Hawaiian Hoary Bat Tier 1 Mitigation Research Plan

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1.0 Introduction

The Nā Pua Makani Wind Project (Project) Habitat Conservation Plan (HCP) describes a mitigation program to compensate for potential Project take of 34 Hawaiian hoary bat (*Lasiurus cinereus semotus*) or ʻōpeʻapeʻa comprised of: 1) Habitat management efforts and 2) Research. Nā Pua Makani Power Partners, LLC (NPMPP) contracted Tetra Tech, Inc. (Tetra Tech) to develop detailed management and research plans associated with the mitigation components described under HCP Tier 1 Hawaiian hoary bat take levels for review and approval by the regulatory agencies and the Endangered Species Recovery Committee (ESRC). The Nā Pua Makani Hawaiian hoary bat Tier 1 Habitat Management Plan (Habitat Management Plan) describes the corresponding management plan (Tetra Tech 2024). This Research Plan leverages the actions of and habitat changes resulting from the Habitat Management Plan within the Poamoho Management Area (PMA). This Research Plan compares temporal habitat changes within control sites where ungulates are present and no or minimal invasive species management is performed to add depth to the understanding of the effects of the management actions (Tetra Tech 2024).

Based on input from the U.S. Fish and Wildlife Service (USFWS) and the Department of Land and Natural Resources (DLNR)—Division of Forestry and Wildlife (DOFAW) and supported by the recommendation for approval of the Project's HCP by the ESRC, the PMA of the DLNR ʻEwa Forest Reserve was selected as the appropriate location to carry out management efforts for the Hawaiian hoary bat. During the HCP approval process, the ESRC, USFWS, and DOFAW emphasized the importance of monitoring and tracking the effectiveness of management actions carried out at the PMA, as bat mitigation activities have not been performed in a largely intact, but simultaneously imminently threatened ecosystem before. As a result, the ESRC and regulatory agencies agreed that it was important to investigate, through supplemental research, the results of mitigation actions at the PMA. The Research Plan is intended to collect data that will help inform future habitat management decisions targeted to benefit the Hawaiian hoary bat. This additional focused research, as part of the mitigation effort described in the HCP, expands on the required basic effectiveness monitoring described in the Habitat Management Plan (Tetra Tech 2024).

2.0 Mitigation Framework

As described in Section 1.0, the Project's Tier 1 bat mitigation plan is comprised of two elements: the Habitat Management Plan (Tetra Tech 2024) and this Research Plan. These two elements work in tandem to achieve and document direct benefits to the Hawaiian hoary bat and to gather additional data on the mechanism for those benefits that should help guide the effective allocation of future management resources.

Based on input from USFWS and DOFAW during the development of the HCP, this blended approach is focused primarily on habitat management actions; however, given the novel threats and condition of the PMA, both agencies reinforced the importance of developing a more robust understanding of the effects of these actions than would be achieved through standard evaluative monitoring. The Habitat Management Plan (Tetra Tech 2024) specifically evaluates whether actions to protect and restore habitat and bat prey resources increase acoustic activity by Hawaiian hoary bats through an evaluative monitoring program. The Habitat Management Plan monitoring is designed to 1) document the increases in bat acoustic activity within the management area and 2) document increases in availability of prey species associated with changes in the vegetation community achieved through habitat management.

3.0 Research Approach

This Research Plan adds a control study to the Habitat Management evaluative monitoring program to increase understanding of how and when management efforts yield benefits. The primary objective of this study is to better understand in what way and how quickly habitat degradation affects arthropod communities that are important foraging resources for Hawaiian hoary bats. Specifically, this study investigates 1) the pace at which key invasive species modify biomass and diversity of arthropod communities once established, 2) how arthropod communities change in response to changes in the dominance of invasive species within a plot, 3) any correlations between documented environmental factors (e.g., elevation, slope) and the rate of establishment of invasive species or the rate of their expansion within plots, and 4) how active management and ungulate exclusion in an area influences observed changes.

This information should improve our understanding of the scale and timeline of habitat impacts (and associated impacts to bat prey) averted through the habitat management actions. Gaining this understanding should provide land managers information to help prioritize actions related to habitat management in relation to goals of contributing to Hawaiian hoary bat recovery. Finally, a detailed evaluation of site characteristics over time in the vicinity of an observed boundary—marking changes in the level of bat acoustic activity—may help reveal factors associated with these changes (Montoya-Aiona 2020, Montoya-Aiona et al. 2023).

4.0 Study Area

4.1 Site Description

The study area included in this Research Plan consists of two distinct areas: the PMA, which serves as the experiment site where habitat management will occur (and is included in the Habitat Management Plan (Tetra Tech 2024) and portions of the adjacent ʻEwa Forest Reserve and adjacent properties, which encompass the control site where habitat management will not occur. Both areas are primarily DLNR-owned forested habitat along the leeward summit of the central Koʻolau Mountains[1]. The PMA is located above Wahiawā in the ʻEwa Forest Reserve (Figure 1) and is

[1] The northern fencing unit of the PMA includes 70 acres on Kamehameha Schools' property within the Kawailoa Training Military Reservation.

proposed to be part of the state Natural Area Reserve System. Native, mid-elevation (490 – 730 meters above sea level) forest occurs in the PMA, but habitat-altering invasive plant species are present over significant areas, and prior to fence construction feral pigs (*Sus scrofa*) were a significant problem and remain a threat (Figure 2; Tetra Tech 2016). Pigs alter habitat, spread invasive species, and continue to degrade forest in unfenced portions of the ʻEwa Forest Reserve. The ʻEwa Forest Reserve provides habitat for the Hawaiian hoary bat and use of the PMA and the vicinity has been documented (Tetra Tech 2016, Thompson and Starcevich 2022). Ungulate-proof fences have been installed on two parcels, one 654 acres and the other 653 acres; combined these comprise the PMA. The protected PMA includes protection priority 1 watershed areas (DLNR 2011) and key native forest habitat that afford native plants and animals opportunities for protection through active management. DLNR is responsible for long-term management of the PMA and relies heavily on the Koʻolau Mountains Watershed Partnership (KMWP) to support management of the area.

Due to insecure funding and a high need for habitat protection and management throughout the Koʻolau Mountains, consistent financial commitments are necessary. Habitat management funding from the Project will ensure management of habitat and maintenance of fences for the PMA over the next eight years. This associated Research Plan will improve managers' understanding of the effects of management actions and management inaction on resources important to the conservation of the Hawaiian hoary bat.

4.2 Habitat Management Actions within the Poamoho Management Area

Habitat management actions that will be carried out as part of NMPP's Hawaiian hoary bat mitigation program include fencing repair and maintenance, ungulate removal (as required[2]), and habitat restoration, primarily through invasive plant species control. Out-planting of native plant species may be considered as part of the program to reduce the risk of erosion or otherwise accelerate benefits beyond those achievable through natural recruitment processes. Overall, the goals of these actions are to restore natural gap dynamics, open natural waterways, increase ecosystem diversity, and protect the PMA against on-going habitat degradation that would be anticipated without a long-term, stable, and secure funding source. By achieving these goals, NPMPP expects to observe increases in bat prey species abundance and diversity (e.g., Haddad et al. 2001, Taki et al. 2010). Changes in prey species are expected to coincide with increases in bat acoustic activity (Coleman and Barclay 2013, Frick et al. 2023). Habitat management actions will not occur outside of the PMA.

4.3 Vegetation Status

Habitat within the PMA and adjacent portions of the ʻEwa Forest Reserve are dominated by an intact, but imminently threatened, mesic to wet native ʻōhiʻa (*Metrosideros polymorpha*) forest. The area hosts the diverse array of native plants expected in mid-elevation mesic and wet forests on

[2] The fenced units within the PMA are ungulate free; however, periodic damage to the fence could allow pigs to access the area. Regular fence inspections and monitoring for ungulate activity will ensure that any incursions are identified promptly and the pigs are removed before causing significant damage.

Oʻahu (e.g., koa [*Acacia koa*], uluhe [*Dicranopteris linearis*] ʻōlapa [*Cheirodendron* spp.]), as well as significant populations of invasive plant species (e.g., mule's foot fern [*Angiopteris evecta*], strawberry guava [*Psidium cattleyanum*], and manuka [*Leptospermum scoparium*]). Incipient populations of other habitat-modifying weeds such as albizia (*Falcataria falcata*) and cane tibouchina (*Chaetogastra herbacea*) also occur in the area. Though these numbers are currently low, active management is needed to ensure that populations do not grow beyond controllable levels.

4.4 Hawaiian Hoary Bat Status

With limited data collection, Hawaiian hoary bat acoustic activity has been documented within the PMA at relatively low rates. During a 30-day deployment of one acoustic monitor (April 14, 2014 – May 13, 2014) one bat was detected (April 22, [pregnancy reproductive period]) (Tetra Tech 2016)[3]. Similarly, during a series of deployments of acoustic detectors with one to two-week sampling periods (672 detector nights and 8,064 detector hours) from December 2019 to March 2020 at 80 sites in the vicinity of the PMA, only 39 detections were recorded, with most of the detections (15) in grazed grassland habitat; ungrazed evergreen forest had 11 detections (Davidson 2020). Results from an island-wide acoustic monitoring research project suggests a generally low occupancy rate at the upper elevation of the PMA (average 0.0164 detections/detector-night June 2017 – October 2021) with detections concentrated in the lactation (mid-June – August) and post-lactation (September – mid-December) seasons (Site-046 in Thompson and Starcevich 2022). Another nearby site at a lower elevation (Site-055) included a higher activity rate (0.0398 detections/detector night) and showed a similar temporal distribution of activity (Thompson and Starcevich 2022). Results from the detectors distributed more broadly within the Koʻolau Mountains suggest that bats are likely present at low levels throughout the year with the lowest occupancy rates occurring during the pregnancy season (April – mid-June). Closer scrutiny than achievable in a project on the scale of Thompson and Starcevich (2022) is likely to reveal significantly more detail on the occupancy rates, seasonality, and habitat preferences of the Hawaiian hoary bat within the PMA and more broadly in the central Koʻolau Mountains.

Within the context of the Hawaiian hoary bat island-wide acoustic monitoring study, Thompson and Starcevich (2022) suggests the central Koʻolau Mountains is situated on the southern and eastern edge of the region within which the majority of Hawaiian hoary bat detections occur. Specifically, results from Thompson and Starcevich (2022) found higher detection rates in the northern Waianae and northern Koʻolau Mountains and generally in northwestern Oʻahu.

[3] Summary data only in Tetra Tech (2016).

5.0 Materials and Methods

Bat prey and vegetation conditions will be tracked at nine monitoring plots (control plots) distributed randomly but considering logistical factors and capturing a range of initial conditions relative to level of establishment of target invasive species in the control plots.

5.1 Planned method

Nine 0.5-hectare (20 meter x 25 meter) control plots will be established outside but proximate to the PMA (Figure 3). Initial delineation of the plots will include the establishment of photo points at the plot's corners and the collection of baseline data including GPS location, invasive vegetation cover, slope, and elevation. Control plots will be delineated by the degree of invasive vegetation cover to evaluate its effect on arthropod abundance (Emery and Doran 2013). Three control plots will contain no observed presence of mule's foot fern, strawberry guava, manuka, or Mollucan albizia (invasive species deemed likely to form large monotypic habitat altering stands), serving as an initial condition of "native forest." Three control plots will include areas where one of these invasive species are established but have not yet dominated the vegetation community, representing and initial condition of "established invasive species" (ground or canopy cover < 5 percent[3]). Three control plots will include areas where the selected invasive species is dominant within the vegetation community (ground or canopy cover > 30 percent[4]), serving as an initial condition of "invasive species dominated." Plot locations meeting the habitat selection criteria above and safety and logistical requirements will be identified within randomly selected grid cells covering the PMA control plot buffer (Figure 3). Logistics, including implementation of practices to avoid spreading invasive plant species, will require grouping of control plots into clusters to allow monitoring of 3 – 4 individual plots per day. To ensure independence, control plot locations will be at least 200 meters apart.

5.2 Alternative method

Should the proposed control plot layout prove impractical in the field due to terrain (e.g., plot size/shape not allowing for safe and practicable collection of data on a regular basis) or vegetation density (e.g., dense patches of uluhe which could be damaged through the regular collection of monitoring data), control plots will be modified to be linear transects. Ultimately, all plots will be of the same type (linear or rectangular), including evaluative monitoring plots proposed in the

[4] Percentages are approximate values, subject to adjustment based on identification of ranges found within otherwise suitable monitoring plots. Choice of ground cover or canopy cover as measure of species dominance is dependent on species. For example, strawberry guava stands only come to dominate ground cover through leaf litter, and this is not common at the elevations associated with the PMA. In the vicinity of the PMA canopies dominated by strawberry guava often have associated understories dominated by Koster's curse (*Clidemia hirta*), a species deemed "beyond control" by management agencies. Mollucan albizia's dominance similarly exerts its influence at the canopy level, resulting in the transition of understory to bare earth or invasive groundcover species.

Management Plan (Tetra Tech 2024). The decision on which approach to use will be based on a preliminary site visit upon the approval of the Management Plan and Research Plan.

The alternative linear transect plots would be 100 meters long and allow for the same sampling and data collection protocols. In this case all work would be performed from a flagged central transect line and sampling would be limited to 2.5 meters on either side of the transect line (5-meter survey buffer). Five photo points would be established along the transect path at regular intervals: 0, 20, 40, 60, and 80 meters.

5.3 Plot locations and sampling schedule

Control plots will be distributed outside the southern, western, and northern boundaries of the PMA (habitat east of the PMA abruptly changes to sheer cliffs and is substantially different than within the PMA so has been excluded). These sites may be located on the ʻEwa Forest Reserve or other within areas managed and owned by other cooperating entities (i.e., Army Natural Resources Program of Oʻahu and Kamehameha Schools) (Figure 3). The specific locations will be selected within a 400-meter buffer of the perimeter fence (Figure 3), but potential sites may be excluded based on accessibility[5], logistical considerations, landowner restrictions, habitat selection criteria, and similarity in forest structure and elevation to evaluative monitoring plots selected in the PMA (Tetra Tech 2024). Control plot locations meeting the criteria above will be identified within randomly selected grid cells. The goal is to identify a distributed set of control plots where invasive species management levels are reduced from those within the PMA and feral ungulates have access but where forest conditions are otherwise like the evaluative monitoring plots identified for the Habitat Management Plan (Tetra Tech 2024). Based on available data from KMWP (Figure 2), the primary invasive species present in these control plots is expected to be mule's foot fern; however, the overall presence of a range of invasive species cover values within control plots will be measured.

Arthropod sampling will occur four times a year in each monitoring year (Years 1, 3, 5, and 8), matching the timing of arthropod sampling within the evaluative monitoring plots (Tetra Tech 2024). Timing of quarterly sampling will be consistent across all sampling years and align with bat reproductive periods as defined by Gorresen et al. (2013): lactation (mid-June to August), post-lactation (September to mid-December), pre-pregnancy (mid-December to March), and pregnancy (April to mid-June). Vegetation sampling will occur once annually each monitoring year in Years 1, 3, 5, and 8 during the peak blooming period for annual vegetation (April to June), matching the timing of the vegetation sampling within the evaluative monitoring plots (Tetra Tech 2024). Photos will be taken at the established photo points for each control plot, and sampling will include:

- Plants
    - Invasive plant species absolute percent cover
    - Plant species richness
- Arthropods

[5] Proximity to landing zones or trails and allowing safe and regular access to perform required monitoring.

- Diversity
- Abundance (i.e., biomass)

5.4 Vegetation monitoring

This section initially describes how the planned method (see Section 5.1) would be used to monitor vegetation in control plots in the vicinity of the PMA. A second section describes how that sampling approach would be adjusted if the alternative sampling plot approach (see Section 5.2) is used.

5.4.1 Planned method

Plant species richness and invasive plant species absolute cover will be evaluated within control plots using the methods described within this section and consistent with the methods and timing described in the Habitat Management Plan(see Section 5.0 and Tetra Tech 2024). Control plots differ from evaluative monitoring plots within the PMA. Control plots will not undergo habitat management whereas evaluative monitoring plots within the PMA will be managed consistent with habitat management practices deployed throughout the PMA.

To measure invasive plant species absolute percent cover, the relative area covered by each invasive species will be estimated in ten 1-meter^2 quadrats located around the boundary of each control plot (approximately 9 meters apart; Figure 4). Bonham (2013) and KMWP staff were consulted to determine if the sampling design would be suitable for quantifying invasive species absolute percent cover. Given the relative abundance of mule's foot fern in the PMA and adjacent area, Tetra Tech determined that the sampling design would adequately differentiate and track changes in amounts of invasive species cover over time. Invasive plant species absolute percent cover will be averaged for each of the individual nine control plots based on the species cover in each of the ten quadrats within each control plot.

To measure plant species richness in each control plot, all individual species (includes trees, shrubs, grasses, and ferns) will be counted in ten 1-meter^2 quadrats located around the boundary of each control plot (same plots used to estimate invasive plant species absolute percent cover, above) (e.g., Keeley and Fotheringham 2005, Young and Johnstone 2011). Plant species richness values from each quadrat will be averaged for each of the nine control plots. A supplemental search will be conducted in each control plot following invasive plant species and plant species richness data collection to identify any plant species that did not occur within the quadrats and will be added to species richness measurements for each control plot. The supplemental search will be a 15-minute to one-hour effort providing meandering survey coverage over the remainder of the control plot (Huebner 2007, Young and Johnstone 2011, Bourdaghs 2014).[6] This will ensure a consistent level of effort among control plots.

[6] If no new species are added and coverage of the entire control plot is complete within 15 minutes, the supplemental search will end. If new species are added, additional time will be added up to one hour or until the entire control plot has been surveyed.

5.4.2 Alternative method

Under the linear transect monitoring approach sampling quadrats would be positioned adjacent to, but outside, the foot trail forming the transect and located at: 5, 15, 25, 35, 45, 55, 65, 75, 85, and 95 meters from the transect starting point. Sampling outside of the quadrats for other plant species would occur within the 5-meter survey buffer along the 100-meter long transect. In all other respects, vegetation sampling protocols would match those described in section 5.4.1.

5.5 Bat prey monitoring

This section initially describes how the planned method (see Section 5.1) would be used to monitor bat prey in control plots in the vicinity of the PMA. A second section describes how that sampling approach would be adjusted if the alternative sampling plot approach (see Section 5.2) is used.

5.5.1 Planned method

Arthropods will be sampled in each control plot using two methods: a light trap or malaise trap and sweep nets or a vacuum aspirator. Each sampling method is best suited for certain taxa, and the use of multiple sampling methods may give more complete results than the use of a single method (McCravy 2018). Light traps are an extremely common and efficient trapping method, attracting insects towards the light where they are funneled into a collection container. Malaise traps are large tent like structures made of netting that funnel insects into a common area (Montgomery et al. 2021) Both light traps and malaise traps target flying insects, such flies (Diptera), wasps, flying ants, bees (Hymenoptera), true bugs (Hemiptera), moths (Lepidoptera) (Montgomery et al. 2021). The malaise trap would be modified to include a collection reservoir (e.g., a pan with collecting liquid) at the bottom as well as the top to ensure beetles are collected (DOFAW pers. comm May 25, 2023). Spatial placement is extremely important for both of these trap types given that light traps are only effective at a distance of less than 30 meters (Truxa and Fiedler 2012) and malaise traps must be within the flight path of the insect (Montgomery et al. 2021).

Vacuum aspirators and sweep nets collect insects directly from vegetation, capturing both flying and non-flying insects, and can also be used to collect epigeic (i.e., live on the soil surface) arthropods (McCravy 2018). Both sweep nets and vacuum aspirators have been found to result in similar species richness, however the mean size of invertebrate biomass was greater for sweep netting than vacuum sampling. Vacuum sampling was more effective at collecting small (less than 5 cm) invertebrates, whereas sweep netting captured large (greater than 5 cm) Orthoptera and Lepidoptera larvae at higher rates (Doxon et al. 2010).

Collection using sweep nets or vacuum aspirators will be conducted along five parallel 20 meter transects, approximately 1 meter wide, spaced 5 meters apart (Figure 4) over the course of one day. Malaise traps or light traps will be placed at the center of each of the control plots (Figure 4). Malaise traps would operate for one to two weeks per quarterly sampling period and light traps would operate two to three nights per quarterly sampling period. All samples collected will be combined for each control plot. Arthropods collected during each sampling period with a body length ≥ 5 millimeters will be sorted to order, size, and oven-dried for 48 hours at 65°C (Gorresen et al 2018). Size classifications with include ≥ 5 to 10 millimeters, >10 to 20 millimeters, and > 20 millimeters. Biomass was chosen as it has shown to be a better response variable when investigating trophic interactions and can provide a more accurate picture of the processes driving changes in community structure (Saint Germain et al 2007).

5.5.2 Alternative method

Under the linear transect monitoring approach sweep net or vacuum aspirator sampling would occur along the entire 100-meter long transect. The Malaise trap or light trap would be positioned at approximately at the mid-point (50 meters) of the 100-meter long transect. In all other respects, insect sampling protocols would match those described in section 5.5.1.

5.6 Roles and Responsibilities

The division of responsibilities shown in Table 1 is based on NPMPP's intent to contract with KMWP to conduct fieldwork with oversight from Tetra Tech.

Table 1. Anticipated Responsibilities by Entity

Tetra Tech	KMWP	NPMPP
Implementation management	Responsible for all monitoring	Coordination with Tetra Tech and KMWP
Lead initial control plot establishment in Year 1	Initial control plot establishment assistance in Year 1	Review annual reports
Lead initial insect prey trap set up in Year 1	Assist with initial insect prey trap set up in Year 1	Review of adaptive management actions, if needed
Training on implementation protocols	Lead quarterly bat prey monitoring and yearly vegetation monitoring in Years 1, 3, 5, and 8	
Quarterly check-in site visits during Year 1 to ensure that implementation is proceeding as intended, perform troubleshooting as needed	Provide quarterly data summary for annual reporting	
Author annual report	Complete adaptive management responses as identified and funded	
Provide desktop and field support as needed for adaptive management		

5.7 Best Management Practices

Management staff will implement the best management practices below to prevent the introduction and spread of alien plants, animals, insects, and forest pathogens within the PMA. Risk will be minimized by regular and thorough cleaning of field gear between deployments and limiting deployments to smaller areas within the PMA. When moving between different parts of the PMA is required in a single deployment, especially if moving from heavily infested areas to more native areas, new field gear will be used to minimize the risk of spreading invasive species.

Footwear - Daily

- Spray down boots or tabis with hose removing excess mud and debris from tread, spikes, laces, and tongue as well as between the toes of tabis
- Scrub outside of boots or tabis with stiff brush to remove finer particles focusing on tread of boot and tabis as well as inner Velcro of tabis
- Spray boots or tabis again to rinse off last of debris as well as spray out inside of footwear
- Repeat if necessary if lingering mud or seeds remain
- Hang to dry and spray with 70 percent isopropyl alcohol

Field Tools - Daily

- Spray heads and body or handle of tools with hose to remove accumulated mud and plant material
- Scrub head until clean
- Spray down once more to rinse
- Hand tools and chainsaws shall be wiped down with 70 percent isopropyl alcohol. The chain shall be removed and soaked in 70 percent isopropyl alcohol for ten minutes.

Backpacks and Clothing – No schedule

- Remove everything from inside of backpack and any side pockets
- Hang from secure location and spray inside and outside of pack with hose making sure to spray out any tucks and folds in the backpack material
- Scrub areas with seams with stiff brush
- Spray with hose once more to rinse
- Clothes will be cleaned, washed, and dried in a dryer.

Trucks – Weekly (or when moving from heavily infested areas to less infested areas)

- Wash exterior of trucks with soap and water
- Spray undercarriage with high pressure hose to remove accumulation of mud and debris
- Remove any floor mats and wash with soap and water
- Vacuum out interior of trucks

6.0 Analysis

This Research Plan uses data from the Habitat Management Plan (Tetra Tech 2024), supplemented by the addition of control plots to compare the changes in invasive plant and arthropod communities within and outside the PMA over time. These analyses should help inform how areas where management levels are reduced and feral ungulates are present evolve in comparison to areas with more intensive management and no ungulates.

An Analysis of Covariance (ANCOVA) will be conducted on data from the nine plots outside of the PMA described here (control plots) and the 15 plots within the PMA and subject to the beneficial actions described in the Habitat Management Plan (evaluative monitoring plots; Tetra Tech 2024). This analysis will compare the effects of that habitat degradation, through the impacts of invasive species, on arthropod biomass and richness within the PMA versus outside the PMA. Year, initial status, inside PMA/outside PMA treatments will be the main effects while invasive plant species cover, plant species richness, slope, and elevation will be covariates. A PERMANOVA (Anderson 2001) will be used to compare arthropod and invasive plant community composition among site initial conditions and inside PMA/outside PMA treatments over time. Canonical analyses of principal coordinates (CAP; Anderson and Willis 2003) will be used to visualize how arthropod and invasive plant communities shifted.

7.0 Benefit to bats

Understanding how plant communities and associated Hawaiian hoary bat prey evolve in the absence of intensive management (e.g., removal of invasive plants and exclusion of ungulates) will provide information relevant to habitat management decision-making associated with the goals of protection and recovery of the Hawaiian hoary bat. This information in combination with results from the Habitat Management Plan monitoring (Tetra Tech 2024) should help land managers prioritize actions to benefit the Hawaiian hoary bat and better understand how to prioritize actions in native forest that is significantly impacted by invasive species. The granularity of detailed field studies such as this can illuminate important aspects of life history and related ecological processes that are important to identifying effective habitat management tools for specific sites. This study specifically provides an opportunity to improve our understanding of how habitat and bat prey interact with and without management actions, as well as the role invasive species management can have on improving the availability of bat prey in a native-dominated, but imminently threatened forest environment.

8.0 Adaptive Management

The Research Plan is subject to field conditions that may affect specific field protocols (e.g., the planned quadrat size), the comparability of data over time, or significantly change conditions at one or more of the evaluative monitoring or control plots. NPMPP will coordinate closely with KMWP throughout the implementation of the Research Plan (and the associated Habitat Management Plan) to ensure potential issues are minimized, and monitoring and data collection methodologies are consistent in areas with and without ungulates. However, if conditions within the evaluative monitoring or control plots change such that they significantly impact the ability of NPMPP to collect data, or the potential analysis or interpretation of research results, NPMPP will work with the USFWS and DOFAW to identify a suitable approach to adjust the research study design. In addition, if adaptive management triggers additional monitoring in the management area due to not meeting the success criteria, additional monitoring would also occur in the control site.

Such adjustments could include the incorporation of alternative analysis procedures, the addition, elimination, or substitution of evaluative monitoring or control plots, or other adjustments identified based on the specific conditions being addressed.

9.0 Budget

The estimated combined budget for habitat monitoring at the PMA and the control site is shown in Table 2. Based on varying levels of effort required to conduct evaluative and research monitoring, Tetra Tech estimates three quarters of monitoring (staffing, materials, reporting, and analysis costs) are attributable to the Management Plan and one quarter of the costs are attributable to the Research Plan (Tetra Tech 2024). This cost distribution accounts for additional analysis and field work associated with bat acoustic monitoring work in the PMA and the lower number of control plots. This categorization results in an estimate of $177,178 in research funding, exceeding the $100,000 in research funding required by the Project HCP for Tier 1 bat mitigation. Year 1 costs are significantly greater due to one-time only labor costs associated with set up of the monitoring plots and the purchase of monitoring equipment. If adaptive management is required, additional costs may result.

Table 2. Estimated Budget for Habitat Monitoring, Analysis, and Reporting

Description	Entity	Year 1 Total[1]	Years 3, 5, 8 Total (Annual)[1]
Salaries and Fringe Benefits (Intermittent)	KMWP	$49,200	$43,200
Salaries and Fringe Benefits (3 partial FTE)	Tetra Tech	$111,381	$33,851
Subtotal (staffing)		**$160,581**	**$77,051**
Helicopter (41 days Year 1/36 days Years 3, 5, 8)	KMWP	$47,338	$36,067
Bat acoustic detectors (15)	Tetra Tech	$22,500	$3,000
Insect traps (15)	Tetra Tech	$1,500	--
Other materials and supplies	Tetra Tech & KMWP	$1,500	$500
Vehicle use, fuel, maintenance	KMWP	$5,000	$5,000
Training	KMWP	$1,300	$1,300
Travel	Tetra Tech & KMWP	$10,538	$3,360
Utilities	KMWP	$1,500	$1,500
PCSU administration	KMWP	$7,261	$5,073
Overhead	KMWP	$11,546	$9,600

Description	Entity	Year 1 Total[1]	Years 3, 5, 8 Total (Annual)[1]
Subtotal (materials, transport, and administration)		**$109,983**	**$65,400**
Hawaiʻi GET	Tetra Tech	$5,757	$1,679
Grand Total		**$276,321**	**$144,130**
[1] Amount includes management and research plan costs combined			

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Figures

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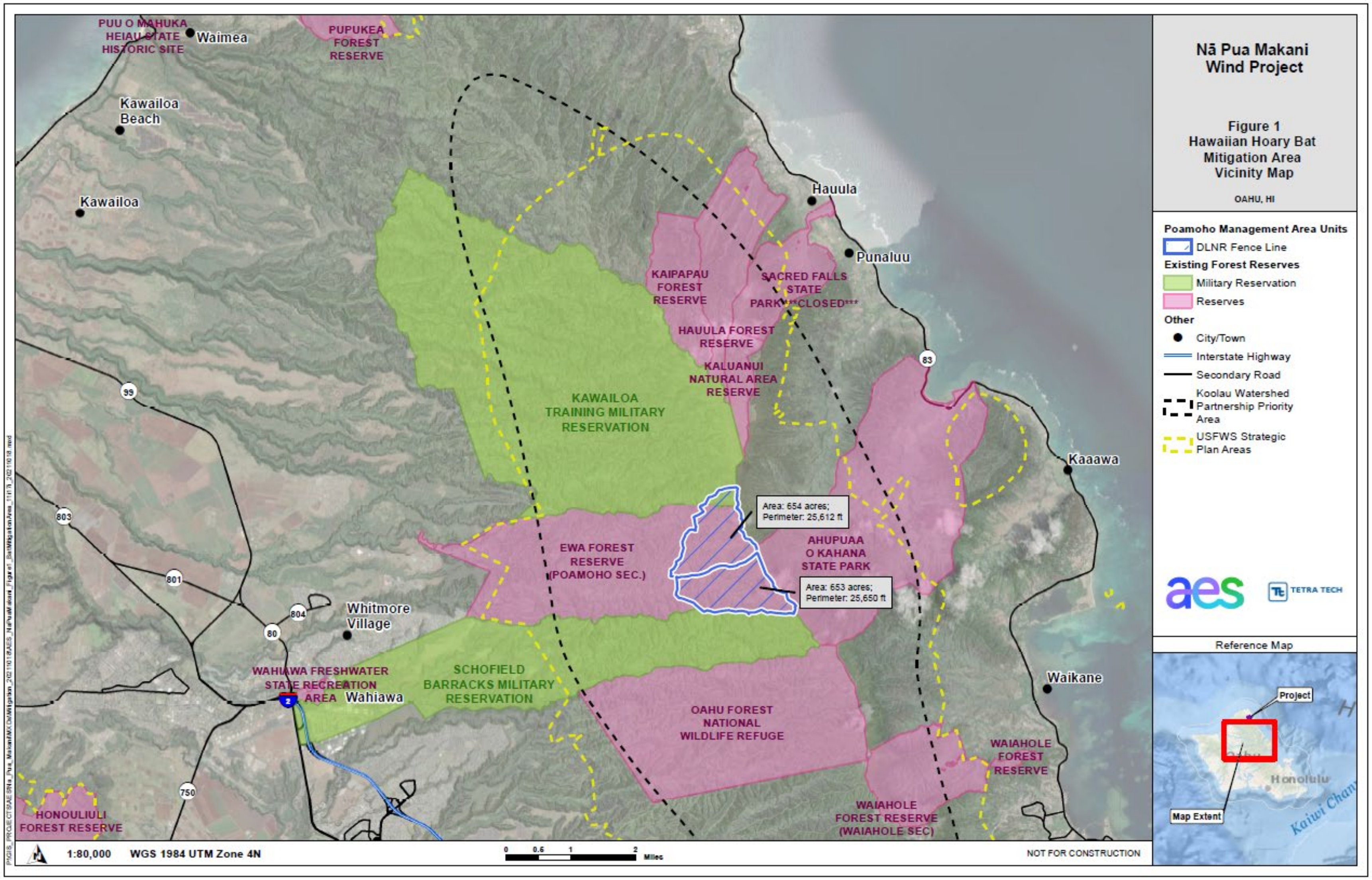
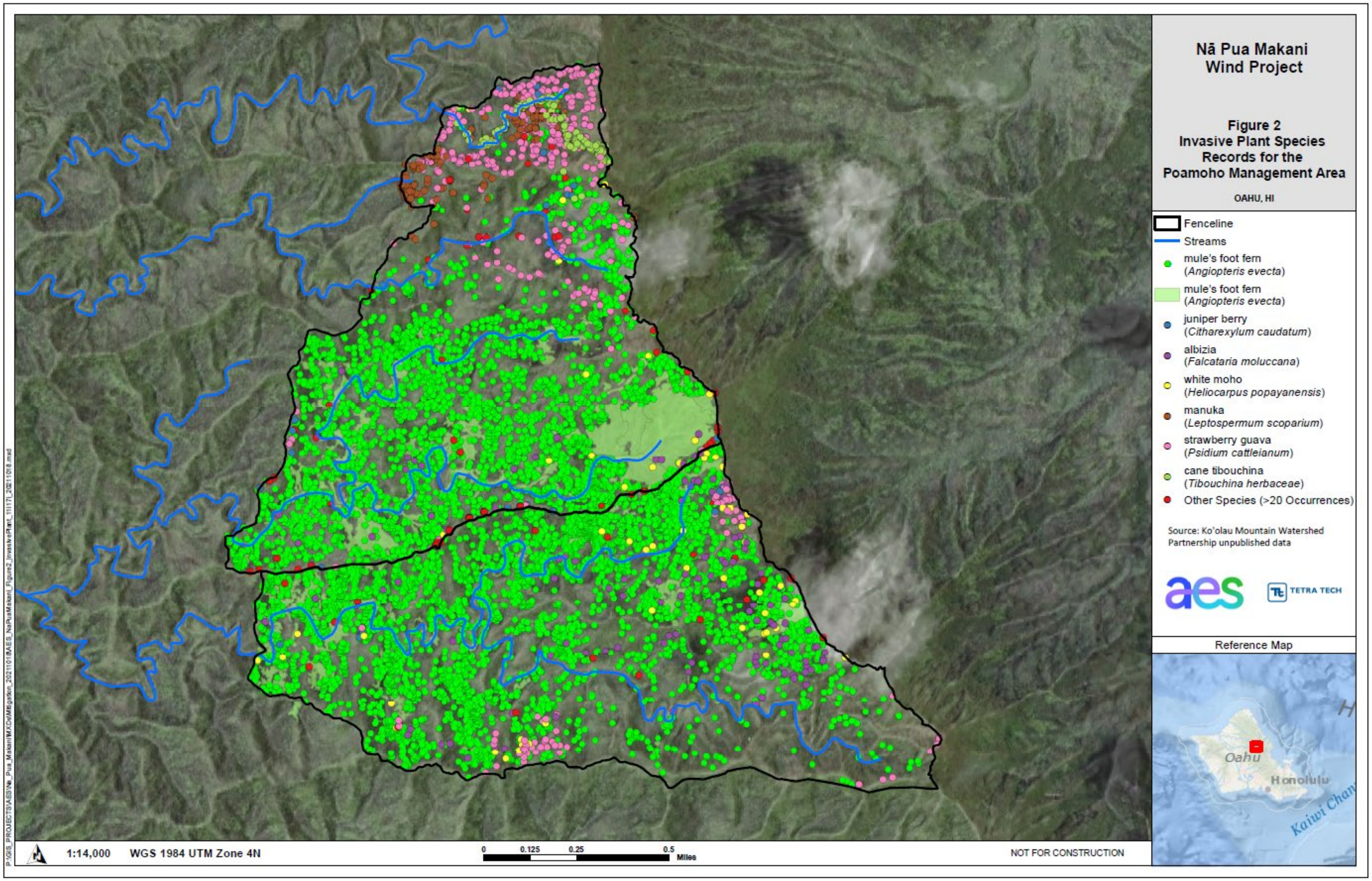
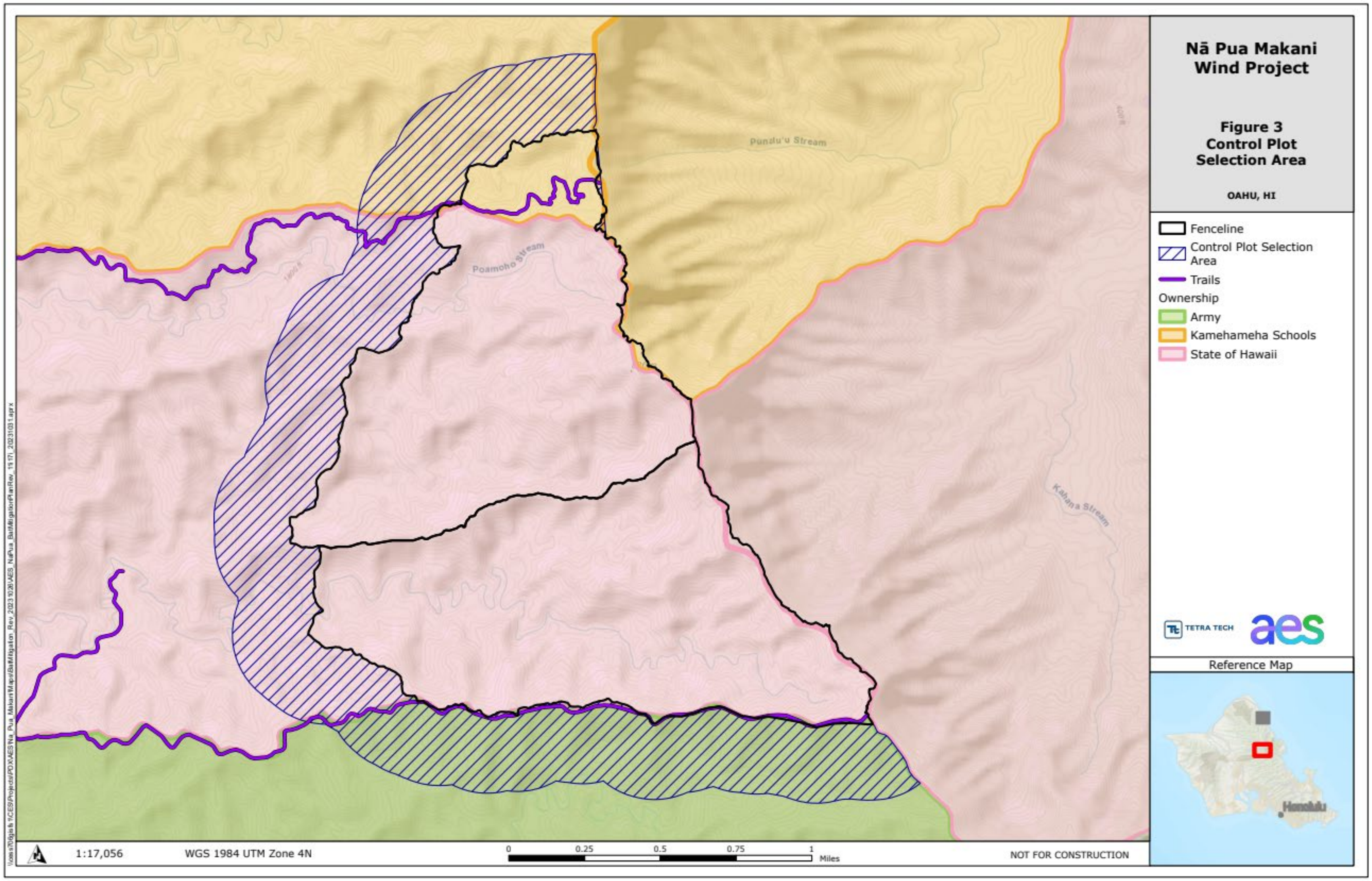

PUU O MAHUKA HEIAU STATE HISTORIC SITE
Waimea
PUPUKEA FOREST RESERVE
Kawailoa Beach
Kawailoa
Hauula
Punaluu
KAIPAPAU FOREST RESERVE
SACRED FALLS STATE PARK ***CLOSED***
HAUULA FOREST RESERVE
KALUANUI NATURAL AREA RESERVE
KAWAILOA TRAINING MILITARY RESERVATION
Kaaawa
Area: 654 acres; Perimeter: 25,612 ft
EWA FOREST RESERVE (POAMOHO SEC.)
AHUPUAA O KAHANA STATE PARK
Area: 653 acres; Perimeter: 25,650 ft
Whitmore Village
WAHIAWA FRESHWATER STATE RECREATION AREA
Wahiawa
SCHOFIELD BARRACKS MILITARY RESERVATION
OAHU FOREST NATIONAL WILDLIFE REFUGE
Waikane
WAIAHOLE FOREST RESERVE
WAIAHOLE FOREST RESERVE (WAIAHOLE SEC)
HONOULIULI FOREST RESERVE
1:80,000
WGS 1984 UTM Zone 4N
Miles
NOT FOR CONSTRUCTION
Nā Pua Makani Wind Project
Figure 1
Hawaiian Hoary Bat Mitigation Area Vicinity Map
OAHU, HI
Poamoho Management Area Units
DLNR Fence Line
Existing Forest Reserves
Military Reservation
Reserves
Other
City/Town
Interstate Highway
Secondary Road
Koolau Watershed Partnership Priority Area
USFWS Strategic Plan Areas
TETRA TECH
Reference Map
Project
Honolulu
Map Extent


Nā Pua Makani Wind Project
Figure 2
Invasive Plant Species Records for the Poamoho Management Area
OAHU, HI
Fenceline
Streams
mule's foot fern (Angiopteris evecta)
mule's foot fern (Angiopteris evecta)
juniper berry (Citharexylum caudatum)
albizia (Falcataria moluccana)
white moho (Heliocarpus popayanensis)
manuka (Leptospermum scoparium)
strawberry guava (Psidium cattleianum)
cane tibouchina (Tibouchina herbaceae)
Other Species (>20 Occurrences)
Source: Ko'olau Mountain Watershed Partnership unpublished data
aes
TETRA TECH
Reference Map
Oahu
Honolulu
1:14,000
WGS 1984 UTM Zone 4N
0
0.125
0.25
0.5
Miles
NOT FOR CONSTRUCTION



Nā Pua Makani
Wind Project
Figure 3
Control Plot
Selection Area
OAHU, HI
Fenceline
Control Plot Selection Area
Trails
Ownership
Army
Kamehameha Schools
State of Hawaii
Reference Map
Punalu'u Stream
Poamoho Stream
Kahana Stream
1:17,056
WGS 1984 UTM Zone 4N
0
0.25
0.5
0.75
1
Miles
NOT FOR CONSTRUCTION

Figure 4. Example Planned Monitoring Plot Layout