e ka wahine iloko o ka ohu,	Respond o woman there in the mists,
O ka ohu noho i ke kuahiwi, kualono,	Mist which sits upon the mountain ridges and peaks,
Iloko i Ihikalani hale kumu ohu,	There in *Ihikalani*, mountain-house that is source of the mist,
Paihi kau ao ole ka lewa lani,	The sky clears, there is not a cloud above,
I ka noho a ka wahine kinolau,	At the place where the woman of many body-forms lives,
He kino he lau o Laukaieie,	Body form of the leaves of the *'ie'ie*
E i a'e ka wahine nona ka lei,	The woman for whom the *lei* was made, speaks,
I uo ia e Hinauluohia,	It was bound together by *Hinauluohia*,
He liko no ka lama i ka nahele,	from buds of the *lama* in the forest,
O ka hala me ka lehua,	Of the *hala* and *lehua*,
Ke lawe ala ka makani i ke ala,	The wind carries the fragrance,
Puia i ke ala kai o Pakaalana,	It mixes with the fragrance of the sea at *Paka'alana*,
Ke awili ia me ka lau lipoa	Interwoven with the *lipoa* seaweed.
He wahine noho lae kahakai,	There the woman resides on the costal promontories,
Alualu huakai o na pali,	Gathering the sea-spray along the cliffs.
Ke lele la ka wai o Kawaikapu,	The water leaps from the falls of Kawaikapu,
Ke iho la i na pali,	Descending along the cliffs,
E iho e Laukaieie, e Laukapalai,	Descend o *Lauka'ie'ie*, *Laukapālai*,
E Lauakolea, pili lau i o uka,	*Lau'ākōlea*, companion of the upland *lau-ī*
E iho mai.	Descend.

This *mele* is an example of the depth of the relationship shared between Hawaiians and their environment. It demonstrates the spiritual attachment of Hawaiians to the mountain lands and forest life—they being more than earth and plant. Each of the plant forms are the embodiments of creative forces of nature, and when respected and called upon, they were believed to help the one calling upon them. These plant and weather forms could ensure safe passage through the mountain lands, or cause one to lose one's way.

This inter-relationship between the land and the people who inhabit it, nourished through daily practice of their culture, has forged a strong bond of Hawaiian culture to the Hawaiian landscape (Maly and Maly 2004). To a practitioner of Hawaiian culture, nearly every feature of the *ahupua'a* has value as a cultural resource, from the water to the stones to the vegetation and other organisms.

Today, substantial portions of the WMA are active rangeland. The history of cattle ranching on the slopes of Kohala Mountain extends back over 150 years. Ranching remains an important part of the history, culture, economy, and lifestyle of much of the modern day culture of the region.

E. Public Access and Outdoor Recreation

Pig hunting within Hawai'i's forests has become a popular activity over the past century and is an important part of contemporary local culture. DLNR's Division of Forestry and Wildlife records show that there were an average of 114 hunter trips per year into the Kohala Forest Reserve and Restricted Watershed between 2000 and 2004. In that time, the average reported harvest of pigs was 53 animals per year for all areas combined. These numbers likely under-report harvest, because many hunters do not report their catch. The pig hunting community on the island is comprised mainly of local residents. It is common practice for hunters to frequent the same locations and develop a familiarity with a given area. Pig hunting is a long-standing practice for many of the older *kama'aina* families that come from rural parts of the region. Most pig hunters interviewed during the development of this document valued the hunting lifestyle as much as any other aspect of the activity.

There are three public hunting areas on Kohala Mountain, Units B (16,460 acres), D (4,770 acres) and K (10,530 acres). All units allow pig hunting with dogs, but Unit D is restricted to weekends and holidays only, whereas Units B and K have daily hunting access. The maximum take each day is two animals per hunter. Access to these hunting areas is for individuals that hold a current Hawaii Hunting License.

Seasonal game bird hunting is also a popular recreational activity within the private and leased ranchlands included in the WMA. The suite of upland game species include Erkels and Grey Francolins, California Quail, Kalij and Ringneck Pheasant, Turkey and Peafowl. All of these game bird species were intentionally introduced for sport hunting.

Public access to Kohala Mountain is limited. Users generally gain access from one of five locations: Waipi'o Valley-Muliwai, the Pololū Valley overlook, upslope from the east edge of the Koaia Tree Sanctuary above Kohala Mountain Road, and from the road above the Waimea reservoirs in the Pu'u Ki area. The first two of these trails are State-managed Na Ala Hele trails and provide unrestricted public access. Four-wheel drive access through leased pasture lands leads to an access gate into the natural area reserve above the Koaia Tree Sanctuary.

At Pu‘u Ki, near the Waimea reservoirs, lessee permission and a hunting license or permission from DLNR is required for forest reserve access. Private land owners may permit other forest users to access mauka lands through their property on an individual basis. (See Figure 7).

Many local residents access the watershed in order to collect materials used in practicing *hula*, or used in leis, such as maile (*Alyxia oliviformis*) and ferns. Some likely supplement their diet with fruits and other foods gathered from within the watershed.

Other users of Kohala Mountain include campers, naturalists and birders, adventure hikers, and helicopter-supported sight-seeing groups. Much of the mountainous interior remains inaccessible except to the experienced user who is prepared to stay overnight. Some ecotourism[7] occurs within the WMA. There are commercially-operating tours in select locations, which provide tourists with access to remote sites of natural beauty. Ecotourism can provide an avenue for education, as well as a potential source of income for private and public landowners.

Kohala Mountain provides a tremendous opportunity to educate adults and children alike about the unique ecosystems and biodiversity of Hawai‘i. The WMA offers numerous potential sites for scientific research and for field trips to reinforce classroom curricula. However, access into the WMA for educational purposes must be conducted in a manner to maximize public safety and minimize potential human impacts.

[7] Ecotourism has been defined as nature-based travel to natural areas to experience and study unique flora, fauna, and culture in a manner that is ecologically responsible, and sustains the well-being of the local community.

IV. THREATS TO THE KOHALA WATERSHED

> ***C.S. Judd, Superintendent of Forestry, 1924:***
>
> The native forest, however, is peculiarly constituted in that it is readily susceptible to damage. The shallow-rooted trees depend for proper moisture and soil conditions on the undergrowth of bushes and ferns and when the latter, the first to be attacked by stock, are injured or removed, the tree roots dry out, the trees are weakened and begin to decline, and an opening is made in the forest for the invasion of destructive insects and fungi and of the more vigorously-growing foreign grasses and other plants which choke out native growth and prevent tree reproduction. It is always dangerous for this reason to make any opening in the native forest and the only safe way to preserve it and keep it healthy and vigorous is to maintain it inviolable from all attacks and keep the ground well shaded and dark.

The historical activities of clearing for agriculture and grazing, timber and fuelwood harvesting, road construction, and mining no longer threaten to reduce or fragment Kohala's forested watershed. Today, the primary threats to the watershed of Kohala Mountain are from alien plants and animals and their effects, including some feral and domestic cattle, and other factors such as wildfire and climate change.

Invasive species pose the gravest threats to Hawai'i's environment and the lives of its residents. Alien species cause large scale ecosystem changes, damage crops, and are pests to agriculture and quality of life (Smith 1985; Ramakrishnan and Vitousek 1989; and Vitousek 1990, 1992; ARMCA 1999; Mack *et al.* 2000; ISSG 2001). In fact, the effects of alien species worldwide have become so severe that a number of national councils and international conventions have formed to assess the issues and develop strategies for action (ARMCA 1999; Genovesi 2000; NISC 2000).

A. Invasive Plant Species

Alien plant invasions and their ecological effects are most severe on oceanic islands, as evidenced by the extinction of whole groups of species, such as snails and ground nesting birds, from Hawai'i (Loope 1992; Burney *et al.* 2001). In fact, alien plant invasions into Hawai'i are considered to be worse than in any other place in the world (Taylor 1982).

The problem of alien species invasion in native habitats is a well-documented management problem in Hawai'i's natural areas (Smith 1985; DLNR 1989; HEAR 2004; Cuddihy and Stone 1990). It is estimated that over 900 alien plant species are naturalized in Hawai'i; this number grows annually (Loope 1998; Staples and Cowie 2001). It is estimated that 20 to 50 new non-native species arrive in Hawai'i every year (Loope and Canfield 2000), mostly via aircraft, ship cargo, or mail (CGAPS 2001). Dispersal and spread may be by any number of mechanisms, such as animals (fur, feathers, clothes, or feces), wind, or water (Smith 1985).

Once established, successful invaders may out-compete native plants for nutrients or water, and quickly modify a native ecosystem by changing the vegetation. Often, invaders homogenize plant communities, simplifying their physical structure and species composition.

Invasive plants interfere with ecological processes and functions, such as reducing the ecosystem's ability to capture fog and store rainfall and fog water for steady release into streams. Plant invasions also cause the loss of species that depend on often geographically-restricted habitats (Loope 1998). Many invasive plant root structures do not hold the soil well when the plants form monotypic stands, which can accelerate geologic processes like erosion. Erosion from monotypic stands of waiawi (*Psidium cattelianum*) and *Tibouchina herbacea* in conjunction with pig disturbance increases the frequency of landslides in the valley areas. This in turn accelerates geologic erosion and decreases water quality, resulting in reef sedimentation.

Alien plant species found within the WMA are profiled in Appendix A. Known invasives include broomsedge (*Andropogon virginicus*), kahili ginger (*Hedychium gardnerianum*), yellow ginger (*Hedychium flavescens*), *Melastoma candidum*, banana poka (*Passiflora tarminiana*), fountain grass (*Pennisetum setaceum*), blackberry (*Rubus argutus*), palm grass (*Setaria palmifolia*), fireweed (*Senecio madagascarensis*), *Tibouchina herbacea*, *Clidemia hirta*, and *T. urvelliana*.

Weed species are most prevalent at the interface between pasture and forest, edges of the forest reserve, along trails, and in disturbed areas. Observations of non-native plant invasions during 1989 DLNR surveys of the Pu'u O 'Umi Natural Area Reserve yielded detailed accounts of alien species distributions by community type (DLNR 1989). DLNR mapped incipient[8] populations of alien plants starting to establish within disturbed areas along ridges, trails, and in pig-rooted areas. Non-native plants appeared infrequent in uluhe-dominated areas, which provide an effective buffer between disturbed areas and intact forests deeper in the Reserve. Very few non-native plants were observed in much of the forest, and some bogs were pristine. Fireweed was not present on DLNR transects in 1996, but by 2001 was present in 40% of the transects.

B. Feral Ungulates[9]

The effects of Hawai'i's extreme isolation are illustrated well by its absence of a single native mammalian herbivore. Hoofed grazing animals, a group of mammals present on islands and continents throughout most of the world, are completely absent from Hawai'i's evolutionary history. The lack of the pressures associated with hoofed grazers, such as trampling and heavy browsing and grazing, resulted in the loss of defenses to such pressures as species evolved to adapt to new niches and new evolutionary pressures.

When the Polynesians first came to Hawai'i, they brought along the relatively small (40-50 lbs) Polynesian pig. Recent archaeological studies suggest that the early Hawaiians kept their carefully-tended pigs close to their homes, preventing them from running loose in the forest (Loope 2001). When Europeans arrived over 1,000 years later, they brought with them the domestic hog, a much larger animal than the Polynesian pig. Over the first 100+ years of occupation, the hog became well-established in the wild. A historical account by Isabella Bird also provides insight into the continued threat posed by feral ungulates to the region: "We rode over level grass-covered ground, till we reached the Hāmākua bush, fringed with dead trees, and full of 'ōhi'as and immense fern trees, some of them with a double tier of

[8] Incipient plants are present but not yet a problem.
[9] Feral refers to domesticated animals that have adapted to living in the wild. Ungulates are mammals having hoofs, such as cattle, pigs, and horses.

fronds...There are herds of wild goats, cattle, and pigs on the island, and they roam throughout this region, trampling, grubbing, and rending, grinding the bark of the old trees and eating up the young ones. This ravaging is threatening at no distant date to destroy the beauty and alter the climate of the mountainous region of Hawai'i" (Maly and Maly 2004).

Cattle

In 1793, Captain George Vancouver delivered domestic cattle (*Bos taurus*) as a gift to King Kamehameha I. A 20-year prohibition on their use (*kapu*) was issued, and they were allowed to proliferate across the landscape without harm from the Hawaiian population. During that time, they exacted heavy impacts on the native vegetation as well as cultivated crops (Cuddihy and Stone 1990; Bergin 2004).

Currently, most cattle grazing takes place on private, managed lands. However, wild cattle persist in limited forested areas on private and public property, where inadequate or absent fencing has allowed cattle to wander into the forest in search of highly palatable foods. Unmanaged cattle are recognized as being a major destructive agent in Hawaiian ecosystems and have had a significant effect on montane mesic forests (Stone 1985). On Kohala Mountain, a feral cattle population numbering in the hundreds occurs on Ponoholo Ranch, Parker Ranch and Surety Kohala Corp. lands west of Pololū Valley. For over 10 years, staff hunted and trapped feral cattle on the Parker Ranch lands, bagging over 1,500 head. The Parker Ranch Hunting Club offers tourists the opportunity to hunt "Vancouver bulls" in this area. There are also cattle populations at the back of Waipi'o Valley, and at Awini.

Pigs

The damage caused by feral pigs (*Sus scrofa*) in native rain forests was recognized in the early 1900s when the Hawai'i Territorial Board of Agriculture and Forestry began a feral pig eradication project that lasted until 1958 and removed 170,000 pigs from forests statewide (Diong 1982). In a 1930 Hawai'i Planter's record, G.A. McEldowney reported that pigs were a bigger threat to watersheds than cattle or goats because they eat seeds and seedlings of trees, upturn soil, and cause erosion. Stone (1985) attributes rising pig population densities and expanding distributions to benefits associated with human activities and mutualistic relationships with certain alien plants such as banana poka and strawberry guava and the increasing availability of animal protein from earthworms as contributing factors.

Pigs depredate native plants, facilitate the spread of alien plants through seed dispersal and creation of sites favorable for colonization, vector disease and pathogens, and facilitate erosion (McEldowney 1930; Giffin 1978; Katahira 1980; Cooray and Mueller-Dombois 1981; Diong 1982; Loope and Scowcroft 1985; Stone 1985; and Aplet *et al.* 1991).

Cory (2000) provides a good summary of the scientific literature on the effects of pigs in native Hawaiian ecosystems. Harmful ungulate activity includes:

- Destroying native habitat through trampling, eating, and rooting;
- Creating soil disturbance, accelerating degradation, erosion, landslides and sedimentation;
- Spreading the seeds of invasive species;
- Direct predation on native species such as tree ferns (*Cibotium* spp.), other succulent-stemmed plants, and invertebrate species; and
- Serving as carriers and vectors of parasites and diseases. Parasites (fleas, lice, hookworms, tapeworms, Trichinae [source of Trichinosis in humans], etc.) and diseases

(Typhus, Leptospirosis, Cryptosporidiosis and Brucellosis) transmittable to humans are described in more detail under Section E "Aquatic Pollutants."

The effects of feral ungulates on the Kohala watershed hydrology is similar to the effects of alien plants in that they reduce and change understory vegetation, thereby affecting the vegetation's ability to capture fog, and store and release fog and rain water to streams and groundwater. As a result of opening the understory canopy to light and wind, mid-canopy air becomes drier, making it intolerable for many epiphytes and mosses that are important in fog capture, rainfall storage, and water release into streams and groundwater. The open canopy causes an increased evaporative draw from soil and vegetation. In addition, pigs create exposed soil, thereby causing erosion of nutrient-rich organic matter resulting in decreased surface water quality, and more favorable sites for colonization by invasive plants.

Studies that have removed pigs from similar environments in Hawai'i generally have shown recovery of native species following removal. A number of studies evaluating the response of vegetation following exclusion of pigs found increases in cover and density of native plants. Response of individual sites varied and was related to the degree and duration of disturbance prior to initiating removal or restoration (Katahira 1980; Higashino *et al.* 1982; and Drake and Pratt 2001).

Pigs are, for the most part, considered a pest to ranchers due to the high amount of damage that they inflict including predation on domestic livestock. (Giffin 1977). Similar sentiment comes from residential subdivisions where pigs root up yards and gardens. In the rainforest, rooting results in erosion and loss of topsoil. Native plant seedlings, saplings, and adults are also consumed by feral pigs (Giffin 1977). Generally in the rainforests of Kohala, food, water, and cover are abundant year round. Hunting has been identified as the primary cause of feral pig mortality on the island. In places where hunting pressure is light, such as in large sections of the WMA, the carrying capacity of the habitat may be exceeded, resulting in serious intraspecific[10] competition. When this happens, food availability appears to be the major limiting factor (Giffin 1977).

Feral pig activity has been observed on all transects in the Pu'u O 'Umi Natural Area Reserve, but the intensity of damage varies by location and vegetation type. Pu'u O 'Umi NAR surveys prior to 1989 noted that pig damage in the 'Ōhi'a-Olapa Montane Wet Forest was generally old and light, with a few sections in which moderate, freshly-browsed vegetation and rooting was evident (DLNR 1989). Species such as the Hawaiian orchid (*Liparis hawaiensis)*, 'ōhāwai (*Clermontia* spp.), and pa'iniu (*Astelia menziesiana*) were often present only as epiphytes, suggesting that pigs have already removed these species from the ground cover.

C. Other Non-Native Animals

Fifty-three (or more) birds, 33 reptiles and amphibians, and 19 mammals are naturalized[11] in Hawai'i. Smaller animals also have the potential to become serious pests in the Kohala watershed. Rats, in particular, may have a significant effect on native vegetation and bird species. Black rats (*Rattus rattus*) and Polynesian rats (*Rattus exulans*) are the dominant

[10] Intraspecific competition is competition between animals of the same species.
[11] Naturalized species are non-native species that have sustained reproductive populations in the wild.

species throughout most of Hawai‘i’s forests. They consume the seeds, fruits, and flowers of numerous native plant species, including many rare ones (Atkinson 1977; Stone 1985). Rats are known to eat the fruits of native Pritchardia (loulu palms) and Clermontia, and strip the bark of some native plants (Cuddihy and Stone 1990; USFWS 2000). They are the biggest contributor to the demise of sandalwood today. Rats also prey on native bird eggs and nestlings. Like ungulates, rats can affect water quality by serving as vectors for water-borne diseases such as Leptospirosis and Cryptosporidiosis. There are no estimates of the rat population in Kohala; however, it likely rises and falls in response to forage availability and other factors.

Other non-native animals that may pose problems in the watershed include mongoose, feral cats, dogs, mice, and birds. Non-native forest birds have been observed in all vegetation types. Species present included Hwamei (*Garrulax canorus*), Japanese White-eye (*Zosterops japonicus*), and Northern Cardinal (*Cardinalis cardinalis*). These species compete with native forest birds for food and other resources, provide vectors for avian diseases, and are vectors for the spread of alien plants such as Clidemia, kahili ginger and strawberry guava.

Over 3,300 alien arthropods are estimated to be naturalized in Hawai‘i; this number grows by 20-40 per year. Alien arthropod species have been introduced intentionally and unintentionally over the past few centuries for a variety of reasons. Impacts of alien invertebrates include direct consumption of rare plants, interference with plant reproduction, predation and parasitism of native animals, transmission of disease, alterations to soil formation processes, and hybridization with native forms (Howarth 1985). Many alien invertebrates occur within the WMA, but little is known about their specific populations and distribution. The Pu‘u O ‘Umi NAR Management Plan reports that the portions of the Reserve closest to the pasture lands of Waimea have high numbers of non-native millipedes and isopods foraging in leaf litter and in living foliage (DLNR 1989). Other non-native species include flies, predatory flatworms (*Geoplana* sp.), and the introduced omnivorous snail (*Oxychilus alliarius*). Both the *Geoplana* and the *Oxychilus* represent a threat to native land snails.

Numerous alien aquatic species that exhibit the characteristics of being invasive[12] threaten to cause ecological and economic harm to Kohala’s freshwater streams and their users. Exotic fish, mollusks, and crustaceans likely compete with the native stream fauna of Kohala Mountain. The loss of these native stream fauna would have cascading effects, degrading the entire native stream ecosystem. Invasive aquatic species could also cause economic impacts to agricultural users of water, resulting from crop damage, infrastructure damage, or contamination. But, perhaps more noticeably, such changes could threaten the historical Hawaiian practice of eating ‘*o‘opu* and *‘o‘pae kala‘ole* from mountain streams.

Introductions of aquaculture and aquarium species into streams occur via flooding, effluents discharged back into the streams, intentional introduction, and by overland travel. The Tahitian Prawn is suspected in the decline of native *‘opa‘e kala‘ole* and *‘o‘opu* populations

[12] According to Staples and Cowie (2001),both terrestrial and aquatic invasive species worldwide possess the following general characteristics:

- adaptable to, and able to thrive in, different habitats and a wide range of conditions;
- rapid growth rate of individuals, thereby able to displace other plants or animals;
- easily dispersible to new localities; and
- have reproductive characteristics that allow for rapid population growth.

observed by Hāmākua farmers (Okamura 1995). Invasive fish used in aquaculture, such as the Saltwater Tilapia (*Sarotherodon melanotheron*) and Chinese Catfish (*Carius fuscus*), prey on native fish, crustaceans, and arthropods, thereby altering the structure of the stream ecosystem. In addition, disease and pathogens associated with cage-reared species could potentially spread through streams and ditches. Fish used in the aquarium industry, such as the Mexican Minnow (*Poecilia mexicana*), Convict Cichilid (*Cichlastoma nigrofaciatum*), and the Swordtail (*Xiphophorus helleri*) directly compete with native stream fauna for food and other resources (Nishimoto 2004; USFWS 2003).

Invasive alien fish, mollusks, crustaceans, and arthropods already exist within streams and ditches in the WMA. This plan seeks to comply with the goals of the Hawai'i Aquatic Invasive Species Management Plan to minimize harmful ecologic and economic impacts of invasive aquatic species, through the prevention and management of their introduction, expansion, and dispersal into, within, and from the Kohala WMA.

D. Human Activities

Most human activities in the watershed are done with good intentions. Hikers access the watershed for its natural beauty, unique plant and bird species, and sweeping views; in the process, they gain a greater appreciation for the natural environment of Kohala Mountain. Hunters provide a benefit to the natural environment by helping to manage pig populations. State and private land managers build fences to protect forested areas and unique plant and animal species from disturbance of ungulates and people. However, these seemingly benign practices can also have a negative impact on the watershed if not conducted in a responsible manner. Humans can damage vegetation directly through trampling and over-collection, and indirectly by introducing weed seeds or by providing the ignition source for fire. Fence-lines constructed without care to prevent introductions and spread of alien species, or unmaintained fences, become avenues for the spread of weeds.

Native plant collection occurs within the WMA, mostly seasonally, subsistence or on a small scale. *Maile* is the primary plant collected. The prevalence of plant collection is unknown and data mostly anecdotal.

Illicit cultivation of marijuana (*Cannabis sativa*) also occurs in the Kohala Mountain watershed. Growers provide a mechanism through which soil bacteria, fungi, and other alien plant pathogens can enter new areas and establish within the remote sections of the watershed. *Cannabis* cultivation is likely to also contribute to the introduction and spread of weeds within the watershed. In addition, marijuana growers sometimes confront recreational users of the watershed and are a threat to hiker safety. Interestingly, the Kohala Mountain watershed was used in a similar manner for illicit distilleries brewing okolehao in the late 1800s and posed many of the same concerns for user safety of these areas.

E. Aquatic Pollutants

Very little information exists about specific aquatic pollutants originating in the Kohala Mountain watershed. Anecdotal information and the fact that these water sources have been used for domestic and agricultural water supplies for centuries suggest that the water of Kohala Mountain is generally of the highest quality. That being said, the Department of

Health's most recent list of impaired waters in Hawai'i includes Wailoa/Waipi'o Stream, Niulili Stream, Waikama Stream, and Aamakao Stream, all of which have their headwaters in the Kohala Mountain WMA. These streams exceed State water quality standards for turbidity and/or nutrients during the dry season.

Sediments

Most water quality problems in the upper watershed do not have anthropogenic origins; rather, they are related to soil erosion, which is a natural process in forested areas, that can be amplified by animal, and to a lesser extent human, disturbances that open up greater areas of the forest floor to increased rates of erosion. These pollutants occur as siltation, suspended solids, turbidity, nutrients, and pathogens.

The sediments eroding from forestlands into streams contribute to a high rate of suspended solids, which are comprised of eroded silts and clays, organic detritus and plankton. High levels of suspended sediment produce a "muddy" appearance in stream waters. These muddy waters affect more than just aesthetics. Suspended sediments can:

- stress native fish like *o'opu*, and hinder their ability to find food;
- damage the gills of some fish species, causing them to suffocate;
- increase water turbidity, which limits light penetration and impairs photosynthesis for aquatic plants;
- raise water temperatures; or
- lower dissolved oxygen concentrations, which at decreased levels can kill aquatic vegetation, fish, and bottom dwellers.

Once these sediments finally settle on the bottom of streambeds, irrigation ditches, and reservoirs, they produce other detrimental impacts. High sedimentation levels can:

- affect levels of nutrients, solids and oxygen-demanding materials;
- eliminate essential habitat and bury food sources and spawning sites for stream life;
- smother bottom-dwelling organisms *'opa'e* and periphyton[13]; and
- reduce the capacity of stream channels and ditches to carry water and of reservoirs to hold water.

Toxins and Bacteria

Swimming in the streams could result in Leptospirosis and Cryptosporidiosis, potentially fatal illnesses caused by water-borne micro-organisms spread by pigs, dogs, mongooses, rats, and even frogs. A few people become ill each year from wading in ponds or drinking water from affected springs and streams. The Department of Health does not currently conduct any regular monitoring of stream pathogens in the WMA.

Leptospirosis is a bacterium, transmitted from animals to humans where people contact the bacteria through water or mud that has been contaminated by animal urine or droppings. About 500 cases, including 7 deaths, have been reported in Hawai'i in the past decade. According to DOH statistics, the windward side of the Island of Hawai'i historically reports the largest number of cases. Waipi'o Valley is considered a hot spot, where people most often are exposed.

[13] Periphyton are the algae attached to bottom vegetation and rock surfaces.

Cryptosporidiosis is a diarrheal illness caused by a microscopic intestinal parasite, Cryptosporidium. People are typically exposed by eating food or drinking water contaminated with feces of infected animals, including cattle, rodents, cats, dogs, and humans.

F. Wildfire

Because Hawai'i's flora have evolved with infrequent, naturally-occurring episodes of fire, most native species are not fire-adapted and are unable to recover well after wildfires. Alien plants, particularly grasses, are often more fire-adapted than native species and will quickly exploit suitable habitat after a fire (Cuddihy and Stone 1990). On the leeward side of Kohala Mountain the forested watershed abuts pasturelands, with kikuyu grass (*Pennisetum clandestinum*) as the dominant grass species. A wildfire started in grasslands bisected by major roadways could quickly spread into the forest reserve.

Fires cause the removal of vegetation cover, loss of the soil-anchor feature of root masses, and exposure of bare mineral soil. This combination makes burned areas susceptible to high levels of erosion. Fire suppression is difficult in the forested watershed of Kohala Mountain because of its relative inaccessibility to vehicular traffic, so helicopters would likely be used in the event of a fire.

Fire risk, or the potential for fire, is contingent on frequency of human activity and climatic conditions. The wildland-urban area interface and camping sites are important factors as ignition sources. Climatic conditions are often related to seasonal rainfall, where dry summer months and brisk winds can lead to high-risk fire conditions (USFWS 1998). Wildfire hazard, describing the fire intensity, depends upon topography and fuel source.

G. Climate Change

Global and local climate change have the potential to affect the Kohala watershed hydrology through altering rainfall patterns and elevating cloud banks. Changing climate would affect the abundance and seasonality of precipitation, thereby affecting agricultural water users over a broad geographic area. Watershed functions would be compromised from the drying of the air, vegetation and soil, resulting from an elevation of the cloud bank.

Rare ecosystems and species may be affected by relatively rapid changes in precipitation, temperature, and humidity that result from a rapid and drastic change in regional or local climate patterns. At the Monteverde cloud forest in Costa Rica, researchers found declines in cloud forest epiphytes and amphibians to be correlated with a rise in the overhead cloud bank. Costa Rica also displays evidence that regional land-use change can have a significant influence on formation of cloud banks. The deforested Caribbean lowlands downslope of Monteverde remained relatively cloud-free in the dry season, while adjacent forested regions had well-developed cumulus cloud fields (Bubb 2004).

Climate change would also impact the local culture and lifestyle. Populations of culturally-used plants, such as maile (*Alyxia oliviformis*), may decline. Even the modern paniolo lifestyle that is characteristic of the region would be affected by a decline in rangeland quality resulting from a drying climate. Recreational opportunities might also be adversely affected.

V. MANAGEMENT PROGRAM

As early as the 1800s, land tenure documents, survey records, and government communications outline efforts made by ranching and plantation interests as well as the Crown and government lands and native Hawaiians to work together to insure the health and quality of the watershed in light of increased development and human population growth. Historical records reveal the changes to the land and its water source as a result: "Many of the old springs are now dry," "the woods have for years been continually receding from the coast and lands once well wooded are completely bare," "water stands in small pools instead of running in continuous streams," "The forests of the Kohala mountains are dying…the complaint of the people is well founded. The water they use is fouled in many places by cattle, horses and other animals, and as the stream is sluggish it has no chance to free itself of impurities," "The recession of the forest in the Kohala district is one of the most marked examples of the change in natural conditions that is to be found anywhere in the Territory. If the edge of the forest is permitted to be pushed further back it is my belief that the consequences to the lower lands will be serious" (Maly and Maly 2004).

Today, the Kohala Watershed Partnership (KWP) carries on the history of landowners and affected communities working together with its primary GOAL to maintain a healthy watershed as a reliable source of high quality water for North Hawai'i. To achieve this primary GOAL, this chapter identifies OBJECTIVES related to the protection of water resources and watershed functions and the management of threats to these resources. Because the watershed of Kohala Mountain supports unique plant and animal communities that have value to society, this chapter also includes GOALS and OBJECTIVES related to the protection of biodiversity. Recognizing that a management program cannot be effectively implemented without sufficient infrastructure and personnel, recommendations addressing the administration of the program are incorporated. Finally, the chapter addresses compatible public use of the watershed.

Outlined in this chapter are OBJECTIVES and recommended ACTIONS to implement the primary GOAL and another six major goals over a 20 year period. Under each management GOAL, there will be one or more OBJECTIVES, each followed by a brief description of current management activities. Each objective will identify specific management ACTIONS to achieve the OBJECTIVE. GOALS and OBJECTIVES are long-range and not subject to significant change. However, specific ACTIONS may need to be further refined through the management process, as new information is obtained and circumstances evolve.

The management program outlined here was developed in a series of planning meetings held by the Kohala Watershed Partnership, drawing from previous information and planning efforts, and with input from landowners, resource managers, and community members. Management OBJECTIVES and specific ACTIONS build upon recommendations developed by the Natural Area Working Group (NAWG), Kona/Kohala Natural Resource Area Workshop (K/K), Kohala Forest Management Group (KFMG), and the Waimea Water Roundtable (WWR). Summaries of statements and recommendations from past efforts are included in Appendix C. Recommended ACTIONS that were incorporated into this Plan from earlier efforts include, in brackets, the acronym of the earlier effort and a number which refers to the item number in Appendix C.

The proposed management program in this Plan also draws upon the information gathered through interviews of knowledgeable individuals. However, the Kohala watershed partners

acknowledge the importance of gathering additional community input before the management program is finalized. To accomplish this, public workshops will be conducted in the communities most closely affecting, and affected by, management actions contemplated in the Kohala watershed. Comments received from the public will be incorporated into a revised watershed management plan and an Environmental Assessment (EA). These documents will then be available for further review and comment during a 30-day public comment period. Following this public comment period, the management plan and EA will be finalized and submitted to the Board of Land and Natural Resources with the Conservation District Use Application (CDUA) for proposed actions within the Conservation District.

Costs for implementing recommended actions can vary considerably depending on when an action is implemented, who does the work (volunteer vs. employee vs. contractor), and other factors. It was the opinion of the KWP that costs need not be identified in this plan, knowing that when specific projects are budgeted for implementation, cost details will be provided.

The primary goal of the Kohala Watershed Partnership is to show improvements in water and environmental quality by enabling comprehensive and sustainable watershed management projects that address the threats to the watershed, while maintaining its integrity and protecting its economic, sociocultural, and ecological resources.

Management Goal 1: Protect Water Resources.

Resource experts over the last century have recognized the importance of the forested watershed in promoting infiltration and groundwater recharge, with the overstory and understory both performing important watershed functions. More recently, scientists have proven that fog drip represents a significant amount of precipitation captured (Juvik and Ekern 1978; Juvik and Nullet 1995), most notably in the fog belt on the windward sides of tropical montane cloud forests, such as that found on Kohala Mountain. The structurally-complex[14] Hawaiian forest plays a vital role in intercepting cloud water. The fog belt on windward Kohala Mountain extends from the 3,000-ft. elevation to enclose the summit area.

***Objective 1a**: Maintain a structurally-complex vegetative cover that promotes infiltration and groundwater recharge and minimizes erosion.*

Recommended Actions
Manage threats as recommended below to minimize disturbances to robust forested watershed.

***Objective 1b**: Protect, enhance, and manage high yield watershed areas to maintain water quantity and quality.*

Several statutes and regulations exists to protect surface water quality and quantity: Chapter 342D, HRS, related to state water quality standards; Chapter 174C, HRS, Hawai'i Water Code; and Chapter 13-105, HAR, related to restricted watersheds. Each is implemented by a different agency of the State government. The Safe Drinking Water Branch of the Department

[14] Structurally-complex vegetation is that which is multi-canopied or has many strata or layers, such as a cloud forest environment that possesses moss, lichen, and epiphyte layers covering rocks, soil, and stems; and additional layers of ferns, sedges, shrubs, low–stature trees, and overstory trees. Strucurally-complex forests usually have a high total leaf surface area.

of Health protects Hawai'i's drinking water sources (surface water and groundwater) from contamination through the administration of the Safe Drinking Water Program, Underground Injection Control Program (UIC), Groundwater Protection Program (GWPP), and the Drinking Water State Revolving Fund (DWSRF).

While a portion of Kohala Mountain was designated under Chapter 13-105, HAR, as the Kohala Restricted Watershed in order to protect public water supplies that are vulnerable to contamination by public access, most people interviewed as part of the management plan development process agreed that access restrictions are rarely enforced and do little to afford real protection to surface water quality.

The windward area between the backs of Honokāne and Kawainui valleys *mauka* to the summit ridge arguably generate the greatest combined water yield of Kohala Mountain. The area captures more than 100-150 inches of rain on average every year, intercepts significant amounts of fog drip, and contains the headwaters of the major streams feeding domestic and agricultural supplies. This is the area of cloud forest formation, a phenomenon known to contribute as much as one third or more the amount of rainfall to total precipitation. Based on the distributions of the cloud forest on Kohala Mountain and the area of maximum rainfall, which occurs slightly *makai* of the area of cloud persistence, we believe these areas comprise the significant portion of the watershed in which groundwater infiltration is occurring. For these reasons, management of approximately 6,600 acres (delineated in Figure 8) is a priority to protect forest areas that are important for maintaining high yield watersheds. This area coincides with the areas proposed for fencing in the KFMG's Action Plan Outline of Projects, for which there was broad agreement (Figure 8; Appendix C - KFMG (13)).

Three upland units spanning the area from the back of Honokāne Nui east to Pu'u O 'Umi and the rim of Kawainui Valley include: Big Valley (A: 900 acres), which contains the headwaters of Honokāne stream; Upper Kawainui (B: 1,600 acres), which protects the headwaters of more streams and, therefore, a greater yield of water. Both of Units A and B are mainly comprised of sections of the Pu'u O 'Umi Natural Area Reserve. The Upper Ohiahuea (Unit C) contains the headwaters of Ohiahuea stream. The majority of this 2,100 acre unit is comprised of the Kohala Forest Reserve with the additional acreage including a tiny portion of the Pu'u O 'Umi NAR . A fourth unit, Upper Laupāhoehoe Nui (Unit D), captures prime watershed between 3,500 and 4,000 feet on the windward slope and is in relatively good condition. This unit includes approximately 2000 acres and is comprised of the upper third of the privately-owned Laupāhoehoe Nui ahupua'a along with a section of the NAR.

Recommended Actions
Fence high yield watershed areas A: Big Valley (approx 900 acres) [KFMG(13); K/K (20)]; B: Upper Kawainui (approx 1,600 acres); C: Upper Ohiahuea (2,100 acres); and D: Upper Laupahoehoe Nui (2000 Ac).
Remove feral pigs within high yield watershed area A, B C, and D, using most appropriate combinations of methods, as dictated by terrain, management access, and other management considerations.
Prevent the introduction of potentially harmful new weeds and manage existing weeds within high yield watershed area A, B, C and D.
Review Kohala Restricted Watershed designation for its effectiveness in protecting water quality and quantity and recommend changes, as appropriate.

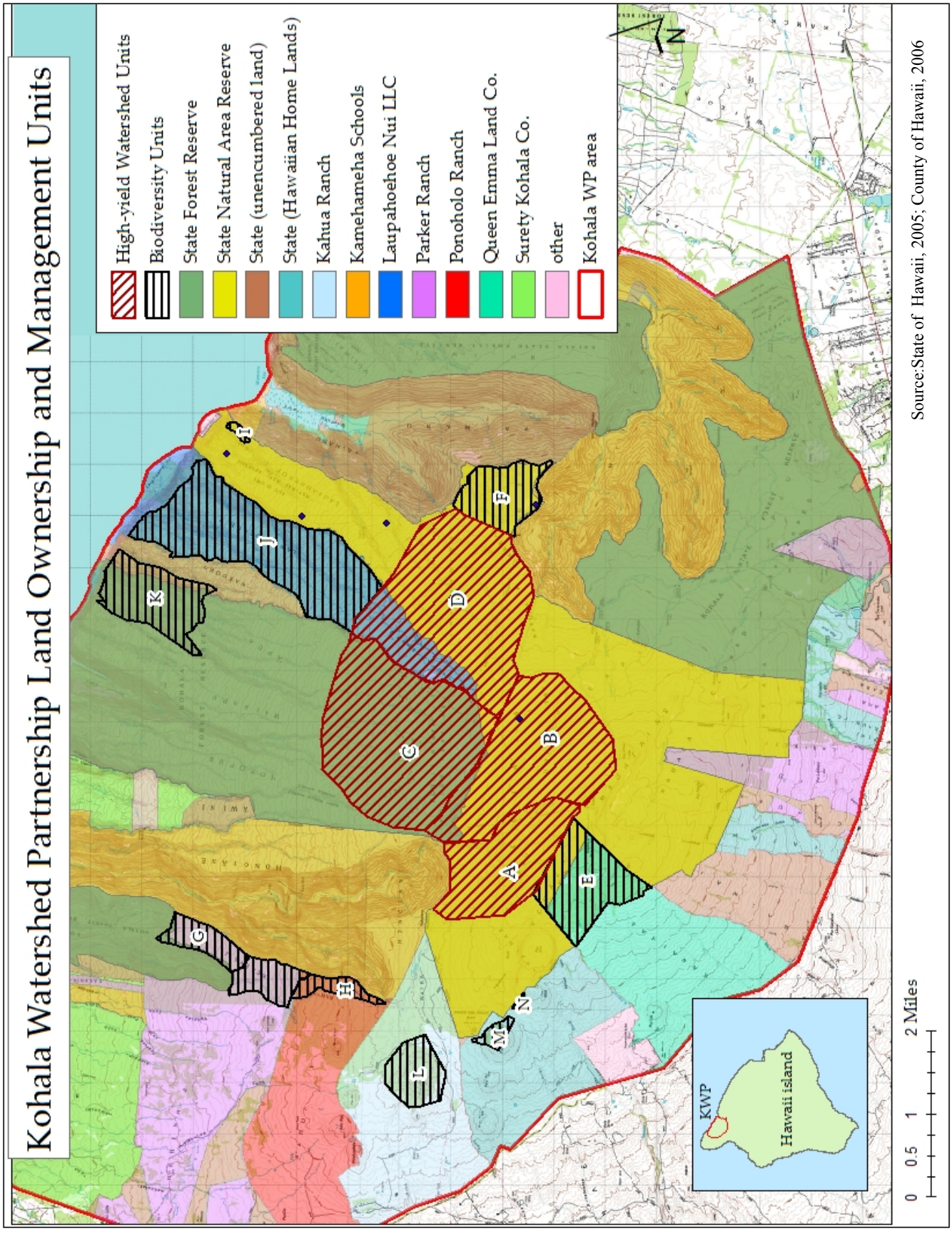

Figure 8. Land Ownership within the Kohala Mountain Watershed Management Area

***Objective 1c**: Monitor the quality and integrity of ground water, surface waters, and aquatic environments.*

Surface and ground water quality on Kohala Mountain are generally regarded as high. The State DOH has monitored stream water quality in the more accessible streams on the western and eastern sides of the WMA. However, little regular groundwater and surface water monitoring has been undertaken within the majority of the WMA; therefore, baseline information is needed for long-term monitoring.

In addition, little information exists pertaining to the current biological condition of Kohala's streams; however, the streams are generally considered to be intact. Stream assessment protocols that utilize biological criteria are needed to obtain information critical to management. Management actions should also be developed and implemented in coordination with DLNR's Division of Aquatic Resources and consistent with the Hawai'i Draft Aquatic Invasive Species Management Plan (2003).

From the mid-1800s, the large agricultural operators around Kohala Mountain kept detailed records of water and weather data (WWR no date). These records included information on rainfall, temperature, evaporation, soil moisture content, stream flow and more. As Hawai'i's economic base has shifted away from agriculture, less of this information has been collected on a regular basis. This deficiency of new data renders it difficult to make informed decisions about watershed health, water allocation, and sustainable yields. Furthermore, additional information is needed about the resources within the watershed and appropriate management techniques in order to make educated management decisions.

Recommended Actions
Develop programs to monitor long-term impacts to water quality and watershed health, in cooperation with other watershed partnerships.
Develop a monitoring program to measure sedimentation, stream flow, turbidity and nutrients on a subwatershed or valley level, in collaboration with Federal and State agencies. [WWR(3)]
Establish network of satellite-transmittable telemetric meteorological monitoring stations in cooperation with the University of Hawai'i at Hilo. [WWR(5)]
Assess the biological integrity of streams in upper Kohala Mountain, as necessary.

***Objective 1d**: Develop a thorough understanding of the nature of groundwater resources affected by Kohala Mountain.*

USGS has estimated the average annual recharge in the Hawi Hydrologic Study Area. Similar studies have not yet been completed for the other two Kohala Mountain hydrologic units, Waimanu and Māhu-kona. However, an assessment of groundwater conditions was conducted for the districts of North and South Kona and South Kohala from 1991 to 2002. This State Commission on Water Resource Management study provided baseline data to support and inform planning decisions related to development and well-drilling for that region.

Developing estimates of groundwater resources, rates of recharge, and sustainable yield can be a daunting task. However, further developing this understanding is necessary in order to

develop and manage groundwater resources responsibly, as demands for these resources continue to increase.

Recommended Actions
Conduct study of groundwater recharge dynamics for Waimanu and Māhu-kona hydrologic units, in coordination with USGS.
Undertake research to improve understanding of both the surface and sub-surface hydrology of Kohala Mountain, especially the connection between Kohala Mountain water and groundwater of the Waimea Plains. [WWR(3)]

***Objective 1e**: Support appropriate water development to meet the needs of future demand.*

Kohala Mountain provides the lifeline for North and South Kohala and parts of Hāmākua with respect to water. Existing domestic water systems throughout the region are approaching capacity, given rapid urban development and increasingly-stringent water treatment requirements. Agricultural water systems are taxed during periods of drought, and by decaying infrastructure, and changing demands. There is an increasingly urgent need to convert domestic consumption to groundwater sources and leave existing surface water sources for agriculture.

Recommended Actions
Participate in the Waimea Water Roundtable to work toward common solutions to water issues affecting Waimea and its environs.
Implement plans to increase use of groundwater for domestic water supplies (DWS).
Support planned improvements to the Waimea Irrigation System to improve water conveyance efficiency, add storage capacity, and expand service to provide livestock drinking water.
Support enhancement and maintenance of stock water storage and dispersal systems.
Support continued use of existing ditches for agricultural and other purposes, as long as they are being used in a reasonable manner with no wastage.
Study the interest in and feasibility of restoring the ditch system with minimal adverse impact to ecological services.

Management Goal 2: Prevent New Introductions and Control Existing Invasive Plant Species.

The Mack *et al.* (2000) literature review panel found that successful invasive species control depends more on commitment and continuing diligence than on the efficacy of specific tools themselves. They also found that control of biotic invasions is most effective when it employs a long-term, ecosystem-wide strategy rather than a tactical approach focused on battling individual invaders (Mack *et al.* 2000).

Once present in the watershed, each species usually has to be managed individually, sometimes using a variety of techniques. The management approach should consider the species' distribution, mode of spread, and other factors. The manager has a wide range of techniques and tools available that could be applied. The how, where, and why of how those

techniques are applied are decisions that depend on the individual circumstance. The Nature Conservancy's Wildland Invasive Species Program "Weed Control Methods Handbook" (2002) provides a thorough overview of weed control techniques and provides other information in support of their application, and Hiebert and Stubbendieck's "Handbook for Ranking Exotic Plants for Management and Control" (1993) helps provide a decision-analysis process for prioritizing alien species for control.

There are some invasive plant species (*e.g.*, fire weed (*Senecio madagascarensis*) and palmgrass (*Setaria* sp.) that are impractical to control at a landscape scale at this time due to their broad dispersal mechanisms (*e.g.*, wind, birds) and limitations in management funding and access. These species may simply have to be tolerated for the time being, or longer, unless an effective biocontrol can be found.

Available methods and techniques include: mechanical, grazing, prescribed fire, chemical, and biological. Mechanical control methods include manual pulling, digging, snipping, cutting, girdling, grinding, and others. Mechanical control can be labor-intensive and expensive. However, volunteers can be effectively utilized for well-defined projects. Methods such as cut-stump, frill, and notch-cut follow treatment immediately with a spot application of herbicide. Some mechanical techniques can cause damage or ground disturbance, stimulating growth of weedy species; eradicating an entire stand of one alien species can open the canopy to allow replacement by another opportunistic alien species. The practical way to avoid such mass disturbance-triggered reinvasion is to remove and replace slowly, in gaps, filling the gaps created by removal with species of choice. This method requires follow-up maintenance.

Cattle and sheep have been used effectively to reduce wildfire grass fuels in pastures and other grasslands on the island. Cattle have been effectively used at Puʻu Waʻawaʻa Ranch to reduce wildfire fine fuels through intensive roadside grazing. Cattle are also currently being utilized in Kohala Ranch, on the lower southwest slopes of Kohala Mountain below the WMA, to keep wildfire fuels reduced around homes in the subdivision. Sheep have been used to reduce wildfire fuels in a perimeter fuelbreak for Waikii Ranch. Use of grazing animals may also be an effective method of managing growth of invasive woody plants now or in the future. Grazing animals would be used only on pastures and other grasslands, not in the forest.

Prescribed fire could be used to remove or reduce stands of alien species or to reduce roadside stands of wildfire fuels. It is unlikely that prescribed fire will be used in the watershed for any purpose, but, should it need to be used, burn planning will be done cooperatively following established procedures and using best management practices.

Chemical control methods are often an important tool in invasive plant management, especially where mechanical control methods are not feasible, where biological control techniques are not available, and when cost and time constraints dictate. When used responsibly and with caution, herbicides can be an effective tool to quickly kill a plant, keeping it from entering its next reproductive cycle; in many instances, the dead plant tissues form a mulch ground cover. Another benefit of herbicide use is the relative ease with which it can be applied compared to more intensive mechanical methods. Non-restricted herbicides are carefully used by resource managers throughout the state as part of alien plant management programs (Tunison 1992; Tu *et al.* 2001).

Precautions should be taken to avoid impact to native species; generalist herbicides should be used sparingly in areas with a high occurrence of endangered species or sensitive and rare ecotypes. The application methods and equipment that minimize the risk to adjacent plants are preferred. Pesticide usage will be in full compliance with state and federal regulations. Additional techniques for alien plant control, such as aerial spraying of herbicides, may be considered for use in the future as these techniques are developed.

Biological control is another tool used effectively by managers worldwide in controlling alien plant and animal species. Biological control uses predators and disease organisms of invasive pests from their native ranges to damage targeted weeds. Australia is currently using biological controls to target over 60 weeds for control (Briese 2004). However, some land managers in Hawai'i are reluctant to use biocontrol agents due to their unpredictability and irreversibility, and a long list of failures in Hawai'i (Howarth and Medeiros 1989). The process of finding a biological agent can be difficult and expensive, with uncertain results as well.

But, according to the Coordinating Group on Alien Pest Species (CGAPS)[15], biological control needs to be a key component of any effective long-term control program, because it provides the only cost-effective method for reducing the negative impacts of priority invasive species that are already well-established in Hawai'i. The technique has had several amazing successes throughout the world and in Hawai'i, including effective control of the following species that once were more widespread in the Kohala Mountains: painiu or prickly pear cactus (*Opuntia* sp.), pamakani (*Ageratina riparia)*, banana poka (*Passiflora tarminiana*), and lantana (*Lantana camara*).

For banana poka, the *Septoria pasiflorae* Leaf Spot fungus has proven successful. A one-time application of the fungal agent sprayed onto leaf and stem tissue spreads without assistance during winter months and periods of high rainfall affecting photosynthesis and other physiological processes. Inoculations of *Septoria* at different forest sites in Hawai'i, Kauai, and Maui resulted in estimated 80 to 95% biomass reductions over more than 2,000 hectares of native forest by 1999 (Trujillo *et al.* 2001). In October 2000, DLNR personnel observed *Septoria* in the Pu'u O 'Umi NAR behind Kahuā Ranch and near Pu'u Mala. It is believed that this occurrence originated from wind-borne spores blown in from Hāmākua or Hualālai where it had been previously introduced. It has not yet been confirmed that the Big Valley introduction of *Septoria* has successfully established. No *Septoria* was found on a June 26, 2001, site visit and no follow-up observations have been made since then (DLNR 2004b).

Pseudomonis bacteria is also present on banana poka in Big Valley and the Pu'u Mala area of Kahuā Ranch. It also causes some defoliation, although not as much as *Septoria*. Banana poka is also easily rooted out by hand.

A biocontrol pathogen has been discovered for *Clidemia hirta* as well. The *Colletotrichum* fungus was identified in Panama in 1984 and brought to Hawai'i and tested in 1985. The pathogen causes severe premature defoliation and tip dieback (Trujillo *et al.* 1986). This fungal biocontrol has been used along the Aiea Loop Trail on O'ahu with success. DLNR's Division of Forestry and Wildlife started introducing the *Colletotrichum* fungus into the WMA in

[15] The Coordinating Group on Alien Pest Species is a multi-agency partnership to coordinate more effective protection for Hawai'i's economy, environment, health, and way of life from harmful alien pests.

the winter of 2004-2005. It was applied monthly during winter months by DOFAW along the Muliwai trail and other locations on the island (DLNR 2004b).

Kahili ginger (*Hedychium gardnerianum*) is an extremely aggressive invader of forest understories and affects large areas in Hawai'i. USGS research has demonstrated that the wilt-causing bacterium *Ralstonia solanacearum* attacks and is highly specific to ginger (USGS-PIERC 2004). This pathogen lives in the soil and gets into the plant either through wounds or root absorption. Once inside the host, the pathogen will cause severe wilting of ginger stems and eventually kill the entire plant. Individual rhizomes will rot and decay within 6–8 weeks of infection, with entire mounds taking anywhere from 1 to 2 years to completely decay away, depending on size. Field trials have been underway on the Island of Hawai'i for 5 years and appear to demonstrate good long-term control (Landcare Research 2004). Biocontrol for fireweed (*Senecio madagascarensis*) and palm grass (*Setaria* sp.) should be initiated immediately.

***Objective 2a**: Prevent the introduction of new potentially-invasive plant species.*

Many potentially-invasive plant species are not yet established in the WMA, but could become so without preventative action. Prevention requires a rigorous education and outreach program to inform land users and the public about weed dispersal and ways to mitigate unintentional introductions.

Recommended Actions
Coordinate with affected industries and interests in the ranching, farming, and horticulture industries to develop mechanisms to create a quarantine barrier to new weed introductions without unduly restricting the long-term productivity of the primary industries operating within or around the WMA. Establish operational protocols to prevent new introductions of invasive plant species.
Identify potential future invaders, likely mechanisms and pathways of introduction, and locations of vulnerability.
Develop an education and outreach program that concentrates prevention awareness campaigns toward the source of likely invasive species, in their place of origin. [NAWG(43)]
Inform watershed users prior to their arrival, upon their arrival, and again upon their departure, about the effects of introduced species and their modes of introduction and spread, and what steps can be taken to prevent introduction and spread of invasive plant species in the watershed.
Support interagency programs to evaluate modes of transmission and develop interdiction programs at ports of entry to the island.

***Objective 2b**: Manage the spread of incipient and well-established weed pests.*

Many invasive plant species are well established within the WMA, and management, other than biocontrol, may not be practical for these. Others have only gained a foothold and may be eradicable with a moderate amount of effort. Interdiction and interception, education and awareness, and conscientious cultural and agricultural practices are required to effectively manage them.

Over the past 10 to 20 years there has been a large body of information printed related to alien species ecology and management. Review of a selection of national and international-level planning documents outlining strategies or directing programs found approaches to be similar in their emphases of the following three steps: 1) prevention; 2) detection, evaluation and response; and 3) building organizational frameworks for long-term management programs (NISC 2000; Genovesi 2000; ARMCANZ 1999; Mack *et al.* 2000).

Many invasive plant species are well-established and cannot effectively be managed or removed given practical constraints of available funding. Many of these species may have to be tolerated for the time being or indefinitely. If there are locations that are not yet occupied by a particular species that may be worthy of keeping free of that one or more invasive species, it may be worthwhile to designate such locations early. Many invasive species distributions are restricted to certain portions of the watershed. For some of these, it may be feasible to first assess and start eliminating satellite populations before working on core populations, a technique used with success locally and abroad (DLNR 2004; Moody and Mack 1998). Control and eradication, however, is achievable for many other species.

Recommended Actions
Regularly assess distribution of problem weed species and maintain current distribution maps.
Prioritize areas for management for each problem species.
Develop and implement an integrated pest management approach that utilizes the appropriate technique or combinations of techniques for each problem weed species.
Manage the spread of problem weeds in watershed management units A-N.
Assess the feasibility of eradicating *Tibouchina urvelliana* population from the Honopue Valley east slope.
Start monitoring program for banana poka and Clidemia.
Develop a biocontrol maintenance program for banana poka and Clidemia.
Conduct a monitoring program in conjunction with management projects to document short- and long-term changes in watershed quality. Revise management strategy, as appropriate, based on monitoring results.
Work with the landscape industry and Hawai‘i Department of Agriculture to address the introduction of new invasive weed species.

***Objective 2c**: Conduct monitoring and research to determine efficacy of control measures and to identify occurrences and distribution of other new species.*

Monitoring is an important component of any management program. Monitoring on Kohala Mountain is challenging due to the inaccessible nature of most of the watershed. A monitoring approach that builds upon the best features of the existing monitoring program will need to be developed. Alternative monitoring programs and methodologies will have to be evaluated and considered. Meanwhile, it will be useful to continue to conduct basic monitoring while developing an improved approach. DLNR collected monitoring data of weed presence along 24 transects within the Pu‘u O ‘Umi Natural Area Reserve in 1996 and 2001.

Recommended Actions
Evaluate current monitoring program to identify strengths and weaknesses, and

assess alternative monitoring methodologies. Streamline overall monitoring program to increase efficiency while obtaining reliable information.
Continue to monitor the patterns of distribution of incipient and well-established weed species and effectiveness of management actions using previously-established transects and other means.
Extend monitoring program to cover the entire watershed management area.
Conduct research on additional control methods for priority species.
Explore alternative techniques for large-scale monitoring, including ground and aerial photography and remote sensing.
Initiate biocontrol research for fireweed and palm grass, and lobby Big Island Invasive Species Council for funding and support.

Management Goal 3: Control Non-Native Animal Populations within Designated Areas. There are a number of techniques available to manage and remove non-native animals, including public hunting, staff hunting, contract hunting, aerial shooting, snaring, trapping, and poisoning. Techniques vary widely in their cost, effectiveness, and length of time taken to complete. A most striking comparison of methods and costs was made between Hawai‘i Volcanoes National Park (HAVO), where hunting, trapping, snaring and fencing was used to control pigs, and Namadgi National Park (NNP) in New Zealand, where pigs were poisoned. Both strategies reduced pigs, but methods at HAVO cost 34 times more ($1,180/km^2) (Hone and Stone 1989). At Hakalau Forest National Wildlife Refuge in Hāmākua, managers found the same array of techniques that HAVO used to be effective, but they were costly and took time. Hakalau's Feral Ungulate Management Plan provides a thorough analysis of methods for reducing feral pig populations (Walker 1996).

In Hawai‘i, use of poisons for eradicating mammalian pests has been restricted to locally depressing rat populations through use of diphacinone rodenticide bait blocks for periods of time. Recent experiments with aerial broadcast rodenticide bait pellets in Kilauea Forest resulted in unexpected indirect effects on non-target animals, an event that will lead to further research on its use prior to approval of aerial broadcast as an allowable method in Hawai‘i. Poisons have not been used for cattle, pigs, or goats.

Reeser and Harry's (2004) review of Hawaiian examples of where ungulate populations are successfully kept at low or zero population levels over large area highlighted four requirements: 1) a strategy of barriers to isolate populations, 2) take of significantly greater percentages from populations than can be replenished by reproduction and ingress from adjoining areas, 3) barrier inspection and maintenance, and 4) vigilance in monitoring and removal of animal population increase and ingress.

Most of the feral pig and cattle management alternatives will entail the use of fencing. Fences are unmatched in utility when it comes to managing wild animals across natural landscapes. Fences are typically used to exclude pigs by completely surrounding the management area, but are sometimes also used strategically in small pieces to block movements across narrow passes and ridges.

A small proportion of the hunters who use the public lands on Kohala Mountain are generally opposed to fencing and removal of pigs for natural resource management purposes. Recent vandalism of a 10-acre rare plant protection fence in the leeward forest illustrates this point.

However, most of the local residents interviewed early in the management plan development process indicated that they would support fencing some areas in order to steward important watershed and unique native forest values.

Animals will be removed from watershed (Management Goal 1) and biodiversity (Management Goal 4) management units as they become fenced, at the discretion of the partnership. Techniques used to remove animals will depend upon accessibility, cost, and other factors. The primary tools available include hunting (public, staff, contract), aerial shooting, snaring, and live trapping.

***Objective 3a**: Remove feral cattle from the watershed management area.*

There has been limited and unsustained control of the feral cattle in the WMA. These feral cattle are found primarily in the forested areas of Ponoholo Ranch, Parker Ranch and Surety Kohala Corp., west of Pololū Valley. These landowners have expressed support for an eradication effort. There are also cattle populations at the back of Waipiʻo Valley, at Awini and in the Puʻukapu section of the WMA. A monitoring program conducted in conjunction with the eradication program will document the recovery of these forested areas.

Recommended Actions
Construct new or replace/repair existing forest reserve boundary fence west of Honokāne Valley and at Puʻukapu.
Improve and regularly maintain boundary fences to prevent future ingress by cattle.
Eliminate feral cattle from the watershed area using available techniques.
Conduct a monitoring program in conjunction with control efforts to document short- and long-term changes in the forest cover and quality resulting from cattle removal.

***Objective 3b**: Implement pig control to minimize loss of watershed vegetation cover, watershed soil erosion, and human health risks associated with animal-borne diseases.*

DLNR monitored pig presence along 24 transects within the Puʻu O ʻUmi Natural Area Reserve in 1996 and 2001. Feral pigs have been removed from two exclosures within the WMA: the 100-Ac bog unit between Waimanu and Kawainui valleys and a 10-Ac unit protecting rare and endangered plants on the leeward side.

Hunting by the public can be well-utilized as a first phase of control in areas that are easily accessible. However, it is generally limited in its effectiveness because it is hard to apply enough hunting pressure to an area to reduce the animals within the timeframe needed to achieve management goals (Molokai Hunting Test Working Group 1998). For these reasons, if public hunting is going to be used to reduce animals in a watershed or biodiversity management unit, it would be best used as the first phase in an approach that follows with more intensive methods. In addition, modeling techniques in animal control efforts will need to be used to ensure that population numbers are being reduced at desired levels.

Staff hunting and contract hunting are time consuming, expensive, and increasingly difficult to complete, as has been demonstrated at Hawaiʻi Volcanoes National Park, in the ʻŌlaʻa-Kīlauea Partnership Forest, and at Hakalau Forest National Wildlife Refuge (Hone and Stone 1989; Katahira *et al.* 1993; Anderson and Stone 1993). Aerial shooting has been used effectively in dryer areas where there is visibility to the forest floor. Snaring is a proven, effective tool for controlling pigs in Hawaiian forests. It is the most effective legal method for rapid and

complete removal of all animals from an area (Anderson *et al.* 1993). Snaring is particularly effective in remote, difficult-to-access, and steep terrain. There is general opposition from hunting and animal rights groups and individuals to the use of snares, based upon the suffering that improperly-set snares can cause.

Live trapping is another technique proven successful on the island. At the Honomalino Preserve in South Kona District of Hawai‘i Island, The Nature Conservancy has removed 99% of the pigs from their primary management unit, and 60% of pigs from the adjacent secondary unit. A benefit of trapping is that animals and meat can be easily salvaged; however, it is labor intensive and its application limited to areas within reasonable vehicular access.

According to Reeser and Harry (2004), current control strategies for pigs include:

- Fence management unit (4’ hogwire with no gaps up to 2,000 acres);
- If not remote, public/volunteer shooters to make initial population reduction;
- Professional shooters with dogs kill most remaining population;
- Baiting with papaya helps concentrate pigs for shooting and/or snaring;
- Professional technicians set snares to eliminate remaining populations;
- Snares are used to take any strays and to monitor for new entries; and
- Keep fences mended.

Fencing at Hakalau Forest National Wildlife Refuge began in 1988. Managers now have enclosed 14,150 acres in 8 units, using almost 44 miles of fencing at an average of more than $28,000 per mile. Since the feral ungulate management program began, more than 1,100 pigs and 260 wild cattle have been removed. Hakalau’s mountainous terrain, with steep gullies and rifts, is similar to that of Kohala Mountain.

Evaluations of the use of public hunting as a means to control feral pig and cattle populations in Hawai‘i show that public hunting is generally ineffective due to the loss of interest associated with increasing hunt difficulty (Hone and Stone 1989; Katahira *et al.* 1993). Staff hunting (with dogs for pig hunting) is more effective due to the diligence of the effort; however, it becomes increasingly difficult and expensive to remove the last few animals and complete the task. Snaring was first used to control feral pigs in Hawai‘i on Maui in 1993. The method has been found to be cost-effective and thorough when used in combination with fencing.

Recommended Actions
Remove pigs from high yield watershed areas A-D.
Remove pigs from biodiversity conservation units E-N (see Objective 4a).
Conduct a monitoring program in conjunction with ungulate control efforts to document short- and long-term changes in the forest cover and quality resulting from pig removal. Revise management strategy, as appropriate, based on monitoring results.
Seek partnerships with organized hunting groups and community volunteer hunters to utilize their skills for pig control, as needed. [KFMG(5 & 14); NAWG(10)]
Expand pig monitoring transects throughout remaining portion of watershed management area.
Develop and use modeling techniques in animal control efforts to ensure reduction of pig populations at desired rates and levels.

***Objective 3c**: Slow the rate of introduction and manage established alien aquatic species.*

Alien aquatic species impact agriculture, disrupt native stream community structure, and permanently change the make-up of the stream fauna that is so intricately interwoven into Hawaiian legend and practice. The current ecological condition of Kohala's streams needs to be assessed and documented. This baseline condition will serve as a measure for future management and monitoring. An ecological monitoring program that uses biological and physical criteria to characterize various biotic and environmental features will be developed (Englund and Arakaki 2004; Englund *et al.* 2003; Kido and Smith 1997).

In order to prevent the loss of native stream biota, it will be necessary to work cooperatively with aquaculturists, the aquarium industry, and the greater Kohala Mountain community to minimize the potential for introduction of potentially invasive aquatic species. Topics that could be addressed cooperatively include: wild release, live sale, distribution of stocks, species that travel overland, and effects to taro agriculture.

The Aquatic Invasive Species Management Plan for the State of Hawai'i (Shluker 2003) identifies seven objectives related to minimizing the harmful ecological and economic effects of Aquatic Invasive Species (AIS). Actions include: 1) Increase coordination and collaboration; 2) Minimize introductions; 3) Establish systems for rapid response, eradication, control, and restoration; and 4) Increase education and outreach.

Recommended Actions
Conduct a collaborative planning effort with affected stakeholders to identify biological stream and ditch issues and propose solutions.
Implement measures needed to minimize future introductions to and dispersals within or from the WMA.
Evaluate stream bioassessment and monitoring approaches and develop one for long-term use within the WMA to assess conditions of streams and presence of invasive species.
Conduct baseline surveys and inventories of perennial streams within the WMA to assess conditions of streams and presence of invasive species.
Develop distribution map for invasive alien aquatic species.
Conduct outreach with North Kohala, Waimea, and Waipi'o schools and communities.
Revise management goals based upon baseline assessment and monitoring.

***Objective 3d:** Reduce the impacts of rats and other small mammals and promote control of other non-native animals as appropriate.*

Rats are widespread throughout the WMA. In 2003, rodenticide was broadcast over a large area near Volcano to experiment with the use of a large-scale management technique for rat control. However, there were unanticipated effects to non-target species (Tummons 2004); as a result, this method cannot be used at this time.

Coqui frogs are now present in parts of North Hawai'i. Feral rabbits have been spotted periodically in Waipi'o and elsewhere in the WMA. Other non-native species, such as snakes, known to be very invasive and ecologically as well as economically disruptive, threaten to

arrive to Kohala's slopes at any time. Managers need to be prepared to respond with swift action to unpredicted establishment of new alien species.

Recommended Actions
Use appropriate control methods in targeted areas where they threaten native plant and animal species. Ensure that control methods are consistent with goals of water quality protection.
Depress rodent populations near rare tree snail and plant populations, particularly during sensitive life cycle stages for species known or suspected of being adversely affected by rodents.
Conduct a monitoring program in conjunction with rodent control to document mortality and management success.
Develop a prevention and interdiction strategy for incipient species that reduces opportunities for introduction of potentially invasive or disruptive species and prepares managers to swiftly react to new introductions.

Management Goal 4: Protect Unique Biological Communities and Rare Species.
Conservation of remaining hotspots of biodiversity (locations that harbor clusters of rare species and unique biological communities), such as in the Kohala Mountains, is important to conserve Hawai'i's biological heritage. Kohala Mountain's unique biological resources are also important at the regional and global scales as the extent of natural environments and overall number of species decrease. Therefore, an important component of this plan is to conserve and protect rare species and the habitats that support them, and other unique ecological communities (refer to Section II.C Biological Resources for more information about unique and rare species and ecosystems that occur within the WMA). Additionally, it is important to note that natural and cultural resources are considered one and the same. Preserving the biological integrity of the area will also preserve its cultural resources.

Currently, DLNR has 4 fenced ungulate exclosures (Figure 9) within the WMA totaling 140 acres: one protects a rare bog ecosystem (Waimanu Bog Unit: Unit O); the second an intact leeward plant community (Kilohana Stream Unit: Unit Q); and the Waikapu Unit (Unit P) near Kaukini cabin protecting 9 acres of mid elevation uluhe forest. Unit R, the Waiakamali Gulch/Koaia Sanctuary will be expanded to include an additional 300 acres for restoration of riparian habitat. Individuals or small populations of rare plants have also been fenced for protection. Queen Emma Land Company has also hired a contractor to create restoration research exclosures with native species in leeward stream corridors on its land in the WMA. Other fencing projects for protection of unique biological communities and populations of rare species are proposed on both private and public lands. Cattle fences are also maintained by a number of private landowners along the border of the forest.

The following management actions will protect a total of approximately 3,910 acres, within the watershed management area. Biological communities to be protected are mapped in Figure 8. Appendix D provides detailed descriptions of each biodiversity conservation unit and the specific resources to be protected.

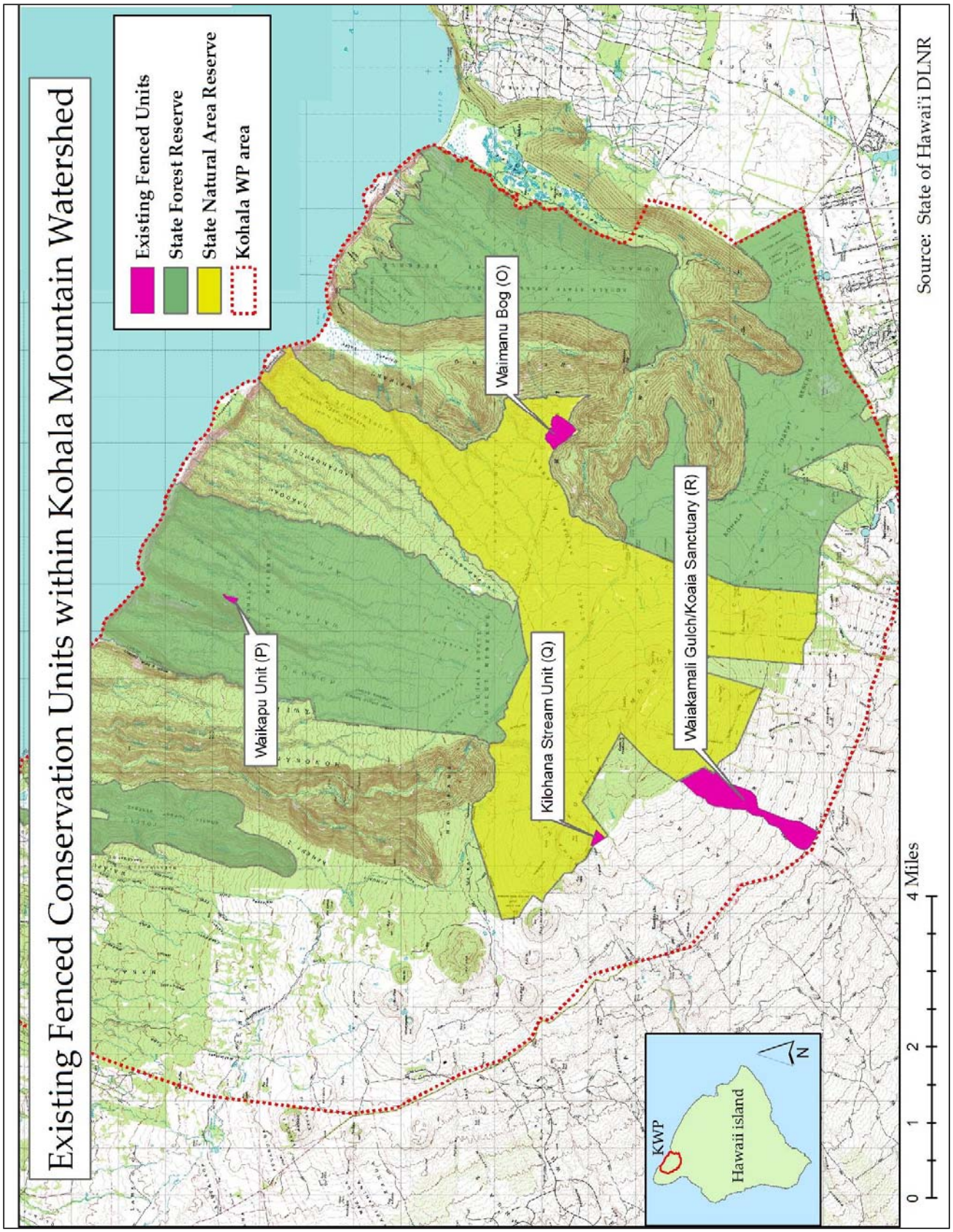

Figure 9. Existing Fenced Conservation Units in the Kohala Mountain Management Area

***Objective 4a**: Protect unique plant and animal communities within the WMA.*

Recommended Actions
In coordination with the State, Queen Emma Land Company (QEL), and its lessees, evaluate the feasibility of fencing approximately 640 acres of biodiversity conservation unit E: Eke to protect unique ecological communities, culturally-significant natural features, and leeward stream headwaters.
Use fencing to create strategic barriers around biodiversity conservation unit F: Waimanu Bog Plateau (430 acres).
In coordination with the State and Parker Ranch, evaluate the feasibility of fencing biodiversity conservation unit G: Kaneaʻa (500 acres).
In cooperation with Ponoholo Ranch, fence biodiversity conservation unit H: Ponoholo Pupukaniʻoe (160 acres to protect unique plant and animal species, including the rare Partulina tree snail). Monitor effects of ungulate removal and habitat management on snail populations and habitat.
Fence biodiversity unit I: Kaimu (20 acres) and other small ecological communities, such as important bird and snail habitats, and single rare, threatened or endangered plant populations using small fence units ("spot fencing") and other management techniques, as appropriate. [K/K (10)]
Fence biodiversity conservation unit J: Lower Laupahoehoe Nui (1,530 acres).
Fence biodiversity conservation unit K: Lower Ohiahuea (565 acres) protecting lowland wet forest in the Kohala Forest Reserve.
In cooperation with Kahuā Ranch, upgrade fence and remove pigs in biodiversity unit L: Puʻu Pili (290 acres).
In cooperation with DHHL and Kahuā Ranch, fence biodiversity unit M and N: Puʻu Lapalapa and Puʻu Mala (65 acres).
Fence and restore priority stream corridors in leeward Kohala as appropriate and as agreed to by landowner and/or leesee.
Control weeds within fenced ungulate exclosures (see Objective 2b).
Collect seeds of native rare species within fenced units and store for future use or propagate following guidelines established by the Hawaiʻi Rare Plant Recovery Group (HRPRG).
Outplant propagules of rare species into fenced units as appropriate.
Support KWP partners conducting conservation activities on their own lands.
Continue to conduct rare plant surveys to document location and health of rare plant populations. [NAWG(2)]
Initiate restoration and outplanting activities in Unit R and other appropriate areas within the WMA.

***Objective 4b**: Control priority invasive aquatic species in windward streams within the WMA.*

Kohala streams also support a unique and diverse fauna. Dozens of freshwater streams entering the ocean along the windward coastline support a relatively intact and diverse native stream fauna for Hawaiʻi. There are many small streams that drain from the Kohala summit, most of which harbor native aquatic insects, fishes, crustaceans, and mollusks. Currently, there is inadequate data pertaining to the ecological condition of Kohala's streams, but the

general opinion among biologists is that they are relatively intact compared to those of Hāmākua and other islands.

However, numerous alien aquatic species that exhibit the characteristics of being invasive threaten to cause ecological and economic harm to Kohala's freshwater streams and their users. Exotic fish, mollusks, and crustaceans threaten the stream fauna of Kohala Mountain. The loss of these native stream fauna would have cascading effects, degrading the entire native stream ecosystem, and causing economic impacts to agricultural users of water.

Recommended Actions
Comply with goals of the Hawai'i Aquatic Invasive Species Management Plan to minimize harmful ecologic and economic impacts of invasive aquatic species through the prevention and management of their introduction, expansion, and dispersal into, within, and from the Kohala WMA.
Establish a baseline condition and a monitoring program that uses biological and physical criteria to characterize various biotic and environmental features.

Management Goal 5: Prevent and Minimize Wildfire.

***Objective 5a**: Protect the watershed management area from the threat of wildfire.*

Because Hawai'i's flora are generally not fire-adapted and the forested watershed of Kohala Mountain is relatively inaccessible, fire prevention is the preferred wildfire management alternative for the WMA. Because the wildland-urban interface is the area most prone to fire starts, particularly along roadways, managing the fine fuels in the grasslands of leeward Kohala will be essential to minimizing the risk of fire spreading into the forested watershed.

Recommended Actions
Assess the fire history and fuel load distribution within the WMA.
Develop fuels mitigation measures along ignition corridors that border the WMA.
Create signage informing users that use of pyrotechnic devices and unattended campfires are prohibited within the WMA.
Develop a coordinated response plan to guide response in the event of a fire.

Management Goal 6: Manage Access for Compatible Public Use.

People have been accessing the forested watershed of Kohala Mountain since the time of the ancient Hawaiians to gather building materials and fuel, sources of cordage, adornment for display of rank, water, birds, herbs and medicines, and craft materials. Some of these uses still exist today. Other uses, such as hunting for ungulates and various forms of recreation, originated relatively more recently. It is the intent of this plan to support and encourage forms of public use in areas where it is compatible with conservation of water and related watershed values.

Forms of public use allowed within DLNR lands vary dependent upon land use designation. To access Forest Reserves, a license or permit is required from DLNR for camping, special use, collecting, commercial harvest, and access (HAR 13-104). Public access into the Restricted Watershed is prohibited except by permit for official duties, research and scientific

pursuits, public hunting and fishing as allowed under Chapters 13-122 and 13-123, HAR, recreational and educational purposes, and collection of plants for personal use (HAR 13-105). Within the NAR, hiking, nature study, and bedroll camping without a tent or other temporary structure are allowed. Hunting is a allowed activity pursuant to hunting rules. Within DLNR's Koaia Plant Sanctuary, hiking and walking, nature appreciation and scientific studies, photography, and hunting as authorized by law are allowed.

***Objective 6a**:* Support continued public hunting on DLNR-managed lands, where compatible with the conservation of water and related watershed values.

There are approximately 32,000 acres of public lands within the WMA in which hunting is currently allowed. Hunting is allowed in the entire NAR, all sections of the Kohala Forest Reserve, and in the Kohala Restricted Watershed. However, the majority of this area is difficult to access due to its remoteness. Hunting is not allowed on lands of the Department of Hawaiian Home Lands (DHHL). Most hunting occurs on the leeward side of Kohala Mountain, but local groups of hunters also access via the Na Ala Hele Muliwai trail from Waipiʻo Valley and via the Pololū Valley trail. Figure 8 shows trails from which hunters access the forest reserve.

Currently, there is no accurate estimate of hunting catch per unit effort (pigs caught per hunting trip) because of inconsistent reporting among hunters. In order to better manage public use and ungulate populations in the WMA, improved documentation of pig harvest will be required. In addition, modeling techniques should be used to better assess the effects of hunting and other management activities on the pig population.

A recommended project that emerged from the meetings of the Kohala Forest Management Group (KFMG) was the establishment of a Game Management Area (GMA) on Kohala Mountain, specifically in the Muliwai area between Waipiʻo and Waimanu valleys. Interviews during the management plan development process also discovered strong interest from a few members of the hunting community in the establishment of perpetual hunting areas within the watershed. Other people interviewed suggested the Puʻukapu area of the forest reserve as a possible GMA site. At this time, no State GMAs on Kohala Mountain have been established by DLNR's Division of Forestry and Wildlife. Establishment of GMAs on Kohala Mountain would provide dedicated areas where community members could access the forest for hunting, and also provide a setting for scientific research related to developing big game management techniques and programs. However, because hunting is currently allowed within all Forest Reserve, NAR and Restricted Watershed lands within the WMA, and DLNR-DOFAW land managers believe that forest and watershed resources within the Forest Reserve and NAR can be best protected under existing rules, there are no plans to dedicate areas as GMAs or designate areas for game production. Furthermore, formal rules establishing GMAs have not been established by DLNR.

Recommended Actions
Maintain existing hunting access points at Muliwai Trail in Waipiʻo Valley, at Pololū Valley, and from near Waiakamali Gulch above Hwy 250.
Develop new access for public hunting on public lands. Consult with hunters who frequently use the watershed to determine suitable and appropriate locations for establishment of additional new public hunting access points.
Develop and implement a program to increase awareness among newer and long-

time Kohala pig hunters regarding the benefits of reporting harvest catch to DLNR. (Reporting hunter effort and harvest helps document the degree of hunting, which helps legitimize the practice as a popular public use.)

***Objective 6b**:* Establish and maintain suitable hiking access trails where the activity is compatible with conservation of water and related watershed values.

At this time, there are only two public trails within the WMA - the Muliwai trail and the trail into Pololū Valley. A third moderately popular public access, although not a maintained trail, is from the top of a 4WD access route east of Waiakamali Gulch. One other trail, accessed from the end of White Road, is also commonly used to access the watershed; however, it is not a legal access trail. A recommendation arising from the Kohala KFMG was the resolution of issues surrounding the White Road access.

Much of Kohala Mountain is not suitable for hiking because of access and safety issues. In addition, hikers can unwittingly cause environmental damage that affects sensitive ecosystems and degrades watershed functional processes. However, carefully sited hiking trails and controlled access can provide visitors and residents with an experience of a lifetime, in which they gain a greater appreciation for the natural environment of Kohala Mountain. In this way, access enhances public awareness and nurtures an environmental ethic.

Recommended Actions
Maintain existing trails at Pololū and Muliwai and enhance signage to indicate that users are entering the Kohala WMA and request that they take precautions to insure that they are not inadvertently introducing potentially-harmful alien species.
Work with appropriate agencies to resolve access and parking issues at the White Road - Upper Hāmākua Ditch trail in order to legitimize use of this popular trailhead. [KFMG (10)]
Establish a boardwalk and interpretive signage in the bog ecosystem near Alakahi stream for controlled use for educational and scientific purposes.
Develop use classifications for the WMA or revise DLNR's proposed areas for differing intensities of recreational use to reflect management goals.
Monitor trail usage and impacts to assess effects over time.

***Objective 6c**:* Permit public access to and over private property only with explicit permission of private property owner or representative.

Public access to and over private lands requires explicit permission from the property owner or lessee. Hunting with permission of landowners also occurs over portions of the nearly 36,000 acres of privately owned or leased property within the WMA. Private land owners also regulate public access across their private lands to public lands beyond. Access over Surety Kohala Corp. land to public lands containing Kapaloa Falls is permitted from the Kohala Ditch trail provided users obtain permission and sign a waiver at the Surety Kohala Corp. office in Hawi prior to setting out. Other landowners regulate public use in a similar manner - with signed permits and waivers.

Chapter 520, HRS, "Landowners' Liability", encourages landowners to make their land and water areas available to the public for recreational purposes by limiting their liability toward

users (Appendix B). However, there remains considerable reservation from private landowners regarding the public use of their lands.

Recommended Actions
Work with appropriate agencies, landowners, and lessees to resolve liability issues for access over private property.

***Objective 6d**:* Ensure that cultural practices, and archaeological and other cultural sites within the WMA are identified, protected, and enhanced.

The State DLNR currently has a contract with a cultural specialist to document native traditions, customs, and practices associated with the Kohala-Hāmākua mountain lands, and a historical overview of the land and activities of people in the region from the early 1900s through the present day. However, not all areas of the WMA have been surveyed for cultural and historic resources.

Recommended Actions
Survey, document, and protect culturally significant areas within the WMA, in collaboration with cultural resource specialists.
Develop a policy statement on how the KWP will respond to requests for access for traditional and cultural practices.
Ensure the long-term availability and sustainability of resources for traditional resource gatherers, working with *kūpuna* and others.
Collect and disseminate information on legends and place names of Kohala Mountain.

***Objective 6e**:* Generate community awareness and support of watershed values and management activities on Kohala Mountain.

Educating the public about the Kohala Mountain watershed, its values, threats to these values, and management activities is vital to the KWP's primary goal of watershed protection. Conservation education and watershed awareness will help reduce unwanted human impacts on the landscape. Greater awareness about the Kohala Mountain watershed should also translate into greater support for management efforts, in the form of a greater community voice for conservation measures, less vandalism of infrastructure, and increased volunteerism.

Enhancing public access into the watershed for hiking, as described under Objective 6b, in conjunction with the development of interpretive materials such as trail guides will serve to both improve the visitor experience and augment environmental and cultural awareness. People who have had a memorable experience in a natural environment often become keen advocates for that environment.

Successful education efforts often target schools and children, with the belief that teaching younger generations not only plants the future seeds of effective conservation but also extends this knowledge to their parents. The Hawai'i Island YMCA received a grant in 2001 for a Kohala Forest Outreach and Education Program. This program conducted community and school surveys about environmental concerns and educational needs related to the Kohala forest, sponsored the first ever "Water Festival" in Kohala, staffed displays and educational

exhibits at community events, and developed environmental educational materials for the local schools. Funding for the Kohala Forest Outreach and Education Program lapsed at the end of 2002.

Public education and outreach are also helpful in recruiting a cadre of volunteers to assist in certain management activities, especially in labor intensive efforts such as fence construction, weed control, and trail maintenance. Volunteers tend to be extremely enthusiastic, but often require an organized volunteer program to help keep motivation levels high.

Recommended Actions
Develop and organize ongoing public outreach programs in coordination with local community and educational organizations. [NAWG (40); KFMG (12)]
Develop public education programs to help manage the negative effects of human activities on the watershed and inspire people about the unique resources of the watershed.
Develop or secure quality teaching materials that could be used in local schools to educate children about the resources and values of Kohala Mountain for use in conjunction with field trips to sites in the watershed. [KFMG(12)]
Develop interpretive signage along trails, identifying natural and cultural features, and providing general information about the unique environments of Kohala Mountain.
Develop pocket trail guides for residents and visitors that provide access and safety information, as well general information about the watershed resources of Kohala Mountain.
Develop a volunteer program for the Kohala Mountain watershed, in coordination with DLNR. [NAWG(37)]
Develop a KWP liability waiver for volunteer and stewardship programs in the WMA.
Educate elected officials and other decision-makers about the resources, values, and management issues of Kohala Mountain in order to ensure broad base of support for proposed activities.

Management Goal 7: Provide Effective Administrative Coordination and Infrastructure.
Implementation of the management plan is a long-term commitment that requires sufficient personnel and financial resources to not only manage the natural resources but develop and maintain the physical infrastructure. The Kohala Watershed partners will join together to seek funds and potential new partners for the projects recommended in this plan. Cooperation and effective communication among partners and other land users and managers will be critical to the success of this management effort.

***Objective 7a**:* Provide and maintain the appropriate infrastructure and administration to allow for effective watershed management.

Recommended Actions
Hire a watershed coordinator to: i) coordinate the implementation of the plan; ii) raise needed funding from a variety of sources; iii) assist partners in implementation projects; and iv) hire staff and obtain equipment, transportation and communication systems as needed.

Complete the process for an Environmental Assessment for the Kohala Watershed Management Plan.
Coordinate use of manpower, equipment, and communication systems throughout the watershed.
Maintain management infrastructure in the WMA.
Maintain communication among partners to facilitate information sharing. Develop clear and effective processes for intra-partnership communication.
Seek participation of other landowners in or adjacent to the WMA and of other entities that are stakeholders in the watershed.
Identify future infrastructure needs to facilitate management activities.
Revise and update watershed management plan as management needs change, management techniques evolve, and new data become available.

VI. MANAGEMENT PROGRAM INDICATORS

The following is a list of indicators that may be used to gauge the success of the various management actions. The best types of indicators are direct measurements that show the impact of the management program on the resources of the watershed.

Management Goal 1: Protect Water Resources.
- Percent forest cover by forest type
- Incidence of disease or pest infestation
- Miles of fencing, or number of fencing projects to protect high-yield watershed
- Basal stream flow of perennial streams
- Level of deep monitor wells, ground-water recharge rates and aquifer sustainable yields
- Levels of nutrients, dissolved oxygen, suspended sediment, turbidity, siltation or temperature change
- Level of rainfall gauging and fog drip
- Area and percent of forest land with significant soil erosion

Management Goal 2: Prevent New Introductions and Effectively Control Existing Invasive Plant Species.
- Percentage cover of invasive weeds vs. native forest cover
- Temporal change of invasive species distribution
- Number of weed control projects completed

Management Goal 3: Control Non-Native Animal Populations within Designated Areas.
- Ungulate sign in plots or along transects (scat, soil disturbance, browse evidence)
- Miles of fencing, or number of fencing projects
- Rate of rodent trapping success
- Level of forest disease incidence
- Level and distribution of invasive aquatic species in WMA streams

Management Goal 4: Protect Biodiversity and Rare Species.
- Viable populations of endangered/threatened species
- Number of restoration projects/outplantings
- Miles of fencing, or number of fencing projects
- Percent of riparian areas along streams
- Presence of biological indicator stream fauna

Management Goal 5: Prevent and Minimize Wildfire.
- Number and extent of fires in the area
- Amount of fine fuels removed

Management Goal 6: Manage Access for Compatible Public Use.
- Hunting catch per effort (pigs caught per hunting trip)
- Percentage of WMA accessible to controlled hunting programs
- Number of hikers or people involved in outdoor recreation
- Condition of selected high traffic trails and access routes (maintenance levels)
- Impact of humans on soil compaction, vegetation disturbance, or new trail cutting
- Number of surveys/consultations conducted for cultural sites
- Protect and enhance traditional and customary practices

- Number of school groups taking field trips into WMA
- Number of trail guides available/distributed
- Number of volunteers or volunteer hours used in management activities
- Hours spent in direct contact with communities

Management Goal 7: Provide Administrative Coordination and Infrastructure.

- Number of cooperative on-the-ground projects, and number of partners involved
- Dollars expended for watershed protection projects
- Funding dollars acquired
- Partner attendance to meetings
- Number of seminars, workshops or other events to facilitate information-sharing
- Partnership membership rate

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APPENDICES

Appendix A
PARTIAL LIST OF ANIMALS AND VASCULAR PLANTS OF THE KOHALA MOUNTAIN WATERSHED

Status:

USFWS
- END Endangered
- T Threatened
- C Candidate species
- SOC Species of Concern (unofficial designation)

WORLD CONSERVATION UNION (IUCN)
- CR Critically endangered
- EN Endangered
- VU Vulnerable
- NT Near threatened
- LC Least concern

- X Presumed extinct

Affinity:
- N Non-native
- P Polynesian introduction
- I Indigenous
- E Endemic

Family	Taxon	Common/Hawaiian name	Affinity	Status
I. Flora **Pteridophyta (ferns and fern allies)**				
Grammitidaceae	*Adenophorus hymenophylloides*	pai	E	
Grammitidaceae	*Adenophorus pinnatifidus*		E	
Grammitidaceae	*Adenophorus tamariscinus*	wahine noho mauna	E	
Grammitidaceae	*Adenophorus tripinnatifidus*		E	
Marattiaceae	*Angiopteris evecta*	mule's-foot fern	N	
Aspleniaceae	*Asplenium acuminatum*	lola	E	
Aspleniaceae	*Asplenium adiantum-nigrum*	ʻiwaʻiwa	I	
Aspleniaceae	*Asplenium contiguum*		E	
Aspleniaceae	*Asplenium haleakalense*		E	
Aspleniaceae	*Asplenium horridum*	ʻiwa	I	
Aspleniaceae	*Asplenium kaulfussii*	kūau	E	
Aspleniaceae	*Asplenium lobulatum*	piʻipiʻi lau manamana	I	
Aspleniaceae	*Asplenium polyodon*	pūnana manu	I	
Aspleniaceae	*Asplenium trichomanes* subsp. *densum*	ʻoāliʻi	E	
Aspleniaceae	*Asplenium unilaterale*	pāmoho	I	
Athyriaceae	*Athyrium microphyllum*	ʻākōlea	E	
Blechnaceae	*Blechnum appendiculatum*		N	
Thelypteridaceae	*Christella dentata*	paiʻiʻihā	N	
Dicksoniaceae	*Cibotium chamissoi*	hāpuʻu	E	
Dicksoniaceae	*Cibotium glaucum*	hāpuʻu pulu	E	
Dicksoniaceae	*Cibotium menziesii*	hāpuʻu ʻiʻi	E	
Pteridaceae	*Coniogramme pilosa*	loʻulu	E	
Athyriaceae	*Deparia petersenii*		N	
Gleicheniaceae	*Dicranopteris linearis*	uluhe	I	
Athyriaceae	*Diplazium molokaiense*		E	END

Athyriaceae	*Diplazium sandwichianum*	hōʻiʻo	E	
Gleicheniaceae	*Diplopterygium pinnatum*	uluhe lau nui	E	
Blechnaceae	*Doodia lyonii*		E	SOC
Dryopteridaceae	*Dryopteris fusco-atra*	ʻiʻi	E	
Dryopteridaceae	*Dryopteris glabra*	kīlau	E	
Dryopteridaceae	*Dryopteris hawaiiensis*		E	
Dryopteridaceae	*Dryopteris sandwicensis*		E	
Dryopteridaceae	*Dryopteris unidentata*	ʻakole	E	
Dryopteridaceae	*Dryopteris wallichiana*	ʻiʻo nui	I	
Dryopteridaceae	*Dryopteris* sp.		E	
Lomariopsidaceae	*Elaphoglossum alatum*	hoe a Māui	E	
Lomariopsidaceae	*Elaphoglossum paleaceum*	mākuʻe	I	
Lomariopsidaceae	*Elaphoglossum wawrae*	laukahi	E	
Grammitidaceae	*Grammitis hookeri*	mākuʻe lau liʻi	I	
Grammitidaceae	*Grammitis tenella*	kolokolo	E	
Lycopodiaceae	*Huperzia phyllantha*	wāwaeʻiole	I	
Grammitidaceae	*Lellingeria saffordii*	kihe	E	
Polypodiaceae	*Lepisorus thunbergianus*	pākahakaha	I	
Lycopodiaceae	*Lycopodiella cernua*	wāwaeʻiole	I	
Lycopodiaceae	*Lycopodium venustulum*		I	
Thelypteridaceae	*Macrothelypteris torresiana*		N	
Hymenophyllaceae	*Mecodium recurvum*	ʻōhiʻa kū	E	
Dennstaedtiaceae	*Microlepia strigosa*	palapalai	I	
Nephrolepidaceae	*Nephrolepis cordifolia*		I	
Nephrolepidaceae	*Nephrolepis multiflora*		N	
Dryopteridaceae	*Nothoperanema rubiginosa*		E	
Ophioglossaceae	*Ophioderma pendulum*	puapua moa	I	
Pteridaceae	*Pityrogramma calomelanos*	silver fern	N	
Polypodiaceae	*Polypodium pellucidum*	ʻae	E	
Psilotaceae	*Psilotum complanatum*	moa	I	
Psilotaceae	*Psilotum nudum*	moa	I	
Dennstaedtiaceae	*Pteridium aquilinum* var. *decompositum*	kīlau	E	
Pteridaceae	*Pteris cretica*	ʻōali	I	
Pteridaceae	*Pteris excelsa*	waimakanui	I	
Blechnaceae	*Sadleria cyatheoides*	ʻamaʻu	E	
Blechnaceae	*Sadleria pallida*	ʻamaʻu	E	
Blechnaceae	*Sadleria squarrosa*	ʻapuʻu	E	
Blechnaceae	*Sadleria souleyetiana*	ʻamaʻu	E	
Hymenophyllaceae	*Sphaerocionium lanceolatum*	palai hinahina	E	
Hymenophyllaceae	*Sphaerocionium obtusum*	palai lau liʻi	E	
Lindsaeaceae	*Sphenomeris chinensis*	palaʻā	I	
Gleicheniaceae	*Sticherus owhyhensis*	uluhe	E	
Hymenophyllaceae	*Vandenboschia davallioides*	palai hihi	E	
Magnoliophyta (angiosperms) Liliopsida (monocots)				
Poaceae	*Agrostis avenacea*	heʻupueo	I	
Poaceae	*Andropogon virginicus*	broomsedge	N	
Orchidaceae	*Anoectochilus sandvicensis*	jewel orchid	E	SOC, VU
Poaceae	*Anthoxanthum odoratum*	sweet vernalgrass	N	
Liliaceae	*Astelia menziesiana*	paʻiniu, kaluaha	E	

Poaceae	*Axonopus fissifolius*	narrow-leaved carpetgrass	N	
Poaceae	*Bambusa* sp.	bamboo	N	
Poaceae	*Briza minor*	little quaking grass	N	
Poaceae	*Calamagrostis expansa*	Maui reedgrass	E	C, VU
Cyperaceae	*Carex alligata*		E	
Arecaceae	*Cocos nucifera*	niu, coconut	P	
Araceae	*Colocasia esculenta*	kalo, taro	P	
Commelinaceae	*Commelina diffusa*	honohono	N	
Agavaceae	*Cordyline fruticosa*	kī, ti	P	
Poaceae	*Cynodon dactylon*	bermuda grass	N	
Cyperaceae	*Cyperus halpan*	umbrella sedge	N	
Cyperaceae	*Cyperus pilosus*	umbrella sedge	N	
Poaceae	*Deschampsia nubigena*	hairgrass	E	
Poaceae	*Dichanthelium cynodon*		E	
Poaceae	*Dichanthelium hillebrandianum*		E	
Poaceae	*Digitaria ciliaris*	Henry's crabgrass	N	
Poaceae	*Digitaria* sp.	crabgrass	N	
Poaceae	*Ehrharta stipoides*	meadow ricegrass	N	
Cyperaceae	*Eleocharis* sp.	spikerush, kohekohe	N	
Poaceae	*Eragrostis grandis*	lovegrass	E	
Poaceae	*Eragrostis variabilis*	kāwelu	E	
Poaceae	*Festuca* sp.	fescue	N	
Pandanaceae	*Freycinetia arborea*	ʻieʻie	I	
Zingiberaceae	*Hedychium coronarium*	white ginger	N	
Zingiberaceae	*Hedychium flavescens*	yellow ginger	N	
Zingiberaceae	*Hedychium gardnerianum*	kāhili ginger	N	
Poaceae	*Holcus lanatus*	common velvet grass	N	
Poaceae	*Isachne distichophylla*	ʻohe	E	
Joinvilleaceae	*Joinvillea ascendens* subsp. *ascendens*	ʻohe	E	C
Juncaceae	*Juncus effusus*	Japanese mat rush	N	
Juncaceae	*Juncus ensifolius*	rush	N	
Juncaceae	*Juncus planifolius*	rush	N	
Juncaceae	*Juncus tenuis*	rush	N	
Cyperaceae	*Kyllinga brevifolia*	kiliʻoʻopu	N	
Orchidaceae	*Liparis hawaiensis*	ʻawapuhiakanaloa	E	SOC
Juncaceae	*Luzula hawaiiensis* var. *hawaiiensis*	wood rush	E	
Cyperaceae	*Machaerina angustifolia*	ʻuki	I	
Cyperaceae	*Machaerina mariscoides* subsp. *meyenii*	ʻahaniu	E	
Cyperaceae	*Oreobolus furcatus*		E	
Poaceae	*Panicum repens*	torpedo grass	N	
Poaceae	*Paspalum conjugatum*	Hilo grass	N	
Poaceae	*Paspalum dilatatum*	Dallis grass	N	
Poaceae	*Paspalum fimbriatum*	Panama paspalum	N	
Poaceae	*Paspalum scrobiculatum*	ricegrass, mauʻu laiki	I ?	
Poaceae	*Paspalum urvillei*	Vasey grass	N	
Poaceae	*Pennisetum clandestinum*	kikuyu grass	N	
Agavaceae	*Pleomele hawaiiensis*	hala pepe	E	END, EN
Poaceae	*Poa annua*	annual bluegrass	N	

Arecaceae	*Pritchardia lanigera*	loulu	E	SOC, EN
Cyperaceae	*Pycreus polystachyos*		I	
Cyperaceae	*Rhynchospora chinensis*	kuolohia, beak-rush	I	
Poaceae	*Sacciolepis indica*	Glenwood grass	N	
Poaceae	*Setaria gracilis*	yellow foxtail	N	
Poaceae	*Setaria palmifolia*	palmgrass	N	
Poaceae	*Setaria verticillata*	bristly foxtail	N	
Poaceae	*Sporobolus africanus*	smutgrass	N	
Poaceae	*Sporobolus indicus*	West Indian dropseed	N	
Cyperaceae	*Uncinia uncinata*		I	
Magnoliopsida (dicots)				
Fabaceae	*Acacia koaia*	koai‘a	E	SOC, VU
Amaranthaceae	*Achyranthes mutica*		E	END, CR
Asteraceae	*Ageratina adenophora*	Maui pāmakani	N	
Asteraceae	*Ageratina riparia*	Hāmākua pāmakani	N	
Asteraceae	*Ageratum conyzoides*	maile hohono	N	
Euphorbiaceae	*Aleurites moluccana*	kukui	P	
Betulaceae	*Alnus nepalensis*	Nepal alder	N	
Apocynaceae	*Alyxia oliviformis*	maile	E	
Primulaceae	*Anagallis arvensis*	scarlet pimpernel	N	
Euphorbiaceae	*Antidesma platyphyllum*	hame	E	
Asteraceae	*Artemisia australis*	‘āhinahina	E	
Asteraceae	*Bidens hawaiensis*	ko‘oko‘olau	E	
Asteraceae	*Bidens hillebrandiana* subsp. *hillebrandiana*	ko‘oko‘olau	E	SOC
Rubiaceae	*Bobea elatior*	‘ahakea lau nui	E	
Rubiaceae	*Bobea timonioides*	‘ahakea	E	SOC, EN
Urticaceae	*Boehmeria grandis*	‘ākōlea	E	
Hydrangeaceae	*Broussaisia arguta*	kanawao	E	
Cannabaceae	*Cannabis sativa*	marijuana, paka lōlō	N	
Fabaceae	*Canavalia hawaiiensis*	‘āwikiwiki	E	
Brassicaceae	*Cardamine flexuosa*	bittercress	N	
Casuarinaceae	*Casuarina equisetifolia*	common ironwood	N	
Apiaceae	*Centella asiatica*	Asiatic pennywort	N	
Caryophyllaceae	*Cerastium fontanum*	common mouse-ear chickweed	N	
Euphorbiaceae	*Chamaesyce multiformis*	‘akoko	E	
Amaranthaceae	*Charpentiera obovata*	pāpala	E	
Araliaceae	*Cheirodendron trigynum*	‘ōlapa	E	
Asteraceae	*Cirsium vulgare*	bull thistle	N	
Campanulaceae	*Clermontia calophylla*	‘ōhā wai	E	SOC, EN
Campanulaceae	*Clermontia drepanomorpha*	‘ōhā wai	E	END, EN
Campanulaceae	*Clermontia kohalae*	‘ōhā wai	E	
Campanulaceae	*Clermontia parviflora*	‘ōhā wai	E	
Campanulaceae	*Clermontia waimeae*	‘ōhā wai	E	SOC, EN
Campanulaceae	*Clermontia* sp.	‘ōhā wai	E	

Melastomataceae	*Clidemia hirta*	Koster's curse	N	
Menispermaceae	*Cocculus trilobus*	huehue	I	
Asteraceae	*Conyza bonariensis*	hairy horseweed	N	
Rubiaceae	*Coprosma ochracea*	pilo	E	
Rubiaceae	*Coprosma pubens*	pilo	E	
Asteraceae	*Crassocephalum crepidioides*		N	
Cupressaceae	*Cryptomeria japonica*	Tsugi pine	N	
Apiaceae	*Cryptotaenia Canadensis*	honewort	N	
Lythraceae	*Cuphea carthagenensis*	tarweed	N	
Campanulaceae	*Cyanea pilosa*	hāhā	E	
Campanulaceae	*Cyanea pilosa* subsp. *pilosa*	hāhā	E	
Campanulaceae	*Cyanea pycnocarpa*	hāhā	E	SOC, X
Campanulaceae	*Cyanea tritomantha*	ʻakū	E	C, VU
Gesneriaceae	*Cyrtandra kohalae*	haʻiwale	E	SOC, X
Gesneriaceae	*Cyrtandra paludosa*	moa	E	
Gesneriaceae	*Cyrtandra platyphylla*	ʻilihia	E	
Gesneriaceae	*Cyrtandra* sp.	haʻiwale	E	
Campanulaceae	*Delissea parviflora*		E	SOC, X
Ebenaceae	*Diospyros sandwicensis*	lama	E	
Sapindaceae	*Dodonaea viscosa*	ʻaʻaliʻi	I	
Caryophyllaceae	*Drymaria cordata*	pipili	N	
Asteraceae	*Dubautia plantaginea*	naʻenaʻe	E	
Onagraceae	*Epilobium billardierianum*	willow herb	N	
Asteraceae	*Erechtites valerianifolia*	fireweed	N	
Myrtaceae	*Eucalyptus robusta*	swamp mahogany	N	
Theaceae	*Eurya sandwicensis*	ānini	E	SOC, VU
Moraceae	*Ficus macrophylla*	banyan	N	
Moraceae	*Ficus rubiginosa*	banyan	N	
Rosaceae	*Fragaria vesca*	strawberry	N	
Oleaceae	*Fraxinus uhdei*	tropical ash	N	
Rubiaceae	*Gardenia remyi*	nānū	E	C, VU
Geraniaceae	*Geranium homeanum*	cranesbill	N	
Proteaceae	*Grevillea robusta*	silk oak, ʻoka kilika	N	
Gunneraceae	*Gunnera petaloïdea*	ʻapeʻape	E	
Rubiaceae	*Hedyotis acuminata*	au	E	
Rubiaceae	*Hedyotis hillebrandii*	manono	E	
Rubiaceae	*Hedyotis littoralis*		E	SOC
Rubiaceae	*Hedyotis terminalis*	manono	E	
Malvaceae	*Hibiscadelphus hualaiensis*	hau kuahiwai	E	END, CR, X
Malvaceae	*Hibiscus kokio*	kokiʻo	E	SOC, VU
Malvaceae	*Hibiscus tiliaceus*	hau	I	
Apiaceae	*Hydrocotyle sibthorpioides*	marsh pennywort	N	
Apiaceae	*Hydrocotyle verticillata*	pohe	N	
Clusiaceae	*Hypericum mutilum*	St. John's wort	N	
Asteraceae	*Hypochoeris radicata*	hairy cat's ear	N	
Aquifoliaceae	*Ilex anomala*	kāwaʻu	I	
Convolvulaceae	*Ipomoea indica*	koali ʻawa	I	
Convolvulaceae	*Ipomoea littoralis*	morning glory	I	
Viscaceae	*Korthalsella complanata*	hulumoa	I	

Viscaceae	*Korthalsella cylindrica*	hulumoa	E	
Loganiaceae	*Labordia hedyosmifolia*	kāmakahala	E	
Loganiaceae	*Labordia helleri*	kāmakahala	E	
Loganiaceae	*Labordia hirtella*	kāmakahala	E	
Verbenaceae	*Lantana camara*	lākana	N	
Epacridaceae	*Leptecophylla tameiameiae*	pūkiawe	I	
Campanulaceae	*Lobelia hypoleuca*	kuhi‘aikamo‘owahie, ‘ōpelu	E	SOC
Onagraceae	*Ludwigia palustris*	marsh purslane	N	
Primulaceae	*Lysimachia mauritiana*		I	
Myrtaceae	*Melaleuca quinquenervia*	paperbark	N	
Melastomataceae	*Melastoma candidum*		N	
Rutaceae	*Melicope clusiifolia*	alani, kolokolo mokihana	E	
Rutaceae	*Melicope hawaiensis*	mokihana kūkae moa	E	SOC, VU
Rutaceae	*Melicope pseudoanisata*	alani	E	
Myrtaceae	*Metrosideros polymorpha*	‘ōhi‘a	E	
Malvaceae	*Modiola caroliniana*		N	
Myoporaceae	*Myoporum sandwicense*	naio	I	
Myrsinaceae	*Myrsine lanaiensis*	kōlea	E	
Myrsinaceae	*Myrsine lessertiana*	kōlea lau nui	E	
Myrsinaceae	*Myrsine sandwicensis*	kōlea lau li‘i	E	
Rubiaceae	*Nertera granadensis*	mākole	I	
Oleaceae	*Nestegis sandwicensis*	olopua	E	
Solanaceae	*Nothocestrum breviflorum*	‘aiea	E	END, CR
Apocynaceae	*Ochrosia haleakalae*	hōlei	E	C, EN
Rosaceae	*Osteomeles anthyllidifolia*	‘ūlei	I	
Oxalidaceae	*Oxalis corniculata*	‘ihi ‘ai, yellow wood sorrel	P ?	
Passifloraceae	*Passiflora tarminiana*	banana poka	N	
Piperaceae	*Peperomia cookiana*	‘ala‘ala wai nui	E	
Piperaceae	*Peperomia hypoleuca*	‘ala‘ala wai nui	E	
Piperaceae	*Peperomia macraeana*	‘ala‘ala wai nui	E	
Piperaceae	*Peperomia membranacea*	‘ala‘ala wai nui	E	
Piperaceae	*Peperomia tetraphylla*	‘ala‘ala wai nui	I	
Piperaceae	*Peperomia* sp.	‘ala‘ala wai nui	E	
Celastraceae	*Perrottetia sandwicensis*	olomea	E	
Apiaceae	*Peucedanum sandwicense*	makou	E	T
Lamiaceae	*Phyllostegia ambigua*		E	
Lamiaceae	*Phyllostegia floribunda*		E	C
Lamiaceae	*Phyllostegia vestita*		E	
Lamiaceae	*Phyllostegia warshaueri*		E	END
Phytolaccaceae	*Phytolacca sandwicensis*	pōpolo kū mai	E	
Urticaceae	*Pilea peploides*		I	
Urticaceae	*Pipturus albidus*	māmaki	I	
Nyctaginaceae	*Pisonia brunoniana*	pāpala kēpau	I	
Nyctaginaceae	*Pisonia umbellifera*	pāpala kēpau	I	
Pittosporaceae	*Pittosporum hawaiiense*	hō‘awa	E	SOC
Pittosporaceae	*Pittosporum undulatum*	Victorian box	N	
Pittosporaceae	*Pittosporum viridiflorum*	Cape pittosporum	N	
Pittosporaceae	*Pittosporum* sp.	hō‘awa	E	
Plantaginaceae	*Plantago lanceolata*	narrow-leaved plantain	N	

Plantaginaceae	*Plantago major*	broad-leaved plantain	N	
Rutaceae	*Platydesma remyi*		E	C, EN
Rutaceae	*Platydesma spathulata*	pilo kea	E	
Asteraceae	*Pluchea symphytifolia*	sourbush	N	
Polygonaceae	*Polygonum capitatum*	knotweed	N	
Polygonaceae	*Polygonum punctatum*	water smartweed	N	
Sapotaceae	*Pouteria sandwicensis*	ʻālaʻa	E	
Lamiaceae	*Prunella vulgaris*	selfheal	N	
Rosaceae	*Prunus cerasifera*	Methley plum	N	
Myrtaceae	*Psidium cattleianum*	strawberry guava	N	
Myrtaceae	*Psidium guajava*	common guava	N	
Rubiaceae	*Psychotria hawaiiensis*	kōpiko ʻula	E	
Rubiaceae	*Psychotria hawaiiensis* var. *hillebrandii*	kōpiko ʻula	E	
Rubiaceae	*Psydrax odoratum*	alaheʻe	I	
Ranunculaceae	*Ranunculus repens*	creeping buttercup	N	
Apocynaceae	*Rauvolfia sandwicensis*	hao	E	
Rosaceae	*Rubus argutus*	blackberry	N	
Rosaceae	*Rubus hawaiensis*	ʻākala	E	
Rosaceae	*Rubus rosifolius*	thimbleberry	N	
Polygonaceae	*Rumex acetosella*	sheep sorrel	N	
Polygonaceae	*Rumex crispus*	curly dock	N	
Polygonaceae	*Rumex giganteus*	pāwale	E	
Polygonaceae	*Rumex* sp.	dock	N	
Santalaceae	*Santalum paniculatum*	ʻiliahi, sandalwood	E	
Caprifoliaceae	*Sambucus mexicana*	Mexican elder	N	
Goodeniaceae	*Scaevola chamissoniana*	naupaka kuahiwi	E	
Goodeniaceae	*Scaevola sericea*	naupaka kahakai	I	
Caryophyllaceae	*Schiedea diffusa*		E	SOC
Caryophyllaceae	*Schiedea globosa*		E	SOC
Anacardiaceae	*Schinus terebinthifolius*	Christmas berry	N	
Asteraceae	*Senecio madagascariensis*	fireweed	N	
Taxodiaceae	*Sequoia sempervirens*	redwood	N	
Cucurbitaceae	*Sicyos cucumerinus*	panunukuahiwi	E	
Malvaceae	*Sida acuta*		N	
Malvaceae	*Sida fallax*	ʻilima	I	
Smilacaceae	*Smilax melastomifolia*	hoi kuahiwi	E	
Asteraceae	*Sonchus oleraceus*	pualele, sow thistle	N	
Fabaceae	*Sophora chrysophylla*	māmane	E	
Lamiaceae	*Stenogyne calaminthoides*		E	
Lamiaceae	*Stenogyne cranwelliae*		E	C
Lamiaceae	*Stenogyne oxygona*		E	SOC, X
Asteraceae	*Taraxacum officinale*	common dandelion	N	
Combretaceae	*Terminalia catappa*	tropical almond	N	
Araliaceae	*Tetraplasandra hawaiensis*	ʻohe	E	
Araliaceae	*Tetraplasandra oahuensis*	ʻohe mauka	E	
Melastomataceae	*Tibouchina herbacea*	glorybush	N	
Melastomataceae	*Tibouchina urvilleana*	lasiandra	N	
Urticaceae	*Touchardia latifolia*	olonā	E	
Campanulaceae	*Trematolobelia grandifolia*		E	SOC
Campanulaceae	*Trematolobelia macrostachys*	koliʻi	E	

Fabaceae	*Trifolium repens*	white clover	N	
Urticaceae	*Urera glabra*	ōpuhe	E	
Ericaceae	*Vaccinium calycinum*	ʻōhelo, ʻōhelo kau lāʻau	E	
Ericaceae	*Vaccinium dentatum*	ʻōhelo	E	
Ericaceae	*Vaccinium reticulatum*	ʻōhelo	E	
Verbenaceae	*Verbena litoralis*	ōwī	N	
Scrophulariaceae	*Veronica plebeia*	trailing speedwell	N	
Scrophulariaceae	*Veronica serpyllifolia*	thyme-leaved speedwell	N	
Fabaceae	*Vigna marina*	mohihihi, nanea	I	
Violaceae	*Viola maviensis*		E	SOC
Thymelaeaceae	*Wikstroemia monticola*	ʻākia	E	
Thymelaeaceae	*Wikstroemia pulcherrima*	ʻākia	E	
Thymelaeaceae	*Wikstroemia sandwicensis*	ʻākia	E	
Flacourtiaceae	*Xylosma hawaiiense*	maua	E	
Asteraceae	*Youngia japonica*	oriental hawksbeard	N	
II. Fauna **Chordata** **Amphibia** **Anura**				
Bufonidae	*Bufo marinus*	cane toad	N	
Leptodactylidae	*Eleutherodactylus coqui*	coquí frog	N	
Ranidae	*Lithobates catesbeianus*	bullfrog	N	
Aves **Anseriformes**				
Anatidae	*Anas wyvilliana*	koloa maoli, Hawaiian duck	E	END, EN
	Charadriiformes			
Charadriidae	*Pluvialis fulva*	kōlea, Pacific golden-plover	I	LC
	Ciconiiformes			
Ardeidae	*Nycticorax nycticorax hoactli*	ʻaukuʻu, black-crowned night heron	I	LC
	Columbiformes			
Columbidae	*Streptopelia chinensis*	spotted dove	N	
	Falconiformes			
Accipitridae	*Buteo solitarius*	ʻio, Hawaiian hawk	E	END, NT
	Galliformes			
Phasianidae	*Phasianus colchicus*	ring-necked pheasant	N	
	Passeriformes			
Cardinalidae	*Cardinalis cardinalis*	northern cardinal	N	
Fringillidae	*Carpodacus mexicanus*	house finch	N	
Dicruridae	*Chasiempis sandwichensis sandwichensis*	Hawaiʻi ʻelepaio	E	
Timaliidae	*Garrulax canorus*	hwamei, melodious laughing-thrush	N	
Drepanididae	*Hemignathus virens virens*	Hawaiʻi ʻamakihi	E	LC
Drepanididae	*Himatione sanguinea sanguinea*	ʻapapane	E	LC
Timaliidae	*Leiothrix lutea*	red-billed leiothrix	N	
Estrildidae	*Lonchura punctulata*	nutmeg mannikin	N	
Drepanididae	*Vestiaria coccinea*	ʻiʻiwi	E	NT
Zosteropidae	*Zosterops japonicus*	Japanese white-eye	N	
	Procellariiformes			

Procellariidae	*Pterodroma sandwichensis*	ʻuaʻu, Hawaiian petrel	E	END, VU
Procellariidae	*Puffinus newelli*	ʻaʻo, Hawaiian shearwater	E	T, EN
	Strigiformes			
Strigidae	*Asio flammeus sandwichensis*	pueo, Hawaiian short-eared owl	E	
Actinopterygii (ray-finned fishes)				
	Cypriniformes			
Cyprininae	*Carassius auratus*	goldfish	N	
Cyprininae	*Cyprinus carpio*	common carp	N	
	Cyprinodontiformes			
Poeciliidae	*Gambusia affinis*	mosquitofish	N	
Poeciliidae	*Poecilia mexicana*	shortfin molly	N	
Poeciliidae	*Poecilia reticulata*	guppy	N	
Poeciliidae	*Xiphophorous hellerii*	green swordtail	N	
	Perciformes			
Gobiidae	*Awaous guamensis*	ʻoʻopu nākea, giant stream goby	I	
Gobiidae	*Bathygobius cotticeps*	cheek-scaled frill goby	N	
Gobiidae	*Bathygobius fuscus*	common frillfin goby	N	
Eleotridae	*Eleotris sandwicensis*	ʻoʻopu ʻakupa, Hawaiian sleeper goby	E	
Gobiidae	*Eviota epiphanes*	pygmy goby	N	
Gobiidae	*Lentipes concolor*	ʻoʻopu ʻalamoʻo, red-tailed stream goby	E	
Centrarchidae	*Lepomis macrochirus*	bluegill sunfish	N	
Menidae	*Mene maculata*	moonfish	N	
Centrarchidae	*Micropterus dolomieu*	smallmouth bass	N	
Centrarchidae	*Micropterus salmoides*	largemouth bass	N	
Cichlidae	*Oreochromis aureus*	blue tilapia	N	
Cichlidae	*Oreochromis macrochir*	longfin tilapia	N	
Cichlidae	*Oreochromis mossambicus*	Mozambique tilapia	N	
Cichlidae	*Oreochromis niloticus*	tilapia	N	
Gobiidae	*Oxyurichthys lochotus*	point-tailed ʻoʻopu	N	
Gobiidae	*Sicyopteris stimpsoni*	ʻoʻopu nōpili, clinging stream goby	E	
Gobiidae	*Stenogobius hawaiiensis*	ʻoʻopu naniha, black-headed stream goby	E	
	Salmoniformes			
Salmonidae	*Oncorhynchus mykiss*	rainbow trout	N	
	Siluriformes			
Clariidae	*Clarias fuscus*	Chinese catfish	N	
Ictaluridae	*Ictalurus punctatus*	channel catfish	N	
Mammalia				
	Artiodactyla			
Bovidae	*Bos taurus*	cattle	N	
Bovidae	*Capra hircus*	goat	N	
Suidae	*Sus scrofa*	pig, puaʻa	P	
	Carnivora			
Canidae	*Canis lupus familiaris*	domestic dog, ʻīlio	P	
Felidae	*Felis silvestris catus*	domestic cat	N	
Herpestidae	*Herpestes javanicus*	Indian mongoose	N	
	Chiroptera			

Vespertilionidae	*Lasiurus cinereus semotus*	ʻōpeʻapeʻa, Hawaiian hoary bat	E	END
	Rodentia			
Muridae	*Mus musculus*	house mouse	N	
Muridae	*Rattus exulans*	Polynesian rat, ʻiole	P	
Muridae	*Rattus rattus*	black rat	N	
Arthropoda **Arachnida** **Araneae (spiders)**				
Philodromidae	Unid. genus	crab spiders	E	
Theridiidae	*Argyrodes* sp.	comb-footed spiders	E	
Theridiidae	*Theridion grallator*	happyface spider	E	
Thomisidae	*Misumenops anguliventris* ?	crab spider	E	
Thomisidae	*Misumenops facundus*	crab spider	E	
Thomisidae	*Misumenops* sp.	crab spider	E	
Tetragnathidae	*Tetragnatha* sp.	long-jawed spiders	E	
	Pseudoscorpionida (false scorpions)			
Chernetidae	*Eumecochernes* sp. ?	false scorpion	E	
Entognatha **Collembola (springtails)**				
Unid. family		springtail	?	
Insecta **Odonata (damselflies and dragonflies)**				
Aeshnidae	*Anax strenuus*	dragonfly	E	
Coenagrionidae	*Megalagrion blackburni*	large red damselfly	E	
Coenagrionidae	*Megalagrion calliphya*	damselfly	E	
Coenagrionidae	*Megalagrion hawaiiense*	Hawaiian damselfly	E	
	Orthoptera (grasshoppers, katydids, and crickets)			
Tettigoniidae	*Banza* sp.	cone-headed katydid	E	
Gryllidae	*Laupala* sp.	sword-tail cricket	E	
Gryllidae	*Leptogryllus* sp.	tree cricket	E	
Gryllidae	*Prognathogryllus* sp.	tree cricket		
	Hemiptera (true bugs)			
Delphacidae	Unid. genus	planthopper	E	
Psyllidae	Unid. genus	jumping plant lice	E	
Cixiidae	*Iolania perkinsi*	planthopper	E	
Miridae	*Koanoa* sp.	leaf bug	E	
Anthocoridae	*Lasiochilus* sp.	pirate bug	E	
Veliidae	*Microvelia vagans*	ripple bug	E	
Nabidae	*Nabis blackburni*	damsel bug	E	
Nabidae	*Nabis curtipennis*	damsel bug	E	
Nabidae	*Nabis oscillans*	damsel bug	E	
Nabidae	*Nabis* n. sp.	damsel bug	E	
Lygaeidae	*Neseis whitei brachypterus*	seed bug	E	X
Reduviidae	*Nesidiolestes selium*	thread-legged bug	E	X
Miridae	*Nesidiorchestes* sp.	leaf bug	E	
Miridae	*Nesiomiris* sp.	leaf bug	E	
Cicadellidae	*Nesophrosyne* sp.	leafhopper	E	
Pentatomidae	*Oechalia acuta*	stink bug	E	X
Cixiidae	*Oliarus* sp.	planthopper	E	
Miridae	*Orthotylus hedyoticola*	leaf bug	E	
Miridae	*Orthotylus kassandra*	leaf bug	E	

Miridae	*Orthotylus metrosideri*	leaf bug	E	
Miridae	*Orthotylus* sp.	leaf bug	E	
Miridae	*Pseudoclerada* sp.	leaf bug	E	
Saldidae	*Saldula exulans*	shore bug	E	
Saldidae	*Saldula oahuensis*	shore bug	E	
Miridae	*Sarona adonias*	leaf bug	E	
Miridae	*Sarona hamakua*	leaf bug	E	
Miridae	*Sarona mamaki*	leaf bug	E	
Miridae	*Sarona* sp.	leaf bug	E	
Neuroptera (lacewings and antlions)				
Chrysopidae	*Anomalochrysa fulvescens*	green lacewing	E	
Chrysopidae	*Anomalochrysa fulvescens rhododora*	green lacewing	E	
Chrysopidae	*Anomalochrysa maclachlani*	green lacewing	E	
Hemerobiidae	*Micromus longispinosus*	brown lacewing	E	
Hemerobiidae	*Micromus paradoxus*	brown lacewing	E	
Hemerobiidae	*Micromus rubrinervis*	brown lacewing	E	
Hemerobiidae	*Micromus subochraceus*	brown lacewing	E	
Hemerobiidae	*Micromus vagus*	brown lacewing	E	
Coleoptera (beetles)				
Curculionidae	*Achalles* sp.	true weevil	E	
Scarabaeidae	*Adoretus sinicus*	Chinese rose beetle	N	
Carabidae	*Blackburnia ewingi*	ground beetle	E	
Carabidae	*Blackburnia hawaiiensis*	ground beetle	E	
Carabidae	*Blackburnia kilauea*	ground beetle	E	
Carabidae	*Blackburnia molokaiensis*	ground beetle	E	
Eucnemidae	*Dromaeolus* sp.	false click beetle	E	
Curculionidae	*Dryophthorus squalidus*	true weevil	E	
Nitidulidae	*Eupetinus* sp. (2)	souring beetle	E	
Nitidulidae	*Gonioryctus* sp.	souring beetle	E	
Hydrophilidae	*Limnoxenus semicylindricus*	water scavenger beetle	E	
Carabidae	*Mecyclothorax* sp. (5)	ground beetle	E	
Nitidulidae	*Nesopetinus* sp. (2)	souring beetle	E	
Curculionidae	*Nesotocus munroi*	true weevil	E	X
Curculionidae	*Oodemus* sp.	true weevil	E	X
Cerambycidae	*Parandra puncticeps*	long-horned wood borer	E	
Aglycyderidae	*Proterhinus* sp.	primitive weevil	E	
Dytiscidae	*Rhantus pacificus*	diving beetle	E	
Curculionidae	*Syagrius fulvitarsis*	Australian fern weevil	N	
Scolytidae	*Xyleborus* sp. nr. *hawaiiensis*	bark beetle	E	
Anobiidae	*Xyletobius* sp.	death-watch beetles	E	
Diptera (true flies)				
Dolichopodidae	*Campsicnemus* sp.	long-legged fly	E	
Drosophilidae	*Drosophila murphyi*	Hawaiian picture wing fly	E	
Drosophilidae	*Drosophila ochrobasis*	Hawaiian picture wing fly	E	END
Drosophilidae	*Drosophila pisonia*	Hawaiian picture wing fly	E	
Drosophilidae	*Drosophila pullipes*	Hawaiian picture wing fly	E	
Drosophilidae	*Drosophila setosifrons*	Hawaiian picture wing fly	E	
Drosophilidae	*Drosophila setosimentum*	Hawaiian picture wing fly	E	
Drosophilidae	*Drosophila silvestris*	Hawaiian picture wing fly	E	
Drosophilidae	*Drosophila sobrina*	Hawaiian picture wing fly	E	

Drosophilidae	*Drosophila sproati*	Hawaiian picture wing fly	E	
Dolichopodidae	*Eurynogaster* sp.	long-legged fly	E	
Tipulidae	*Limonia stygipennis*	crane fly	E	
Muscidae	*Lispocephala* sp.	house fly	E	
Ephydridae	*Neoscatella* sp.	shore fly	?	
Tephritidae	*Trupanea apicalis*	fruit fly	E	
Tephritidae	*Trupanea crassipes*	fruit fly	E	
Tephritidae	*Trupanea* nr. *pantosticta*	fruit fly	E	
Tephritidae	*Trupanea* sp.	fruit fly	E	
Hymenoptera (bees, wasps, and ants)				
Sphecidae	*Ectemnius atripennis*	square-headed wasp	E	
Sphecidae	*Ectemnius polynesialis*	square-headed wasp	E	
Sphecidae	*Ectemnius rubrocaudatus*	square-headed wasp	E	
Sphecidae	*Ectemnius tumidoventris*	square-headed wasp	E	
Ichneumonidae	*Enicospilus* sp. ?	wasp	E	
Colletidae	*Hylaeus difficilis*	yellow-faced bee	E	
Colletidae	*Hylaeus dumetorum*	yellow-faced bee	E	
Colletidae	*Hylaeus laeta*	yellow-faced bee	E	
Colletidae	*Hylaeus pubescens*	yellow-faced bee	E	
Vespidae	*Odynerus* sp. (2)	potter wasp	E	
Diapriidae	*Platymischoides* sp.	wasp	E	
Lepidoptera (moths and butterflies)				
Pterophoridae	Unid. genus	plume moth	N	
Sphingidae	*Agrius cingulata*	sweet potato hornworm	N	
Noctuidae	*Agrotis ceramophaea*	moth	E	
Noctuidae	*Agrotis charmocrita*	moth	E	
Noctuidae	*Agrotis dislocata*	moth	E	
Noctuidae	*Agrotis ipsilon*	black cutworm moth	N	
Noctuidae	*Agrotis psammophaea*	moth	E	
Alucitidae	*Alucita objurgatella*		N	
Tortricidae	*Amorbia emigratella*	Mexican leaf-roller moth	N	
Noctuidae	*Ascalapha odorata*	black witch moth	N	
Noctuidae	*Athetis thoracica*	moth	N	
Tortricidae	*Bactra straminea*	leaf roller	N	
Carposinidae	*Carposina dispar*	fruit moth	E	
Carposinidae	*Carposina gracillima*	fruit moth	E	
Carposinidae	*Carposina herbarum* ?	fruit moth	E	
Carposinidae	*Carposina inscripta*	fruit moth	E	
Carposinidae	*Carposina nigronotata*	fruit moth	E	
Carposinidae	*Carposina olivaceonitens*	fruit moth	E	
Noctuidae	*Chrysodeixis eriosoma*	moth	N	
Crambidae	*Eudonia* sp. (10)	moth	E	
Geometridae	*Eupithecia craterias*	inchworm	E	
Geometridae	*Eupithecia monticolens*	inchworm	E	
Geometridae	*Eupithecia orichloris*	inchworm	E	
Geometridae	*Eupithecia staurophragma*	inchworm	E	
Geometridae	*Fletcherana roseata*	inchworm	E	
Noctuidae	*Haliophyle compsias*	moth	E	
Noctuidae	*Haliophyle euclidias*	moth	E	
Noctuidae	*Haliophyle ignita*	moth	E	
Sphingidae	*Hyles wilsoni*	hawk moth	E	

Noctuidae	*Hypocala deflorata*	moth	N	
Cosmopterigidae	*Hyposmocoma* sp.	moth	E	
Geometridae	*Macaria infusata*	inchworm	N	
Noctuidae	*Melipotis indomita*	moth	N	
Sphingidae	*Manduca blackburni*	Blackburn's sphinx moth	E	END
Pyralidae	*Maruca testulalis*	moth	N	
Crambidae	*Mestolobes minuscula*	moth	E	
Crambidae	*Mestolobes* sp.	moth	E	
Crambidae	*Omiodes accepta*	moth	E	
Crambidae	*Omiodes anastreptoides*	moth	E	
Crambidae	*Omiodes continuatalis*	moth	E	
Crambidae	*Omiodes monogona*	moth	E	
Noctuidae	*Ophiusa disjungens*	moth	N	
Crambidae	*Orthomecyna exigua* subsp. *exigua*	moth	E	
Tortricidae	*Panaphelix marmorata*	leaf roller	E	
Tortricidae	*Pararrhaptica sublichenoides*	leaf roller	E	
Tortricidae	*Pararrhaptica subsenescens*	leaf roller	E	
Tortricidae	*Pararrhaptica* sp. (2)	leaf roller	E	
Noctuidae	*Peridroma selenias*	moth	E	
Noctuidae	*Pseudaletia unipuncta*	army worm moth	N	
Noctuidae	*Pseudaletia* n. sp.	moth	E	
Noctuidae	*Schrankia altivolans*	moth	E	
Geometridae	*Scotorythra arboricolans*	inchworm	E	
Geometridae	*Scotorythra artemidora*	inchworm	E	
Geometridae	*Scotorythra gomphias*	inchworm	E	
Geometridae	*Scotorythra hyparcha*	inchworm	E	
Geometridae	*Scotorythra goniastis*	inchworm	E	
Geometridae	*Scotorythra* n. sp. nr. *kuschei*	inchworm	E	
Geometridae	*Scotorythra rara*	inchworm	E	
Geometridae	*Scotorythra* sp.	inchworm	E	
Tortricidae	*Spheterista pleonectes*	leaf roller	E	
Sphingidae	*Theretra nessus*	yam hawkmoth	N	
Oecophoridae	*Thyrocopa fraudulentella*	moth	E	
Oecophoridae	*Thyrocopa* sp.	moth	E	
Crambidae	*Udea endopyra*	moth	E	
Crambidae	*Udea liopis*	moth	E	
Crambidae	*Udea pyranthes*	moth	E	
Crambidae	*Uresiphita polygonalis* subsp. *virescens*	moth	E	
Nymphalidae	*Vanessa tameamea*	Kamehameha butterfly	E	
Malacostraca (crustaceans) **Decapoda**				
Atyidae	*Atyoida bisulcata*	ʻōpae kalaʻole, mountain shrimp	E	
Atyidae	*Halocaridina rubra*	ʻōpae ʻula, red shrimp	E	
Palaemonidae	*Macrobrachium grandimanus*	ʻōpae ʻoehaʻa, Hawaiian prawn	E	
Palaemonidae	*Macrobrachium lar*	Tahitian prawn	N	
Cambaridae	*Procambarus clarkii*	Louisiana crayfish	N	
Mollusca **Gastropoda (snails, slugs, etc.)** **Pulmonata**				

Achatinellidae	*Partulina physa*		E	SOC
Achatinellidae subf. Tornatellidinae	?		E	
Succineidae	?		E	
Neritoida				
Neritidae	*Neritina granosa*	hīhīwai, stream limpet	E	

Appendix B

Selected Hawai‘i Revised Statutes (HRS) and Administrative Rules (HAR).

Authority	Law/Rule	Title	Summary
DLNR-DOFAW	Chapter 13-104, HAR	Rules Regulating Activities within the Forest Reserve	-DLNR can issue permits for camping, special use, collecting, commercial harvest, and access.
DLNR-DOFAW	Chapter 13-105, HAR	Rules Regulating Restricted Watersheds	-Entry prohibited except by permit for official duties, research and scientific pursuits, public hunting and fishing as permitted under chapters 13-122 and 13-123, HAR, recreational and educational purposes, and collection of plants for personal use.
DLNR-DOFAW	Chapter 13-106	Plant Sanctuary Rule	-Purpose of rule is to conserve, manage, and protect threatened, endangered, and rare native plants by the establishment of plant sanctuaries; -Plant sanctuaries designated by BLNR; -Permits hiking and walking; nature appreciation and scientific studies; photography; and hunting as authorized by law.
DLNR-DOFAW	Chapter 13-107, HAR	Threatened and Endangered (T&E) Plants	-Purpose of rule is to conserve, manage, protect and enhance native T&E plants. -Prohibits collecting, possessing, transporting, propagating, and outplanting T&E species from wild populations without license for propagation, education, cultural or scientific purposes or to enhance survival of species. -No selling of T&E plants unless species has been approved by department for commercial use; all T&E species from garden-grown stock can be used commercially.
DLNR-DOFAW	Chapter 13-121, HAR	Rules Regulating the Hunting of Wildlife on Public and Other Lands	-Hunting allowed only with license or permit.
DLNR-DOFAW	Chapter 13-122, HAR	Rules Regulating Game Bird Hunting	-Hunting allowed only with valid hunting license from the State in designated hunting areas during open seasons and hunting days for specified game bird species and complying with bag limits. -Public hunting areas include among other things game management areas, forest reserves, natural area reserves, restricted watershed.
DLNR-DOFAW	Chapter 13-123, HAR	Rules Regulating Game Mammal Hunting	-Chapter 123, Exhibit 11. "Game mammals to be taken, daily bag limits, hunting periods, hunting days, and special conditions for the island of Hawai‘i."

Authority	Law/Rule	Title	Summary
DLNR-DOFAW	Chapter 13-124, HAR	Indigenous Wildlife, Endangered and Threatened Wildlife, and Introduced Wild Birds	
DLNR	Chapter 13-130, HAR	Rules for Hawai'i Statewide Trail and Access Program (Na Ala Hele)	
DLNR-DAR	Chapter 13-100, HAR	Protected Freshwater Fisheries Resources: Oopu and Hinana	-It is prohibited to fish for, catch, take, injure or kill any oopu or hinana. -Only oopu or hinana raised in private ponds or waters may be harvested and sold.
DLNR-CWRM	Chapter 174C, HRS	State Water Code	-States that the waters of the State are held for the benefit of the citizens of the State and that the people of the State are beneficiaries and have a right to have the waters protected for their use. -Establishes the Commission on Water Resource Management. -CWRM can designate water management area and establish administrative control over withdrawals and diversions of ground and surface water to ensure reasonable beneficial use of the water resources in the public interest. -Permit required for any consumptive use of water in designated water management area, except for domestic consumption of water by individual users. -Authorizes CWRM to establish and administer statewide instream use protection program. -All stream diversions must obtain permit from CWRM.
DLNR-CWRM	Chapter 13-167, HAR	Rules of Practice and Procedure for CWRM	
DLNR-CWRM	Chapter 13-168, HAR	Water Use, Wells, and Stream Diversion Works	
DLNR-CWRM	Chapter 13-169, HAR	Protection of Instream Uses of Water	-Includes interim instream flow standards for Hawai'i Island.
DLNR-CWRM	Chapter 13-170, HAR	Hawai'i Water Plan	
DLNR-CWRM	Chapter 13-171, HAR	Designation and Regulation of Water Management Areas	
DLNR-Land	Chapter 13-190, HAR	Water and Land Development: Dams and Reservoirs	-Rules governing the design, construction, operation, maintenance, enlargement, alteration, repair, and removal of dams, reservoirs, and appurtenant works in the State.

Authority	Law/Rule	Title	Summary
DLNR-Land	Chapter 13-195, HAR	Rules for Natural Area Reserves	-Established to preserve in perpetuity specific land and water areas which support communities, as relatively unmodified as possible, of the natural flora and fauna, as well as geological sites. - Hiking, nature study, and bedroll camping without a tent or other temporary structure are permitted. Hunting is a permitted activity pursuant to hunting Sec. 13-209-3 rules of the department.
DLNR-NAR	Chapter 13-208, HAR	Rules of practice and procedure for the Natural Area Reserves (NAR) System Commission	
DLNR-NAR	Chapter 209, HAR	Rules Regulating Activities with NAR	-Includes permitted activities, prohibited activities, special use permits, and penalties.
DLNR	Chapter 198, HRS	Conservation Easements	-Conservation easement is defined as an interest in real property created by deed, restrictions, covenants, or conditions, the purpose of which is to preserve and protect land predominantly in its natural, scenic, forested, or open-space condition.
Land Use Commission	Chapter 205, HRS	Land Use Commission (LUC)	-Establishes a Land Use Commission. -Establishes four major land use districts in which all lands in the State shall be placed in either urban, rural, agricultural, or conservation districts and specifies permitted uses in each district. -Any district boundary amendments over 15 acres must be processed by the LUC.
	Chapter 205A, HRS	Coastal Zone Management	
	Chapter 343, HRS	State Environmental Review Law	-Establish a system of environmental review which will ensure that environmental concerns are given appropriate consideration in decision making along with economic and technical considerations.
	Chapter 344, HRS	State Environmental Policy	
	Chapter 520, HRS	Landowners' Liability	-The purpose of this chapter is to encourage owners of land to make land and water areas available to the public for recreational purposes by limiting their liability toward persons entering thereon for such purposes.
DOH	Chapter 340E, HRS	Safe Drinking Water	
DOH	Chapter 342D, HRS	Water Pollution	
DOH	Chapter 342E, HRS	Nonpoint Source Pollution Management and Control	

Authority	Law/Rule	Title	Summary
DOH	Chapter 11-23, HAR	Underground Injection Control	- Establish a state underground injection control (UIC) program in order to protect the quality of the state's underground sources of drinking water (USDW) from pollution by subsurface disposal of fluids.
DOH	Chapter 11-54, HAR	Water Quality Standards	

Appendix C
Summaries of Earlier Planning and Management Efforts

The following are summaries of statements and recommendations made in earlier efforts that related to watershed management. Some of these recommendations have been incorporated into this Kohala Mountain Watershed management plan and are noted within Chapter V of the document.

KOHALA FOREST MANAGEMENT GROUP (KFMG)

This community-based planning group was created in 1995 to address issues specific to Kohala Mountain. The primary goal of the KFMG was to balance the needs of people with the needs of the native ecosystems. Over 40 meetings were held over a 5-year period.

Outline of Issues and Concerns Resulting from Meetings of the KFMG - 2000

Ecosystem Management Needs -- consensus achieved 10 June 1997

1. We should try to preserve plants, birds, and ecosystems in some areas.
2. Creating pig-free areas is a good method of analyzing the effects of pigs on the recovery of native ecosystems.
3. We need to be open to trying strategies that may have been tried before or that haven't been tried before, whatever we think will or might work. This is a unique place from an ecosystem, species, and community perspective.
4. There are incompatible uses of native forest, because some believe that pigs are good for the forest while others feel they cause unacceptable damage.
5. Hunting should be utilized as a management tool in some areas to keep pig populations down.
6. The proposed Awini Watershed Unit has the highest priority (after the bog) for designation as a pig-free zone.
7. There will be pig control and fencing in some areas.

Action Plan Outline of Projects (broad agreement was reached on these items)

8. Add Awini Watershed Unit (1,385 acres) to Pu'u O 'Umi NAR.
9. Establish GMA on Kohala Mountain. The most suitable area is probably the Muliwai area between Waipi'o and Waimanu valleys.
10. Provide public hunting and hiking access to the forest across the DHHL lands at the end of White Road.
11. Establish an ecotourism program, modeled after the one established on West Maui, where the proceeds are applied to the efforts of the land managers to enhance hunter access, remove weeds, grow and out-plant native plants, and maintain fences.
12. Develop an outreach and education program for Kohala Mountain.
13. Construct 18.35 miles of perimeter fence in the following areas and remove pigs from exclosures: (a) Awini Watershed Unit (6.65 miles); (b) Pu'u Ahia (5.3 miles); (c) Big Valley watershed (1.7 miles); and (d) North Slope/Kawainui headwaters (4.7 miles). No other pig-free areas will be proposed.
14. Establish a program for removal of pigs from within fenced exclosures and in unfenced portions of the NAR, including: helicopter transportation of hunters and dogs into specific areas; and sponsoring a hunting tournament.
15. Establish a sustainable agroforestry system where the main animal component would be pigs. These would provide subsistence and recreational hunting opportunities for the

community. Management goals would be for habitat enhancement to provide high sustainable game yields.
16. Establish an ongoing banana *poka* eradication program with the goal of eliminating the non-native *poka* from the upper Kohala Mountain.
17. Establish a program for reforesting and maintaining the State lands between the Koaia Tree Sanctuary and the NAR.
18. Conduct a pig movement study to determine their random and/or seasonal movements. The research would involve capturing 20 pigs and fitting them with radio collars and tracking them from the ground and/or by helicopter.

NATURAL AREA WORKING GROUP (NAWG) - 1995

The goal of the NAWG was to address the question "how do we fairly balance and accommodate the various interests that have a stake in the Natural Area Reserves System (NARS) and maintain a healthy forest and social community?" Two resolutions adopted by the Legislature in 1993 were the impetus for the creation of the NAWG, which was composed of individuals from public, private, and community interest groups, all of whom have a stake in the future of Hawai'i's forests. The group sough to find reasonable resolutions to differences of opinion over fencing, pig hunting, protection of forests and watersheds, and the management of Hawai'i's various forest lands and rare, threatened and endangered species. The NAWG members reached consensus on the following 45 recommendations.

Resource Management

1. Expand hunting areas by looking at encumbered and unencumbered State lands. Areas that are adjacent to or surround existing public hunting areas may provide expanded hunting opportunities.
2. More surveys need to be done to inventory the native species in the NARS.
3. Cooperative programs with public hunters should be developed and shown to be effective.... In Pu'u O 'Umi, the proposed fence should not be built and public hunters assist in keeping pig levels low.
4. Some forest reserves should be designated as GMAs.
5. Identify and manage specific areas for public hunting. These designated areas should not compromise the survival of native species.
6. Look at existing boundaries of the NARs. Boundary modifications either increasing or decreasing reserves in size may be necessary after review.
7. Identify leased lands that could be used for GMAs or that should be preserved as areas best suited for native species. There should be an increase in both GMAs and NARs.
8. Look at improving access to land-locked areas.
9. Service projects should be organized; for example, removing old fence posts or cleaning up forest areas.
10. Utilize assistance from the hunters for managing pigs in the NARs so that meat is not wasted.
11. Create district/regional areas for the purpose of populating game animals.
12. Successful management and enforcement mechanisms should be implemented in GMAs.
13. As a beginning step in developing Resolutions, field trips need to take place so that the members of the NAWG have a clear definition of what are considered damaged or threatened areas, and what are considered excellent as opposed to poor hunting areas to provide a common base of knowledge and understanding.
14. Review and modify State leases to allow/accommodate public access.

15. Create a position for the hunters in the management plan for GMAs, so that they assist in data collection. Hunters play an integral part in acquiring information relevant to the assessment of GMAs.
16. Conduct more research on pig migration, reproduction, damaging effects to the forest, and where these activities occur. Conduct a study on the correlation between pigs in areas where native species are found and the level of direct impact that the pig imposes on the areas.
17. Create a mechanism to alert hunters of "fresh pig signs", especially when such signs are presented in easily accessible areas.
18. Review relative information from the Public Laws and 5F American Indian Tribal Acts.
19. Audit the Pittman-Robertson federal funds over the last 3 to 4 years to see if funds could be spent more effectively, identify gaps in the program, and identify possible disproportionate use of funds. Also audit the revolving State fund generated from hunting licenses.
20. Identify existing traditional routes to the ocean and the forest and develop policies to preserve those accesses.
21. Develop a community program for maintenance and preservation of forest areas. Include broad community interests.
22. Examine federal policies regarding the taking of meat off of federal lands to see if hunters could be allowed to do so.
23. Re-establish the State Ranger System to increase the level of visibility and effectiveness in enforcement.
24. Lobby for more funds and additional staffing for inventorying and monitoring, habitat management, game management, and public education.
25. Expand and develop a more effective mechanism for the enforcement of hunting laws and regulations, especially in the prosecution of illegal hunting/poaching. Look at increasing penalties for poaching.
26. Better manage areas where rare, threatened, and endangered native species have been identified with no overall net loss of GMAs in the region.
27. The outer edges of the NARs should serve as buffer zones. Hunters should be utilized to assist in the management of maintaining low pig numbers in these buffer areas.
28. Begin a dialogue between enforcement agencies and the hunting community to address existing and potential disagreements/misunderstandings.
29. Open up/improve existing roads/easements.
30. Develop RFMACs (Regional Forest Management Advisory Council) that focus on the concerns identified by the community.
31. Continue the NAWG as a means of monitoring the implementation of these recommendations, to oversee the pilot RFMAC, and as a continuing form for discussion of forest management issues.
32. Re-examine State policy on stray game to determine status of the policy and whether additional discussion is needed for species not currently addressed by the NAWG. The NAWG decided to focus on ungulates and not on small mammals, such as stray cats, mongoose, or rats.

<u>Community Participation</u>

33. Monitor the growth of native species, introduce or add more native species in the appropriate areas, and get community groups directly involved in both activities.
34. Develop mechanisms for joint monitoring (community and government agencies) for birds, medicinal plants, water, weeds, native plants, cultural sites, etc.

35. Develop and implement a mechanism that coordinates existing public and private stewardship/partnerships with the goals and interests of the community, such as the NAWG process.
36. Look at increasing community participation in game management by having the various interests represented in the Animal Species Advisory Commission and island councils.
37. Create a position in DOFAW for a Volunteer Coordinator on each island.
38. Work on statutory changes so that the community has more control over board, commission, and committee appointments. A beginning step could be voicing who the community recommends as a representative.

Education

39. Create a forum to carry on the task of working with the public on natural resource issues.
40. Develop a "hands on" educational program that includes all facets of the forests including both pig hunting activities and conservation efforts.
41. Bring information gathered in the NAWG process back to the general public.
42. Lobby for the creation of an Education/Information Specialist within the Island of Hawai'i Branch of DOFAW.
43. Modify and expand existing efforts and develop new ways to heighten public awareness of the dangers of alien pest species introductions.
44. Expand and modify the Hunter Education Program to include conservation needs and increase opportunities for participation.
45. Develop a mechanism to convey information to the public regarding existing NARS activities and cooperative activities that are NARS-related.

WAIMEA WATER ROUNDTABLE (WWR) - 1996-97

The purpose of the WWR was to work toward common solutions of water issues as they flow across many terrains, bringing them into integrated beneficial use in the watershed. The goal of the group was to share knowledge and work cooperatively to achieve mutual goals for Waimea's water resources. The group was advisory and establishes a communication link among those in the private sector, government, the community and water users.

From WWR Synopsis of 1996-97 Meetings

1. Need for better understanding of current policies, management options, agriculture statistics, information on water use, availability of water resources and status of water distribution system.
2. Importance of pursuing groundwater resources as a way to deal with drought conditions and the unreliability of Waimea's surface water system.
3. Data acquisition is critical: Need more data water budgets for the Kohala area, real time rainfall data, streamflow, wind speed, temperature, soil moisture, evaporation, solar radiation, fog drip, runoff, water level (for groundwater), infiltration (for groundwater), etc.
4. Need to protect watershed to maintain water supply.

Climatological Stations Proposal

5. Establish climatological data gathering stations to improve quantity and quality of water and weather data available for the Waimea area (at Waimea airport and in Kohala watershed).

KONA/KOHALA WATERSHED PLANNING TASK FORCE AND WORKSHOP - 1993

The task force was convened in 1992 in response to concerns by landowners about the proposed reclassification of agricultural lands in Kona and North Kohala into Conservation District zoning. Its purpose was to plan a series of public informational workshops intended specifically to build the common base of knowledge pertaining to the Kohala and Kona watersheds and natural resources. Based on the information presented to the workshops, the task force adopted the following "Statements of Agreements."

1. People (landowners/managers/stakeholders) respond better to incentives than to penalties.
2. Persons who are impacted by an action need to be involved in the process of developing and implementing the action.
3. Planning and management techniques need to be site specific and not broad brush. Natural Resource planning especially needs to be site specific.
4. Water resource development in the Kona area is in the early discovery phase.
5. Current weather patterns in the area are effected by vog which reduces rainfall.
6. Tree cover can increase effective water recharge in fog drip area where infiltration is adequate and evapotranspiration is reduced.
7. Regulatory coordination and consistency between different agencies needs to be established.
8. The current biological resources in the area are incompletely known but can be identified through further surveys.
9. Abandoned cane land and pasture will not become fog drip forest without money, effort, and appropriate geography.
10. It is important to protect existing native biological resources where possible.
11. A well-managed pasture can be a good watershed and provides additional cultural and economic benefits.
12. There is a list of permitted uses in the county agricultural district which may not be acceptable for watershed protection.
13. Recent discovery of additional high-level water resources in the Kona area suggests that there may be more groundwater available in this area than previously believed. Sustainable yields in general must be evaluated on an aquifer specific basis.
14. Native forests including both plant and animal life need active management to survive.
15. Adding a mitigation process to the State endangered species law could allow for more creative protection options.
16. The conservation district rules and process need to be revised with relation to scale of activity. They also need to be consistently applied and made more user friendly.
17. Successful agricultural activities require greater flexibility than currently permitted in conservation district.
18. Conservation district lands have less value than agriculture district land in terms of collateral and cash flow loans from a bank.
19. Native ecosystems and some other uses in Kona and Kohala watershed can co-exist if properly managed.
20. Maintaining watershed recharge is important to the future of economic development.
21. We need to map areas of high water recharge and those having valuable native resources separately.

22. The relationship of the high level aquifer and basal aquifer in the Kona area is not well known.
23. Government and non-government natural resource agencies are interested in establishing natural resource management partnerships with landowners.
24. Natural resource management incentives need to be developed, marketed, and user friendly.
25. The Island of Hawai‘i water situation is different from that on O‘ahu.
26. Fog drip can significantly increase effective precipitation but the amount of recharge generated is dependent on other factors.
27. There are a number of new partnerships and cost sharing programs available for natural resource management. Although these need better marketing, increased user friendliness, certainty of sustainability of funding and certainty of commitment from both sides, they are seen as a step in the right direction for cooperative resource management.
28. County and State planning maps and documents are not always in agreement which causes differing expectations and conflicts.
29. Long-term water management, planning, and development requires integrated collaborative planning efforts between the state, county, and private sectors to work.
30. Investment in the development of sustainable forest resources (timber, ecotourism, water recharge, habitat, etc.) requires long horizons and regulatory certainty.
31. Landowners have a right to economic use of their land and this right needs to be fairly balanced with protection of public trust resources.
32. Land use rights may provide incentives to private landowners for appropriate management practices. Removal of these land use rights may be detrimental to encouraging appropriate management practices.
33. Natural resource protection strategies should be tailored to the specific resources and the individual landowner’s needs.
34. Further education is important to bring everyone along.
35. Traditional agricultural practices are changing.
36. Some non-native plants and animals are a resource on the Kona/Kohala lands.
37. Additional dollars are needed to support management efforts in the Kona/Kohala watershed area.
38. The expansion of noxious plants is detrimental to natural resources and requires money and time to rectify.
39. A portion of the value of water harvested should be used to pay for management of the watershed.
40. Fire is a significant threat to natural resources and fire management requires money and coordination.
41. Deadlines are necessary to move any process along but excessively restrictive time deadlines will adversely affect the process.
42. A facilitated process which includes representation of all stakeholders is essential to a successful outcome for Kona/Kohala watershed planning process.
43. A right to harvest or a method for compensation if harvest is denied is needed to encourage commercial forest investment.
44. If there is a need to regulate the area, then the regulating agency should be required to come see what’s there.
45. Changes in county tax laws are necessary to encourage responsible natural resource management.
46. Early surveys, i.e. archeological and biological, are essential to avoid conflicts.

47. Compaction of land effects recharge.
48. Aquifer boundaries in the Kona/Kohala area need to be more accurately defined and understood.
49. Courts are not the most effective place to resolve natural resource disputes.
50. Existing information suggests that current agricultural and residential uses within the Areas of Critical Concern have not contaminated water quality.
51. All water resources need to be protected from degradation and contamination, especially the Kona high-level aquifer because of the lack of information on the current characteristics of the aquifer.
52. Land use controls in and of themselves do not necessarily promote natural resource management. Well thought out land use controls an incentives can serve to enhance natural resource management.
53. Diversification is an essential component of the future of agriculture.
54. Existing grandfathering process within the Conservation District uses do not provide for the flexibility necessary to diversify quickly to take advantage of market and product changes.
55. Native Hawaiian montane forests (between 3,000 and 6,000 feet) make excellent watersheds.
56. Ohia with grass can be a good watershed.
57. Many landowners have been good stewards of the resources they value. As societal values change, former management practices should be recognized in the context of the values of their time.
58. The amount of water that can be safely developed in the Kona/Kohala area is not known at this time.
59. Efforts to address some current regulatory and management needs in the Areas of Critical Concern may be enhanced by the coordinated, collaborative efforts of many agencies and individuals.
60. Population expansion generates conflicts in natural resource management.
61. No single land use designation may be appropriate for the Areas of Critical Concern.

Appendix D

Proposed Biodiversity Conservation Units

Unit E:‘Eke Unit (640 acres)

This unit contains the highest quality forest remaing in the Kohala mountains. It rises from the southwest flanks in the pasture land to the summit of Kohala, Ka‘unu Kaleio‘ohie at 5, 480-ft elevation. Populations of *Schidea diffusa, Anoectochilus sandvicensis*, three species of *Labordia, Tetraplasandra oahuensis, Cyanea tritomantha*, and five species of *Clermontia* including the endangered *Clermontia drepanomorpha* are present.

The headwaters for five agriculturally-important streams, such as Keawewai stream, are derived here. This forested area is also the headwaters for Kohakohau stream, which is a main supplier for municipal and agricultural water in the Waimea area.

Of the 7 native forest birds still extant in the Kohala region, six are found in this unit. Included are the endangered Hawaiian Hawk and the endangered Hawaiian duck, Koloa maoli. This region of forest contains all the necessary remaining environmental criteria necessary for native forest birds to exist. This unit contains 475 acres that is privately owned by the Queen Emma Foundation, with the remaing acreage part of the State of Hawai‘i Pu‘u O ‘Umi NAR.

Unit F : Waimanu Bog Plateau Unit (430 acres)

This 430 acre unit encompasses the existing 110 acre Waimanu Bog exclosure in the Pu‘u O ‘Umi NAR. Through retrofitting an existing fence and some other strategic fencing of not more than 0.8 mi, an ungulate-free unit will exist. Besides containing the headwaters for Waimanu Valley, this is the only place on the island that *Trematolobelia macrostachys* (aka koli`i) is known to inhabit.

The make up of the unit consists of the remaining bog margins not protected in the current exclosure as well as windswept wet shrubland comprised mostly of Kolea lauli‘i, ‘Olapa, ‘Ōhi‘a and ‘Ohelo mixed in with native grasses, shrubs, Uluhe, and three feet of sphagnum moss. Within this wet shrubland is one of two native orchids found on the island, *Liparis hawaiensis*.

Unit G: Kanea‘a Unit (500 acres)

This parcel is owned by Parker Ranch and includes approximately 500 acres along the rims of Honokāne and Pololū Valleys. Due to its location between the two valleys, elevation, aspect, and winds derived from topography, it is unusually drier in this region than in other parts of the mountain. Besides the dominant ‘Ōhi‘a canopy, trees that dominate the understory are comprised of Alani, Ie‘ie, Hame, and ‘Ahakea. While there are other trees present, this unique assemblage provides for some interesting forest structure. The tree snail *Partulina physa* is known from the vicinity, and is dependant on canopy trees for survival.

The major threat to this forest is a large population of wild cattle. They use this area to access the valleys and the uplands. While the cattle have done significant damage to the understory and recruitment of juvenile trees, the older established trees are still present.

Unit H: Ponoholo Pupu kani‘oe Unit (160 acres)

This 160 acre unit will protect the core population of the native tree snail, *Partulina physa*, on the island. This area is part of the Ponoholo Ranch. While the area has been severely degraded, remnant stands of ‘Ohi‘a and other native trees still support these tree snails.

Fencing using existing roads and or trails to completely encircle the area will be used. Rats prey directly upon the snails, making rodent control a priority for management. Fencing to keep out feral and domestic livestock as well as feral pigs will prevent further degradation of the remaining forest.

Unit I: Kaimu Unit (20 acres)

This 20 acre unit will protect one of the last remaining, lowland wet forest stands in Pu‘u O ‘Umi NAR. Located on a bench near the pali and adjacent to the Kaimu Canyon, this unit contains an unusually large diversity of native forest plants and trees for its relative size. Included in this unit are ‘olopua, gardenia, ala‘a, ‘iliahi and a few species of *Melicope*.

The weeds present in the lands of Laupahoehoe within the Pu‘u O ‘Umi NAR are far more prevalent than those of the more northwestern proposed units. Further inland from the coastal cliffs, the native lowland forest is quickly replaced by non-native and invasive Guava/Waiawi forest with clidemia, Malobar melastome, palm grass understory.

Unit J: Lower Laupahoehoe Nui (1530 acres)

This parcel is owned by Laupahoehoe Nui, LLC. Due to the size and elevational gradient of this large unit, a number of species will be protected including the rare loulu palm *Pritchardia lanigera*. New species and new island records for species are always being discovered in Kohala, particularly along the sea cliffs. A discovery of a plant in the genus *Neraudia* was made here recently. Removal of feral pigs from the area will greatly enhance the ability of many rare species to persist, while improving water quality along the numerous streams that occur within the unit. This lower unit also connects to the high yield upper watershed and provides an entire ahupua‘a that will be protected.

Unit K: Ohiahuea Unit (565 acres)

This unit includes a section of the Kohala Forest Reserve which represents some of the steepest and remote land in Kohala. It will stretch from Ohiahuea canyon to Waimaile stream from the abandoned ‘Awini section of the Kohala ditch trail to the Coastal sea cliffs (Pali). It will require approximately 2.3 miles of strategic fencing barbless constriction wire, and natural barriers, of which most would utilize the existing abandoned ditch trail complex.

Contained in this proposed unit are some of the finest remaining examples of lowland wet forest stands in the State. The unit also includes the rare native gardenia, *Gardenia remyi*. This area also contains an entire ridgeline stand of enormous Ginseng trees called ‘Ohe or *Tetraplasandra hawaiensis*. Also present are some fine stands of lowland wet lama forest that continue to sustain themselves despite the weed invasions, rats, and rooting done by feral pigs.

Unit L: Pu‘u Pili (290 acres)

Pu‘u Pili is a self contained watershed unit and is located on Kahuā Ranch. While it is currently functioning, the watershed services provided could be enhanced by the removal of feral pigs and the occasional stray domestic cattle. The forest is very similar to that of the entire west end of Pu‘u O ‘Umi NAR and the ‘Eke unit. All of the five *Clermontia* species, known from Kohala mountain, are present as well as all the forest birds including the ‘Io and and waterbirds such as Koloa maoli.

Unit M: Pu‘u Lapalapa (55 acres) Unit N: Pu‘u Mala (10 acres)

These small units are similar to Pu‘u Pili. Portions of the slopes on these cinder cones are still forested. This forest provides adequate structure that make them more valuable as forest then pasture. The slope is steep enough to provide an intermittent stream when tradewinds prevail.