Gap Analysis Report

Prepared for U.S. Army Garrison – Hawaii

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This report is prepared under Contract #: W911S0-04-D-0002-0183 to CALIBRE Systems Inc., (prime contractor, POC: Heather LaRowe) and teammates Crop Production Services-Timberland Division (POC: Ron Lemin) and Arbor Global (POC: Kevin Eckert)
Executive Summary

Team CALIBRE (i.e., CALIBRE Systems, Inc., Crop Production Services, and Arbor Global) began operational research in 2010 at Schofield Barracks Military Reservation and Makua Military Reservation to support initiation of a long-term U.S. Army Garrison, Hawaii (USAG-HI) Integrated Vegetation Management Plan (IVMP) intended to (1) support and enhance training while simultaneously minimizing risk of fire and environmental impacts to the site and surrounding area; (2) improve and maintain a sufficient fire line/buffer for threatened and endangered (T&E) species; and (3) develop and prepare the most cost efficient and sustainable approach to vegetation management using techniques such as cultivation of desirable vegetation cover, mowing/harvesting, biological control (including grazing), and herbicide and/or plant growth regulator application. The IVMP goal is to develop and cost-effectively maintain a low growing (6”-12”) vegetative ground cover that remains green throughout the year such that fire cannot propagate and spread to off-site areas.

The purpose of this Gap Analysis Report is to (1) summarize results of Team CALIBRE’s literature review and interviews of key personnel at USAG-HI and subject matter experts in the field of vegetation management, and (2) describe the process and findings of preliminary herbicide testing conducted by Team CALIBRE to address gaps in support of developing an effective USAG-HI IVMP.

Based on results of the Gap analysis and preliminary testing, Team CALIBRE recommends further actions needed for development of a long-term IVMP that will support military training, while protecting USAG-HI sensitive natural and cultural resources.
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1. Introduction
The mission of US Army Garrison – Hawaii (USAG-HI) is to “provide sustainable installation support and services for Joint Warfighters, their families and the military community that meets current and future mission requirements, safeguards human health, improves quality of life, and enhances the natural environment.” Important to fulfilling the mission is the goal to “maximize training support while minimizing the impact on the natural environment and community.” The objective is to provide realistic, relevant, and available training facilities to the 25th Infantry Division and other tenant units. USAG-HI is responsible for conserving over 100 federally listed endangered species. Fire is the number one threat to endangered species from military training. Significant restrictions exist on the use of live-fire training infrastructure during periods of high fire hazard due to access challenges, limitations put forth within Biological Opinions that guide Range management, transformational changes in equipment and doctrine, increased environmental pressures, the presence of invasive grass species that facilitate the rapid spread of fire, and numerous wildland fires that have encroached into sensitive natural and cultural areas.

To reduce fire hazards created from live fire training, permit exploded Ordnance (UXO) clearance and support the construction of a new Range, the USAG-HI Range Division (RD) allocates a large portion of funds [approximately $750,000 over the past five years on Schofield Barracks Military Reservation (SBMR), Figure 1, alone] to apply herbicide, conduct prescribed burning, then apply a second herbicide treatment to reduce vegetation. The initial result of this treatment regime is the creation of bare ground, which results in soil destabilization, runoff and water quality problems associated with herbicides and other contaminants that leach from the site into groundwater. The unintended result of this treatment regime is reestablishment of aggressive, highly flammable, invasive species that now comprise the primary vegetation community at SBMR, Makua Military Reservation (MMR) (cover photo), and other USAG-HI training sites.

Figure 1. Schofield Barracks Military Reservation, Oahu, 2011.
Team CALIBRE reviewed readily available references, formed a team of vegetation experts to analyze data gaps and define methodologies, protocol, and best management practices; evaluated existing field conditions; and initiated preliminary testing of precision-applied herbicides to determine prescriptions that warrant further rigorous testing.

2. **Methodology**

2.1. **Identification of Existing Conditions**

In order to initiate the gap analysis, knowledge and understanding of past treatments of USAG-HI ranges, significant current conditions, and vegetation management practices and goals was required. Team CALIBRE’s extensive knowledge and experience with vegetation management throughout Hawaii and the US mainland facilitated analyzing the effectiveness and challenges of past treatments, current conditions and the likely result of alternative treatments. To identify USAG-HI vegetation management goals, past practices and research that were conducted, Team CALIBRE interviewed the following knowledgeable, experienced personnel at USAG-HI Range Division (RD) and Environmental Division (ENV):

- Vic Garo, Chief Operations Officer, RD
- Frank Raby, Range Operations Manager, RD
- Ken Torre, Training Support Manager, RD
- Michelle Mansker, Chief, Natural Resource Section, ENV
- Joby Rohrer, Senior Natural Resource Management Coordinator, ENV
- Jane Beachy, Ecosystem Restoration Program Manager, ENV

Information collected during these interviews included vegetation management goals and desired results, vegetation management techniques and materials that were currently applied, the reason that each technique was used, the advantages and disadvantages of each technique, timing of vegetation management applications, and location of applications. We collected information on past formulations of herbicides, tank mix rate, application rates, and method of application via personal communications with personnel named above and documented reports.

Team CALIBRE completed focused site visits and reviews of conditions at MMR and SBMR in August 2010, accompanied by RD and ENV staff that provided general information and responded to questions regarding past treatments and vegetation management goals. Team CALIBRE already possessed a comprehensive knowledge and understanding of past management practices and vegetation management challenges through its members’ extensive experience and knowledge gained by working within the vegetation management industry and living in Hawaii.
To assist in identifying necessary research to complete gaps in knowledge and provide the framework for the IVMP, Team CALIBRE reviewed numerous documents and online resources. Content that was considered relevant to this Gap analysis is summarized in the remainder of this section or is referenced throughout the document using footnotes. Most of the descriptions are taken directly and verbatim from key portions of executive summaries, abstracts or conclusions statements within the reference and amended to focus on the general areas relevant to this study. Publications are listed in alphabetical order, by author.


The grassland fire behaviour pocket card recently developed for use by wildland and rural firefighters in Canada and New Zealand offers a practical field guide for quickly estimating the near worst case fire behaviour potential in grasslands. At the same time it reinforces an awareness of the need for adopting safe work practices when attempting to contain grass fires in an effort to avoid burnovers and entrapments, thereby eliminating firefighter injuries and fatalities.


Three control treatments were tested including mechanical removal, herbicide application and grazing using cattle to reduce the fuel loads at Marine Corps Training Area Bellows (MCTAB), on the island of O'ahu, Hawai‘i. The total fine fuel load at MCTAB was found to average 6 tons/acre. Results indicated that grazing by cattle was most effective in lowering the fuel bed depths of Guinea grass on MCTAB. Effect of treatment on reduction of Guinea grass fuel loads varied with time. Mechanical treatment was the most effective in rapidly reducing Guinea grass; however, the grazing treatment was most effective in maintaining low fuel loads over 5 months post application of treatment. At the end of the experiment, fuels in the grazing plots also appeared to be less continuous than other treatments and; therefore, not expected to carry fast moving fires. Grazing treatment appeared to be most effective in maintaining lower total fine fuel loads, five months post application of treatments.


*Panicum maximum* cannot be accurately modeled using standard NFFL fuel models. The types of fire behavior observed during test burns prove beyond any doubt that this fuel
type has a propensity for fast moving, high intensity grass fires. There seemed to be a
break point in the RH and fuel moisture, below which fires exhibited behavior that would
be uncontrollable in a wildland suppression situation; however, such observations are
difficult to confirm with empirical data.

Winds did not appear to have as great an effect on fire behavior as would be expected. In
fact, the most intense fire behavior was observed during periods of low winds. This may
have been due to the high heat output released by the burning fuels. This model is
applicable to any location dominated by the *Panicum maximum* fuel type, a large portion of
the lowland landscape on the island of Oahu. By combining the model with accurate spot
weather forecasts, fire behaviorists can give a very good estimate of what the fire
perimeter and fire behavior will be in the coming 12-24 hours.

The future of fire behavior prediction, associated FDRS’s, and fire management
improvements is still open. New technologies and methods of prediction are currently
being developed that incorporate a spatial component into the system. The current system
rates fire danger based upon the highest fire danger throughout the installation. With a
spatially based FDRS, locations of the training area that are at lower fire danger ratings
could continue to be used despite the fact that some areas are under higher fire danger
rating.

  Management Concerns at Makua Military Reservation*, Center for Ecological
  Management of Military Lands, Colorado State University, Fort Collins, CO.

This publication suggested challenges of fire management at MMR can be overcome with
proper fuel management, effective data collection and analysis, and appropriate fire
suppression training and preparedness. If fuel management (including appropriate future
maintenance) is carried out successfully and guidelines are enforced, the fires that do occur
will burn under conditions that allow effective fire suppression before endangered species
habitat is impacted. Although fire risk can never be eliminated completely, the Army will
have improved capabilities for managing the fires that may occur. By initially proceeding
with caution, monitoring conditions under which operations are conducted safely, and
improving fire management techniques whenever possible, undesired fire impacts will be
reduced and the Army will have the use of MMR as a live fire range for the foreseeable
future.

  and South Ranges, Schofield Barracks, Oahu*, Center for Ecological Management of
  Military Lands, Colorado State University, Fort Collins, CO.

Existing fire management at Schofield Barracks is adequate, but there is room for
improvement. The most logical course of action is to reduce or eliminate the possibility of
an ignition occurring in dry, windy conditions. The best way to accomplish this task is with a fire danger rating system. The current state of fuel distribution allows for the opportunity to continue to stop fires at the fire break, as long as aggressive fuels management is implemented immediately. Maintenance of the fire break road and minimization of the extent and density of pyrophytic grasses above the fire break should be top priorities. If the recommended improvements in this report are implemented and combined with current management practices, there is no reason to believe that the Schofield fire management program can’t be one of the most successful in the Islands.


This memorandum provides interim policy on the certification of installation pesticide applicators and contractor employees performing pest management work on DoD installations. The measures of merit for installation pest management are: Measure of Merit 1 dictates that by the end of FY 97, 100 percent of all DoD installations will have pest management plans prepared, reviewed, and updated annually by pest management professionals. Measure of Merit 2 dictates that by the end of FY 2000, the amount of pesticide applied annually on DoD installations will be reduced by 50% from the FY 93 baseline in pounds of active ingredient. Measure of Merit 3 dictates that by the end of FY 98, 100 percent of all DoD installation pesticide applicators will be properly certified within two years of employment.


This project compared five rights-of-way treatments to determine their impacts on wetlands on utility rights of way (ROW). The conclusion reached was that there was no significant impact to wetlands from any of the vegetation management techniques used on utility ROW in Massachusetts. Mechanical treatments resulted in higher impacts on the cover value for wildlife than those involving herbicides. Residue from petroleum products (bar oil and hydraulic fluid) were recovered on the leaf letter from mechanically treated sites. No herbicide residues were recovered from herbicide treated sites.


Integrated Vegetation Management, or IVM, is being used by many right-of-way management organizations across the United States. IVM is an in-depth and sophisticated system of information gathering, planning, implementing, reviewing, and improving vegetation management treatments. IVM is used to understand, justify, choose among, selectively apply, and monitor different types of treatments, with an overall goal of eliciting
site specific, ecosystem-sensitive, economically sensible, and socially responsible treatment effects that lead to refined achievement of management objectives.


Leaching behavior of six pesticides and bromide were investigated at five test sites in Hawaii: Poamoho, Kunia, and Waimanalo on Oahu; Kula on Maui; and Mana on Kauai. The intent of the study was to evaluate the relative leaching behavior of the pesticides and to compare their leaching behavior to that of bromide tracer. Soil properties that affect transport are water conduction, organic carbon content, mineralogy, pH, and texture/structure. These factors affect pesticide half-life, sorption coefficient, and their movement in soils. Compounds with a longer half-life persist for a longtime in soil. Compounds with a high sorption coefficient adsorb strongly to soil and are less likely to be carried down by percolating water. Compounds with low sorption potential and long half-life are candidates for excessive leaching, unless they are extremely volatile and the volatilization is the primary mode of pesticide loss.

The soil profile data revealed that the bromide center of mass at the Kunia site moved about 1.5 m in 16 weeks. The imazaquin front at the Kunia site traveled more than 1.2 m over 8 weeks. However, the concentration front dissipated over the 8 weeks to below detection. At other sites, the front did not get past 0.6 m. Most of the chemicals were still present in the top 0.6 m after the 16-week study period.

Laboratory sorption data showed that imazaquin and sulfometuron methyl have very low sorption potential (< 10 mL/g). Also, most metabolites appear to be mobile. The mean half-life values for several chemicals from laboratory degradation studies may not be reliable due to extreme variations in data.

The Attenuation Factor screening model used by the Hawaii Department of Agriculture suggests that all chemicals, with the exception of trifloxystrobin, have the potential to leach. Many of these are applied at low doses. Low dose pesticides raise issues about their potency. Some pesticides are considered less toxic to mammals and are considered “safer” from this perspective. However, low dose pesticides residues may be of concern to aquatic ecosystems downstream and downstream water users.

Invasive fire prone grasses like Guinea grass (*Panicum maximum*) have become the dominant cover on several training areas in the Pacific including Marine Corps Training Area Bellows (MCTAB), Hawaii. Dense stands of Guinea grass provide fuel for fast moving, high intensity fires thereby aggravating fire risk to weapons firing training and threatening wildlife and their habitats. Military installations spend millions of dollars to mitigate risk from such fire prone grasses. Traditionally, mechanical removal and prescribed fire were used to reduce Guinea grass fuel loads in Hawaii. MCTAB personnel and land managers in the Pacific seek alternative fuel reduction treatments such as mechanical, herbicide and grazing to reduce Guinea grass fuel loads; however, very little information is available.


Encroachment of exotic (nonnative) plants into natural NPS areas is inconsistent with policy. Previous attempts to control such plants in Hawaiian NPS areas have involved mechanical removal or treatment with herbicides, but these methods as presently employed are inadequate to provide control on a long-term basis for many exotic species; they are also expensive and continuous. Previous efforts to control noxious weeds in Hawaii with phytophagous insects were conducted by the Hawaii State Department of Agriculture primarily for agricultural interests. Similar approaches for the control of exotic plants in Hawaii Volcanoes and Haleakala National Parks may have positive as well as cautionary aspects, which must be considered. A literature review revealed numerous references to insects and diseases associated with Hawaii’s exotic plants, or related species, in other regions of the world. Some of these, or other suitable organisms not included in this report, may offer potential in future biological control programs.


The INRMP guides implementation of USAG-HI’s integrated natural resources management program on its properties from 2010 through 2014. This plan is prepared in cooperation with the U.S. Fish and Wildlife Service (USWFS) and the Hawai‘i Department of Land and Natural Resources (DLNR).

SBMR is the primary range complex with limited light maneuver training areas for USAG-HI at 9,520 ac (3,506 ha). There are four native vegetative communities located on SBMR: Montane Wet, Lowland Wet, Lowland Mesic, and Aquatic Natural communities.
Collectively, there are approximately 3,544 ac (1,433.9 ha) of forest outside of the cantonment area in SBMR. *Metrosideros/Acacia/Dicranopteris* and *Schinus* spp.-dominated forests account for approximately 93 percent of the land area outside of the cantonment area. Four endangered animals (one bird, one terrestrial snail, two insects) have been documented at SBMR, along with 23 federally listed and 8 candidate plant species. About 1,900 ac (774 ha) of SBMR have been designated as critical habitat for the O'ahu ‘elepaio (*Chasiempis sandwichensis ibidis*). Four O'ahu IP management units are located on SBMR and on five Mākua IP management units. Species of greatest conservation need include 8 bird taxa, 1 mammal species, 3 invertebrate species, and possibly 4 fish taxa, along with 68 plant taxa. Present on SBMR are some 8 non-native mammals; 10 endemic/indigenous and 31 non-native birds; 6 endemic and 14 non-native fish; 12 endemic terrestrial and 10 endemic aquatic invertebrates, along with 4 non-native terrestrial and 6 aquatic invertebrates; and possibly as many as 15 non-native herpetofauna. Some 259 plant taxa have been documented. Three ant species are considered invasive as are 20 plant species. The O'ahu Natural Resources (ONR) staff has identified 13 incipient plant species.

The primary drainages for the military reservation are the Waikōloa Gulch and the Waikele Stream. Also, the North Fork of the Kaukonahua Stream flows along the northeast boundary of SBMR, along with two tributaries. All streams on SBMR flow north into the Pacific Ocean at Waialua, with the exception of the Waikele, which flows into Pearl Harbor from the north. Many streams on SBMR are intermittent. All streams are somewhat degraded; especially drainages affected by the impact area and associated erosion. Stream quality is also affected by non-point pollution from adjacent crop lands. Soil erosion is locally significant in areas where natural drainage and gulches occur, particularly in the military reservation along Ayres Avenue and McMahon Road in the north, and Duck Field in the south. However, the dry climate and lack of permanent streambeds may reduce the risk of erosion, as well as areas where soils are not developed because of exposed lava.

MMR is located in an amphitheater-shaped valley, covering 4,190 ac (1,736 ha). Wildland fires resulting from live-fire training are the greatest threat to natural resources and endangered species located at and adjacent to MMR. Two native vegetative communities have been identified at MMR: Lowland Mesic and Lowland Dry Vegetation communities. Four forest communities are present and account for 469 ac (189 ha) of land cover, or about 11 percent. One federally listed bird, 1 mammal, and 1 snail species are documented on MMR, along with 33 federally listed and 5 candidate plant species have been documented at MMR. Seven additional federally listed plant species occur within the Mākua Action Area. O'ahu ‘elepaio critical habitat was designated on MMR. Critical habitat for 32 plant species is present within the MMR action area, but there is no critical habitat for plants on the installation. Four bird, 2 marine mammals, and 1 invertebrate species, along with 79 plant species of greatest conservation need may be present. There are four
Mākua IP management units located on the installation and 19 management units off the installation. Potentially, 2 marine mammals and 3 non-native mammal species (e.g., pigs, goats, and rats) have been observed at MMR. Bird observations (mostly informal) include 2 forest species, 1 raptor, 1 sea bird, 1 migratory shorebird, and 11 non-native species. Thirteen herpetofauna may be present at MMR, including one threatened marine turtle. There are no records for fish. Nine endemic/indigenous and 13 non-native invertebrates have been observed. Six non-native ant species have been documented. Some 284 plant species have been identified. Nineteen invasive/weed species have been located at MMR, along with 17 incipient species that the NR staff control and eradicate.

The primary drainages at MMR are the Punaohaku Stream from the north and the Mākua Stream from west-central MMR; both are intermittent. There are possible palustrine wetlands on MMR, characterized by native trees, shrubs, or persistent emergent species. Possible riverine wetlands and possible palustrine wetlands associated with seep areas in the Mākua Stream drainage are protected using a variety of training restrictions. Soil erosion can be significant where slopes are steep because of the high shrink-swell potential of soils. Erosion and sediment control practices are used when road and firebreak repair/maintenance is performed to minimize sediment impacts to stream channels.

The grass/wildland fire cycle is an unresolved issue. Because of the rapid and widespread expansion of non-native invasive species grasses throughout the Island of O'ahu and the resulting increase in fuel loads, wildland fire now poses a significant threat to native habitats, particularly dry forest systems. Ecological approaches to break the grass/wildland fire cycle are needed. Fire models must be adapted for the Pacific Islands region to predict fire hazards/severity (behavior). Elements of the models should include, but are not limited to, fuel loading, fuel moisture dynamics, live/dead rations, and microclimate and weather. Of particular importance to DoD are self-sustaining means to prevent and control fire in highly vulnerable areas (e.g., military training areas).


This survey describes the soil series and mapping of the five Islands surveyed, including Oahu.


This publication describes firebreaks and fuelbreaks developed for the MMR and includes Kaluakauila, Kahanakahiki, Pahole, Upper Kapuna, Wes Makaleha, Ohikilolo, and Lower
Ohikilolo. Fuelbreak areas are defined and illustrated within each area. The new fire protection systems will be operational within five years or prior to implementation of Column C in the Weapons Restrictions Table, whichever occurs earlier. Because mowing or aerial herbicide treatment is expected to produce a thick layer of dead grass that will take several years to decompose, aerial herbicide and mowing treatments will begin no later than two years after the completion of this Biological Opinion in order to ensure that the fire break is operational within five years.


Integrated Vegetation Management (IVM) has been used for the maintenance of vegetation along an electric utility transmission right-of-way (ROW) at the Green Lane Research and Demonstration Area, Montgomery County, Pennsylvania, U.S., since 1987. The wire–border zone method creates a forb–grass–short shrub cover type in wire zones and a tall shrub cover type in border zones. This area has been studied annually since 1987, which makes this project one of the longest continuous studies documenting the effects of mechanical and herbicidal maintenance on flora and fauna along an electric transmission ROW.

Excellent control of target trees was noted in 1999 in wire zones of mowing plus herbicide units; in contrast, tree control was poor in wire zones of mechanical units (mowing and handcut). Competition with existing plants and wildlife predation on tree seeds on a ROW keeps tree invasion to a minimum. Thus, over the years since 1987, IVM and the wire–border zone method of ROW maintenance have increased the time between treatment cycles, thereby reducing labor and chemical costs for ROW maintenance.

2.2. Identification of Management Alternatives

Based on research and analysis of past vegetation management practices, Team CALIBRE identified practical management alternatives thought to possess the best potential to cost-effectively manage undesirable vegetation and achieve USAG-HI vegetation management goals. These alternatives are based on standard integrated vegetation control options within the categories of biological, mechanical, manual, cultural and chemical as modeled on successful utility vegetation management programs. Proposed alternatives were reviewed with ENV and RD staff to determine priorities for preliminary testing. Alternatives selected to be actively researched by Team CALIBRE included planting (cultural), and herbicide applications (chemical). Prescribed grazing (biological) is shown to be effective in maintaining a low-growing vegetation layer. According to USAG-HI ENV

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staff, mowing (mechanical) is currently practiced in certain areas of MMR. The results of these practices, published and unpublished, will be reviewed and incorporated within the final IVMP.

2.3. Identification of Specific Trial Areas
Specific trial areas for preliminary research and testing were identified on MMR and SBMR through coordination with USAG-HI ENV Natural Resource staff and Cultural Resource staff. To ensure cost-efficiency of limited funds during conduct of trials, the majority of vegetation management test applications were located on sites identified by ENV and RD staff as fuels management areas or fire breaks.

RD identified a required fire break along the access road along the west end of the impact area at SBMR West Range (WR) (Figure 2). This fire break was defined to be 60 meters wide and generally followed along the east side of the access road. Via site visits, Team CALIBRE determined that vegetation conditions within this area included a diversity of grasses, shrubs, medium-sized and tall trees.

![Figure 2. SBMR fire break treatment site extending along road, 2011.](image)

ENV identified a number of fire breaks and fuels management areas at MMR (Figure 3). These areas were described within the "Reinitiation of the 1999 Biological Opinion of the U. S. Fish and Wildlife Service for U.S. Army Military Training at Makua Military Reservation Island of Oahu," dated June 2007. Via helicopter, Team CALIBRE and ENV staff redefined
some of the boundaries of the fuels management areas on the slopes and ridges in January 2011. Vegetation conditions changed since these areas were originally defined in 1999. The modified target areas better delineated current grasslands and avoided sites with a tree cover that could resist fire. An additional fuels management area was added by ENV and Team CALIBRE in January 2010 along Farrington Highway at the south end of MMR. The previously defined fire break along Farrington Highway was modified to address cultural resource concerns.

![Figure 3. MMR Treatment Sites. Areas denoted in yellow and purple are test plot application sites, 2011.](image)

In January 2011, Team CALIBRE initiated trials of herbicides shown to be effective in controlling target species found at MMR and SBMR, specifically Guinea grass (*P. maximum*) and common broadleaf species. These trials were approved by USAG-HI to provide further information for review and consideration in establishing a research plan necessary for developing an effective IVMP. Based on results of preliminary field monitoring on mortality and long-term control of target vegetation, Team CALIBRE was confident that satisfactory control would be accomplished within all test plots.

Additional sites for treatments in March and May 2011 were identified by Team CALIBRE and ENV staff. These sites were located within the upper slopes and isolated areas of MMR (yellow and red areas in Figure 3) and in the Kahuku Training Area (KTA) (Figure 4) and

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3 Personal communications with Edison Hidalgo supported by unpublished, greenhouse research data conducted by Mr. Hidalgo.
4 Experience of Team CALIBRE’s Kevin Eckert
included tree and shrub target species that are not currently present in test plots at SBMR WR or the primary testing sites at MMR.

Figure 4. KTA Treatment Sites – Test Plot Application Sites (Green and Red)

2.4. Identification of Research Protocols
To identify specific control methods to be tested, Team CALIBRE reviewed and presented existing data to key Hawaii, US and international vegetation management professionals (referred herein as the Gap Analysis Team) to assist in identification of potentially effective control methods or herbicide applications. The following individuals contributed to this review:

- Michelle Mansker, Joby Rohrer and Jane Beachy, USAG-HI ENV,
- Shannon Payne and Mike Bresell, USAG-HI RD consultants,
- Dr. James Leary, University Hawaii,
- Dr. Diane Drigot, Marine Corps Base Hawaii, Environmental Division,
- Edison Hidalgo, Allen Teshima, and Ronnie Turner, DuPont,
- Matt Kapaliku Schirman, Hui Ku Maoli Ola native plant specialists, and
- Chad Kacir, U.S. Natural Resources Conservation Service.

Based on recommendations of the Gap Analysis Team and expertise of Team CALIBRE, research protocols were identified to allow testing of techniques and methods while protecting sensitive natural and cultural resources. Protocols are described below.

2.4.1 Herbicide Application Equipment
All herbicide applications were conducted using a Bell JetRanger helicopter with a conventional boom and 61 - 0.020 Accuflo nozzles on stainless drop down tubes. The
equipment is capable of providing a Global Positioning System (GPS) assisted spray pattern of greater than 1000 micron droplets in a 50-70 foot effective swath (Figure 5). To ensure a safe and effective application of herbicides, the aircraft uses a SATLOC brand GPS navigation system that utilizes a Differentially Corrected Global Positioning System (DGPS) for electronic navigation. All aerial applications and TimberMark spot treatments incorporated GPS-assisted swath placement and/or location to maintain a uniform and precise application. In addition to GPS navigation, the aircraft was equipped with a “real-time” moving map display that showed the treatment site(s), sensitive “no-spray” areas, and areas previously treated. The boom/nozzle configuration (including controlled pressure and nozzle orientation) provides a 95% controlled droplet application, with skips not to exceed 5%. The application equipment and onboard GPS provided GPS guidance information to be exported into a Geographic Information System (GIS) depicting both spray on and off data. The aircraft was equipped with nozzles capable of uniform distribution at the specified rate. Nozzles were directed with the slipstream not to exceed a maximum of 10 degrees downward and nozzles were positioned uniformly along the boom. The spray boom height was at an adequate distance from target species, low enough to obtain proper distribution, uniform coverage and to ensure a safe, accurate, responsible and efficacious treatment. Additionally, the application equipment provided GPS data that was exported into a GIS and supplied to USAG-HI ENV for permanent record and archival. Flight paths (depicted spray and non-spray) and spot treatment locations were recorded and provided to USAG-HI.

For spot treatments, the helicopter was equipped with the TimberMark™ Aerial Spot Treatment Device (Figure 6), a helicopter-mounted herbicide application device originally designed for marking of timber stands and capable of delivering an accurate spot treatment application of herbicide to small, hard to reach areas. The nozzles provide spot applications using large droplet spray technology (> 1000 micro droplet size) to minimize drift. TimberMark™ utilizes on-board computer controls and a GPS to provide precise
application, coverage, and mapping to meet specific target requirements. In addition, the on-board computer provides constant regulation and an accurate GPS record of each application treatment delivered.

![TimberMark Unit](image1)
![Ground View](image2)
![Aerial View](image3)

*Figure 6. TimberMark application device used by Team CALIBRE.*

TimberMark’s aerial spray technology was used on individual target trees, small sites and areas that were difficult to access with a helicopter boom. TimberMark was also used to pick up misses, and can be further used to paint mark sensitive area boundaries, and provide treatment of vegetative spots that may re-colonize following the first application.

### 2.4.2 Herbicide Mixing Protocols

To prevent contamination of test mixes with other herbicides and ensure the integrity of the applications, specific mixing and equipment cleaning protocols were developed by Team CALIBRE based on extensive research experience and subject matter expertise provided by Edison Hidalgo, DuPont’s Global Weed Scientist for Specialty Crops.

The standard mixing protocol required that initial herbicide solutions be prepared using only the basic herbicides, such as glyphosate and sulfometuron methyl. Additional herbicides were then added to the basic solution as specified for subsequent test solutions. With this protocol, the first batch to be prepared and applied included the fewest compounds. The next batch prepared contained an increase in the amount of those same compounds or involved the addition of a third compound. Residuals of the previous batch in the hoses were recirculated in the tank to ensure consistent application (Figure 7).
When eliminating a highly active compound from a batch, including Oust, Escort and/or imazapyr, all mixing and application tanks and equipment were thoroughly cleaned as follows:

- The previous solution was totally drained and all spray tanks, booms and hoses were thoroughly rinsed with clean water.
- The tank was filled with clean water and a commercially approved spray tank cleaner or one gallon of household ammonia for every 100 gallons of water.
- Cleaning solution was circulated through the tank and hoses for at least 15 minutes;
- Hoses, booms, and nozzles were flushed with the cleaning solution,
- Nozzles and screens were removed and cleaned separately in a bucket containing cleaning agent and water,
- Rinsate was disposed of on a labeled site or at an approved waste disposal facility (if a commercial cleaner was used, label directions for disposal of rinsate were followed),
- Steps above were repeated when the tank was empty, rinsing with equivalent amounts of an ammonia solution to better solubilize sulfometuron methyl in the cleanout procedure,
- A final rinse of the tank, boom, and hoses was completed with clean water.

For small batches, test batches were mixed in separate tanks that were either new or cleaned according to the established protocol.

2.4.3 Weather Considerations

Efficacy of herbicide applications can be influenced by precipitation and off-target movement by wind. Application of herbicides did not take place when wind speed was variable, when wind speed created a significant off-site herbicide drift potential, or during periods of rain or predicted heavy rain. The threshold for discontinuing applications during precipitation was when water could be observed flowing off leaves. If heavy rain was forecasted within 1 hour of application, then applications were discontinued since herbicide could be washed off the leaves and the application could become ineffective. “Rainfast windows” refer to the time required for the product to pass through the leaf cuticle and get into the plant. The rainfast window for Garlon 4 Ultra is 45 minutes, for
Roundup Pro Max it is approximately one hour before a heavy rain. Conversely, Oust XP needs to be “watered” into the soil. Therefore, a moderate rain (not heavy precipitation that erodes soil) is beneficial to carry the herbicide into the soil where it is absorbed into the target plants. Thresholds are dependent on the product being used.

2.4.4 UXO Considerations
Given the history of weapons testing on MMR and SBMR, hazards from UXO are present. To minimize risks from UXO, wherever UXO may be present, U.S. Army EOD staff accompanied Team CALIBRE during on-site data collection to assess vegetation conditions prior to treatment and at post-treatment intervals.

2.4.5 Cultural Resources Considerations
Numerous, sensitive archeological sites are located on MMR and SBMR. Many of these sites are identified, but the presence of UXO, difficult terrain, heavy vegetation cover and lack of records potentially render some sites undiscovered at this time. To avoid damage to sensitive archeological sites, no sites were disturbed without consultation and approval of the USAG-HI Cultural Resources Division (CR).

USAG-HI CR advised that aerial applications conducted at SBMR would not adversely impact archeological sites and therefore no identification was required. Ground activity conducting soil sampling and installation of plants at MMR did pose the potential for disturbance of archeological sites. USAG-HI CR provided Team CALIBRE with maps and GIS polygons to overlay and site each archeological site on treatment maps. No soil disturbance will be conducted until completion of a Section 106 permit process and approval by the USAG-HI CR.

Soil disturbance for sampling was postponed due to delays in completion of the Section 106 permit process initiated by USAG-HI CR.

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5 Personal communication with Vic Garo, RD.
6 Personal communication with Michelle Mansker, ENV.
8 Personal communication with Alton Exzabe and Lauren Morawski, USAG-HI Environmental Division Office, January 10, 2011.
2.4.6 Marking of Test Plots and Sensitive Sites

USAG-HI provided Team CALIBRE with GIS polygons that identified application sites and sensitive sites. Sensitive sites that were identified included defined archeological sites shown in Figure 7 above, threatened and endangered (T&E) species locations, and native plant locations (Figure 8). In order to ensure sensitive sites were avoided during herbicide applications, Team CALIBRE added these polygons to planning maps and the helicopter GPS guidance system used during applications. Pre-spray maps were created and provided to USAG-HI ENV for review prior to uploading into the helicopter guidance system. All sensitive area data provided by USAG-HI to Team CALIBRE were buffered by at least 100 feet to ensure drift was not an issue. Team CALIBRE relied on USAG-HI ENV or RD to indicate whether or not sensitive sites were already buffered when data were provided.
In order to accurately treat designated test plots and avoid sensitive sites, the helicopter pilot used the data entered into the GIS navigation system aboard the helicopter. The pilot entered the unique identifier assigned to the specific test plot into the helicopter GIS navigation system, which displayed the plot polygon and provided navigation guidance to permit the pilot to fly to the site. Sensitive area data were displayed whenever they were near to the treatment site. The pilot applied the herbicide solution to the designated site using the GIS screen. The GIS screen depicted the treatment site and surrounding area and illustrated the exact area where the application was applied by showing a green swath on the GIS screen. The application area was highlighted on the GIS screen when the
application boom was activated and then discontinued when the application boom was shut off. The green highlighting on the GIS navigation screen enabled the pilot to see exactly where the application boom was activated over the ground and avoid application skips, over-sprays and direct applications to properly marked sensitive sites.

2.4.7 Vegetation Data Collection

Measurement of vegetation conditions was conducted through visual surveys and photos. A vegetation data collection schedule identified in October 2010 was initiated in January 2011 to define the pre-treatment population condition (immediately prior to or at treatment) and establish a baseline to help measure treatment efficacy post-application at the following intervals:

- 2 weeks after treatment,
- 6 weeks after treatment,
- 12 weeks after treatment,
- 24 weeks after treatment, and
- Continuing at 12 week intervals until vegetation populations reach stable composition and density, or further treatments are conducted.

A total of 19 test plots were established (see Figure 2 in Section 2.3 Identification of Specific Trial Areas). Each test plot included three vegetation sample sites (Figure 9). The number of subsequent survey plots was determined by the coefficient of variability between all of the survey plots within each treatment plot and to provide reasonable sample distribution throughout the plot.

![Figure 9. Vegetation Survey Plot Layout, USAG-HI, 2011.](image)

To provide consistency and remove bias, vegetation sample sites were located 250 feet from each end of the plot and 100 feet from the front boundary. The third survey plot was located in the measured center of the treatment plot. The center of each vegetation sample site is marked with a flagged stake.

Each vegetation sample site was round and included 1/10 of an acre measured as a radius of 33 feet from the staked center point. Data collection was conducted visually using the
Braun-Blanquet method of vegetation measurement recommended by the US Forest Service.\(^9\) Braun-Blanquet is a system that was used successfully by CPS and Arbor Global during previous vegetation community monitoring research projects, and was used extensively by Dr. William C. Bramble, Professor of Forestry (ret.), Pennsylvania State College, to measure and analyze vegetation community conditions and eco-system changes resulting from various vegetation management treatments.\(^10\) Braun-Blanquet is a method of describing the characteristics of a vegetation community. It was devised by J. Braun-Blanquet in 1927 to survey large areas very quickly. Two scales are used. One consists of values from 1 to 5 that define the proportion of the area covered by the subject species. The second scale defines species sociability, or grouping. Data were collected within defined plot areas. The review and estimation of the percent coverage and sociability of vegetation within each survey plot is recorded.

Two photo stations were established for each treatment plot to provide a general comparative overview of vegetation conditions. Each photo station was located at a distance of 50 feet from the front and 50 feet from the end of the treatment plot. Photo stations were marked with a flagged stake. Photos were recorded while standing on the photo station location and shooting in a direction toward the plot corner on the opposite side and furthest diagonal corner of the treatment plot to capture a view as broad as possible of the vegetation condition in each plot (Figure 9). The field of view within the photo frame was aligned to capture the best rendition of vegetation conditions. To standardize photos, the upper border of the frame was aligned and centered with the opposite side and furthest corner of the treatment plot. The photographer made all reasonable effort to standardize the field of view across successive photos.

2.4.8 Soil Sampling

Measurement of the fate and mobility of the herbicide hexazinone was conducted through analysis of soil samples at various soil depths and time progression according to Arbor Global and CPS's extensive experience testing the fate and mobility of field applications of herbicides and according to sampling protocols used by Dr. Norton Nickerson\(^11\). Hexazinone was selected for measurement because it is the most persistent and mobile herbicide applied. The research team believed that if hexazinone did not move significantly, then other herbicides with lower environmental fate and mobility would not persist or move off-site.

A recent pesticide leaching study, performed by Chittaranjan Ray, et al. at the University of Hawaii Water Resource Research Center\(^12\), described four agricultural herbicides, including

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sulfometuron methyl, as having the potential to leach given the volcanic ash soils present on Hawaii. Ray et al. did not test the influence of heavy vegetation cover, comparable with that found with Guinea grass populations at USAG-HI, on leaching potential. Rates of sulfometuron methyl that were applied by Team CALIBRE were lower than Ray et al used. Further, Team CALIBRE believes that if its testing shows that hexazinone does not leach in these conditions, then sulfometuron methyl would be less likely to leach based on the Ray et al. results.

Approval for sub-surface soil sampling and other work that requires excavation requires completion of the Section 106 National Historic Preservation Act consultation process. Since approval from USAG-HI CR was not received at the time this report was finalized, no sub-surface samples were collected for analysis.

Surface soil samples were collected from three vegetation sample sites within each plot where the higher rates of hexazinone were applied and mixed to form one sample for each soil depth. These sites were located at the same location as the vegetation data collection sites shown in Figure 3. Data were initially collected during herbicide applications using surface-mounted collection materials as recommended by the Pesticide Branch of the Plant Industry Division of the Hawaii Department of Agriculture. Initial data were collected using 16 collection units placed on the soil surface at each defined soil sample site. Collection units were arranged on the ground in a systematic pattern with one unit placed at each of the cardinal and intermediate compass points at a distance of three feet from the staked center of the sample plot. The next row of units was placed at each of the cardinal and intermediate compass points at a distance of six feet from the staked center of the sample plot. Samples were removed immediately after application, bagged, and sent to the Analytical Pesticide Technology Laboratories, Inc. in Reading, Pennsylvania for analysis.

Team CALIBRE strongly recommends sub-surface sampling be completed upon receiving USAG-HI CR to complete fate and mobility research. The first samples should be collected at the soil surface in a location just under the litter layer, and at a depth of six inches. Subsequent samples should be collected at the soil surface, just under the litter layer, and at depths of six and 12 inches. We recommend deeper samples be collected if significant amounts of hexazinone are found at the 12 inch sample. Significant amounts are defined as exceeding established detectable thresholds as defined by the State of Hawaii and/or US Environmental Protection Agency (EPA). To avoid contamination of each sample from previous excavations, test pits should be separated. This technique will eliminate the risk of false readings within previous test pits where soil was disturbed by digging for sample collection and excess soil from current testing is disposed. We recommend test pits be dug a measured distance of three feet to the west of the sample site center at 12 weeks, and three feet to the east of the sample site center at 24 weeks. Samples should then be taken three feet to north of the sample site center and then three feet to the south of the sample site center. Subsequent samples, if required, may be taken following this same pattern, but at distances of six feet from the sample site center.
3. Results

Team CALIBRE’s review of existing literature, evaluation of site conditions at SBMR and MMR, and personal communications with subject matter experts led to the following results:

1. Fire has been a significant management factor at both MMR and SBMR for decades. Due to the presence of T&E species, sensitive habitats, cultural sites and personnel, fire prevention is key to protecting these resources as specified in the INRMP 2010-2014, Island of O’ahu. The richness of the soils, the repeated range fires, the steep terrain, and the past management history have encouraged the establishment of tall growing invasive grasses (Guinea grass) and brush. The spread of the invasive plants, enhanced by uncontrolled fires, continues to diminish the T&E habitat both surrounding and within the ranges.

2. Management of Guinea grass has been accomplished using several control methodologies. The two most common techniques are mechanical mowing and periodic broadcast aerial herbicide applications. Both are temporary solutions (efficacy lasting 6 months or less) that allow for military training to continue until the grasses re-vegetate the range. Herbicide application with a follow-up prescribed burn has been used extensively at SBMR. This combination results in creation of bare ground, which increases erosion of these volcanic soils and creates a negative aesthetic response from the general public. Several issues with the past application techniques have also been found and corrected. Biological control through grazing has been successful; however, cultural and logistic restrictions prevent employing this technique as a primary management alternative (personal communication with Michelle Mansker).

In order to fill gaps in research and better lay a foundation for the IVMP, Team CALIBRE initiated preliminary testing of herbicides known to control Guinea grass and other problematic invasive plants in January, March and May of 2011. Preliminary results indicate varied results ranging from poor to promising based on the products and combinations applied. Continued testing is essential to determine whether rates of herbicide applied or height and biomass of the target species were related to the variation in results. Past herbicide research has shown that treatments are more efficacious when plants are young and growing (personal communication with Edison Hidalgo, DuPont). Further testing involving an earlier application or a combination of mowing and herbicide would be beneficial.
3.1. Analysis of Existing Data and Current Conditions

Interviews of key individuals and an analysis of existing data and site conditions, led Team CALIBRE to several conclusions regarding the current state of vegetation at SBMR and MMR and the desired end state.

3.1.1 Topography and Soils

The SBMR WR is located within the central plateau of Oahu, on the eastern slopes of the Waianae mountain range and encompasses approximately 2,200 acres. The SBMR WR is characterized by folded terrain with deep gullies cutting the area into several compartments. The topography transitions from relatively flat terrain gradually increasing in slope to the base of the steeper elevations of the Waianae Range.

The United States Soil Conservation Service (SCS) indicated there were two primary soil associations within the SBMR WR. These included the Tropohumults-Dystrandepts (T-D) and Helemano-Wahiawa (H-W) soil types. The SCS described the T-D soils as "gently sloping to very steep, well-drained soils that are underlain by soft weathered rock, volcanic ash, or colluvium; on narrow ridges and side slopes." The SCS described the H-W soils as "deep, nearly level to moderately sloping, well-drained soils that have a fine-textured subsoil: on uplands." The “Integrated Natural Resources Management Plan 2010-2014, Island of O‘ahu” further defines primary soil types within the treatment impact area as Helemano silty clay, Kolekole silty clay and Kunia silty clay with characteristics comparable to that described within SCS 1972 (Figure 10).

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14 Integrated Natural Resources Management Plan 2010-2014 Island of O’ahu U.S. Army Garrison Hawai‘i. Center for Environmental Management of Military Lands, Colorado State University, Fort Collins, Colorado. Figure 2.3.f, page 87.
MMR, situated on the western slopes of the Waianae mountain range, covers 4,856 acres. The Range is bordered by steep cliffs, which begin at Farrington Highway near the southwest corner of the property, and surround the impact area.

The SCS 1972 study suggested there were two primary soil associations within the MMR. These include the Lualualei-Fill land-Ewa (L-E) and Rocky land - Stony steep land (R-S) soil associations. The L-E association encompassed the valley where the primary test plots for this study are located. The SCS described the L-E soils as "deep, nearly level to moderately sloping, well-drained soils that have a fine-textured or moderately fine textured subsoil or underlying material, and areas of fill land; on coastal plains." The SCS described the R-S soils as "steep to precipitous, well-drained to excessively drained, rocky and stony land." This assessment was also supported by the Land and Soil Types description within the "Integrated Natural Resources Management Plan 2010-2014 Island of O‘ahu” (Figure 11).
Vic Garo, Chief Operations Officer, RD, informed Team CALIBRE that RD practices erosion control measures as necessary to stabilize and minimize soil erosion.
3.1.2 USAG-HI RD Vegetation Treatment Methods

Prevention of unplanned fires and control of the spread of fires is critical to protect people, property and natural resources. Wildfires and their suppression pose significant risks to personnel, property, cultural resources, and T&E species and their habitat.

Fires were a relatively common occurrence at MMR prior to the 1998. Since 2004, when the MMR was closed to live fire training, there were few recorded fires. The most significant fires within the past 10 years include:

- July 22, 2003. Initiated by a prescribed burn escape and burned approximately 2,100 acres.

Fires at SBMR WR are relatively common due to the frequent live-fire training conducted. These fires are most commonly ignited by ammunition. Range management staff on-hand during live fire exercises control fires as quickly as possible. Sizes of fires vary from less than one acre to over 300 acres, but most are less than 1 acre. Prescribed burning on the SBMR WR impact area occurs annually following the spring herbicide treatment.

Ignition and spread of fires is primarily facilitated by fuels created by tall growing grasses and brush. After fires are established, they burn larger brush and trees and travel with wind to off-site locations that contain native habitat, including threatened and endangered species. The steep terrain and poor access caused by UXO and topography restrict the ability to most effectively contain and control fires.

Analysis of the herbicide-burn-herbicide vegetation management method used by USAG-HI at SBMR indicated the approach was aggressive and costly and failed to provide a long-term solution as demonstrated by observations of SBMR application results by Team CALIBRE from 2007 through the present and communications with Vic Garo, Chief Operations Officer, RD and Allen Teshima, DuPont. This methodology provided an

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16 Personal communication. Vic Garo, Chief Operations Officer, RD; Michelle Mansker, Natural Resource Manager, ENV; Joby Rohrer, Senior Natural Resource Management Coordinator, ENV; Jane Beachy, Ecosystem Restoration Program Manager, ENV.
17 Personal communication. Michelle Mansker, Natural Resource Manager, ENV; Joby Rohrer, Senior Natural Resource Management Coordinator, ENV.
20 Personal communication. Vic Garo, Chief Operations Officer, RD.
23 Personal communication. Vic Garo, Chief Operations Officer, RD; Michelle Mansker, Natural Resource Manager, ENV; Joby Rohrer, Senior Natural Resource Management Coordinator, ENV.
immediate solution, but only short-term reduction in fuels. Within six months, Team CALIBRE and Allen Teshima observed target species, primarily Guinea grass (*P. maximum*), reestablished and increased fire fuels. Herbicide solutions were applied by aerial applications and were reported to be glyphosate and sulfometuron methyl. However, limited funds, tools, materials and practices significantly affected the ability of USAG-HI RD to efficiently control vegetation issues within SBMR. In addition, a growing season that extends for 12 months with periods of limited rainfall tended to exacerbate the vegetation and fire control issues on SBMR.

Additionally, installations are constrained to work within the three 2004 Measures of Merit (MOM) for Pesticide Management. The MOM requires the creation of an installation pest management plan, certification of all applicators, and encourages the reduction of the lbs per acre of active ingredient applied annually since 1993. Any effective control strategy with a reduction in active ingredient usage will be beneficial to maintaining an effective and acceptable vegetation management program.

In 2008, CPS found evidence of procedures that could lead to low efficacy associated with herbicide mixing and applications. Ron Lemin of CPS worked as a batching employee during the 2008 summer application to the SBMR impact area. The mixing and application equipment and practices that had been used previously were employed during this 2008 application. During the mixing process, Mr. Lemin used a conductivity meter to measure the alkalinity (indication that the herbicides were mixed uniformly within the batch tank) of the herbicide within the solution that was applied. Mixing of the herbicide solution was performed only by agitation with the water fill hose (the batching system did not have mechanical or pump agitation). The conductivity readings showed that all of the herbicide was concentrated on the bottom of the batch tank with very little at the top. The result was that applications of the solution from the top of the mix tank did not contain adequate herbicide while solution from the bottom of the tank contained excessive herbicide concentrates. This would result in inadequate control in some areas and adequate control in other areas. This system therefore had proven to be inadequate for applications conducted by Team CALIBRE on any sites under contract with the DOD.

A batching system with effective agitation and circulation is essential in providing uniform mixing of both the amine formulation of glyphosate and the water dispersed granules of the sulfometuron methyl. For the 2010-2011 treatments conducted under this study, a new system was built by Team CALIBRE to facilitate in the application process.

Mr. Lemin also installed a hand held GPS unit in the helicopter to document application coverage. The historic practice to direct the helicopter in its field applications was for the pilot to use ground-based visual cues from a large paper map provided by USAG-HI RD. The GPS readings showed that this system results in significant gaps in ground coverage in many areas with excessive overspray of other areas that are treated multiple times. Additionally, it was impossible to determine where the heavy rates and the weaker rates were applied on the impact area.

Creating a bare ground habitat, as is the current management protocol, reduces the risk of fire, but is only a temporary solution. The first plants to reestablish on the area are aggressive invasive species, usually Guinea grass (*P. maximum*). In the meantime, the exposed ground promotes runoff that can result in water quality problems. The unattractive, brown, bare site is also visible to the public as they travel the roads adjacent to SBMR. On several occasions pictures of the SBMR impact area following herbicide treatments or prescribed burning have appeared in the Honolulu paper.

Although it has not been scientifically determined, there may be a glyphosate resistance issue that has built up on the SBMR WR impact area. Repeated applications of glyphosate (2 per year) over the last decade might lead to a resistant phenotype of Guinea grass that would create a different problem. Glyphosate resistance is a known phenomenon in many areas of vegetation management, but it would only be a theory without further testing.

### 3.1.3 Vegetation Conditions (SBMR WR)

During site visits of SBMR WR, Team CALIBRE found that the majority of the target area is covered with grass. Deep gullies are covered with grass, low shrubs and small trees. Guinea grass (*P. maximum*) is the primary vegetative cover on SBMR WR. Within the SBMR WR firebreak system, the primary invasive species include Guinea grass (*P. maximum*), haole-koa (*L. leucocephala*), Christmas berry (*S. terebinthifolia*), albizia (*Falcataria moluccana*), Cook-pine (*Araucaria columnaris*), lemon-scented gum (*Eucalyptus citriodora*), and silk oak (*Grevillea robusta*). Many other invasive species are present within the firebreak; however, the species listed above are the most common. Native plant species are found within the SBMR WR, but were not present in any significant numbers. Most native species were found outside the firebreak on the surrounding slopes.

### 3.1.4 Vegetation Conditions (MMR)

During site visits of MMR, Team CALIBRE found that the majority of the target area is covered with grass, low shrubs and scattered clumps of trees. Guinea grass (*P. maximum*) is the primary vegetative cover on the lower elevation areas and many sites that have burned on the slopes, outside of the firebreak system. Within the firebreak, populations of haole-koa (*L. leucocephala*) and klu (*Acacia farnesiana*) are also common within the primary test plot area. Primary invasive species found on cliffs, in the upper valley, and on ridge tops include Guinea grass (*P. maximum*), molasses grass (*Melinis minutiflora*), haole-koa (*Leucaena leucocephala*), China berry (*Melia azedarach*), albizia (*Falcataria moluccana*), ironwood (*Casuarina equisetifolia*), silk oak (*Grevillea robusta*), eucalyptus (*Eucalyptus robusta*), kukui (*Aleurites moluccana*), and African tulip (*Spathodea campanulata*). Other invasive species are present, but those listed above are the most common.

Native plant species were also found within MMR, and were present in significant numbers within actively protected sites, outside of the firebreak system. These include populations of akoko (*Chamaesyce celastroides var. kaenana*), a’alili (*Dodonaea viscosa*), wiliwili

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27 Personal communication with Jeffery Phillips, Monsanto and “Facts About Glyphosate – Resistant Weeds” Chris Boerboom, University of Wisconsin; Micheal Owen, Iowa State University, published by Cooperative Extension Service, Purdue University.
(Erythrina sandwichensis), and ma’o hau hele (Hibiscus brackenridgei). Other native and T&E species are also present and are primarily found on upper elevations, outside of the firebreak system. Species lists are maintained and populations monitored and protected by USAG-HI as required under The “Integrated Natural Resources Management Plan (INRMP) 2010-2014 Island of Oʻahu”.

### 3.1.5 Vegetation Conditions (Kahuku Training Area)
In cooperation with ENV, Team CALIBRE conducted special treatments at the Kahuku Training Area (KTA) to test effectiveness of various herbicide solutions on challenging species. Vegetation condition assessments were not conducted by Team CALIBRE. ENV team members identified test sites and individual trees for treatment. Species treated included Chromolaena odorata, Falcataria moluccana, Cupressus lusitanica, Toona ciliata, Ficus microcarpa, Spathodea campanulata, Trema orientalis, Syzigium cumini, Falcataria moluccana, and Grevillea robusta.

### 3.1.6 Vegetation Conditions Summary
Guinea grass (P. maximum) is the most common and noxious of the invasive, fire spreading species found on MMR and SBMR. This species is fast growing and capable of maximum growth rates of six inches to one foot per week with a maximum height of approximately 10 feet. Guinea grass is hard to control, and creates a substantial fuel load, measured at 4 to 9 tons per acre in MMR and 2 to almost 12 tons per acre in SBMR. This grass will grow on or near any open section of bare ground and is normally the first species to re-emerge after herbicide treatments and prescribed or wildfire burns. Guinea grass grows well in dry, sunny areas and invades and disrupts the function of firebreaks, as well as interferes with the use of a vast majority of the training and Range areas.

Off-site areas surrounding SBMR and MMR include T&E species and desirable native plants. Fire breaks and fuels management areas were established to protect these species and habitat adjacent to the Ranges. Because of vegetation challenges associated with invasive species, it is not uncommon for fire to jump firebreaks or circumvent the fuel management areas and burn into the protected zone. Due to the presence of Guinea grass, the Bureau of Land Management (BLM) Fire Rating in the impact area in the dry season increases and, consequently, the range is closed to critical live fire training with incendiary munitions.

### 3.2. Preliminary Trials of Herbicide Application
Mr. Edison Hidalgo at the DuPont Stine-Haskel Research Center performed extensive research (Figure 12 and 13) both in the field and in greenhouse studies on control of

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29 Observations of Team CALIBRE and Personal communications with Michelle Mansker, Chief, Natural Resource, ENV; Joby Rohrer, Senior Natural Resource Management Coordinator, ENV.

30 Observations of Team CALIBRE and Personal communications with Vic Garo, Chief Operations Officer, RD; Michelle Mansker, Chief, Natural Resource, ENV; Joby Rohrer, Senior Natural Resource Management Coordinator, ENV.

31 Personal communications with Vic Garo, Chief Operations Officer, RD.

32 Edison Hidalgo, 2006, Internal DuPont research, Stine_Haskel Research Center, Newark DE.
Guinea grass with DuPont chemistries (Weestar, Oust XP, Oustar, and Velpar) and found that 1-4 oz of sulfometuron methyl (Oust XP) to be efficacious on Guinea grass. The best results occur when the grass is young and actively growing.  

![Guinea grass Control Prescriptions and 28 Day Results Tested by Edison Hidalgo at DuPont's Stine-Haskel Research Center in 2006.](image)

**Figure 12. Guinea grass Control Prescriptions and 28 Day Results Tested by Edison Hidalgo at DuPont's Stine-Haskel Research Center in 2006.**

![Guinea grass Control 28 Days Post Treatment With, 1, 2, 3, and 4 Ounces of Oust XP.](image)

**Figure 13. Guinea grass Control 28 Days Post Treatment With, 1, 2, 3, and 4 Ounces of Oust XP.**

In January 2011, Team CALIBRE began conducting preliminary testing of combinations of herbicides (Figure 14) that are proven to be effective on the primary target species present, which are Guinea grass, haole-koa and Christmas berry. Chemical formulations were applied at various rates within various solutions to test efficacy. Initial applications were based on the extensive experience of Team CALIBRE and Edison Hidalgo of DuPont.

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33 Personal communications with Edison Hidalgo supported by unpublished, greenhouse research data conducted by Mr. Hidalgo.
<table>
<thead>
<tr>
<th>Prescription Name</th>
<th>Chemical</th>
<th>Amount</th>
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<tbody>
<tr>
<td>Standard Solution</td>
<td>Glyphosate (Roundup ProMAX)</td>
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<td>Sulfometuron Methyl (Oust XP)</td>
<td>4 oz.</td>
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<td>Methylated seed oil (MSO)</td>
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<td>Hexazinone (Velpar DF)</td>
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<td>Sulfometuron Methyl (Oust XP)</td>
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<td>Test 3</td>
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<td>Sulfometuron Methyl (Oust XP)</td>
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<td>MSO</td>
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<td>Metsulfuron Methyl (Escort)</td>
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<tr>
<td></td>
<td>4.1 oz. Sulfometuron Methyl (Oust XP)</td>
<td>4 oz.</td>
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<tr>
<td></td>
<td>1.4 oz. Metsulfuron Methyl (Escort)</td>
<td>4 oz.</td>
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<tr>
<td></td>
<td>43.6 oz. Imazapyr (Arsenal)</td>
<td>4 oz.</td>
</tr>
<tr>
<td></td>
<td>MSO</td>
<td>13 oz. (1%)</td>
</tr>
<tr>
<td>Test 9</td>
<td>Glyphosate (Roundup ProMAX)</td>
<td>44.5 oz.</td>
</tr>
<tr>
<td></td>
<td>Lineage Prep</td>
<td>20 oz.</td>
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<tr>
<td></td>
<td>4.1 oz. Sulfometuron Methyl (Oust XP)</td>
<td>4 oz.</td>
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<td></td>
<td>1.4 oz. Metsulfuron Methyl (Escort)</td>
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<tr>
<td></td>
<td>43.6 oz. Imazapyr (Arsenal)</td>
<td>4 oz.</td>
</tr>
<tr>
<td></td>
<td>MSO</td>
<td>13 oz. (1%)</td>
</tr>
<tr>
<td>Test 10</td>
<td>Lineage Prep</td>
<td>30 oz.</td>
</tr>
<tr>
<td></td>
<td>6.1 oz. Sulfometuron Methyl (Oust XP)</td>
<td>6 oz.</td>
</tr>
<tr>
<td></td>
<td>2 oz. Metsulfuron Methyl (Escort)</td>
<td>2 oz.</td>
</tr>
<tr>
<td></td>
<td>65.4 oz. Imazapyr (Arsenal)</td>
<td>6 oz.</td>
</tr>
<tr>
<td></td>
<td>MSO</td>
<td>20 oz. (1.5%)</td>
</tr>
<tr>
<td>Test 11</td>
<td>Glyphosate (Roundup ProMAX)</td>
<td>44.5 oz.</td>
</tr>
<tr>
<td></td>
<td>Sulfometuron Methyl (Oust XP)</td>
<td>4 oz.</td>
</tr>
<tr>
<td></td>
<td>Triclopyr (Garlon 4)</td>
<td>80 oz.</td>
</tr>
<tr>
<td></td>
<td>MSO</td>
<td>13 oz. (1%)</td>
</tr>
</tbody>
</table>

Figure 14. Herbicide prescriptions identified for preliminary testing by Team CALIBRE at SBMR and MMR, January-March 2011.
The basic prescription applied within the majority of the sites within SBMR WR and MMR was 44.5 oz of Roundup ProMAX (glyphosate), 4 oz of Oust XP and 1% MSO (methylated seed oil) via helicopter application at a 10 gallon per acre rate. This prescription was selected based on research by Mr. Hidalgo and because it showed some success in past SBMR treatments. However, adequate data on results was not collected, nor was GPS-guided application conducted. This application was also commonly followed by a prescribed burn after the grass began to die, thus results on application and long term efficacy were not available.

Mr. Hidalgo’s research found that the most effective product for Guinea grass is hexazinone (Velpar), which performed well, and does an outstanding job controlling and preventing the spread of Guinea grass. However, due to its extensive use in pineapple production within Hawaii and the restricted use label, Velpar use diminished over the last ten years. High rates and repeated uses of hexazinone led to ground water contamination in agricultural areas within some parts of Hawaii. Since then, Mr. Hidalgo tested the product Oust XP (sulfometuron methyl) as a possible alternative control scenario for Guinea grass. Research shows that Oust XP works well as a growth regulator in stunting the growth of Guinea grass at an application rate of one oz/acre, and does a better job at controlling Guinea grass at a higher application rate of 4 oz/acre (Stine-Haskel Research Study, 2006).

With the success of both Velpar and Oust on Guinea grass, Mr. Hidalgo recommended Team CALIBRE apply a product called Oustar, which is a combination of hexazinone and sulfometuron methyl, which he found to be somewhat effective solution for Guinea grass control in DuPont greenhouse studies. To best understand the range of efficacy within this environment and minimize the risk of off-target damage, Mr. Hidalgo suggested initial Oustar test rates of 10 oz, 14 oz, 18 oz, and 22 oz per acre. Oustar is not yet a registered product in Hawaii and thus requires a mix of Velpar DF and Oust XP in the appropriate combinations to get the same active ingredient applied. Based on this recommendation, applications were applied at these rates on the North Lobe fire break at MMR in January 2011. Since Velpar DF is a restricted use product, this research required obtaining an aerial permit from the Hawaii Department of Agriculture, Pesticide Branch.

Many of the sites within SBMR WR and MMR include broad-leaf vegetation that is difficult to control with the standard mix of glyphosate and sulfometuron methyl. In these sites, Team CALIBRE included Garlon 4 Ultra (triclopyr) with the Roundup ProMAX and Oust XP. This prescription was used along the fire break at SBMR WR and along the Farrington Highway at MMR in January 2011. The combined use of Garlon 4 Ultra and Roundup ProMAX are based on efficacy results on industrial utility ROW treatments over the last decade in Hawaii.

Prescriptions applied during the March 2011 test applications at MMR included the use of Lineage Prep, and a combination of Lineage Prep and Roundup ProMAX. Lineage Prep is a combination of imazapyr, sulfometuron methyl, and metsulfuron methyl; their equivalent,
respective amounts are represented in italics in the table above. These formulations provide four chemistries working on different plant functions, and may provide better and longer control of target species at lower rates. Trials completed by the USFS on kikuyu grass for koa regeneration on the Big Island have shown that imazapyr provided good results on targeted grass species. Metsulfuron methyl is labeled as an effective woody and herbaceous control product that can control grasses at higher rates. Their addition may prove advantageous in increasing control of target species on MMR.

Team CALIBRE’s findings from preliminary herbicide testing are presented in Appendices A and B of this report.

4. Control Method Recommendations

General control methods considered by the Gap Analysis team included biological (i.e., pests or pathogens of target species), mechanical control (i.e., plant and/or facilitate and maintain desirable ground cover), and chemical applications (i.e., herbicides). Each of these methods was selected or eliminated from recommendation for additional research based on projected, potential efficacy against the target plants, projected cost, operational practicality, and potential for off-target environmental risks.

4.1. Biological Control

Biological control mechanisms (i.e., pests or pathogens of target species) are often considered by the public to be the optimum control mechanism due to their natural actions. Biological controls include pathogens (bacteria, virus, fungus, and mycoplasma–like organisms), pests (insects, mites, bugs, nematodes and similar), animals and parasitic plants. Considerable evidence exists to demonstrate that biological controls can result in significant adverse impacts when they do not behave as expected and damage desirable plants or property. There are numerous examples in Hawaii of alien species introduced for biological control that resulted in a far larger problem than the solution they provided. Examples include the mongoose (*Helogale parvula*) and cane toad (*Bufo marinus*).

Most of the plants commonly encountered in Hawaii are alien species and many of these are invasive. Extensive research into potential controls of invasive plants and testing on that potential control's impact on desirable plants must be conducted before considering release. Identification and testing is an exhaustive process. Because of the extensive time and resources that would be required to identify and pre-test most biological methods, Team CALIBRE recommends that pathogens, pests and parasitic plants not be considered for testing as a long-term vegetation control method.

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35 Personal communications with Mike Donoho, PuuWaawaa Ahupuaa Coordinator, Department of Forestry and Wildlife during 2008 field visit and test plot observations by Team CALIBRE’s Ron Lemin.

Grazing by animals, specifically large herbivores, such as cows, horses, goats and sheep, has been demonstrated to be an effective technique for maintaining vegetation at low heights in some areas. USAG-HI\textsuperscript{37} and the Marine Corps Base Hawaii at Kaneohe\textsuperscript{38} conducted grazing research using cattle and other herbivores. Given the extensive cost and logistics of conducting this research, and the ready availability of published research at USAG-HI on grazing efficacy, further research is not needed; however, grazing could be considered as a technique for long-term vegetation management.

4.2. Mechanical Control
Mechanical applications using mowing machines are currently applied extensively on USAG-HI ranges. Mowing is accomplished through the use of string-trimmers or large mowing machines transported by tractors. This method removes the upper portion of target vegetation, but does not control the roots and stump. This method provides fast control of target species and facilitates removal of fuel from the site. Most vegetation, including the undesirable vegetation targeted within this study, rapidly re-sprouts. Given that this method is a common practice and the response of vegetation is well understood, this method is not recommended for further testing for inclusion in long-term management. However, research studies by Edison Hidalgo (Dupont) have shown that efficacy is increased on Guinea grass when it is shorter and actively growing\textsuperscript{39}. Therefore, a study to combine mechanical mowing with a glyphosate, sulfometuron prescription could provide useful results for the Guinea grass problem occurring on the fire breaks. The long-term IVMP will address the combination of effective management scenarios such as combining both mowing and chemical as desirable solutions to Guinea grass control.

4.3. Cultural Management of Vegetation
Cultural Management of undesirable vegetation includes disrupting the site by breaking the soil, planting competitive crops/vegetation, and modification of site conditions.

Breaking the soil and modifying site conditions with plows, bulldozers, explosives or other physically disruptive techniques can be effective in the short term. However, this technique was eliminated from consideration due to UXO challenges, aesthetic considerations and the knowledge that invasive plants would reestablish quickly.

Modifying site conditions through soil additives or physical site changes was eliminated from consideration for the same reasons as breaking the soil and due to potential for long-term environmental impacts from any additives that may be applied.


\textsuperscript{38} Personal communications with Dr. Diane Drigot, MCBH.

\textsuperscript{39} Personal communications with Edison Hidalgo supported by unpublished internal DuPont greenhouse research data conducted by Mr. Hidalgo.
A separate project funded by AEC with the help of Antonio Palazzo, Research Agronomist for the US Army Corps of Engineers, tested the application of salt spray, glyphosate, and sulfometuron methyl to control Guinea grass. Following control, Mr. Palazzo used a specialized “seed ball” technique to re-vegetate the site. The “seed ball” has been tested using perennial rye grasses, root stolons, and cool season grass seeds. The results are pending, but the “seed ball” might become viable means to re-vegetate the firebreaks following removal of the Guinea grass. Team CALIBRE will monitor this study to coordinate review and consideration of the results for incorporation into the IVMP.

Removal of undesirable vegetation followed by installation of desirable plants is sometimes effectively used to manage undesirable vegetation. Management practices and site conditions must be conducive to enabling desirable plants to effectively compete against undesirable plants for space, nutrients and water. Techniques to remove undesirable plants include cultivation (primarily plowing), or herbicide applications. Undesirable plants are often aggressive, invasive plants. To maintain communities of desirable plants, regular management is required. If not regularly managed, undesirable plants may reestablish and out-compete desirable plants, destroying the plant community.

Team CALIBRE recommends three methods of cultural control to be tested for possible inclusion in a long-term IVMP:

- Selective removal of undesirable plants using herbicide to promote desirable vegetation communities,
- Planting of medium-sized, dense foliage trees to shade out undesirable plants, and
- Installation of low-growing ground-covers (green strips) using a hydro-seeding process, or possibly the “seed ball” technology developed by Mr Palazzo.

These techniques were selected based on their historical success as described in numerous publications and in the extensive experience of Team CALIBRE, and the projected, potential cost-effectiveness of each technique. They are also listed as suggested fire break management scenarios within the Integrated Natural Resources Management Plan 2010-2014 Island of O’ahu (page 33). The promotion of desirable vegetation communities through selective herbicide treatments was successfully demonstrated in Hawaii by Hawaiian Electric Company in managing vegetation on its rights-of-way.

Team CALIBRE plans to plant medium-sized, dense foliage trees to shade out undesirable plants and provide a firebreak that will prevent the propagation and spread of fire, pending

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40 Personal communication with Antonio Palazzo, Research Agronomist, US Army Corps of Engineers.
approval of ground disturbance from USAG-HI Cultural Resources. These trees, primarily native species, are proposed for planting in an area adjacent to the fence that extends along Farrington Highway. Species currently being proposed include kou (*Cordia subcordata*), true kamani (*Calophyllum inophyllum*), milo (*Thespesia populnea*), hala (*Pandanus tectorius*), and mango (*Mangifera indica*). The initial test planting is currently projected to cover an area approximately 1.6 acres in size.

If additional funds are obtained, Team CALIBRE recommends planting five hundred (500) trees throughout the test plot, excluding any archeological sites that are identified by USAG-HI CR who we recommend accompany the planting team. Plantings should be contiguous and provide a dense canopy ground cover to effectively shade and prevent undesirable grass species from establishing in populations that can propagate and spread fire. Installation of these plantings would be most beneficial if completed in November 2011, at the beginning of the rainy season, to facilitate establishment. Three sizes of trees are recommended for planting: 1 gallon, 5 gallon and 25 gallon. Each of these size classes should be divided into two groups. One group should be irrigated until established and the other group should be left with only natural water. Team CALIBRE recommends mulch be applied to one-half of each subgroup to test for increased growth and establishment. Growth and monitoring of these trees is recommended for at least three years, and perhaps longer, depending on unpredictable weather patterns.

4.4. **Chemical Applications**

Chemical applications of herbicides or plant growth regulators are commonly conducted to control undesirable vegetation. The Gap Analysis Team agreed that combinations of various herbicide formulations work effectively. Combinations permit lower application rates for each formulation while often increasing the efficacy of control as compared to one formulation. These combinations can result in lower cost for the application solution and increased control efficacy. Increased control efficacy can further reduce costs by reducing the frequency of applications.

Team CALIBRE recommends TimberMark be used to visually define treatment areas including sensitive areas and habitat prior to aerial herbicide applications. Marking is conducted with a blue, water-based latex paint that is easily viewed from the air. The marked perimeters consist of an equally spaced intermittent line with each paint mark identified with a corresponding GPS coordinate. GIS data, provided either by USAG-HI or Team CALIBRE (with approval from USAG-HI), would be uploaded into the helicopter navigation system to mark sensitive areas and habitats. Boundaries marked with paint provide confirmation of treatment and sensitive area locations prior to herbicide application and provide a visual aid to the helicopter pilot during application.
Team CALIBRE recommends preliminary testing of combinations of herbicides in March 2011 and May 2011 continue with increased replications. Review of the early results of January applications within the North Lobe showed lower than anticipated control (Figure 15); these sites require further monitoring. Reviews of the early results of applications within the South Lobe showed mixed results and also require further monitoring. Summaries of the preliminary observations are located in Appendix A, North Lobe Test Plot Preliminary Findings and Appendix B, South Lobe Test Plot Preliminary Findings.

![Figure 15. Examples of Typical Test Plot Before (left), Then 2 Weeks (center) and 12 Weeks (right) After Treatment showing the regrowth of Guinea grass and resprouting of haole-koa.](image)

Preliminary results and further analysis will permit Team CALIBRE to modify solutions in an attempt to identify the optimum solution that will provide the desired control at the lowest rate/cost. Pending funding, additional formulations and solutions will be tested as soon as final results from the preliminary tests are collected and analyzed, and additional formulations are identified and registered. Based on these preliminary tests, recommendations for additional research may be warranted to support long-term vegetation management.

Team CALIBRE recommends other herbicide formulations that are currently in development or being registered for application (personal communication with Edison Hidalgo, DuPont) also be tested to determine their efficacy on the target species individually and then within solutions. Based on results, these formulations may be considered in long-term vegetation management based on efficacy and cost effectiveness.

A separate project using salt to modify site conditions is being conducted currently. Team CALIBRE will monitor this study to coordinate review and consideration of the results for incorporation into the IVMP.

5. Conclusion
Based on our review of available publications and interviews with key USAG-HI personnel and subject matter experts, current and past USAG-HI technical vegetation management
practices are inadequate to support the military mission and protect sensitive natural and
cultural resources by stabilizing the vegetative community and reducing threats of
wildland fires. Our evaluation of existing conditions indicate Guinea grass and invasive
plants continue to dominate the MMR and SBMR range landscape, threatening T&E species
through habitat depletion and fire danger.

Cost-effective and successful vegetation management practices must be developed and
implemented at USAG-HI to better manage vegetation, reduce costly wildland fires, and
permit military training as required. Management of fire breaks and fuel management
areas, especially when associated with a significant slope and high winds, is a key
consideration in managing undesirable vegetation. Elimination of fire danger species, such
as Guinea grass, within and near these fire control areas would be a significant deterrent to
uncontrolled fires. Additional testing is needed to determine if timing of the herbicide
application can improve Guinea grass efficacy or analyze the timing of the prescribed burn
following application to determine whether it may be decreasing overall efficacy.

The USAG-HI IVMP must involve the creation of green strip fire breaks or plantings of
vegetation to deter the spread of wild fires (INRMP 2010-2014, Island of O’ahu). This will
require additional testing and research beyond the research performed to date. Long term
control strategies need to be employed to obtain results beyond a 6 month period.
Combining mechanical, biological and chemical control methods could be advantageous.
Further testing is required.

Development of cost-effective solutions at USAG-HI is challenged by multiple
environmental, administrative, cultural, and public issues. In order to identify and
implement the most cost-effective, environmentally sound control methods, constant
diligence and research on developing tools, techniques and herbicides will be required.
Herbicide tests that have been completed have demonstrated strengths and weaknesses
and should be expanded to develop the most effective formulations that will best address
vegetation conditions throughout USAG-HI. Management of target species more cost-
effectively than previous methods to achieve USAG-HI goals can be accomplished, but
requires extensive research and application of various control methods appropriate for site
conditions. Continued funding and support will be essential to complete the necessary
testing to create a valid and effective IVMP.

The following actions are recommended for continued research and testing within the next
two years for development of the IVMP:

- Selective removal of undesirable plants using herbicide to promote desirable
  vegetation communities,
- Planting of medium-sized, dense foliage trees to shade out undesirable plants,
• Installation of low-growing ground-covers using a hydro-seeding process,
• Continued testing of herbicide formulations,
• Testing of new herbicide formulas,
• Continued soils and vegetation monitoring

Team CALIBRE thanks USAG-HI for the opportunity to conduct a gap analysis and initiate preliminary research using state-of-the-art tools, techniques, and materials. Team CALIBRE recommends USAG-HI implement recommendations presented in this plan, and fund, as able, an additional two years of research and monitoring in support of developing a long-term, cost effective IVMP.
Appendix A: North Lobe Test Plots
General condition of plants throughout the test site during initial review and assessment:

- Guinea grass (*Panicum maximus*): Generally healthy. Some basal brown stems, flushing growth and seed formation observed.
- Haole koa (*Leucaena leucocephala*): Emerging small brightly-colored healthy leaves and active normal seed fall observed.
- Klu (*Acacia farnesiana*): New growth emerging with bright green sprouts and leaves. Few dried seed pods present.
- Guava (*Psidium guajava*): Dark green leaves and immature, small green fruits.
- Java plum (*Syzygium cumini*): Stunted growth with good form, likely due to dry area. Immature fruits observed.
- Sandalwood (*Santalum ellipticum*): One individual found on 107 2-C. Healthy individual.
- Morning glory (*Ipomaea ochrocea*): One individual found on 101 1-S, healthy and climbing on a haole koa.

**Plot # 101 Treatment Solution 8: 0.5 Velpar, 20 oz Lineage Prep, 13 oz MSO**

**Haole koa**

- Baseline Vegetation Conditions – Healthy, emerging small brightly-colored leaves and active normal seed fall were observed. Cover (i.e., the estimated portion of the sample site comprised of the target plant canopy) at 50%. Sociability medium to large clumps.
- First Post-Treatment Observation (PTO) – Complete leaf drop, dying stems and brittle ends.
- Second PTO – Average 35% regrowth. Epicormic resprouts along main stems observed on all trees. No releaf along branches or tips.
- Third PTO – Average 40% regrowth. Flowering and new leaves observed on one sample site.

**Guinea grass**

- Baseline Vegetation Conditions – Flushing growth and seed formation observed. Grass 9-12 feet in height. Coverage 95%. Sociability medium to large clumps.
- First PTO – 100% brown foliage. Grass height declining to 6 feet tall, with mottled leaves, yellow and brown patches.
- Second PTO – Average 35% regrowth. Grass regrowth observed from inside clumps with brown low, green six feet high.
- Third PTO – Average 35% regrowth. Clumps to 8 feet in height.

**Klu**

- Baseline Vegetation Conditions – Only found in portions of plot. Where found, cover 20%, sociability small clumps.
- First PTO – Complete leaf drop, dying stems.
- Second PTO – Average 30% regrowth.
- Third PTO – Average 30% regrowth.

**Java plum**
• Baseline Vegetation Conditions – Cover restricted to one healthy specimen. Sociability was one individual.
• First PTO – Unaffected.
• Second PTO – Control (i.e., the percent of green, live growth relative to the entire target plants on the sample site) at 20% with only small branch dieback.
• Third PTO – Control increased to 60%.

Morning glory
• Baseline Vegetation Conditions – Cover was restricted to one healthy specimen climbing on a haole-koa. Sociability was one individual.
• First PTO – Control at 50%.
• Second PTO – Control increased to 100%.
• Third PTO – Control remained at 100%.

Sandalwood
• Baseline Vegetation Conditions – Cover was restricted to one healthy specimen. Sociability was one individual.
• First PTO – Control at 70%.
• Second PTO – 10% leaves remaining. Control increased to 100%.
• Third PTO – Control remained at 100%.

Plot #102 Treatment Solution 6: 0.5lbs Velpar, 4 oz Oust XP, 13 oz MSO

Haole koa
• Baseline Vegetation Conditions – Healthy, emerging small brightly-colored leaves and active normal seed fall observed. An average of 75% Cover observed.
• First PTO – Control increased to 100%.
• Second PTO – Average 20% regrowth
• Third PTO – Average 40% regrowth.

Guinea grass
• Baseline Vegetation Conditions: From four to seven feet in height. Cover 95%. Sociability large clumps.
• First PTO – Control increased to 100%.
• Second PTO – Control decreased to 95%.
• Third PTO – Control decreased to 20%.

Plot #103 Treatment Solution 3: 0.95lbs Velpar, 2.8 oz Oust XP, 13 oz MSO

Haole koa
• Baseline Vegetation Conditions – Healthy, emerging small brightly-colored leaves and active normal seed fall were observed. Cover 15% and sociability small clumps.
• First PTO – Control increased to 100%.
• Second PTO – Control decreased to 70%.
• Third PTO – Control decreased to 60%.
Guinea grass
- Baseline Vegetation Conditions – Cover 100%. Sociability pure stands. Eight to ten foot height.
- First PTO – Control at 100%. Stems and clumps lying down, browning, yellowing.
- Second PTO – Control decreased to 85%. Clumps sprouting new green.
- Third PTO – Control decreased to 40%. Resprouts within original clumps with very few outside old clumps.

Klu
- Baseline Vegetation Conditions – Bright green leaves. Cover 60%. Sociability medium to large clumps.
- First PTO – Control at 100%.
- Second PTO – Average 35% regrowth.
- Third PTO – Average 75% regrowth. Flowering observed.

Plot #104 Treatment Solution 2: 0.74lbs Velpar, 2.2 oz Oust XP, 13 oz MSO

Haole koa
- Baseline Vegetation Conditions – Healthy, emerging small brightly-colored leaves and active normal seed fall observed. Cover 70%. Sociability medium to large clumps.
- First PTO – Control at 100%.
- Second PTO – 40% resprouting
- Third PTO – Control decreased to 75%.

Guinea grass
- Baseline Vegetation Conditions – Cover 100%. Sociability pure stands. Heights were over eight feet.
- First PTO – Control at 100%.
- Second PTO – 30% resprouting from clumps.
- Third PTO – 40% resprouting from clumps.

Klu
- Baseline Vegetation Conditions – Cover 10%. Sociability individuals. Trees leafing out.
- First PTO – Control increased to 70%.
- Second PTO – Resprouting, Control decreased to 50%.
- Third PTO – Resprouting, Control decreased to 10%.

Plot# 105 Treatment Solution 6: 0.5lbs Velpar, 4 oz Oust XP, 13 oz MSO

Haole koa
- Baseline Vegetation Conditions – Healthy, emerging small brightly-colored healthy leaves and active normal seed fall observed. Cover 25%. Sociability large clumps.
- The first PTO – Control at 100%.
- Second PTO – Control decreased to 85%.
• Third PTO – Control remained at 85%.

Klu
• Baseline Vegetation Conditions – Small, densely-packed stands. Bright green leaves emerging. Five feet height.
• First PTO – Control at 100%.
• Second PTO – Resprouting, Control decreased to 75%.
• Third PTO – Resprouting, Control decreased to 35%.

Guinea grass
• Baseline Vegetation Conditions – Cover 90%. Sociability large clumps. Heights over 8 feet.
• First PTO – Control at 100%. Heights up to 5”.
• Second PTO – Resprouts from clumps, control decreased to 70%.
• Third PTO – Resprouts from clumps and seedlings, control decreased to 50%.

Plot #106 Treatment Solution 8: 0.5 Velpar, 20 oz Lineage Prep, 13 oz MSO

Haole koa
• Baseline Vegetation Conditions – Healthy, emerging, small brightly-colored healthy leaves and active normal seed fall observed. Cover 20%. Sociability small clumps.
• First PTO – Control at 100%.
• Second PTO – Control decreased to 80%. Unopened, stunted leaves and open leaves on stems.
• Third PTO – Control decreased to 75%.

Guinea grass
• Baseline Vegetation Conditions – Cover 95%. Sociability large clumps. Luxuriant growth, dominant height 10 feet.
• First PTO – Control at 100%.
• Second PTO – Resprouts from clumps, control decreased to 85%.
• Third PTO – Resprouts from clumps, control decreased to 75%.

Klu
• Baseline Vegetation Conditions – Cover 25%. Sociability medium to large clumps. Leaves were freshly emerged.
• First PTO – Control at 100%.
• Second PTO – Control decreased to 85%, resprouts.
• Third PTO – Control decreased to 10%, resprouts.

Plot 107 Treatment Solution 7: 0.5 Velpar, 4 oz Oust XP, 1.5 oz Escort, 13 oz MSO

Haole koa
- Baseline Vegetation Conditions – Healthy, emerging small brightly-colored healthy leaves and active normal seed fall observed. Cover 40% on only one site. Sociability large clumps.
- First PTO – Control at 100%.
- Second PTO – Control decreased to 90%.
- Third PTO – Control increased to 100%.

**Guinea grass**
- Baseline Vegetation Conditions – Cover 95%. Sociability large clumps. Luxuriant growth, dominant height 10 feet.
- First PTO – Control at 100%.
- Second PTO – Control decreased to 90%, resprouting from clumps.
- Third PTO – Control decreased to 70%, resprouting from clumps.

**Guava**
- Baseline Vegetation Conditions – Healthy condition, immature fruit. Cover 5%. Sociability medium to large clumps.
- First PTO – Control at 80%, leaves yellowing.
- Second PTO – Control decreased to 65%, resprouts.
- Third PTO – Control remained at 65%, resprouts.

**Sandalwood**
- Baseline Vegetation Conditions – Healthy. Cover <1%. Sociability was one specimen.
- First PTO – Control at 100%.
- Second PTO – Control remained at 100%.
- Third PTO – Control remained at 100%.

**Plot 108 Treatment Solution 1: 0.5lbs Velpar, 1.6 oz Oust XP, 13 oz MSO**

**Haole koa**
- Baseline Vegetation Conditions – Healthy, emerging small brightly-colored healthy leaves and active normal seed fall observed.
- First PTO – Control at 100%.
- Second PTO – Control decreased to 95%.
- Third PTO – Control decreased to 70%, resprout along stems.

**Guinea grass**
- Baseline Vegetation Conditions – Cover 95%. Sociability large clumps. Luxuriant growth, dominant height ten feet.
- First PTO – Control at 100%.
- Second PTO – Control decreased to 90%.
- Third PTO – Control decreased to 60%, regrowth from clumps.

**Klu**
• Baseline Vegetation Conditions – Cover 25% in one sample site. Sociability medium to large clumps. Leaves were freshly emerged.
• First PTO – Control at 100%.
• Second PTO – Control remained at 100%.
• Third PTO – Control decreased to 80%.

Guava
• Baseline Vegetation Conditions – Green, mature leaves. Cover 20%. Sociability small clumps and individuals.
• First PTO – Control at 100%, yellow leaves.
• Second PTO – Control decreased to 90%.
• Third PTO – Control increased to 95%.

**Plot #109  Treatment Solution 1: 0.5lbs Velpar, 1.6 oz Oust XP, 13 oz MSO**

Haole koa
• Baseline Vegetation Conditions – Healthy, emerging small brightly-colored healthy leaves and active normal seed fall observed. Cover 15%. Sociability individuals and small clumps.
• First PTO – Control at 75%.
• Second PTO – Control remained at 75%.
• Third PTO – Control decreased to 60%, resprouts along stems.

Guinea grass
• Baseline Vegetation Conditions – Cover 95%. Sociability large clumps. Luxuriant growth, dominant height 10 feet.
• First PTO – Control at 100%.
• Second PTO – Control decreased to 75%.
• Third PTO – Control increased to 90%.

Klu
• Baseline Vegetation Conditions – Cover 25%. Sociability medium to large clumps. Leaves freshly emerged.
• First PTO – Control at 75%.
• Second PTO – Control remained at 75%.
• Third PTO – Control increased to 80%.

**Plot #110  Treatment Solution 3: 0.95lbs Velpar, 2.8 oz Oust XP, 13 oz MSO**

Haole koa
• Baseline Vegetation Conditions – Healthy, emerging, small brightly-colored healthy leaves and active normal seed fall observed. Cover 20% on one site. Sociability small clumps.
• First PTO – Control at 100%.
• Second PTO – Control decreased to 70%, resprouts along stems.
• Third PTO – Control decreased to 40%, resprouts along stems.

Klu
• Baseline Vegetation Conditions – Cover 25%. Sociability medium to large clumps. Leaves were freshly emerged.
• First PTO – Control at 85%.
• Second PTO – Control decreased to 75%.
• Third PTO – Control decreased to 20%, resprouts.

Guinea grass
• Baseline Vegetation Conditions – Cover 65%. Sociability medium to large clumps. Luxuriant growth, dominant height 8 feet.
• First PTO – Control at 100%.
• Second PTO – Control decreased to 95%.
• Third PTO – Control decreased to 40%, resprouting from clumps.

Plot #111 Treatment Solution 7: 0.5 Velpar, 4 oz Oust XP, 1.5 oz Escort, 13 oz MSO

Haole koa
• Baseline Vegetation Conditions – Healthy, emerging, small brightly-colored healthy leaves and active normal seed fall observed.
• First PTO – Control at 100%.
• Second PTO – Control decreased to 80%.
• Third PTO – Control decreased to 80%.

Klu
• Baseline Vegetation Conditions – Cover 25%. Sociability medium to large clumps. Leaves were freshly emerged.
• First PTO – Control at 100%.
• Second PTO – Control decreased to 90%.
• Third PTO – Control decreased to 20%, resprouting.

Guinea grass
• Baseline Vegetation Conditions – Cover 50%. Sociability medium large clumps. Luxuriant growth, dominant height 8 feet.
• First PTO – Control at 100%.
• Second PTO – Control decreased to 80%.
• Third PTO – Control decreased to 55%, resprouting from clumps.

Plot #112 Treatment Solution 2: 0.74lbs Velpar, 2.2 oz Oust XP, 13 oz MSO

Haole koa
• Baseline Vegetation Conditions – Healthy, emerging, small brightly-colored healthy leaves and active normal seed fall observed.
• First PTO – Control at 100%.
• Second PTO – Control decreased to 60%.
• Third PTO – Control remained at 60%.

Guinea grass
• Baseline Vegetation Conditions – Cover 80%. Sociability medium large clumps. Luxuriant growth, 6 feet.
• First PTO – Control at 100%.
• Second PTO – Control decreased to 60%.
• Third PTO – Control decreased to 50%, resprouting from clumps.

Klu
• Baseline Vegetation Conditions – Cover 25%. Sociability medium clumps. Leaves were freshly emerged.
• First PTO – Control at 100%.
• Second PTO – Control decreased to 20%.
• Third PTO – Control remained at 20%.

**Preliminary Conclusions:**
Control of all major target species was initially good, as shown through extensive brown foliage; however, all species recovered during the review period. Control appeared to be limited to foliage exposed and did not control the root system of the plants. Heavy ground Cover of Guinea grass restricts ground contact of herbicide solution as demonstrated through the very small detection of hexazione during the initial soil tests. Herbicide rates applied appeared to inadequately provide penetration and satisfactory control of target species.
Appendix B: South Lobe Test Plot Observations
General condition of plants throughout the test site during initial review and assessment:

- **Guinea grass** (*Panicum maximus*): Low levels of basal brown stems, flushing growth and seed drop.
- **Haole koa** (*Leucaena leucocephala*): Large brightly-colored healthy leaves and active, normal seed fall.
- **Klu** (*Acacia farnesiana*): Small, developing, bright green woody growth and leaves.
- **Guava** (*Psidium guajava*): Dark green leaves and yellow fruits.
- **Java plum** (*Syzygium cumini*): Trees form small, likely due to dry site, and well developed with immature fruit.

Additional plants were found only in small numbers or as individuals. These plants were generally in good health and normal condition and included the following species:

- **Morning glory** (*Ipomaea ochrocea*)
- **Carpetgrass** (*Axonopus fissifolius*)
- **Sensitive plant** (*Mimosa pudica*)
- **Cocklebur** (*Xanthium strumarium*)
- **Fireweed** (*Senecio madagascariensis*)
- **Coat buttons** (*Tridax procumbens*)
- **Dandelion** (*Taraxacum officinale*)
- **Plantain grass** (*Plantago lanceolata*)
- **White daisy** (*Bidens alba*)

### Plot #200 Treatment Solution 9: 44.5 oz Roundup Pro MAX, 20 oz Lineage Prep, 13 oz MSO

**Haole koa**

- Baseline Vegetation Conditions – Healthy, emerging small bright leaves and active normal seed fall were observed. Cover 25%. Sociability medium large clumps.
- First Post-Treatment Observation (PTO) – Control at 45%. Dieback, spotty yellowing of leaf, dying stems found.
- Second PTO – Control increased to 60%. Epicormic resprouts along main stems observed on some trees. No releaf along branches or tips.
- Third PTO – Control increased to 70%. Flowering and new leaves observed on dying plants in 10% of instances.

**Guinea grass**

- Baseline Vegetation Conditions – Tall grass-from 7-8 feet in height. Cover 95%. Sociability almost pure stands.
- First PTO – Control at 60%. Grass lying down to 4 feet, browning, with mottled leaves, yellow and brown patches.
- Second PTO – Control increased to 80%.
- Third PTO – Control increased to 85%. Significant brown. Green at bases only.

**Klu**
• Baseline Vegetation Conditions – Small population in only one sample site. Cover 20%, Sociability small clumps.
• First PTO – Control at 35%.
• Second PTO – Control increased to 45%.
• Third PTO – Control increased to 80%.

Plot #201 Treatment Solution 9: 44.5 oz Roundup Pro MAX, 20 oz Lineage Prep, 13 oz MSO

Guinea grass
• Baseline Vegetation Conditions – Cover 25%. Sociability small and large clumps. Heights over 6 feet.
• First PTO – Control at 35%.
• Second PTO – Control increased to 55%.
• Third PTO – Control increased to 75%.

Carpetgrass
• Baseline Vegetation Conditions – Cover 50%. Sociability medium large clumps. Eight to 10 foot height.
• First PTO – Control at 85%.
• Second PTO – Control increased to 90%.
• Third PTO – Control decreased to 80%.

Sensitive plant
• Baseline Vegetation Conditions – Cover 5%. Sociability individuals.
• First PTO – Control at 10%.
• Second PTO – Control remained at 10%.
• Third PTO – Control increased to 80%.

Fireweed
• Baseline Vegetation Conditions – Cover less than 1%. Sociability individuals.
• First PTO – Control at 50%.
• Second PTO – Control decreased to 40%.
• Third PTO – Control decreased to 30%.

Plot #202 Treatment Solution 8: 0.5 Velpar, 20 oz Lineage Prep, 13 oz MSO

Guinea grass
• Baseline Vegetation Conditions – Cover 25%. Sociability medium to large clumps. Eight to 10 foot height.
• First PTO – Control at 65%. Stems still green but lying over.
• Second PTO – Control decreased to 60%. Clumps sprouting new green.
• Third PTO – Control increased to 75%. Resprouting within original clumps.

Carpetgrass
- Baseline Vegetation Conditions – Cover 75%. Sociability small and large clumps. Seeds opening.
  - First PTO – Control at 80%.
  - Second PTO – Control decreased to 75%.
  - Third PTO – Control remained at 75%.

**Morning glory**
- Baseline Vegetation Conditions – Cover 5%. Sociability individuals.
  - First PTO – Control at 60%.
  - Second PTO – Control decreased to 10%.
  - Third PTO – No data. Area was mowed.

**Sensitive Plant/Mimosa grass**
- Baseline Vegetation Conditions – Cover less than 1%. Sociability individual.
  - First PTO – Control at 35%.
  - Second PTO – Control decreased to 10%.
  - Third PTO – No data. Area was mowed.

**Plot #203 Treatment Solution 10: 30 oz Lineage Prep, 20 oz MSO**

**Haole koa**
- Baseline Vegetation Conditions – Healthy, emerging small brightly-colored leaves and active normal seed fall observed. Cover 35%. Sociability medium to large clumps.
  - First PTO – Control at 45%.
  - Second PTO – Control remained at 45%.
  - Third PTO – Control increased to 55%.

**Guinea grass**
- Baseline Vegetation Conditions – Cover 95%. Sociability large clumps. Heights 6 to 8 feet.
  - First PTO – Control at 30%. Grass falling over.
  - Second PTO – Control increased to 55%.
  - Third PTO – Control decreased to 45%.

**Carpetgrass**
- Baseline Vegetation Conditions – Cover 75%. Sociability large clumps.
  - First PTO – Control at 80%.
  - Second PTO – Control remained at 80%.
  - Third PTO – Control decreased to 20%. Mowed.

**Fireweed**
- Baseline Vegetation Conditions – Cover <1%. Sociability individuals.
  - First PTO – Control at 10%.
- Second PTO – Control remained at 10%.
- Third PTO – Control increased to 20%.

**Morning glory**
- Baseline Vegetation Conditions – Cover <1%. Sociability individuals. Growing on Haole koa.
- First PTO – Control at 20%.
- Second PTO – Control remained at 20%.
- Third PTO – Control remained at 20%.

**Java plum**
- Baseline Vegetation Conditions – Cover <1%. Sociability individuals.
- First PTO – Control at 20%.
- Second PTO – Control remained at 20%.
- Third PTO – Control increased to 30%.

**Plot #206 Treatment Solution 10: 30 oz Lineage Prep, 20 oz MSO**

**Guinea grass**
- Baseline Vegetation Conditions – Cover 95%. Sociability large clumps. Heights were 4 to 10 feet.
- First PTO – Control at 75%.
- Second PTO – Control remained at 75%.
- Third PTO – Control increased to 95%. No re-sprout. Dead grass still stands 4 to 10 feet high.

**Haole koa**
- Baseline Vegetation Conditions – Cover <1%. Sociability small to medium clumps.
- First PTO – Control at 70%.
- Second PTO – Control remained at 70%.
- Third PTO – Control decreased to 30%. Resprouting along main stem.

**Klu**
- Baseline Vegetation Conditions – Cover 25%. Sociability is small clumps. 5 to 6 feet in height.
- First PTO – Control at 35%.
- Second PTO – Control remained at 35%.
- Third PTO – Control increased to 85%.

**Java plum**
- Baseline Vegetation Conditions – Cover <1%. Sociability individual. One individual found.
- First PTO – Control at 30%.
• Second PTO – Control remained at 30%.
• Third PTO – Control increased to 90%.

Plot #207 Treatment Solution 8: 0.5 Velpar, 20 oz Lineage Prep, 13 oz MSO

Haole koa
• Baseline Vegetation Conditions – Cover 10%. Sociability individuals.
• First PTO – Control at 80%.
• Second PTO – Control remained at 80%.
• Third PTO – Control remained at 80%.

Klu
• Baseline Vegetation Conditions – Cover 15%. Sociability small to medium clumps.
• First PTO – Control at 35%.
• Second PTO – Control increased to 60%.
• Third PTO – Control increased to 65%.

Guinea grass
• Baseline Vegetation Conditions – Cover 95%. Sociability large clumps. Up to 9 feet in height.
• First PTO – Control at 95%.
• Second PTO – Control decreased to 85%.
• Third PTO – Control increased to 95%.

Plot #208 Treatment Solution 8: 0.5 Velpar, 20 oz Lineage Prep, 13 oz MSO

Haole koa
• Baseline Vegetation Conditions – Healthy, emerging small brightly-colored leaves and active normal seed fall observed. Cover 20%. Sociability medium large clumps.
• First PTO – Control at 90%.
• Second PTO – Control remained at 90%.
• Third PTO – Control increased to 100%.

Guinea grass
• Baseline Vegetation Conditions – Height 4 to 5 feet. Cover 45%. Sociability large clumps to nearly pure stands.
• First PTO – Control at 40%.
• Second PTO – Control remained at 40%.
• Third PTO – Control increased to 65%.

Klu
• Baseline Vegetation Conditions – Bright green leaves. Cover 5%. Sociability individuals and small clumps.
- First PTO – Control at 80%. Leaves fallen, brittle ends found. No resprouting.
- Second PTO – Control remained at 80%. Resprouting observed.
- Third PTO – Control decreased to 70%. Releafing.

**Carpetgrass**
- Baseline Vegetation Conditions – Cover 25%. Sociability, small clumps and individuals. Seeds opening.
- First PTO – Control at 60%.
- Second PTO – Control remained at 60%.
- Third PTO – Control increased to 80%.

**Plaintain grass**
- Baseline Vegetation Conditions – Cover <1%. Sociability individuals.
- First PTO – Control at 10%. Leaf margins browning.
- Second PTO – Control increased to 20%.
- Third PTO – Control decreased to 10%. Site mowed.

**Fireweed**
- Baseline Vegetation Conditions – Cover <1%. Sociability individuals.
- First PTO – Control at 20%.
- Second PTO – Control remained at 20%.
- Third PTO – No data. Area was mowed.

**Preliminary Conclusions:**

Control of all major target species was initially good, and remained satisfactory as indicated by extensive brown foliage. Guinea grass maintained satisfactory Control in all instances except Plot 203. Most other species showed some signs of recovery in certain areas during the review period. Further monitoring of these plots is recommended through January 2012 to measure response of this vegetative community.