

The Rain Follows The Forest

Habai no ka ua i ka ululā`au

A Plan to Replenish Hawaii's Source of Water

Department of Land and Natural Resources - State of Hawai'i

November 2011



Photo: Air Maui

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EXECUTIVE SUMMARY

Immediate action is needed to secure Hawaii's water supply. Hotter, drier conditions and damaged watersheds are escalating the costs and conflicts over water. While climate change is a problem on a global scale, simple, local actions can safeguard Hawaii's declining water sources. Protecting forest watersheds is the most cost effective and efficient way to absorb rainwater and replenish ground water. Watersheds also reduce impacts from climate change by absorbing greenhouse gases and reducing flooding, erosion, and siltation of reefs and fisheries. Additionally, forests sustain irreplaceable cultural and natural values.

Half of Hawaii's forests have already been lost. Alien species, such as feral pigs and goats trample and devour vegetation, leaving bare ground or openings for alien plants that consume more water and increase runoff. Controlling these and other threats requires a large-scale effort to protect these irreplaceable natural assets.

Governor Abercrombie's *A New Day in Hawai'i* plan calls for the stewardship of the natural resources that our survival, economy, and quality of life depend on. Priority actions of the plan include managing invasive species, increasing Hawaii's ability to withstand impacts from climate change, and restoring capabilities of the Department of Land and Natural Resources (DLNR) by finding additional sources of funding. The *New Day* Status Report also tasks the DLNR to ensure mauka watersheds are fully functioning so fresh water resources can be utilized and enjoyed by the people of Hawai'i in perpetuity. *The Rain Follows the Forest* is the Department's plan to implement these central goals of the Abercrombie administration.

The Rain Follows the Forest identifies priority watersheds and outlines on-the-ground actions and projects required to protect and sustain Hawaii's critical water sources. The forests and their ability to capture water depend on the protection provided by the actions listed in this plan. To be successful, these actions must occur on a large scale across ownership boundaries, through agreements and leveraged funds provided by the statewide watershed partnerships. Currently, only 10% of the priority watershed areas are protected. This level of management has taken 40 years to achieve. The Department of Land and Natural Resources' goal is to double the amount of protected watershed areas in just 10 years. This will require approximately \$11 million per year, and create over 150 local jobs. Funding for watershed protection must be commensurate with the magnitude of the threats to Hawaii's water supply. This plan challenges Hawaii's leaders to dedicate funding to ensure the availability and affordability of fresh water, the essence of life on these islands.



Fresh, clean water is an irreplaceable resource. It is fundamental to our well-being. It fuels agriculture, tourism, and sustainable development. In turn, our water supply depends on the health of our *mauka* native forests, which capture and absorb rain. With over half¹ of the original forest lost, and the remainder threatened by exploding populations of invasive species, the forest now relies on us for its survival.

This is the Department of Land and Natural Resources' plan to protect the forests for Hawaii's people.

HAWAII'S WATER SUPPLY IS AT RISK

Our fresh water supply, revered and relied upon since the first ancient Hawaiians arrived on these islands, is declining.^{2,3} If this trend continues, future generations will not have access to water at reasonable rates, and may face tight restrictions. Agricultural, residential, commercial, cultural, and conservation uses are already competing over their share of a shrinking water supply. For example:

- A century-long trend⁴ of declining rainfall has accelerated, with a 12% decline in the last 20 years alone.⁵
- Groundwater head levels in Pearl Harbor, which supplies over 60% of Oahu's municipal water,^{6,7} declined by half since 1910.⁸ Estimates of 'Iao valley's groundwater, which supplies a majority of Maui's municipal water, declined dramatically since the 1990s.⁹
- Lawsuits over stream water diversions continue for decades across the state, from Wailua¹⁰ and Hanapepe,¹¹ Kaua'i¹² to Waiāhole, O'ahu¹³ and East Maui.¹⁴
- By 2030, Lanai's forecasted build-out will require more water than can be sustainably supplied if alternative water sources (e.g. forest protection) are not developed.¹⁵

Scientists predict that climate change will further decrease the future supply of our water resources.^{16,17} At the same time, the demand for these resources will increase.¹⁸ Hotter and drier conditions will increase irrigation demands.¹⁹ Rising sea levels will turn coastal water sources brackish, further threatening fresh water supplies.²⁰



Hahai no ka ua i ka ululā`au

The rain follows the forest

This ancient proverb shows how early Hawaiians clearly understood that water – and their survival – depended on the forests. In the late 1800s, this proverb was proven true after widespread clearing and enormous herds of wild cattle, goats, sheep, and pigs destroyed vast tracts of forests. The result: rivers and springs dried up, followed by water shortages, devastating droughts, and fires. Without water, Hawaii's agriculture – from taro lo'i to sugar cane – was under threat. In the early 1900s, agricultural interests lobbied for a massive effort to plant trees, construct fences, remove thousands of wild hooved animals, and establish forest reserves for water supply. However, in the last half century, the continued introduction and spread of invasive species such as deer and *Miconia* have renewed the need for a massive effort to protect Hawaii's *mauka* lands so future generations will not have to relearn the lessons of the past.

“The future welfare and agricultural prosperity of the Hawaiian Islands depends on the preservation of the forest.” - U.S. Forester E. M. Griffith, 1902.

Investing in the protection of fresh water sources must be the highest priority for Hawaii's public leaders and the DLNR. Forest protection and restoration is the most cost-effective action to alleviate the threats to Hawaii's water sources.

Since the first Hawaiians encountered these islands, the forests have been the wellspring of physical and spiritual nourishment.²¹ The misty uplands are the *wao akua*, realm of the gods, believed to be occupied by spirits.²² Within these forests, the plants and animals have their own significance, individually revered as manifestations of gods, or used for medicines, offerings, or other material needs.²³ The plants and animals, regarded as elders and ancestors,²⁴ evolved unique identities when they arrived and intertwined with the landscape and life forms of Hawai'i. The extinction of the unique inhabitants of the *wao akua* unravels the spiritual, as well as material vitality of Hawai'i. Like water, they are irreplaceable.



THE SOURCE OF WATER

Without vegetation and forest cover, most of our islands' rainfall would quickly run off unused into the ocean.²⁵ Instead, the forest buffers the impact of heavy rains. Rainfall collects on the leaves, branches, and understory, allowing it to drop slowly into the ground.²⁶ Natural underground reservoirs store this water, to be tapped by the wells and tunnels that supply almost all of Hawaii's drinking water.²⁷

Even without rain, Hawaii's native forests can absorb moisture from passing clouds that condense on the thick vegetation. Intercepting cloud drip increases water capture by as much as 30% of rainfall, and increases groundwater re-supply by 10-15%.²⁸ On Lāna'i, fog water supplies even more water than direct rainfall.²⁹ There, loss of the forest's fog capture would reduce by half the island's only water supply.³⁰

THE HIGH COST OF FOREST DEGRADATION

Forests are essential to provide water at affordable rates. Lower groundwater levels mean higher pumping costs to transport water for human use. When groundwater levels decline to a point that they cannot be pumped, expensive alternative water sources are needed – long transport pipes, new wells, and even desalination plants.

Water users already pay for the loss of native forests – and those costs are high. Invasive and widespread strawberry guava evapotranspires 27%-53%³¹ more water than native forests, causing extensive water loss across landscapes. For example, in East Hawai'i invasive plants have already reduced estimated groundwater recharge by 85 million gallons a day.³² When one considers that a 5 million gallon per day desalination plant planned for the `Ewa District on O`ahu will cost \$40 million to construct and over \$5.4 million per year to operate,³³ the superior economic value of protecting our forests is readily apparent.

Even a small percentage reduction in groundwater recharge can be costly. One study indicates that a 1% loss of recharge in the Koʻolau Mountains could cost Oʻahu \$42 million net present value.³⁴ Another study indicates that a 10% loss of recharge in the Koʻolau Mountains could cost \$1.7 million per year - over \$173 million net present value.³⁵ The gradual invasion of alien plants into native forests may have already reduced the estimated groundwater recharge by up to 10% in certain aquifers.³⁶

A VARIETY OF BENEFITS

In addition to being the primary source of our fresh water, Hawaiʻi forests provide many other economic benefits. For example, without a healthy forest to anchor the soil and temper the erosion from heavy rain, large amounts of sediment would wash off the steep mountains and into the ocean, polluting streams, destroying coral reefs, and degrading beaches.³⁷ In this way, forests protect against the increased storms and water shortages that may occur with climate change.³⁸ Forests also absorb large amounts of carbon dioxide, reducing Hawaiʻi's greenhouse gas emissions.³⁹



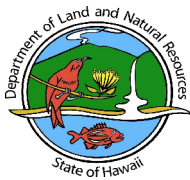
Muddy runoff from eroded lands is the main cause of coral reef loss⁴⁰ in the largest fringing reef in the Main Hawaiian Islands, Molokaʻi.

A University of Hawaiʻi study examined the various services provided by Oahu's Koʻolau forests—including water recharge, water quality, climate control, biodiversity, and cultural, aesthetic, recreational, and commercial values. These services were calculated to have a net present value of between \$7.4 and \$14 billion. Approximately half of that amount is attributed to the forest's contribution to ground and surface water quality and quantity.⁴¹ Other watersheds across the state were estimated to be comparable in value.⁴²

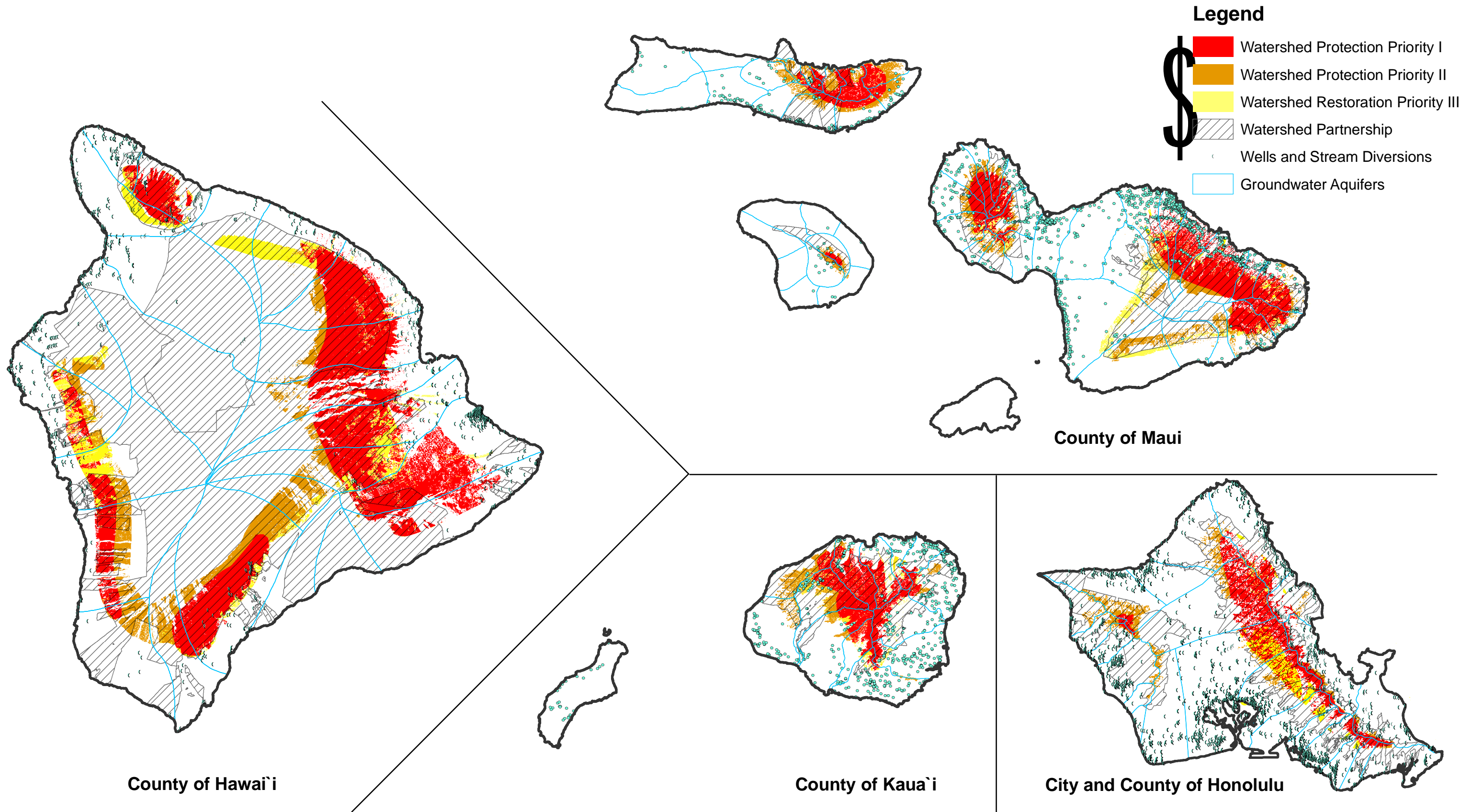
Investing to protect these areas is much more efficient when done early, before the forests have become degraded and require expensive and difficult restoration. Work to remove a weed like strawberry guava that has formed dense thickets can be over forty times more expensive per acre than removal when the trees are still sparse.⁴³ To control strawberry guava in East Hawaii alone, preventing the spread now instead of waiting until the invasion has spread to its fullest extent could save over \$2.7 billion.⁴⁴

Hawaiʻi has a window of opportunity to secure these forests. The next 10-20 years may be a relatively wet period of a recurring climatic cycle⁴⁵ during which the benefits of protection and restoration can be maximized. It is urgent to strengthen the forests now by removing threats before their resiliency and our water supplies are doubly taxed, when climate change coincides with the returning dry phase of the climatic cycle.

Clearly, our forests are enormous economic assets. Just as clearly, their degradation is ongoing and accelerating. The longer Hawaiʻi waits to take significant action to halt this destruction, the higher the costs will be to reverse the damage and ensure our future water supply for current and future generations.



Priority Watershed Areas



See Appendix II for methodology.
Map created November 2011. DLNR (808) 587-4170.

ACTION PLAN

Fortunately there are cost-effective and long-term solutions to reverse the trend of forest degradation. Hawaii's 11 watershed partnerships provide a framework for large-scale protection. These voluntary alliances of public and private landowners and managers cooperate to protect over 2 million acres of forests that supply almost all of the hundreds of millions of gallons of fresh water needed in Hawai'i every year. Working across ownership boundaries, these partnerships leverage State efforts, pool funding, and provide a diverse range of local jobs.⁴⁶ They directly benefit all of Hawaii's people.

But while there is a willingness to partner, funding for these efforts is not sufficient and forest losses continue. Statewide, only 10% (approximately 90,000 acres) of the priority watershed protection areas are fenced from hooved animalsⁱ – the first step towards protection.⁴⁷ This level of management has taken 40 years to achieve. The Department of Land and Natural Resources' goal is to double the percentage of watershed areas protected in the next decade. Expanding protection in priority areas will continue over the long-term.ⁱⁱ

Projects will focus in the mauka native forests that receive the most rainfall and are essential to sustaining the state's water resources,⁴⁸ culture, and biological diversity. The Priority Watershed Area map indicates areas of highest rainfall and re-supply to fund on-the-ground actions proven to benefit watershed health. Appendix I lists the actions that this plan seeks to fund.

Priority areas are based on climatic conditions (elevation, moisture zones including fog and rainfall levels) as well as land cover types that provide high recharge and fog capture. Appendix II describes the methodology for selecting these areas. Watershed partnership boundaries almost completely overlap the priority areas, demonstrating where partnerships have already established a shared mission among landowners to protect these natural resources.

DLNR's 10-year goal will require \$11 million per year.ⁱⁱⁱ This funding will employ more than 150 FTE Hawaii residents with a variety of natural resource jobs. As a participant in all of the watershed partnerships, DLNR will expand protection and implement these actions and policies on State lands.^{iv} Protection must cross ownership boundaries, through agreements forged by the partnerships.

DLNR's watershed partnership program will distribute funds through a competitive process open to public and private entities. The DLNR will also direct funds to build the capacity of the Division of Forestry and Wildlife to administer this program, and support the expanded efforts of the partnerships. Appendix III lists projects proposed by the partnerships as examples of the types of activities needed to implement the plan. In the future, additional projects will also be proposed.

Many factors influence the rate of watershed protection and recovery. Unforeseen technologies may make protection cheaper and more effective, while new introductions of invasive species may make the task harder. While this plan adopts 10-year goals, this level of effort, or more, will be needed over many decades if Hawai'i is to stabilize its water sources. Changes in climate and population growth will alter the demand on these forests and the need to optimize their health. One thing is certain, however – we must start now.

ⁱ Fenced areas are in many stages of hooved animal (ungulate) removal.

ⁱⁱ Priority I and II watersheds encompass approximately 840,000 acres statewide.

ⁱⁱⁱ A 4% yearly interest adjustment is included in the budget.

^{iv} These areas are primarily Forest Reserves, established in large part to protect forests for water supply pursuant to §183 Hawai'i Revised Statutes.

FUNDING

In 2000, the State legislature directed the DLNR to identify additional funding sources to protect Hawaii's watershed forests.⁴⁹ But a decade later, the only dedicated funding source for watershed partnerships is the Natural Area Reserves Special Fund (NAR Fund), which receives a percentage of the State Conveyance Tax from the sale of real property. With recent cuts to the State general funds, a variety of natural resource programs have increasingly relied on the NAR Fund. This has significantly compromised the funds allocated to watershed protection. In fiscal year 2011, 11 partnerships split \$1.25 million, and the five island-based committees that control invasive species and contribute to watershed protection have no authorized dedicated funding whatsoever. Their general fund allocation was eliminated, and they now receive annual legislative allocations from the NAR Fund. In recent years, the NAR Fund has become the funding source for a variety of worthy natural resource programs. But its capacity is stretched to the limit as it is carved up into smaller and smaller shares. This fund is prone to volatile changes in real estate market cycles. Watershed protection is far too important an activity to rely solely on the inevitable and sharp declines of the real estate market. This plan will rely on stable and diversified funding sources from additional sectors that benefit from watershed protection.

Dedicated Funding for Watershed Protection

Watershed protection requires dedicated funding sources for ongoing maintenance of fences, firebreaks, and invasive species removal. While watershed partnerships have typically been able to leverage dedicated State funds with at least 1:1 matching funds,⁵⁰ declining State revenues have reduced their ability to find matching contributions. This significantly compromises their ability to protect and maintain priority watershed areas into the future.

There is widespread support for increased funding for these actions. Previous studies show that 70% of Hawai'i residents support more funding for reefs, ocean environments, forests and watershed areas.⁵¹ Conservation projects that protect watersheds and drinking water, and reduce erosion and invasive species are viewed as "extremely important" by over 4 out of 5 O'ahu voters.⁵² In the effort to continue and dramatically expand watershed protection and restoration, DLNR engaged the services of OmniTrak Group, Inc., to determine Hawaii's willingness to support increased funding of this activity. Preliminary results from this watershed study conducted during October 2011 are consistent with these earlier results, and demonstrates that the public is both aware of the urgent need to increase protection of our water supply and supportive of raising and expending the funds necessary to do so.

Urgent Need to Protect Our Watersheds

In general, the 2011 study showed that the public has a good awareness of the connection between forests and water supply. Respondents noted that "forests are important to Hawaii's fresh water supply" (9.4 on a scale of 1 to 10) and that forest watersheds "capture rainfall and replenish fresh water supplies for our use" (9.2 on a scale of 1 to 10). Further, 59% of respondents indicated the urgent need to increase the protection of the sources (upland forests) of our fresh water supply, and rated the urgency to protect these sources at 8.4 out of 10, with 10 representing "Extremely Urgent."

Willingness to Pay to Protect Our Watersheds

The study also reported that 78% of respondents were supportive of increased funding for watershed protection from \$1 million to \$11 million per year. Subsequently, respondents were presented with the following statement:

“Fresh clean water is an irreplaceable resource, fundamental to our well-being. In turn, our water supply depends on the health of our mauka or upland native forests, which capture and absorb rain. With over half of the original forests lost and the remainder threatened by invasive species, the forests now rely on us for its survival. At the same time, public investment in forest protection has declined.”

After hearing this message, the percent of respondents in *strong* support of increased funding grew from 44% to 58%, and the mean rating for the extent of their support increased to 8.2 out of 10, with 10 indicating “Strongly Support.” A similar result was reported when respondents were provided with the goals of increasing funding (e.g., removing animals like pigs, fencing, and controlling invasive plants like *Miconia*). With this information in mind, 57% were in *strong* support of increased funding and rated the level of their support at 8.3 out of 10, with 10 again indicating “Strongly Support.”

Then, respondents were presented with various means by which the increased funds could be raised (general funds, taxes, or fees). Support for an increase in their monthly water fees was 4.7 out of 10, but a majority supported increased general funding (7.4 out of 10), the use of environment-related taxes (7.4 out of 10), or a visitor-related tax (8.0 out of 10).

Taken together, the results suggest that the public recognizes the immediate need to protect the source of our fresh water and the willingness for government to significantly increase the funding of this activity.

Beneficiaries of Watershed Protection

Certain sectors of our economy are particularly reliant on the health of our watersheds. For instance, protection and restoration of forests provides the visitor industry the dual benefit of preserving water supplies as well as preserving the unique cultural and natural resources that attract people to Hawai‘i. For example, the Ko‘olau forest watershed on O‘ahu is estimated to provide a net present value of \$1-\$3 billion for ecotourism alone.⁵³ However, the unique cultural and natural resources that attract visitors to Hawai‘i are declining. Native species sacred to the Hawaiian culture are disappearing at the highest extinction rate in the nation because of development, introductions of invasive species, and other threats. The lovely, verdant forests that provide the aesthetic backdrop to the visitor industry are being consumed by invasive species. Without forests, bare ground erodes, muddying Hawaii’s beautiful coral reefs and beaches.



“We cannot keep pouring money into marketing Hawai‘i while neglecting to make improvements to the ‘product.’ We need to repair decrepit public facilities, design and build greener buildings, invest in vibrant culture and the arts, and restore our natural environment. This will create economic benefits that ripple through the economy. And it also means you and generations to come will be able to enjoy and do your part in nourishing the natural environment and cultural diversity of Hawai‘i.”

-A New Day In Hawaii Comprehensive Plan

Additionally, resorts are the most water-intensive land use, using over three times more water per acre than industrial and commercial, and five times more water per acre than agriculture.^{54,55} Because of this, water-intensive resort development and expansion can be restricted by limited water supplies.

Protecting watersheds retains Hawaii's ability to be a desirable visitor destination and maintains the water supply needed to fuel development of tourist amenities and accommodations.

Watershed forests can also mitigate negative impacts from certain economic sectors. For instance, forests help Hawaii's natural resources and population adapt to the inevitable challenges of climate change caused by carbon dioxide and other greenhouse gas emissions from burning fossil fuels. Protecting forests alleviates a wide range of threats from climate change predicted to cause hotter⁵⁶ and drier⁵⁷ conditions, and rising sea levels^{58,59} that infiltrate fresh water systems.⁶⁰ Forests will be even more critical for collecting fog drip with less overall rainfall.⁶¹ During predicted increased storm events,⁶² forests are the main defense against soil erosion that floods nearshore waters and coral reefs. Controlling invasive species is particularly important as the climate becomes even more conducive to the spread of invasive plants, insects⁶³ and diseases.^{64,65}

A healthy watershed directly impacts Hawaii's ability to reduce its dependence on oil imports. This task can be done by supporting local agriculture and developing alternative energy sources. Water is critical to produce biofuels, a component of the Hawai'i Clean Energy Initiative from the Hawai'i Greenhouse Gas Emissions Reduction Task Force (Task Force).⁶⁶ For the same reason, local agriculture is dependent on watershed health. The major investment in forest protection in the early 1900s was largely due to the support of agricultural interests that lobbied for increased fencing and tree planting to protect their water source.⁶⁷ Finding new water sources remains a priority for agriculture,⁶⁸ especially as rising temperatures from climate change may increase irrigation needs.⁶⁹

Additionally, the Task Force's Work Plan strongly recommends opportunities for reforestation projects, as these projects provide other benefits including watershed management and native species restoration.⁷⁰ On Hawai'i Island, some of the highest standing densities of carbon can be found in old-growth `ohi'a forests.⁷¹ `Ohi'a forests, the dominant type of the remaining native forests, contain anywhere from 19 to 162 tons of carbon per acre; depending on climate and soil variables.⁷² Destruction of native forests by hooved animals can reduce or practically eliminate stored carbon.⁷³ When invasive plants, such as strawberry guava invade and eventually replace these forests, aboveground biomass can drop by 19-38%.⁷⁴ Strawberry guava infests over an estimated 495,000 acres statewide, with the potential to spread to an additional 680,000 acres of native forest.⁷⁵ Thus, enormous carbon emissions have already and will continue to occur from forest degradation in Hawai'i. For these reasons, reducing and preventing deforestation is the mitigation option with the largest and most immediate carbon stock impact in the short term, according to the Intergovernmental Panel on Climate Change.⁷⁶ Protection of forests from degradation and restoration of forests will help achieve Hawaii's goals to reduce greenhouse gas emissions to 1990 levels by 2020.ⁱ



“Energy independence, environmental sustainability, food sustainability - it all comes back to water. So, we have to figure out where we are going in terms of urbanization and in agricultural production for food, as well as the ideas of biofuels. Water is the key, and its distribution the central factor in terms of policymaking.”

- Governor Abercrombie,
September 13, 2011 Hawai'i
Public Radio interview

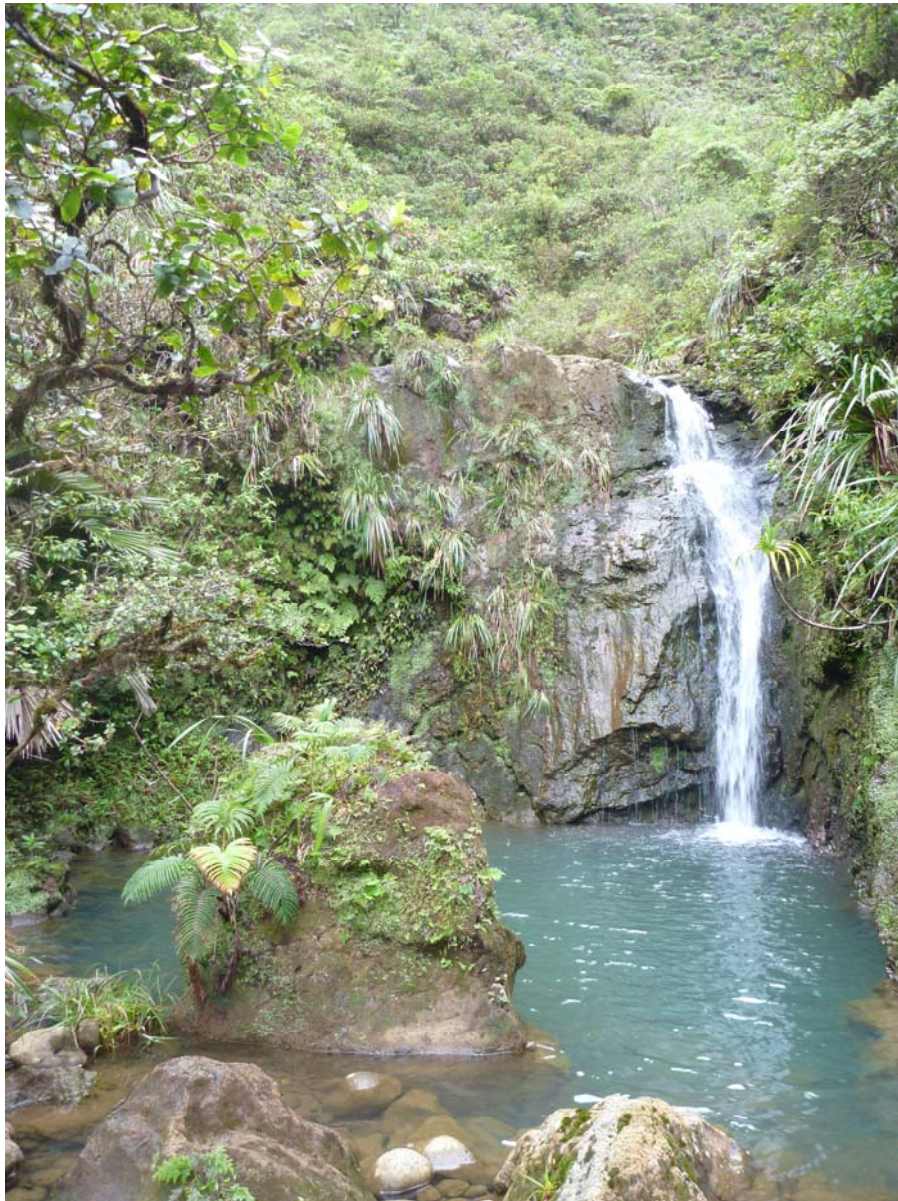
ⁱ Act 234, Session Laws of Hawai'i 2007.

Funding watersheds directly benefits multiple sectors of the economy that depend on or are mitigated by healthy forests. For these reasons, there are multiple funding options with a direct and logical nexus with watershed protection.

CONCLUSION

Watershed protection and restoration must be funded commensurate with its essential role. Hawaii's leaders must come together and incorporate funding policies within the State's overall financial plan. Hawaii must find solutions to reverse the grave decline of the islands' life-giving forests in order to sustain and enrich current and future generations.

Proper, or *pono*, stewardship of our watershed resources is in everyone's best interest. Everyone that relies on water relies on the health of the forests. It is only fair that we all contribute to make sure these forests are not destroyed while we still has the power to protect them, and they still have the ability to sustain us.



APPENDIX I – WATERSHED PROTECTION AND RESTORATION ACTIONS

1. Remove all invasive hooved animals from priority I and II areas.

This action is the essential first step for forest watershed protection.⁷⁷ Hawaii's forests are especially vulnerable to damage from feral ungulates (hooved animals like pigs, goats, sheep, deer, and wild cattle) because the forests evolved without these non-native animals. Ungulates are widespread across the state, demolishing forests by trampling, uprooting, and devouring plants. For example, a single pig can uproot an area the size of a football field in a week.⁷⁸ Pigs spread fatal diseases such as fecal bacteria (enterococcus)⁷⁹ and leptospirosis.⁸⁰ Ungulates spread Hawaii's most destructive weeds,⁸¹ such as strawberry guava.⁸² Removing these animals allows barren and uprooted areas to naturally regrow,^{83,84} reducing runoff and erosion,⁸⁵ and increasing carbon storage.^{86,87}

In the early 1900s, territorial foresters in Hawaii conducted a massive effort to reduce the large-scale degradation of the forests by building miles of fences and removing thousands of feral ungulates.⁸⁸ Over time, fencing has proven to be the most cost-effective and long-term method to reduce the threats of ungulates in remote native forest areas.⁸⁹ Without fences, it is not feasible to continuously reduce animal populations.⁹⁰ Their populations can quickly rebound, even after being reduced by



A forest can re-grow inside a rectangular fenced area in Aunahi, Maui. Photo: Leeward Haleakalā Watershed Restoration Partnership (LHWRP)

40%⁹¹-70%.⁹² Specifications for ungulate removal projects have been approved by the DLNR⁹³ and partners,⁹⁴ which will guide fence construction, ongoing maintenance, and ungulate removal within priority I and II areas. On DOFAW lands, public hunting will be used for the first stage of ungulate removal in fenced areas wherever safe, feasible, and effective,⁹⁵ and DOFAW will encourage hunting access in other areas. Step-overs and gates will allow continued public access into fenced areas.

Fencing core areas within the approximately 840,000 acres of priority I and II watersheds will be incremental. As with all the proposed actions, landowner approval and decades of work will be required. Approximately 35% (280,000 acres) of Division of Forestry and Wildlife (DOFAW) lands are priority I watersheds. Four percent of DOFAW lands are currently fenced.

2. Remove or contain damaging invasive weeds that threaten priority I and II areas.

Invasive weeds degrade native forests. They spread quickly, creating more bare soil,^{96,97,98,99} and increasing the severity of fires.¹⁰⁰ Some of these invasive plants also consume more water^{101,102,103} than old-growth^{104,105} native forests, reducing Hawaii's water supply.¹⁰⁶ Invasion of weeds can also significantly reduce carbon storage.¹⁰⁷ The economic and ecological damage from conversion of a native forest to an invaded forest is enormous. Losses from just the spread of the Miconia tree, if allowed to invade, are estimated at \$273.9 million to \$488.4 million per year.¹⁰⁸ This plan emphasizes weed control primarily in fenced, native areas where weeds have not become widespread, however additional funding is needed to increase control and prevention of new invasive species that will spread to the priority I and II areas. While much of this control is achieved through mechanical and chemical methods, the use and development of approved biological control agents should be encouraged. Biological control agents undergo years of extensive testing to ensure that they only target the species that is being managed, and their use can greatly increase effectiveness while decreasing management costs.

3. Monitor and control other forest threats including fires, predators, and plant diseases.

Wildfires destroy forests and threaten human life and property. Meanwhile, other invasives, besides weeds and ungulates, continually weaken watersheds, such as rats,¹⁰⁹ slugs,¹¹⁰ plant diseases,¹¹¹ and insect predators.¹¹² Prevention and control of these threats is needed to prevent deforestation and lost watershed function in all watershed areas.

4. Restore and plant native species in priority areas and buffer areas.

Improving habitat, monitoring, and in some cases, re-introducing native plants and wildlife is necessary for watershed health. For instance, native birds increase the health of the forest by pollinating, fertilizing, spreading seeds, and managing insect populations. Forests with many types of species are stronger and able to recover from stresses, such as natural disasters or climate change.^{113,114} Planting natives can accelerate recovery in areas that do not have an adequate seed bank or may otherwise be recolonized by weeds. The watershed protection areas are within native forests; species will be planted that complement the health of the ecosystem where they naturally occur. Ungulate removal will usually be required in these areas prior to planting.

In non-native priority III areas, conversion to vegetation that provides higher watershed function may be appropriate through planting and invasive species removal.

5. Establish benchmarks and monitor success of the on-the-ground actions.

As a watershed partner, DLNR approves the management plans based on their consistency with the goals of this plan at the planner, branch, administrator, and chairperson levels. Research, data collection, and distribution will monitor the health of the forest and the completion and success of protective measures. Research will also focus on adapting and improving management and planning strategies.

6. Educate Hawaii's residents and visitors about the cultural, economic, and environmental importance of conserving native forests.

It is important to teach adults and children the scientific and cultural importance of the forests so Hawaii's water sources are appreciated and protected now and in the future. DLNR will continue to train teachers and disseminate high quality educational resources that strengthen environmental literacy. This will help to build an informed citizenry of life-long learners who value Hawaii's uniqueness and live sustainably. DLNR will support continued and expanded Youth



*Fighting forest fires on Moloka'i.
Photo: East Moloka'i Watershed
Partnership*



*Volunteers planting trees at Aunahi.
Photo: LHWRP*

Conservation Corps programs that provide local youth jobs and career opportunities during in-the-field internships. Maintaining and creating access and trails will teach communities about the benefits of forests during volunteer trips and hikes.

The DLNR also seeks to engage those who may not have the opportunity to experience the remote forests first-hand. The dramatic beauty of Hawaii's watersheds can serve as backdrops for news and feature stories on local television, public service announcements, and websites. DLNR will collaborate with educational centers and programs that offer watershed education, while supporting creation of additional programs and centers in new areas, such as central O'ahu. These centers give residents a chance to learn about the forests that sustain them. They also attract visitors interested in the rare and unique native Hawaiian plants and wildlife, and the cultural uses and significance of the forested uplands. Interactive displays and real-time footage from remote cameras can demonstrate the importance of carefully managing these resources. These centers can provide physical locations for organizations to stage work crews, volunteers, and school field trips. Demonstration sites can serve as field trip destinations that show restoration occurring.

7. Promote consistent and informed land use decision-making that protects watersheds.

DLNR will seek to promote land uses that support watershed protection while reviewing leases, set asides, conservation district applications, water use applications, and regulations. To inform these decisions, DLNR must partner with other agencies and organizations to continue basic monitoring and data collection of Hawaii's water use and supply. This information becomes increasingly important as climate change impacts the availability and need for water.



APPENDIX II - METHODOLOGY

A. Identifying Priority Watershed Areas

All lands have watershed value, however different landcover types and climate zones have different levels of groundwater recharge. Potential changes in recharge based on landcover changes was a basis for the prioritization of areas. Protection priority I and II areas (native wet and mesic areas, respectively) are based on climatic conditions (elevation, moisture zones including fog and rainfall levels) as well as land cover types that provide higher recharge and fog capture.¹¹⁵ These areas are assumed to be under threat to be converted to alien forests (especially in wetter areas), or grasslands, if not managed. Conversion would generally result in loss of recharge function, soil retention, and an increase in runoff (see Appendix I). This provides the basis for prioritizing protection in native areas to prevent further loss of these values that may be difficult or costly to restore. Restoration priority III areas are non-native forests or grasslands within fog zones, where reforestation of these areas with natives would generally result in higher groundwater recharge, particularly due to potential fog interception.

The data on moisture levels and habitat types are from “Mapping Plant Species Ranges in the Hawaiian Islands: Developing a Methodology and Associated GIS Layers.”¹¹⁶ Priority I areas are within the “Very wet,” and “Moderately wet” zones. Priority II areas include “Moist mesic” and “Seasonally mesic” zones. These areas are clipped by the “Intact native ecosystems, highest biodiversity” and “Threatened native ecosystems” zones. Priority III areas include “alien forest,” “uncharacterized forest,” and “alien grasslands” from the Hawaii Gap Analysis¹¹⁷ within fog zones (2,000-4,000 ft elevation)¹¹⁸ in wet and mesic areas. Priority III areas also include wet¹¹⁹ non-native¹²⁰ forests that infiltrating water is modeled to reach a drinking water well within 25 years,¹²¹ to include runoff and water quality considerations. Priority III areas have different management strategies (See Appendix I). Continuing studies will update and standardize landcover and groundwater recharge values. As measurements become more specific and measurements available statewide, refinements to this map should occur.

Well and stream diversion points demonstrate which aquifers supply large amounts of water for human use. Note that O`ahu (except Wai`anae), `Iao System (Maui), and Moloka`i are Groundwater Management Areas. The `Iao System (Maui) is also a Surface Water Management Area. For Lāna`i, in lieu of designation and permitting, the Commission on Water Resource Management established a monitoring, oversight, and reporting plan for Lanai's aquifer. Future decisions will also be guided by the County Water Use and Development Plan (Lāna`i plan adopted 2011) (HRS 174C-31). These areas are where the Commission on Water Resource Management has determined that water resources are threatened by existing and/or proposed water withdrawals or diversions.

B. Budget and Accomplishment Projections

The budget includes estimates of the costs of fencing, removing ungulates, and conducting weed control over a 10-year time frame. Most of these management costs (including maintenance, weed control, monitoring, etc) are perpetualⁱ however may decrease over time. Forests and terrain are very different and costs to protect them vary widely. Estimates of management costs for wet native forests were used, to reflect the management needs of priority areas. Approximately \$2,180,000 was allocated per year for coordination, planning, data management, and administrative costs, including costs to maintain existing units and conduct activities beyond ungulate and weed control (e.g. fire protection, education) (Table 1). Then, costs for additional units were estimated by averaging all completed watershed partnership fenced areas for 1) acres per unit – with a standard unit being 1,291 acres; and 2) average acres per mile of fence (517 acres). This information populated the per-unit analysis of costs in Table 2. Estimates of the accomplishments based on budget and costs are provided in Table 3.

ⁱ After the initial 10-year time period conducting the first phase of management, maintenance costs per additional 10 year period includes costs for fence replacement, fence maintenance, weed control at \$300/acre, and a 10% overhead. Low range = \$396,311; High Range = \$774,503; Average = \$560,407.

Table 1.

Budget Projection	10-Year Total (\$)
Proposed Budget (\$11 million +4% increase per year)	132,067,178
Maintenance of existing areas (\$2,180,000+4% increase per year)	26,173,314
Remaining funds available to expand protected areas	105,893,865

Table 2.

Cost per Standard Unit Over 10 Years	Low Range (\$)	High Range (\$)	Average (\$)
Fence installation ⁱ	161,084	422,847	291,966
Ungulate removal ⁱⁱ	134,987	143,189	139,088
Fence replacement cost ⁱⁱⁱ	64,433	169,139	116,786
Fence Maintenance ^{iv}	102,200	102,200	102,200
Weed Control ^v	585,000	1,170,000	877,500
Overhead ^{vi}	104,770	200,737	152,754
TOTAL	1,152,476	2,208,114	1,680,295

Table 3.

Accomplishment Estimates	Low Range	High Range	Average
Cost Per Standard unit (See Table 2).	\$1,152,476	\$2,208,114	\$1,680,295
Number of units that could be protected with remaining funds of \$105,893,895	92	48	70
New protected acres in 10 year period	119,000	62,000	90,300

ⁱ Hawai'i Division of Forestry and Wildlife, unpublished data. Cited in Leonard, D. 2009. Social and Political Obstacles to Saving Birds. In "Conservation Biology of Hawaii's Forest Birds" Edited by Thane K. Pratt, Carter T. Atkinson, Paul C. Banko, James D. Jacobi, and Bethany L. Woodworth. Yale University Press.

ⁱⁱ \$48-60.7/acre from J. Jeffery, U.S. Fish and Wildlife Service, pers. communication. Cited in Leonard, D. 2009. Social and Political Obstacles to Saving Birds. In "Conservation Biology of Hawaii's Forest Birds" Edited by Thane K. Pratt, Carter T. Atkinson, Paul C. Banko, James D. Jacobi, and Bethany L. Woodworth. Yale University Press. With helicopter = \$161/acre. Half of units are helicopter access.

ⁱⁱⁱ 40% of fence installation costs for cyclical replacement assuming fence needs replacement every 25 years.

^{iv} 2 person days/check. Person days= \$160 each. Helicopter access \$1,000 per day. Helicopter fence checks at 5 times/year = \$6,600 per year for helicopter. Non-helicopter fence checks 12 times/year = \$3840/year. Half fences are helicopter checks. Add \$5,000 for replacement costs and materials. Average = \$10,220/unit/year.

^v *High Range*: HAVO Special Ecological Areas wet forest. \$756/acre knockdown sweep, \$150/acre maintenance sweep after 5 years from Loh, R., T. Tunison. Long term management of invasive plant species in Special Ecological Area at Hawai'i Volcanoes National Park - A review of the last 20 years, or where do we go from here? In Kueffer, C. and L. Loope (Eds). 2009. Prevention, early detection and containment of invasive, non-native plants in the Hawaiian Islands: current efforts and needs. Pacific Cooperative Studies Unit Technical Report 166, University of Hawai'i at Mānoa, Department of Botany, Honolulu, HI. Total 10 year costs in 1,300-ac unit= \$900*1,300=\$1,170,000. *Low Range*: Sweep only 50% of area (if portions of area determined to be unfeasible or unsafe to access or not requiring weed control based on aerial surveys) = \$585,000.

^{vi} 10% of total ungulate and weed costs.

APPENDIX III - PROJECTS

Watershed partnerships currently manage many tens of thousands of acres of core watersheds, however funding is needed to expand the protection that is critical to the sustainability of Hawai'i. Below is a list of near-term projects proposed by the partnerships as examples of on-the-ground activities needed to enlarge the area protected from invasive species. In the future, additional projects will be developed to reach DLNR's protection goals.

1. Kaua'i Watershed Alliance: Protect 25,000 acres of wet forest on the Alaka'i Plateau, Wainiha valley, and east facing pali of northeast Kaua'i. Ongoing work requires \$700,000 per year to control weeds, remove ungulates in fenced areas, and maintain the fences. Additional funding is needed to expand protection for the primary water source for the entire island.

2. Wai'anae Mountains Watershed Partnership: Protect the Lualualei, Wai'anae Kai, and Mākaha ahupua'a by fencing and removing pigs and goats, outplanting with community members and school groups, and controlling weeds. This newly formed partnership has matching funds, however additional funding is needed to begin construction and watershed protection to bring water sources to this arid region.

3. Ko'olau Mountains Watershed Partnership: Protect approximately 9,000 acres in the rainiest part of the island's Ko'olau range that provides drinking water for the majority of the state's residents. Phased fence construction and ongoing weed and pig removal will require approximately \$1.3 million/year.

4. East Moloka'i Watershed Partnership: Expand watershed partnership boundaries and management to the east with additional agreements with private landowners to help sustain the future quality and quantity of Molokai's water supply.

5. Lāna'i Forest and Watershed Partnership: Protect 3,100 acres in the Lāna'ihale cloud and mesic forest by installing a 4-mile fence and removing feral mouflon sheep and axis deer. This project site is the critical recharge area that provides much of the water for Lanai's residents and agricultural users. Fence construction is estimated at \$1 million, ungulate removal \$83,000, and fence maintenance (17.5 miles) at \$30,000/year and strawberry guava removal at \$400,000/year.



*Removing strawberry guava from Lanai's forests.
Photo: Lāna'i Native Species Recovery Program*

6. West Maui Mountains Watershed Partnership: Protect an additional 10,100 acres beyond the 21,000 acres currently in management in the West Maui. This watershed provides billion of gallons of surface water and groundwater per year to communities of West Maui and Central Maui, from Paia across to the North Shore, and south from Wailuku through Mākena. Constructing fences, maintaining existing areas, preventing dirt bike damage, and conducting volunteer outreach to protect these areas will require approximately \$2.4 million, with approximately \$410,000 per year in maintenance costs.

7. Leeward Haleakalā Watershed Restoration Partnership: Restore a forested belt around 11,000 acres of the south slope of Haleakalā. By fencing and outplanting koa trees, the partnership hopes to reverse the erosion caused by wild goats, deer, pigs, and cattle. Sedimentation from the erosion harms the once-pristine near-shore marine waters and coral reef ecosystems. Restoring the koa forest will

protect groundwater, stream flow, and potable water and provide recreational, cultural, and agricultural benefits.

8. East Maui Watershed Partnership: Protect 3,500 acres of montane `ōhi`a forest in the upper Hāna Forest Reserve by installing an ungulate-proof fence and removing feral pigs. This native montane rainforest replenishes the aquifers of East Maui; providing a water source for East Maui's residents and agricultural users from Ha`ikū to Hāna and beyond. Fence construction is estimated at \$350,000, ungulate removal \$250,000 and yearly maintenance and weed removal costs at \$100,000/year over the next five years. This project is partially funded; additional funds are needed for the third phase of construction and ungulate removal.



Installing fence in East Maui's watershed

9. Kohala Watershed Partnership: Protect 6,600 acres of high-yield recharge zones that capture 110 million gallons of water per day in the largest aquifer on Kohala Mountain, the source of municipal and agricultural water for the districts of north and south Kohala and Hamākua. The first phase of protection has begun with creation of the Upper Laupāhoehoe Watershed Reserve, a 2,000-acre management area. To date, 1.5 miles of fencing has been constructed with a joint State-partnership crew, with plans made for an additional 3.5 miles in the near future.

10. Mauna Kea Watershed Alliance: Restore 512 acres of fenced, ungulate free mesic/montane forests by controlling invasive grasses and outplanting native high elevation trees to re-establish forest connectivity at Kanakaleonui. Mauna Kea is very significant culturally and provides water that supports coastal ecosystems and productivity, as well as fresh clean water for use in urban areas. A watershed coordinator has just been hired and the watershed management program is being developed, requiring an annual budget of \$300,000-\$400,000.

11. Three Mountain Alliance:

Protect at least 12,000 acres of koa-`ōhi`a forest that replenish the Ka Lae, Na`alehu, and Keaiwa aquifers, providing a water source for Kau's residents and agricultural users. DOFAW, partners and volunteers will fence and remove feral pigs and weeds such as night blooming jasmine, kāhili ginger, *Bocconia*, and strawberry guava. Fence construction is estimated at approximately \$3,500,000; ungulate removal for \$1,350,000 and yearly maintenance and weed removal costs at \$150,000 per year, however costs may increase if additional areas are included. This project is partially funded for planning, compliance and outreach, however additional funds are needed to begin the first phase of fence construction.



Ka`ū Forest Reserve is critical watershed for surrounding agricultural lands and the people of Ka`ū.

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