

# **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 'ōpe'ape'a 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 2023). 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 2023).

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 'Ewa 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 2023).

## 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 2023) 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 2023) 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 2020)) and portions of the adjacent 'Ewa 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 Ko'olau Mountains<sup>1</sup>. The PMA is located above Wahiawā in the 'Ewa Forest Reserve (Figure 1) and

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<sup>1</sup> The northern fencing unit of the PMA includes 70 acres on Kamehameha Schools' property within the Kawaihoa Training Military Reservation.

is proposed to be part of the state Natural Area Reserve System. Native, high-elevation 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 'Ewa Forest Reserve. The 'Ewa Forest Reserve provides habitat for the Hawaiian hoary bat and use of the PMA and the vicinity has been documented (Tetra Tech 2016, Starcevich et al. 2020). 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 Ko'olau 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 Ko'olau 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<sup>2</sup>), 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 'Ewa Forest Reserve are dominated by an intact, but imminently threatened, mesic to wet native 'ōhi'a (*Metrosideros polymorpha*) forest. The area hosts the diverse array of native plants expected in mid-elevation mesic and wet forests on O'ahu (e.g., koa [*Acacia koa*], uluhe [*Dicranopteris linearis*] 'ōlapa [*Cheirodendron* spp.]), as well as

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<sup>2</sup> 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.

significant populations of invasive plant species (e.g., mule’s foot fern [*Angiopteris evecta*], strawberry guava [*Psidium cattleianum*], 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

Hawaiian hoary bats have been detected within the PMA (Tetra Tech 2016, Starcevich et al. 2020). Preliminary results from an island-wide acoustic monitoring research project suggests a generally low occupancy rate (average 0.0153 detections/detector-night June 2017 – October 2019) with detections limited to the lactation (mid-June – August) and post-lactation (September – mid-December) seasons (Starcevich et al. 2020). Results from the detectors distributed more broadly within the Ko’olau 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 Starcevich et al. (2020) 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 Ko’olau Mountains.

Within the context of the Hawaiian hoary bat island-wide acoustic monitoring study, Starcevich et al. (2020) suggests the central Ko’olau Mountains is situated on the southern and eastern edge of the region within which the majority of Hawaiian hoary bat detections occur. Specifically, preliminary results from Starcevich et al. 2020 found higher detection rates in the northern Waianae and northern Ko’olau Mountains and generally in northwestern O’ahu.

## 5.0 Materials and Methods

Fifteen 0.5-hectare (20 meter x 25 meter) monitoring plots (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). Five 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.” Five control plots will include areas where one of these invasive species are established but have not yet dominated the vegetation community, representing an initial condition of “established invasive species” (ground or canopy cover < 5 percent<sup>3</sup>). Five control plots will include areas where the selected invasive species is dominant within the vegetation community (ground or canopy cover > 30 percent<sup>3</sup>),

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<sup>3</sup> 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



serving as an initial condition of “invasive species dominated.” The invasive species that contributes most significantly to control plot invasive species cover will be based on the control plot selection. Selected control plots will meet the required range of invasive infestation, be in areas proximate to the PMA to facilitate monitoring, and similar in other aspects (e.g., elevation and forest structure) to the evaluative monitoring plots within the PMA (Tetra Tech 2023).

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 ‘Ewa Forest Reserve or other within areas managed and owned by other cooperating entities (i.e., Army Natural Resources Program of O‘ahu and Kamehameha Schools) (Figure 3). The specific locations will be selected within a 0.4-kilometer buffer of the perimeter fence (Figure 3), but potential sites may be excluded based on accessibility<sup>4</sup>, landowner restrictions, habitat selection criteria, and similarity in forest structure and elevation to evaluative monitoring plots selected in the PMA (Tetra Tech 2023). Control plot locations meeting the criteria above will be identified within randomly selected grid cells covering areas within a 400-meter buffer of the PMA boundary. 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 2023). 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 2023). 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 2023). 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

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.

<sup>4</sup> Proximity to landing zones or trails and allowing safe and regular access to perform required monitoring.

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

## 5.1 Vegetation monitoring

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 2023). 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<sup>2</sup> 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 15 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<sup>2</sup> 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 15 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).<sup>5</sup> This will ensure a consistent level of effort among control plots.

## 5.2 Bat prey monitoring

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

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<sup>5</sup> 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.

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 as 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  $\geq 5$  millimeters will be sorted to order, size, and oven-dried for 48 hours at 65°C (Gorresen et al. 2018). Size classifications will include  $\geq 5$  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).

### **5.3 Analysis**

This Research Plan uses data from the Habitat Management Plan (Tetra Tech 2023), 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 understand 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 15 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 2023). This analysis will compare the effects of that habitat degradation, through 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.

## **6.0 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 2023) 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.

## **7.0 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 DOW to identify a suitable approach to adjust the research study design.

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.

## **8.0 Budget**

Table 1 describes costs for research tasks independent of the evaluative monitoring and reporting associated with the Habitat Management Plan (Tetra Tech 2023).

**Table 1. Hawaiian Hoary Bat Research Budget**

Task	Description	Cost
<b>Periodic Assessment (Annual Costs in Years 1, 3, 5, 8)</b>		
Field Work	Arthropod collection, vegetation assessment	\$17,000 (\$21,000 in Year 1) <sup>1</sup>
Lab Work	Arthropod analysis	\$8,000
Analysis and Reporting	Statistical analysis and report preparation	\$6,000
<b>Final Assessment (One-Time Cost)</b>		
Analysis and Reporting	Statistical analysis and final report preparation	\$8,000
<b>Total Cost</b>		
Overall Cost	4 monitoring years and final assessment	\$136,000
1. Year 1 costs are expected to be \$4,000 higher to identify and establish control plots.		

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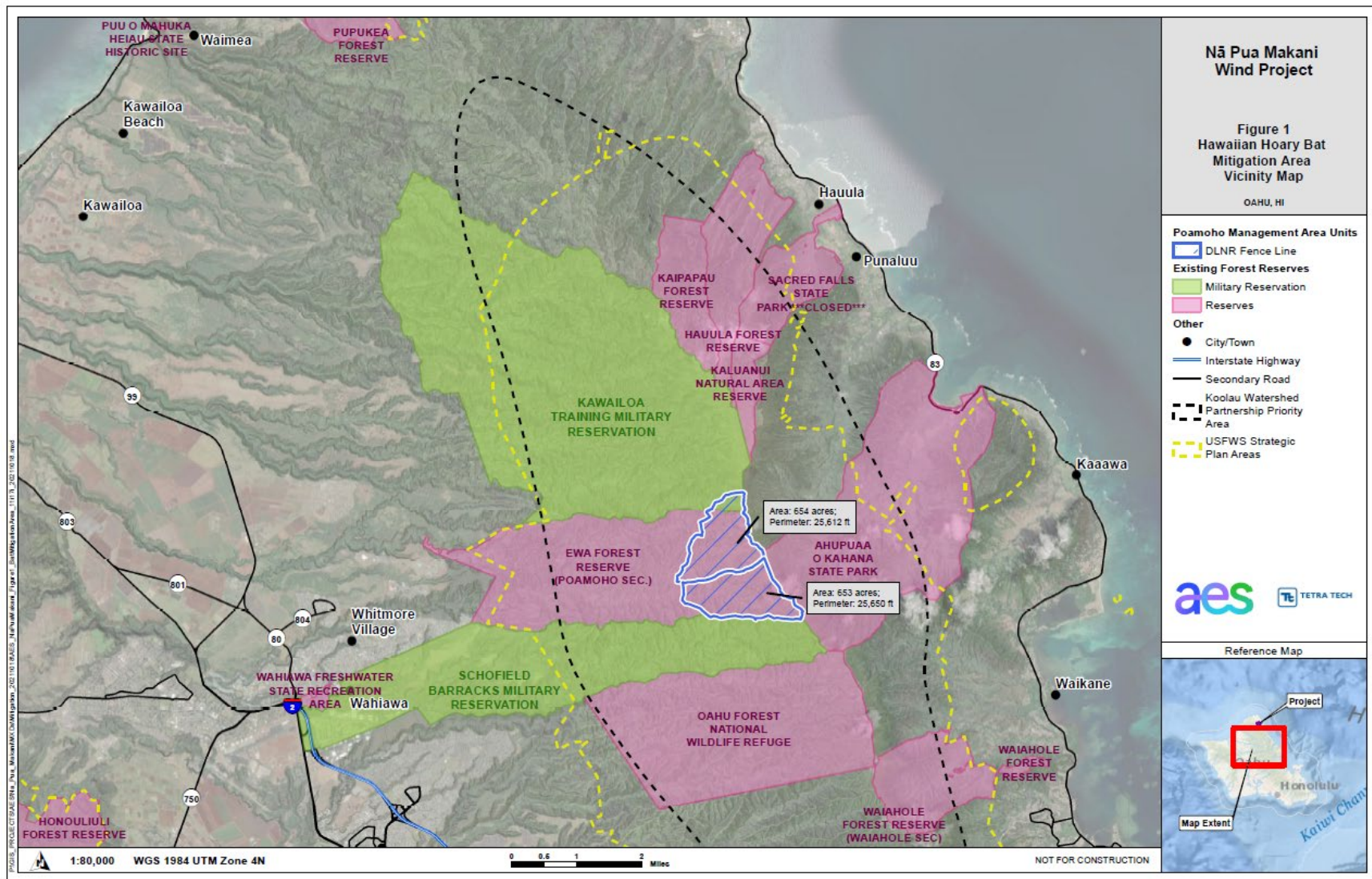
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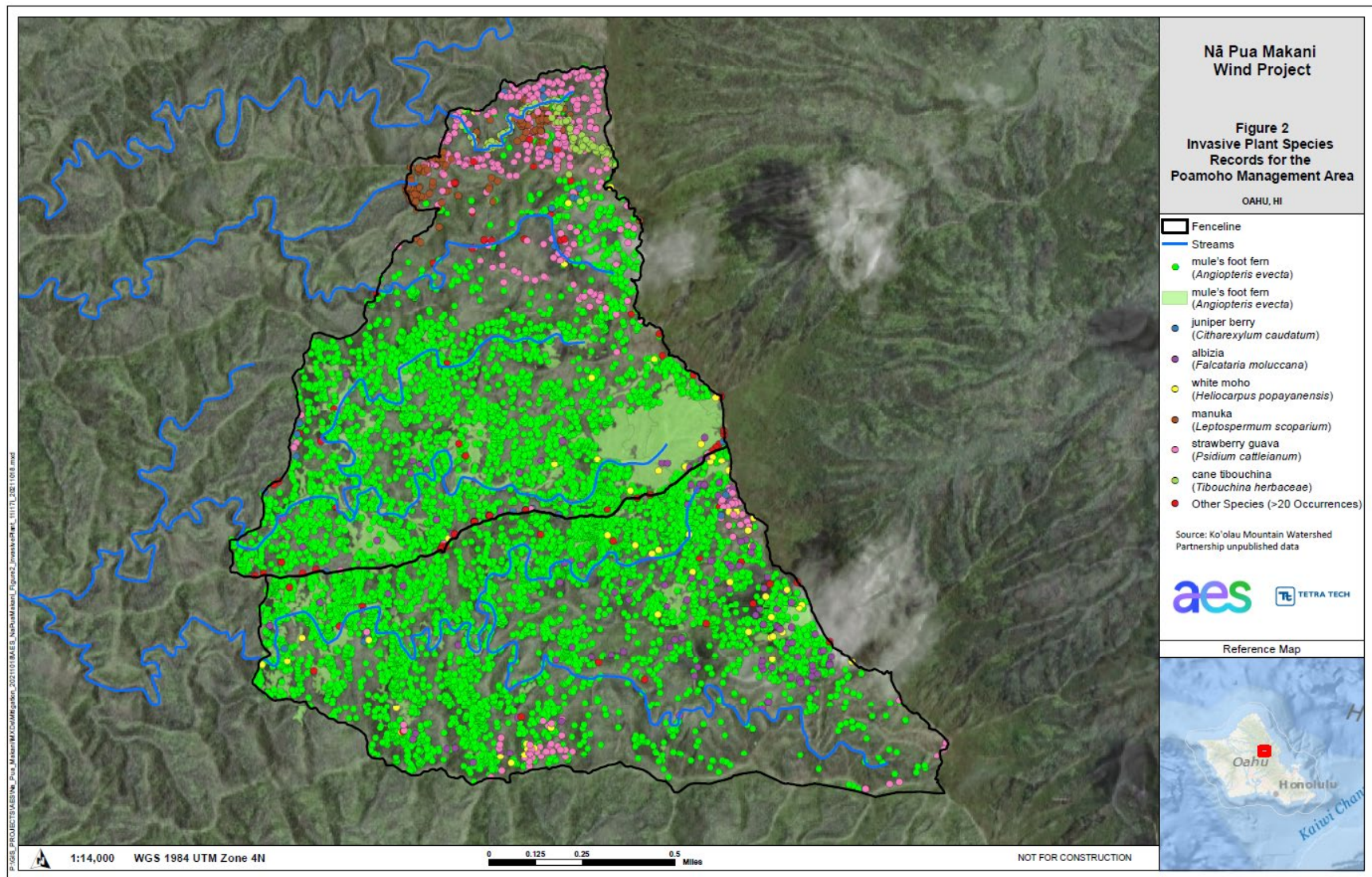


## Figures

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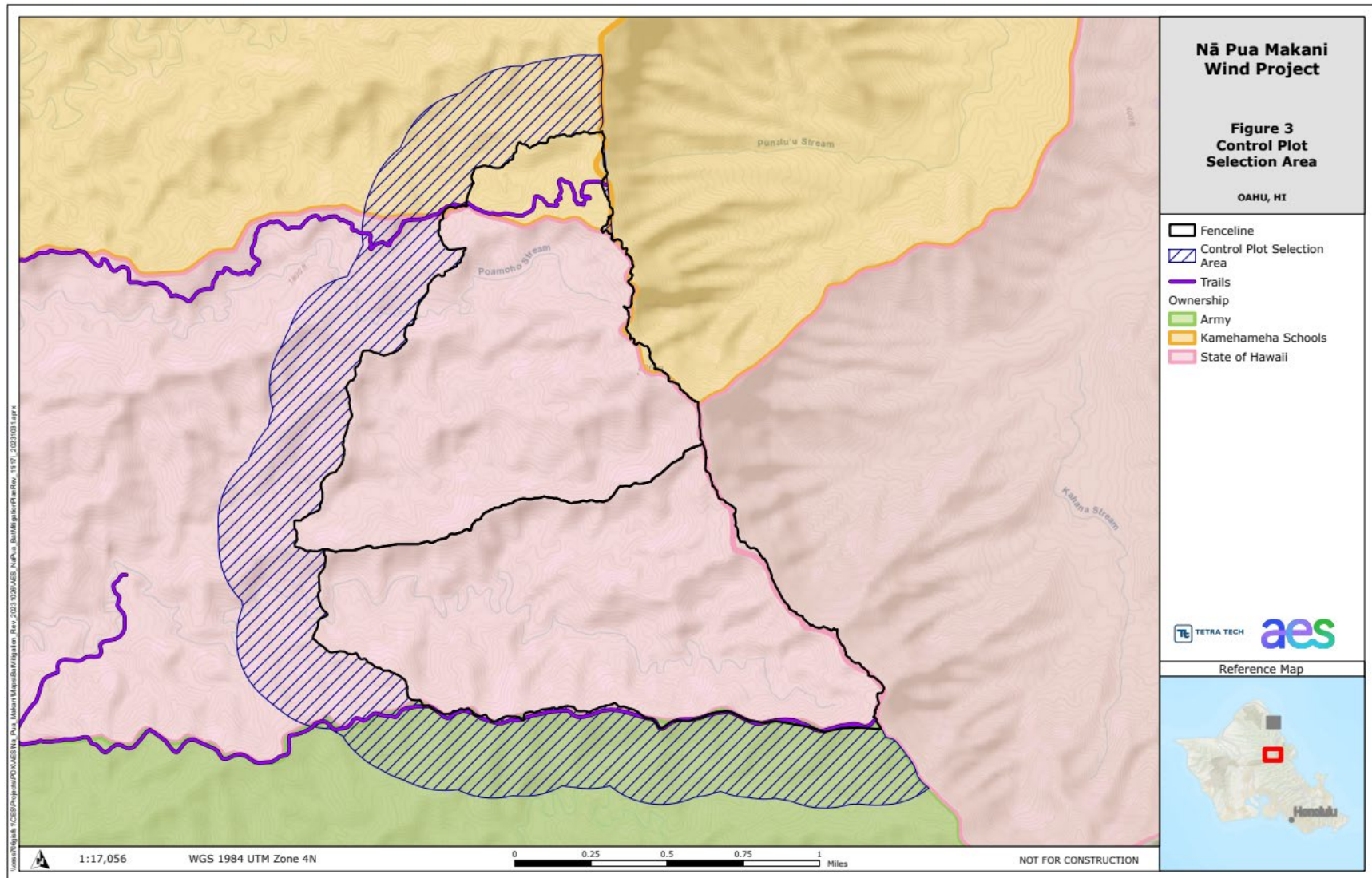


Figure 4. Example Monitoring Plot Layout

