Habitat Conservation Plan

for

Construction of the Advanced Technology Solar Telescope

at the Haleakalā High Altitude Observatory Site Maui, Hawai‘i

October 29, 2010

Table of Contents

List of Figures

List of Tables

1.0 INTRODUCTION AND PROJECT OVERVIEW

1.1 Summary

The Advanced Technology Solar Telescope (ATST) is an applicant action by the National Science Foundation (NSF) for the development of the ATST Project within the 18.166-acre University of Hawaiʻi Institute for Astronomy (IfA) Haleakalā High Altitude Observatory (HO) site at the summit of Haleakalā, County of Maui, Hawaiʻi. This Habitat Conservation Plan (HCP) addresses anticipated impacts to state and federal threatened, endangered, and listed species from the construction of the ATST at HO on Maui, Hawaiʻi (Figure 1) pursuant to Chapter 195D, Hawaiʻi Revised Statutes (HRS 195D). Once construction of the ATST is complete, the operations of the ATST facility is not expected to result in take of listed species under HRS 195D.

The NSF-funded ATST facilities will include a 143-foot (ft) (43.6-meter (m)) tall building housing the telescope, an attached support and operations building, and a utility building (Figure 2). As the largest and most capable solar telescope in the world, the ATST will provide researchers with 2.5-mile (mi) (4-kilometer (km)) resolution images of the Sun's surface. The primary goals of the ATST Project are to understand solar magnetic activities and variability, both because the Sun serves as a key resource for understanding the underpinnings of astrophysics and our understanding of magnetic plasmas, and because activity on the Sun drives space weather. Space weather creates hazards for communications to and from satellites, as well as for astronauts and air travelers. Furthermore, and perhaps most importantly, the variability in solar energy induced by solar activity affects the Earth's climate. The key to understanding solar variability and its direct impact on the Earth rests with understanding all aspects of solar magnetic fields, which in turn control the fluctuating Sun.

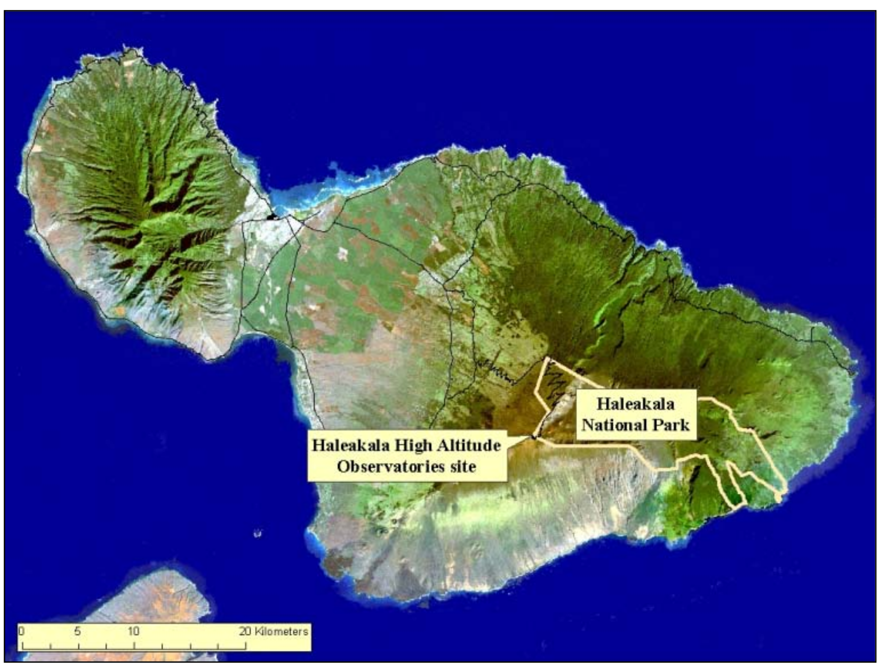

Figure 1. Haleakalā High Altitude Observatory Site location near the summit of and adjacent to Haleakalā National Park, Maui, Hawaiʻi.

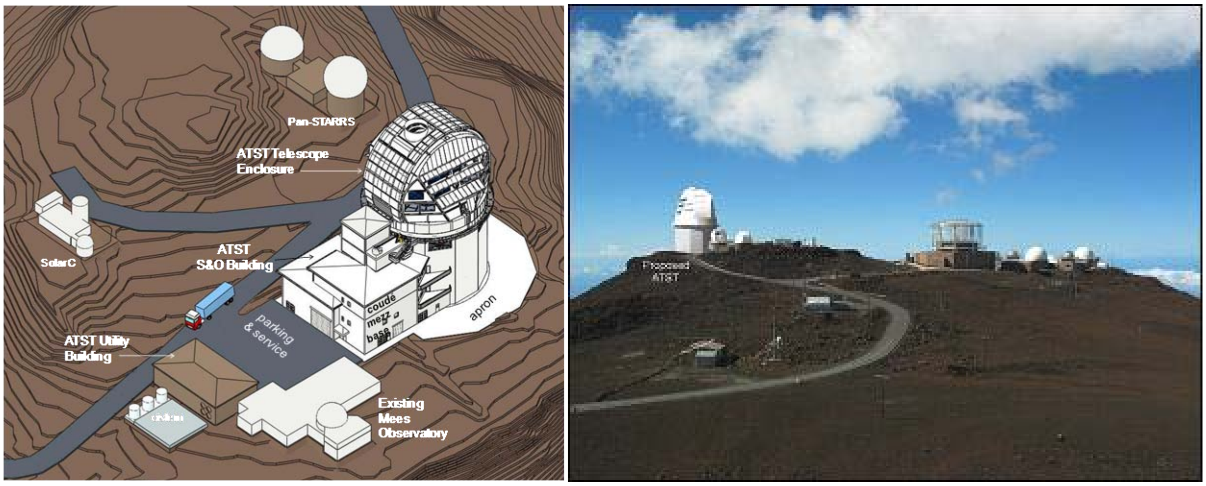

Figure 2. Artist's rendering of proposed ATST telescope enclosure, support and operations building, and utility building as they will appear adjacent to several of the existing observatory buildings including the Mees and the Advanced Electro-Optical System (AEOS) facilities (NSF, 2009).

NSF has determined that the project may cause take of the federally-endangered Hawaiian petrel (ʻuaʻu, *Pterodroma sandwichensis*). HRS 195D-4, states that any endangered or threatened species of fish or wildlife recognized by the Endangered Species Act (ESA) shall be so deemed under HRS 195D. The unauthorized "take" of such endangered or threatened species is prohibited (§195D-4(e)). The definition of "take" in Section 195D-2 is defined as follows: "Take" means to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect endangered or threatened species of aquatic life or wildlife, or to cut, collect, uproot, destroy, injure, or possess endangered or threatened species of aquatic life or land plants, or to attempt to engage in any such conduct." Table 1 is a summary of the take to be licensed by this HCP. The take license is inclusive of all project activities related to both construction and mitigation coverage. In other words, NSF believes that the allotted take of 35 ʻua'u is a conservative estimate and thus also will be sufficient to cover unanticipated take from fence strikes and implementation of predatory control measures. Detailed discussion and calculations of anticipated take are provided in Section 2.4 (Assessment of Potential Effects).

Table 1. Take summary.

Common Name	Scientific Name	No. of Specimens of 6-year Term	Location
Hawaiian petrel (ʻuaʻu)	*Pterodroma sandwichensis*	35 (30 fledglings and 5 adults)	Lands leased or otherwise controlled by the National Science Foundation; TMK 2-2-2-007-008.

Impacts of the project on this listed resource were addressed in the March 28, 2007, informal consultation on the construction and use of the ATST at HO on Maui, Hawaiʻi. Pursuant to 50 CFR § 402.16, NSF is requesting reinitiation of section 7 consultation with the U. S. Fish & Wildlife Service (Service) because, following extensive coordination with the State of Hawaiʻi Dept. of Land and Natural Resources (DLNR) and Haleakalā National Park (Park), new information revealed effects of the action that may affect listed species in a manner or to an extent not considered in 2007. The project also includes mitigation measures to achieve a net recovery benefit for the Hawaiian petrel.

Pursuant to HRS 195D, this HCP provides detailed descriptions of portions of the action along with detailed information outlining the avoidance, minimization, and implementation of mitigation measures to achieve net recovery benefit. Analysis includes information that indicates this project may result in the take of the Hawaiian petrel. Information and documents used in analysis include: (1) NSF's July 2009, Final Environmental Impact Statement (FEIS) for the Advanced Technology Solar Telescope, Haleakalā, Maui, Hawaiʻi (NSF 2009); (2) effects analysis and anticipated levels of take drafted by NSF contractor Nick Holmes and recommended to NSF by the state pursuant to HRS 195D (included in Appendix A); (3) petrel population modeling and mitigation by NSF contractor Nick Holmes (included in Appendix B) (4) three risk analysis documents entitled: (a) Acoustic Evaluation of the ATST Mechanical Equipment Building (Phelps, unpublished); (b) Effect of Lightning Upon Burrowing and Tunneling Birds and Mammals Near ATST (Kithil, National Lightning Safety Institute, unpublished); and (c) Technical Response to Vibration Issues (Barr 2006, unpublished); and, (5) information in our files and associated meeting notes, available upon request.

The ATST Project and the mitigation measures are also summarized and refined in this HCP (see Sections 2.3 and 4.0, respectively). Table 2 summarizes the construction and operation phases of the ATST Project and the mitigation measures that will be employed during those phases. Table 3 summarizes overall mitigation measures to be employed, whether take is lower or as anticipated from the ATST Project. The current baseline population is discussed in Section 4.3- Anticipated Benefits of Fencing and Predator Control Within 328-ac Mitigation Area, and elsewhere in the HCP.

Table 2. ATST Project and HCP implementation summary.

Construction	Operation
Demolition of existing driveway, parking area, and other items at the construction site	Maintenance of driveway, parking area, facilities, etc.
Grading, leveling, excavation, caisson drilling, and building fabrication with restrictions to traffic, equipment location, and vibration	Noise and vibration monitoring
Visibility painting and taping of structures to minimize flight hazards to Hawaiian petrels	Maintenance of the avoidance measures
Install fence	Maintenance of conservation fence and polytape
Invasive species interdiction and control	Invasive species interdiction and control
Long-term predator control	Long-term predator control

Table 3. Mitigation measures summary.

	Take Lower than Baseline	Take As Anticipated
Hawaiian petrel (ʻuaʻu, *Pterodroma sandwichensis*)	Same as baseline	Fencing and predator control within a 328-ac (133-ha) mitigation site to offset adverse project impacts to the Hawaiian petrel
		Monitoring project impacts to the Hawaiian petrel
		Maintain fence
		Monitor to document, and if possible, quantify improved survival and productivity within colony

1.2 Applicant Background

The ATST Project is an applicant action by the NSF for the development of the ATST within the 18.166-acre University of Hawaiʻi Institute for Astronomy HO site at the summit of Haleakalā, County of Maui, Hawai‘i. The mission of the NSF, an independent federal agency created by Congress in 1950, is focused on promoting the progress of science. To carry out its mission, NSF is authorized and directed, “to initiate and support basic scientific research and programs to strengthen scientific research potential and science education programs at all levels in the mathematical, physical, medical, biological, social, and other sciences . . .”

The primary goals of the ATST Project are to understand solar magnetic activities and variability, both because the Sun serves as a key resource for understanding the underpinnings of astrophysics and our understanding of magnetic plasmas, and because activity on the Sun drives space weather. Space weather creates hazards for communications to and from satellites, as well as for astronauts and air travelers. Furthermore, and perhaps most importantly, the variability in solar energy induced by solar activity affects the Earth’s climate.

The construction of the ATST is consistent with this mission and was articulated in the National Academy of Sciences/National Research Council report entitled “Ground-Based Solar Research: An Assessment and Strategy for the Future”, 1998, and in the NSF and National Aeronautics and Space Administration “*Astronomy & Astrophysics Survey Committee Decadal Survey*”, 2000. The ATST would be the world’s flagship facility for the study of magnetic phenomena in the solar atmosphere and would be the first large, ground-based, open-access solar telescope constructed in the United States in more than 40 years.

The July 24, 2009, “*Final Environmental Impact Statement (FEIS) for the Advanced Technology Solar Telescope*,” provides detailed information about the ATST Project. After reviewing the scientific merit of the ATST and the sufficiency of the project management plan, at its August 6, 2009 Board Meeting, the National Science Board authorized the Director of the NSF, at his discretion, to approve funding for construction of the ATST, subject to completion of the federal environmental compliance requirements. The Record of Decision to approve funding of the construction of the ATST was signed by Dr. Ardent L. Bement, Jr., Director of the NSF on December 3, 2009.

1.3 Regulatory Context

The Applicant is seeking an Incidental Take License (ITL) in accordance with Chapter 195-D, Hawai‘i Revised Statutes. This permit is issued by the DLNR.

1.3.1 State Endangered Species Legislation (Chapter 195D, Hawai‘i Revised Statutes)

Section 195D-4, HRS, states that any endangered or threatened species of fish or wildlife recognized by the ESA shall be so deemed by state statute. The unauthorized “take” of such endangered or threatened species is prohibited (§195D-4(e)). The definition of “take” in Section 195D-2, HRS, mirrors the ESA definition. Under §195D-4(g), the Board of Land and Natural Resources (BLNR), after consultation with the Hawai‘i State Endangered Species Recovery Committee (ESRC), may issue a temporary license (subsequently referred to as an “ITL”) to allow take otherwise prohibited if the take is incidental to the carrying out of an otherwise lawful activity. In order to qualify for an ITL, the following must occur:

- The applicant must submit and receive approval of an HCP;

- The applicant minimizes and mitigates the impacts of the take to the maximum extent practicable (i.e., implements an approved HCP);
- The applicant guarantees that adequate funding for the HCP, including both implementation and compliance monitoring, will be provided;
- The applicant posts a bond, provides an irrevocable letter of credit, insurance, or surety bond, or provides other similar financial tools, including depositing a sum of money in the endangered species trust fund created by §195D-31, or provides other means approved by BLNR, adequate to ensure monitoring of the species by the state and to ensure that the applicant takes all actions necessary to minimize and mitigate the impacts of the take;
- Implementation of the HCP increases the likelihood that the species will survive and recover;
- The HCP takes into consideration the full range of the species on the island so that cumulative impacts associated with the take can be adequately assessed;
- The activity permitted and facilitated by the ITL does not involve the use of submerged lands, mining, or blasting;
- The cumulative impact of the activity, which is permitted and facilitated by the license, provides net environmental benefits; and,
- The take is not likely to cause the loss of genetic representation of an affected population of any endangered, threatened, proposed, or candidate plant species.

Section 195D-4(i) directs DLNR to work cooperatively with federal agencies in concurrently processing HCPs, ITLs and ITPs. Section 195D-21 deals specifically with HCPs and its provisions are similar to those in federal regulations. HCPs submitted in support of an ITL application must:

- Identify the geographic area encompassed by the plan; the ecosystems, natural communities, or habitat types within the plan area that are the focus of the plan; and the endangered, threatened, proposed, and candidate species known or reasonably expected to be present in those ecosystems, natural communities, or habitat types in the plan area;
- Describe the activities contemplated to be undertaken within the plan area with sufficient detail to allow DLNR to evaluate the impact of the activities on the particular ecosystems, natural communities, or habitat types within the plan area that are the focus of the plan;
- Identify the steps that will be taken to minimize and mitigate all negative impacts, including without limitation the impact of any authorized incidental take, with consideration of the full range of the species on the island so that cumulative impacts associated with the take can be adequately assessed; and the funding that will be available to implement those steps;

- Identify the measures or actions to be undertaken; a schedule for implementation of the measures or actions; and an adequate funding source to ensure that the actions or measures are undertaken in accordance with the schedule;

- Be consistent with the goals and objectives of any approved recovery plan for any endangered species or threatened species known or reasonably expected to occur in the ecosystems, natural communities, or habitat types in the plan area;

- Provide reasonable certainty that the ecosystems, natural communities, or habitat types will be maintained in the plan area, throughout the life of the plan;

- Contain objective, measurable goals; time frames within which the goals are to be achieved; provisions for monitoring; and provisions for evaluating progress in achieving the goals quantitatively and qualitatively; and,

- Provide for an adaptive management strategy that specifies the actions to be taken periodically if the plan is not achieving its goals.

Section 195D-25 provides for the creation of the ESRC, which is composed of biological experts, representatives of relevant federal and state agencies (i.e., USFWS, USGS, DLNR), and appropriate governmental and non-governmental members to serve as a consultant to the DLNR and the BLNR on matters relating to endangered, threatened, proposed, and candidate species. Duties of the ESRC include reviewing all applications for HCPs, Safe Harbor Agreements, and ITLs, and making recommendations to the DLNR and the BLNR on whether they should be approved, amended or rejected; reviewing all existing HCPs, Safe Harbor Agreements and ITLs annually to ensure compliance, and making recommendations for any necessary changes; and considering and recommending appropriate incentives to encourage landowners to voluntarily engage in efforts that restore and conserve endangered, threatened, proposed, and candidate species. Hence, the ESRC plays a significant role in the HCP planning process. The Applicant has met with the ESRC during the preparation of this HCP.

1.3.2 State Environmental Review: Chapter 343, Hawai‘i Revised Statutes

Chapter 343, Hawai‘i Revised Statutes was developed to establish a system of environmental review, which will ensure that environmental concerns are given appropriate consideration in decision making along with economic and technical considerations (§343-1, HRS). The NSF has completed an EIS related to the project (NSF 2009). The NSF has prepared an EA pursuant to H.R.S. Chapter 343 to address issuance of the ITL and implementation of the conservation measures outlined in this Habitat Conservation Plan.

2.0 PROJECT DESCRIPTION

2.1 Action Area / Geographic Area Encompassed by the Plan

The ATST action area encompasses the area within which the project may affect listed resources, outlined in red on Figure 3. The action area encompasses locations where both adverse and beneficial impacts may occur. As such, the action area includes sites which may be exposed to stressors including project-related noise, vibration, traffic, and flight obstacles. In addition, it encompasses an area that will be protected with proposed conservation fencing and management actions as well as areas within which Hawaiian petrel monitoring management actions will occur.

The outer perimeter of a portion of the action area was dictated by the area within which noise due to project construction will occur. Sound energy level at various frequencies is measured in decibels (dB). The A-weighted decibel scale (dBA) was developed to represent the response of the human ear to sound. The loudest truck noise permitted by Environmental Protection Agency (EPA) standards is 83 dBA (when measured at 50 ft), and the loudest equipment proposed for use at the ATST construction site are rock hammers and rock drills, which produce up to 113 dBA (measured at 10 ft). For the purposes of delineating the action area on the landscape scale, sound attenuation was assumed to be only 6 dBA per doubling of distance, with no additional attenuation assumed to occur for either atmosphere or vegetation (NSF 2006). Along a 0.9 mi (1.5 km) portion of the Park, the action area follows a cliff edge, where the terrain serves as a barrier to road noise. More detailed assessment of anticipated noise levels in the immediate vicinity of the construction site is provided in Section 2.4-Assessment of Potential Effects.

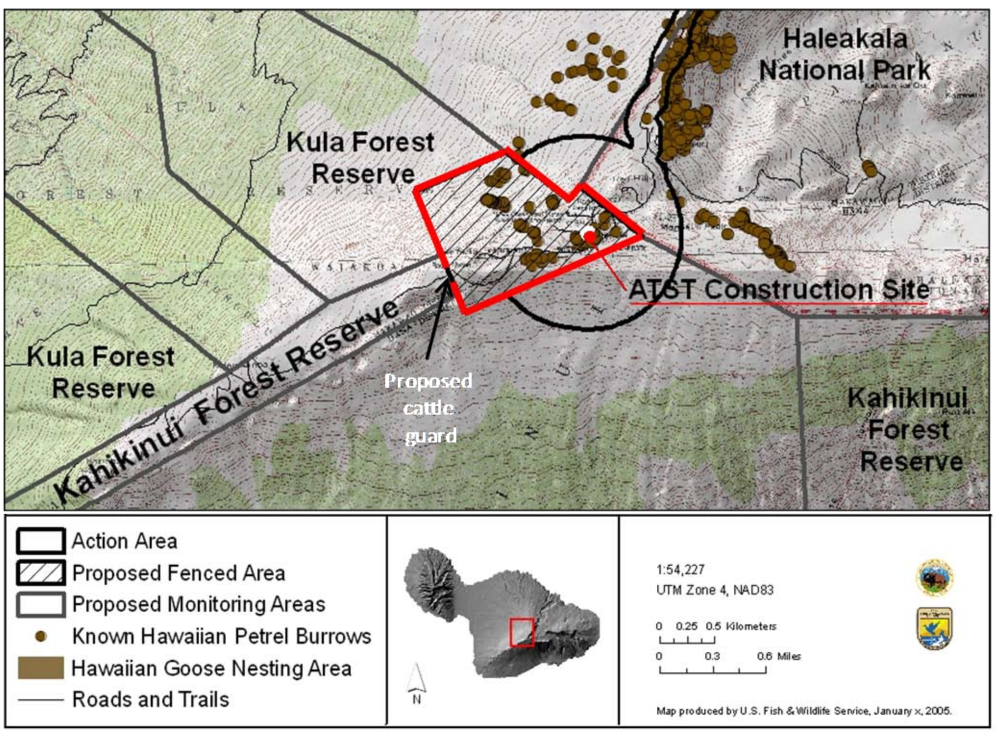

Figure 3. Delineation of the ATST action area (in red), including conservation and monitoring sites.

Pursuant to a thorough literature search (Awbrey and Hunsaker, 1997; Mock and Tavares, 1997; Delaney, *et al*., 1999, South San Francisco Ferry Terminal Project EA, 2003), and additional information regarding existing Park road traffic volume, vegetation and topographic shielding, and avian noise habituation, 65 dBA contour, where there is a clear line of sight to the noise source, was selected as the outer extent of the portion of the action area dictated by noise. Because no specific burrow depth or orientation information was available for the burrows along the road, a burrow attenuation rate of 5 dBA was applied to each burrow for the creation of the action area: therefore, all burrows which, based on these conservative calculations may be exposed to a sound level of 60 dBA as a result of the proposed action were considered to be within the action area. Based on these conservative attenuation rates, the affected area subject to compliance under HRS195D was established as a perimeter extending 2,560 ft (780 m) from the outer edges of the construction site. The total area encompassed by the portion of the action area within which impacts of construction, maintenance, and operation of the ATST may occur is approximate. This area includes portions of adjacent lands to the north in private ownership, to the south owned by the State of Hawaiʻi Dept. of Hawaiian Homelands (DHHL), and to the east by the Park. The NSF will seek to establish agreements with each of these landowners for access to monitor impacts to Hawaiian petrels.

2.2 Environmental Setting

2.2.1 Climate

The climate of the proposed conservation area experiences extreme variations. The conservation fencing area is located at approximately 8,800 to 9,400 ft (2,682 to 2,865 m) elevation, where snow and hail can occur. Rainfall on Maui usually is heaviest in the mid-slope areas, while the beaches and coasts are the driest. Rainfall on Haleakalā is greatest at elevations between 3,000 to 5,000 feet above sea level where the moisture-laden trade winds are cooled as they rise against the mountain front and they are capped by a temperature inversion at approximately 5,000 ft (1,524 m) elevation. The annual average total precipitation on the Haleakalā summit, in the vicinity of the proposed mitigation area, between 1949 and 2005, was 52.92 inches (in) (134 centimeters (cm)). Sustained wind speeds at or near the summit of 50 miles per hour are not unusual; the greatest wind speed recorded at the summit is over 125 miles (mi) per hour (201 km per hour).

2.2.2 Topography and Geology

The Island of Maui, nicknamed "The Valley Isle" and the second largest Hawaiian Island, is a volcanic doublet: an island formed from two volcanic mountains that abuts one another to form the isthmus between them (Figure 4). Mauna Kahalawai, also known as the West Maui Mountain, is the much older volcano and has been eroded considerably. Haleakalā, the larger volcano on the eastern side of Maui, rises above at 10,023 ft (3,110 m). The last eruption occurred at some time between 1650 and 1790, and the lava flow can been seen between Ahihi Bay and La Perouse Bay on the southwest shore of East Maui. Both volcanoes are shield volcanoes and the low viscosity of the Hawaiian lava makes the likelihood of the large explosive eruptions unlikely.

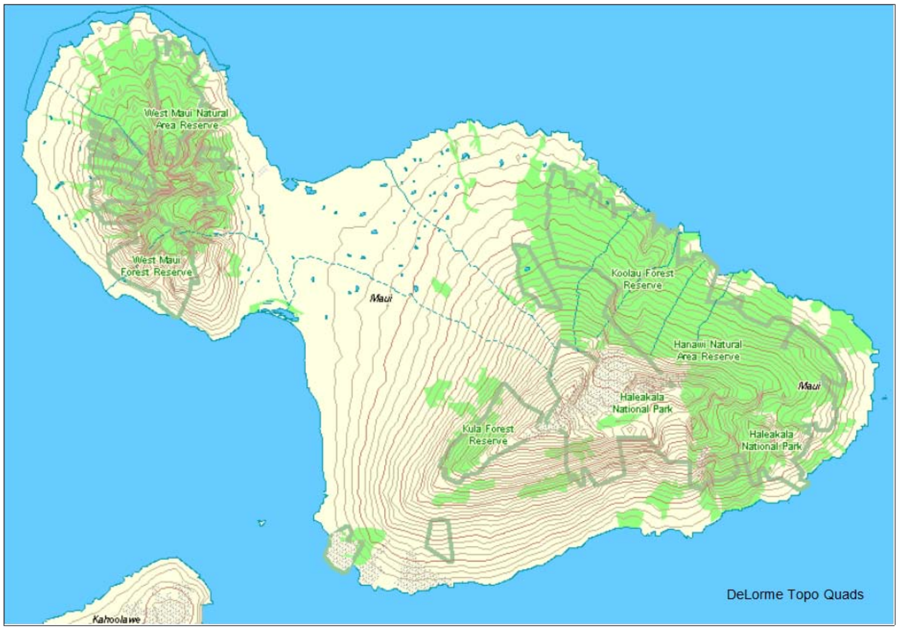

Figure 4. Maui topography, dominated by two large volcanoes.

The topography within the proposed conservation area is rugged and barren, and the elevation drops with an average slope greater than 30 percent. The topography is dominated by lava ledges and cinder debris that were erupted in successive phases along the Southwest Rift Zone during a period beginning about 100,000 years ago.

Over the course of Haleakalā's formation, three distinct phases of eruption have taken place. The first, called the Honomanu Volcanic Series, is responsible for the formation of Haleakalā's primitive shield and most likely its three prominent rift zones. Honomanu lavas are exposed over less than 1 percent of Haleakalā, but are believed to form the foundation of the entire mountain to an unknown depth below sea level. The second series, or Kula Volcanic Series, overlaid the previous Honomanu Series with its lava flows. Eruptions of this series were considerably more explosive than its predecessor, leading to the formation of most of the cinder cones along the three rift zones.

A period of inactivity followed the Kula Series, during which time erosion began to predominate the formation of Haleakalā Crater by forming great valleys leading to the coast. After this long period of erosion, the final volcanic eruptions, called the Hana Volcanic Series, partially filled the deep valleys. Several cinder cones and ash deposits lined the east and southwest rift zones ranging from a few feet in height to large cones more than a mile across at the base and 600 feet high. Lava flows within the Haleakalā Southwest Rift Zone range from 200 to 20,000 years old. Six flows have erupted in this area within the last 1,000 years. During the latest eruption, sometime between 1650 and 1790, lava emerged from two vents and flowed into La Perouse Bay, where a small peninsula was constructed. Recent studies have indicated that Haleakalā volcano may still be active, in light of the numerous eruptions during the last 8,000 years (Bergmanis, *et al.*, 2000).

Geologically, the proposed conservation area is near the central region of the triple junction rift zone where the Southwest Rift Zone, the East Rift Zone and the North Rift Zone meet. Lava deposits in the area are from the geologic time period designated for both the earlier Kula and later Hana series that built Haleakalā.

2.2.3 Hydrology, Drainage and Water Resources

The proposed conservation area is within the Waiakoa and the Manawainui Gulch watersheds. As shown on Figure 5, the groundwater boundaries are the Kamaole and Makawao Aquifer Systems of the Central Aquifer Sector and the Lualailua and Nakula Aquifer Systems of the Kahikinui Aquifer Sector (AFRL, 2005). A sector is a large region with hydro-geological similarities that primarily reflects broad hydrogeological features, and secondarily, geography. A system is an area within a sector showing hydrogeological continuity.

The primary hydrologic unit for describing stream flow is the drainage basin, whereas the principal division for groundwater is the aquifer system. Because groundwater flow is governed by subsurface geological continuity rather than by topographic controls (Yuen and Associates, 1990), the boundaries of drainage basins and aquifer systems do not necessarily coincide. Drainage basin boundaries for the ATST Project are the Waiakoa and Manawainui Gulch watersheds, two of the 112 Maui Watershed Units totaling 466,437 ac.

Within the proposed conservation area, there are only surface water resources. Most streams on Haleakalā are intermittent because of the steep, permeable lava terrain. The nearest intermittent streams are approximately 1.7 miles down slope of the proposed conservation area. Perennial streams at low elevations originate from groundwater springs.

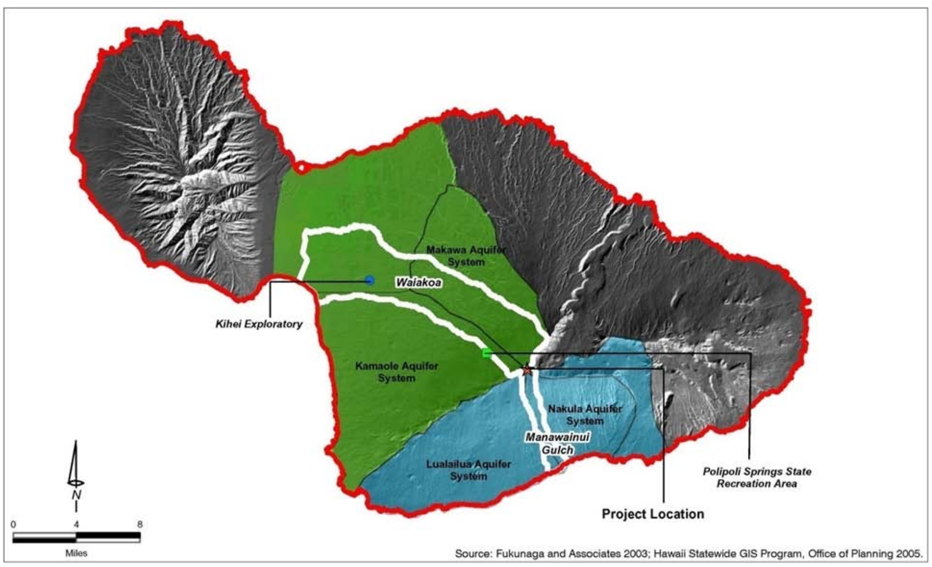

Figure 5. Hydrologic features.

On the slopes of Haleakalā within the proposed conservation area, virtually all precipitation infiltrates the soil profile. Once in the soil, gravity continues to force the water down into the soil. When the water hits a less permeable layer, such as basalt, it flows in the path of least resistance. Driven by gravity, this subsurface water flows down gradient along the surface of the basalt layer. The flow continues along the interface between the highly pervious cinder material and the basalt layer until it either resurfaces as a spring or stream or flows into a fissure in basalt, contributing to groundwater storage (UH IfA, 2005a). All precipitation falling near the summit, including the proposed conservation area, infiltrates and flows subsurface toward the natural drainage courses, such as Manawainui Gulch.

2.2.4 Vegetation Cover

The July 2009, Existing Vegetation Map Layer (U.S. Department of Interior, Geologic Survey 2009) indicates 74 percent of the conservation area is classified as barren, 11 percent is vegetated by Hawaiʻi montane-subalpine dry shrubland, less than 1 percent is vegetated by Hawaiʻi alpine dwarf shrubland, and the remaining 14 percent is classified as developed (including developed, open space, developed low intensity, and developed medium intensity). Shrublands are sparsely vegetated with dwarf native shrubs. Vegetation cover and stature are limited by harsh environmental conditions. Vegetation cover is generally less than 10 percent and vegetation is generally shorter than three ft (one m) tall (UH IfA, 2005).

Vegetation is composed primarily of native shrubs, including *Styphelia tameiameiae* (pukiawe), *Vaccinium reticulatum* (ohelo), Haleakalā silversword (*Argyroxiphium sandwicense subsp. Macrocephalum*), and *Dubautia menziesii* (naenae), herbs, such as *Tetramolopium humile* (tetramolopium), and, grasses, including *Agrostis sandwicensis* (bentgrass), *Deschampsia nubigena (*hairgrass), and *Trisetum glomeratum* (mountain pili). Three species of native ferns: *Asplenium adiantum-nigrum* (iwaiwa), *A. trichomanes* ssp. *densum* (oalii), and *Pellaea ternifolia* (kalamoho), are found tucked into rock crevices and overhangs and on steep slopes. Recent surveys at HO site also found new native species *Dryopteris wallichiana*, *Pteridium aquilinum* var. *decompositum*, and *Silene struthioloide,* which are presumed to have a wider distribution into the proposed conservation area. These same recent surveys also found newly discovered non-native *Ageratina adenophora, Bromus diandrus, Conyza bonariensis, Dactylis glomerata, Festuca rubra, Pennisetum clandestinum, Trifolium repens,* and *Vulpia myuros* (UH IfA, 2005).

2.2.5 Fauna

Fauna within the proposed fenced conservation area consist of common and endangered birds, non-native mammals, and native invertebrates. Common introduced bird species including gamebirds occur within the fenced conservation area. Other introduced fauna occurring in the summit area include the feral goat, feral house cat (*Felis catus*), house mouse (*Mus musculus*), Polynesian rat *(Rattus exulans),* and the roof rat (*Rattus rattus*). The Indian mongoose (Iole manakuke, *Herpestes javanicus)* is occasionally observed on the summit.

The highest elevations of Haleakalā were once considered lifeless, but biologists have recently discovered a diverse fauna of resident insects and spiders. These arthropods inhabit unique natural habitats on the bare lava flows and cinder cones. Because they feed primarily on windblown organic materials, they form an aeolian ecosystem. In Hawaiʻi, aeolian ecosystems are used to describe those that mostly, but not exclusively, exist on non-weathered lava substrates, found at high elevations (Medeiros, *et al.*, 1994). On Haleakalā, there is an aeolian ecosystem extending up the summit from about the 7,550-ft elevation. It is characterized by relatively low precipitation, porous lava substrates that retain relatively little moisture, little plant cover, and high solar radiation. The dark, heat-absorbing cinder provides only slight protection from the extreme temperatures, and thermal regulation and moisture conservation are critical adaptations of arthropods occurring in this unusual habitat.

The Hawaiian petrel occurs within the action area. A full description of status and baseline of the Hawaiian petrel is presented below.

2.2.6 Species Status and Baseline - Hawaiian petrel

Status of the Species

Species Description. The endangered Hawaiian petrel is a medium-sized seabird in the family Procellariidae (shearwaters, petrels, and fulmars). The Hawaiian petrel formerly was treated as a subspecies of *P. phaeopygia*, with the nominate subspecies occurring in Galapagos (*P. p. phaeopygia*). Based on differences in morphology and vocalization, the two subspecies were reclassified as full species in 1993 (Sibley and Monroe, 1993) and genetic analysis confirmed the split several years later (Browne, *et al.*, 1997).

Listing Status. The Hawaiian petrel was listed as endangered on March 11, 1967 (32 FR 4001).

Ecology. The Hawaiian petrel nests on Haleakalā in high elevation burrows located beneath rock outcrops, along talus slopes or along edges of lava flows where there is suitable soil underlying rock substrate for excavation of tunnels. The majority of known Hawaiian petrel burrows are located along the western rim of the Haleakalā crater, where this habitat is most abundant and also where predator control is afforded. Using survey efforts from 1990-1996, previous estimates of burrow density, including part of the mitigation area, range from 5 to 15 burrows per ha, compared to 15 to 30 burrows per ha along the western crater rim. Similarly, in 2004 and 2005, Hawaiian petrel passage rates collecting using ornithological radar were 4 to 7 times greater during summer and fall at the Visitor's Center (Western rim), when compared to Science City, suggesting bird numbers are lower on the western slopes encompassing the mitigation site. Importantly, the population trend at Haleakalā is increasing, which suggests that additional recruitment into this site is possible (Holmes, 2010b).

Burrows are excavated to a depth of three to six ft (one to 1.8 m), but sometimes reach a length of 15 ft (4.6 m) or more. Most of the nests on Haleakalā are in rock crevices in sparsely vegetated, xeric habitat (Simons and Hodges, 1998). Birds spend much of their time at sea where they are known to feed on squid, small fish, and crustaceans displaced to the surface by schools of tuna (Larson, 1967; Simons, 1985). Petrels have been recorded in the Philippines (Rabor, *et al.*, 1970), Japan (Nakamura, 1979), the Gulf of Alaska (Bourne, 1965), and off the coast of Oregon and California (Pyle, *et al.*, 1993). Hawaiian petrels have been tracked taking single trips exceeding 6,200 mi (10,000 km) circumnavigating the north Pacific during the nestling stage (Adams, *et al.*, 2006).

Similar to other members of its family, the Hawaiian petrel has a well-defined, highly synchronous nesting season (Simons, 1985) albeit there is clear evidence of intra-island variation in breeding phenology in Hawai'i, with Haleakalā breeders initiating, and completing, breeding approximately one month earlier than Kaua'i, Lana'i, and Hawai'i Island. Birds arrive in their colonies in late February. After a period of burrow maintenance and social activity they return to sea until late April when egg-laying commences. Non-breeding birds visit the colony from February until late July (Simons and Hodges, 1998). Many of these may be young birds seeking mates and prospecting for nest sites, but some proportion is thought to be mature adults that do not elect to breed.

Non-breeders and failed breeders typically begin leaving the colony once the eggs have hatched. Chicks fledge between late September and late November. Both adults participate in incubating the egg and feeding the chick; after a brief brooding period, both adults are foraging at sea and will have absences from the nest (Simons, 1985). Although adults are occasionally observed to remain after fledglings depart, colonies generally are empty by the end of November. A hiatus of only about three months occurs between the end of one breeding season and the beginning of the next. Hawaiian petrels are thought to begin breeding at about five or six years of age, and roughly 90 percent of breeders attempt to breed each year (Simons and Hodges, 1998). Measurement of annual reproductive success at Haleakalā has yielded highly variable results (63.4 percent, range 38 to 82 percent; Simons, 1985; Hodges, 1994). The mean date of egg-laying recorded on Haleakalā in 1980 and 1981 was May 8 (Simons, 1985). The percentage of years in which adult females laid eggs was estimated to be 89 percent (Simons, 1985). Hatching success (chicks hatched / eggs laid) averaged 74.0 percent (+/-6.9 SD) and fledging success (chicks fledged / chicks hatched) averaged 84.8 percent (+/-16.7 SD) (Simons, 1985; Hodges, 1994). Beginning in mid-February to early March, after a winter absence from Hawaiʻi, breeding and non-breeding birds visit their nests regularly at night, for a period of social activity and burrow maintenance work. Pairs are site tenacious, returning to the same burrow year after year. From mid-March to mid-April, birds visit their burrows briefly at night on several occasions. Then breeding birds return to sea until late April or early May, when they return to lay and incubate their eggs.

Females lay their egg within 24 hours of returning to the burrow. Male and female birds alternate incubation attendance. If the male is in attendance when the female lays the egg, he will take the first incubation shift. In the absence of the male, the female will take a short incubation shift, awaiting the return of the male. Total incubation period ranges from 45 to 58 days (Simons, 1985). Eliminating the first and last incubation shifts, which are shortened by the events surrounding egg-laying and hatching, the overall average shift length is 16.47 days (+/-4.19 days). Males take two incubation shifts while females take only one. The adult's incubation shift is relieved when the other parent returns to the nest after an extended foraging trip at sea. Incubating adult Hawaiian petrels spend almost 95 percent of their time sleeping with their bills buried in their scapular feathers, 3 percent of their time resting quietly in their nest, and the final 2 percent of the time arranging nest material or preening (Simons, 1985). Given weight loss measurements by Simons (1985), undisturbed birds lose 1.54 percent of their initial body weight per day when incubating an egg. Simons (1985) estimated that a male petrel which he found taking a 23-day incubation shift may have lost 35.5 percent of its body weight during the shift. Egg temperature and evaporative water loss are controlled by the incubating adult. Because the metabolism of awake, resting birds is almost twice that of sleeping birds (Simons, 1985), disturbance of incubating birds' sleep could potentially result in more rapid weight loss and an inability of the adult to stay on the egg until its mate relieves it. Although one egg, neglected for three days during the middle of the incubation period, did successfully hatch, the extent to which eggs can tolerate the absence of the incubating adult is not known (Simons, 1985).

During the incubation period, many non-breeding birds also inhabit the colony. Many of these are young birds gaining experience seeking mates and prospecting for nest sites; the remaining portions are experienced breeders that did not elect to breed. Non-breeders and failed breeders typically begin leaving the colony once the eggs have hatched. They continue to visit their burrows at night through early August (Simons, 1985). By September, the only birds visiting the colony are adults returning to feed their chicks (Simons, 1985). Chicks do not appear to require much brooding from their parents. Adults depart from the nest to forage at sea within one to six days after the chick hatches (Simons, 1985). Chicks spend 66 percent of their time alert, resting quietly, 26 percent of their time sleeping, 6 percent of their time preening or stretching, and 2 percent of their time walking around (Simons, 1985). Nocturnal feeding by one parent occurs approximately every other day until the chick is 90 days old. After 90 days, adults appear to continue to feed chicks until the chick refuses food. Chicks fledge between late September and late October, after an average of 111 days after hatching (Simons, 1985). Although adults are occasionally observed to remain after fledglings depart, colonies generally are empty by the end of November.

Historical and Current Distribution and Threats. Hawaiian petrels were abundant and widely distributed in prehistory; their bones have been found in archaeological sites throughout the archipelago (Olson and James, 1982). Introduced avian diseases (Warner, 1968), collection for use as food (Harrison 1990), and introduction of dogs, pigs, cats, rats, and mongoose predators have resulted in substantial declines in the distribution and numbers of this species. This species has no natural terrestrial predators other than the Hawaiian owl (pueo, *Asio flammeus sandwichensis*).

Human hunting, predation by introduced mammals such as Polynesian rats (*Rattus exulans*), dogs (*Canis familiaris*), and pigs (*Sus scrofa*), and habitat alteration caused initial decline of the Hawaiian petrel population and probably its extirpation from Oʻahu (Olson and James, 1982). The introduction of cats, mongoose, and two additional species of rats (*R. rattus* and *R. norvegiceus*) since Euro-American contact along with accelerating habitat loss has led to small relict colonies of Hawaiian petrels in high-elevation, remote locations. The primary reason for the relatively large numbers of petrels and their successful breeding around Haleakalā summit today this is likely due to the fencing and intensive predator control maintained by the Park since about 1982. Elsewhere on Maui and in Hawaiʻi the Hawaiian petrel faces severe threats from non-native predators including rats, cats, mongoose, and introduced barn owls (*Tyto alba*). The petrel's habitat is destroyed or severely compromised by feral ungulates such as goats, and by pigs in wetter and more vegetated environments than the summit of Haleakalā. In addition to crushing burrows and compacting the substrate, these animals provide vectors for non-native invasive plants that alter the vegetation structure and may hinder the birds' access to traditional nesting areas.

Other significant anthropogenic sources of Hawaiian petrel mortality are light attraction and collision with communications towers, power transmission lines and poles, fences, and other structures (Simons, 1983). The Hawaiian petrels fly over 30 miles/hour (48 km/hour) (Day and Cooper, 1995), which likely reduces the ability to detect obstacles in the dark and avoid them. This problem is likely to be exacerbated by the continuing development and urbanization throughout Hawaiʻi. Since 1979, DOFAW on Kauaʻi has supported a program called Save our Shearwaters (SOS) to collect "downed" Newell's shearwaters (*Puffinus auricularis newelli*) and Hawaiian petrels; birds that have either collided with structures or fallen out due to light attraction. According to SOS files, over 30,000 seabirds have been recovered to date. The majority of the birds are Newell's shearwaters, which nest in greater numbers than Hawaiian petrels; however, Hawaiian petrels are recovered on a regular basis. The lower number of Hawaiian petrels recovered may be a function of species differences in susceptibility to light attraction as well as population size (N. Holmes, personal communication).

A breeding colony of the Hawaiian petrel was rediscovered on Lanaʻi near the summit of Lanaihale. Although the petrel colony was historically known to occur, its status was unknown and thought to have dramatically declined until surveys were conducted in 2006 (Penniman, 2007, personal communication). These birds attend the colony at night and nest in burrows in the ground, under dense uluhe ferns (*Dicranopteris* spp.). The nesting habitat of the Hawaiian petrel colony on Lanaʻi is approximately 1,035 ac (419 ha) between 2,297 and 3,379 ft (700 and 1030 m) elevation of ʻōhiʻa lowland mesic forest with uluhe ground cover (Penniman, 2010, personal communication). Monitoring of and research on this population is ongoing, and its size has not been estimated with statistical confidence, but the population appears to be one of the larger known colonies (Penniman, 2010, personal communication).
Hawaiian petrels are currently known to nest on at least five islands (Simons and Hodges, 1998), but their distribution is limited to high elevation sites where predation pressure is lower. Maui may harbor as much as one quarter of the breeding population and most of Maui's petrels nest along the rim of Haleakalā Crater (Simons and Hodges, 1998) in the Park and in the vicinity of the action area. The most recent estimate of breeding petrel numbers in this area is roughly 400 to 600 breeding pairs (Simons and Hodges, 1998; Cathleen N. Bailey, Park Biologist, 2006, personal communication). An accurate estimate of total numbers of Hawaiian petrels is not available; however, estimates range from the thousands to about 34,000 (e.g., Spear, *et al.*, 1995; Ainley, *et al.*, 1995). Spear, *et al.* (1995) estimated the at-sea population size of adult and sub-adult Hawaiian petrels of 19,000 birds (with a 95 percent confidence interval of 11,000 to 34,000). Ainley, *et al*. (1997) estimates a breeding population of about 1,600 pairs on Kauaʻi and Ainley (USFWS, unpublished field notes) estimates that there are a few thousand pair occurring on Lanaʻi and 1,500 on Haleakalā. Darcy Hu (2009, personal communication) located 115 active burrows within the Hawaiʻi Volcanoes National Park (HAVO) in 2006. Jay Penniman currently estimates that between 1,000 and 6,000 Hawaiian petrels come to shore each year on all islands (2009, personal communication).

Environmental Baseline (Status of the Species in the Project Area)

Nesting habitat of the Hawaiian petrel on Maui currently is at elevations above 7,200 ft (2,195 m), although historically the species may have nested at lower elevations (USFWS, 1983). Based on our analysis of the latest Hawaiian petrel burrow GPS location data (Bailey, unpublished), there are 203 Hawaiian petrel burrows located within the action area, including 31 which occur within 1,250 ft (381 m) of the ATST construction site. Vegetation is sparse in nesting areas on Haleakalā Crater owing to the high elevation and dry environment; within the proposed action area vegetation is predominantly grass (*Deschampsia australis*) and bracken fern (*Pteridium aquilinum*). The rocky substrate is disturbed in the immediate area around the construction site due to previous construction activities. There are no shrubs in this area. Hawaiian petrel nesting burrows are located among rock outcrops, under boulders, within the cinder substrate, and along cliff faces. There are four Hawaiian petrel burrow clusters, and a number of isolated burrows, within approximately 1,250 ft (381 m) of the ATST construction site, totaling approximately 31 individual burrows. Burrow clusters and individual burrows to the west and the northwest of the construction site historically have not been highly used by nesting Hawaiian petrels (Bailey, 2009, personal communication); approximately 5 to 10 burrows (mostly inactive) are 500 to 800 ft (244 m) from the construction site to the west. Approximately 61 active burrows are known to occur within the mitigation site; a census of the site during the Fall of 2010 is expected to find additional active burrows (Bailey, 2010).

The largest known nesting colony of Hawaiian petrels is located in and around the Park (Simons and Natividad Hodges, 1998). Approximately 30 known burrows are located along the southeastern perimeter of HO, several burrows are northwest of HO (Figure 6), and additional burrows have been found northeast of the project site (Figure 7) (NPS, 2003). Hawaiian petrels are present at Haleakalā from February through October and are absent from November through January. Park staff search for new burrows and check existing burrows periodically while the petrels are present (Natividad Bailey, 2009).

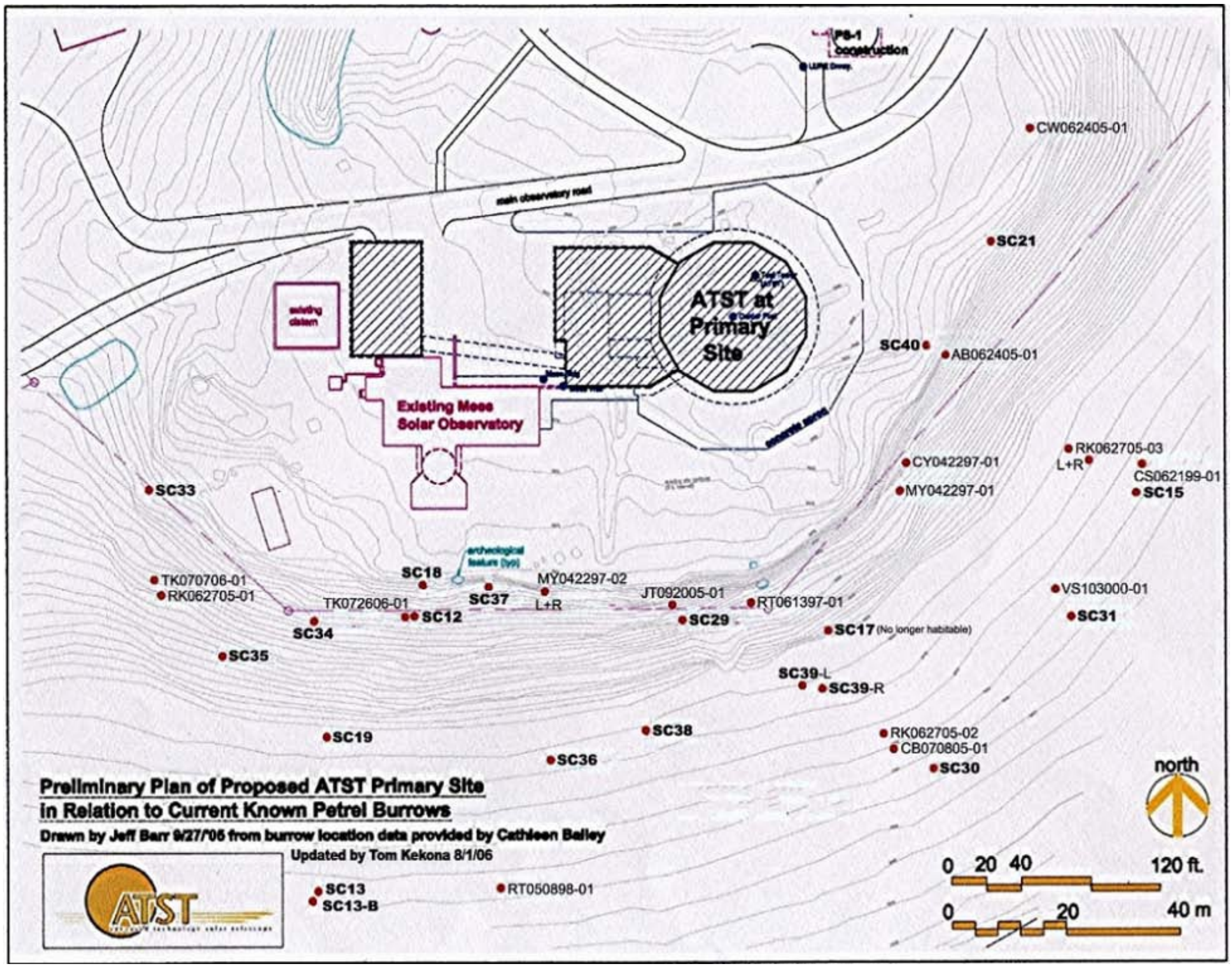

Figure 6. The Hawaiian petrel colony adjacent to the ATST construction site.

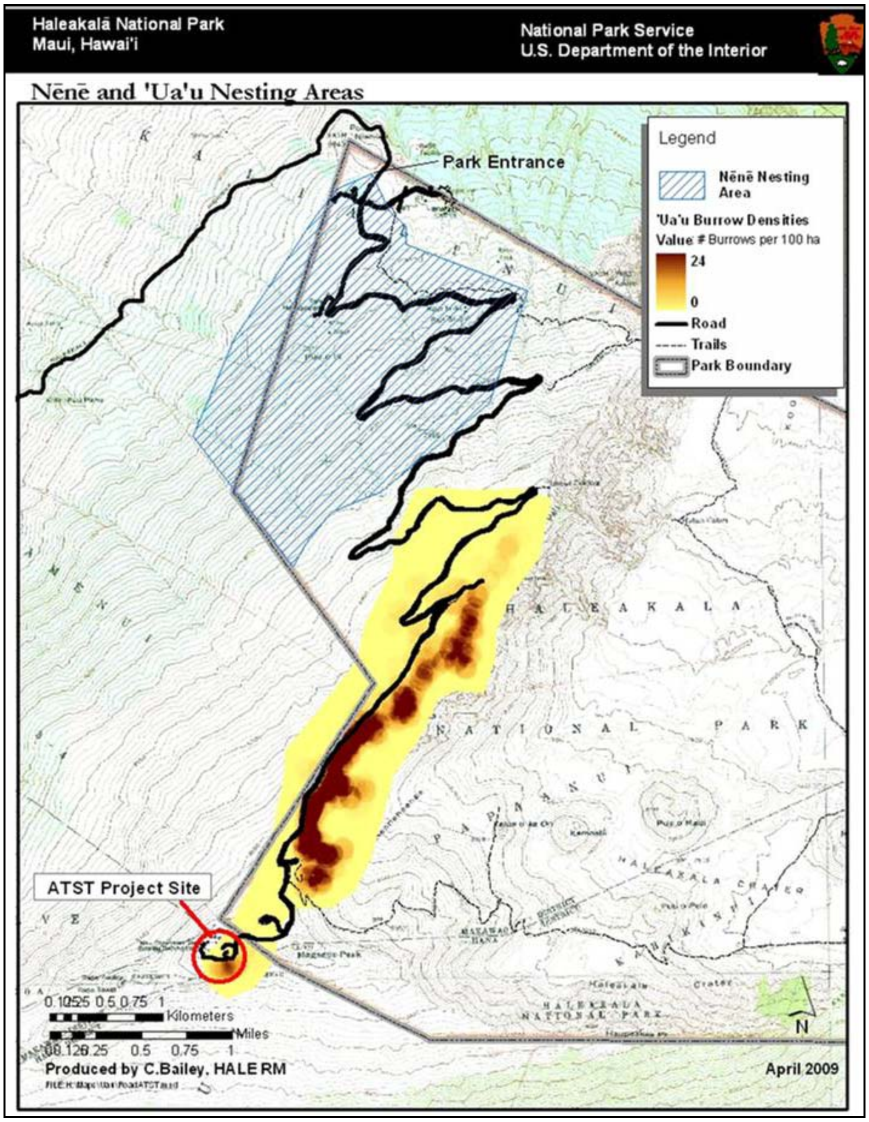

Figure 7. Petrel burrows near summit of Haleakalā.

From mid-February to early March, after a winter absence from their burrows, breeding and non-breeding birds visit their nests regularly at night, for a period of social activity and burrow maintenance work. From mid-March to mid-April, birds visit their burrows briefly at night on several occasions. Then breeding birds return to sea until late April or early May, when they return to lay and incubate their eggs (Simons, 1985). Information provided by Bailey and Duvall (December 9, 2010), confirmed by Fein's analysis of burrow camera data for the ATST site (Fein, 2009, personal communication) indicating birds intermittently occupy their burrows during the day during this period as well.

The birds make their nests in burrows and return to the same burrow every year. The species distribution during their non-breeding season is poorly known, but they are suspected to disperse north and west of Hawai‘i, with very little movement to the south or east. The petrels typically leave their nests just before sunrise to feed on ocean fish near the surface of the water and just before sunset transit from the ocean back to Haleakalā. These birds have evolved with a highly sensitive sense of vision and their high speed and erratic nocturnal flight patterns may increase the possibility of collisions with fences , utility lines, and utility poles (Simons and Natividad Hodges, 1998).

During fall 2004, ABR, Inc. conducted a study for the Maui Space Surveillance Complex (ABR, 2005). Using ornithological radar and visual sampling techniques, this study's objective was to determine movement patterns of Hawaiian petrels near the summit of Haleakalā, including spatial movement patterns, temporal movement patterns, and flight altitudes. Many of the patterns observed in this study matched what is known about the biology of the Hawaiian petrel. Breeding adults, non-breeding sub-adults, and adults are active in the summer when the displaying non-breeders are active and fly erratically and circle the colonies at low altitudes. In contrast, only adults visit the colonies during the fall, when they simply fly in and land at burrows to feed young. It is suspected that fewer birds were seen on the radar in the vicinity of the Maui Space Surveillance Complex than near the crater because the crater is much more active for breeding and displaying birds than is that part of the colony along the southwestern ridge (i.e., the ridge on which the observatories and the Federal Aviation Administration site are located). It is also likely that the birds were well below radar surveillance and not detected, since when near to actual burrows, the birds may fly within only a few feet above ground level.

Threats to the Species and Conservation Needs in the Action Area. Known causes of Hawaiian petrel mortality on Haleakalā from 1994 to 2003 included predation by introduced dogs, cats, rats, mongoose and non-native owls, collision with anthropogenic structures (such as fences, buildings, utility poles, and vehicles) attraction and confusion by anthropogenic light sources, habitat degradation (for instance burrow collapse by feral ungulates), and disturbance from vehicles, hikers, road resurfacing, and other human activities (Natividad Bailey, unpublished). Hawaiian petrels are believed to navigate by stars, so man-made lights may confuse them in-flight. Evidence suggests these birds will fall to the ground in exhaustion after flying around lights, where they are susceptible to being hit by cars or attacked by predators (Simons and Natividad Hodges, 1998). During the 2006 nestling season, petrel burrow cameras captured video of feral ungulates and rats visiting burrows at the HO colony (Fein, 2007, personal communication). The GTE building, in the saddle, northeast of the ATST site was struck by an adult petrel and a juvenile petrel died as a result of flying into a rock outcropping in the Haleakalā Crater on its fledgling flight to sea (Bailey, 2006b, personal communication). Over a two year period in the 1980s, when a new fence, with barbed wire, was built along the Park boundary, 26 birds were recovered along the fence. Prior to fence construction, only 15 petrel burrows were known to occur within the Park and now, possibly owing to ungulate exclusion and predator control implemented by the Park, thousands of burrows are currently recorded in this area. Birdstrike to the fence may not be occurring because the fence was constructed prior to the development of the colony (Bailey, personal communication).

Hawaiian petrels are long-lived birds with low fecundity, delayed maturity and no evolutionary adaptation to mammalian predators. Therefore, depredation from introduced predators has a dramatic effect on the productivity and persistence of populations. Annual reproductive success of Hawaiian petrels on Haleakalā varies (63.4 percent, range 38 to 82; Simons, 1985; Hodges 1994) and is consistent with rates documented for other Procellariformes (Warham 1990). Hodges and Nagata (2001) compared nesting success in areas that are not protected from predators to areas with predator control. Since 1982, the Park has been maintaining 300 small mammal (i.e., cat and mongoose) live traps, including 68 traps within areas occupied by

Hawaiian petrels, two of which are located within HO. On average, nesting success was 14 percentage points higher in areas protected by live traps than in unprotected areas. Even with the 300 live traps in place, predation accounts for 36 percent of known causes of mortality of Hawaiian petrels. Bailey's data (2006b, personal communication) suggests that the high elevation of HO appears to preclude use of the site by cats and mongoose, and no cats or mongoose have been spotted on the petrel burrow cameras installed at this site (Fein, 2006a, personal communication). Rats were responsible for the majority (41 percent) of predation at all sites studied by Hodges and Nagata (2001) because while live trapping appears to prevent increases in rat populations, it is not intensive enough to eliminate these predators from the site.

Informal monitoring of petrel burrow camera images in the summer of 2006 indicated that rats were visiting the petrel burrows in the vicinity of HO (Fein, 2007, personal communication), even though two Park live traps are maintained at that site (Hodges and Nagata, 2001). Feral ungulate exclusion, predator control, and minimization of human disturbance are priority actions for the conservation of Hawaiian petrels in the action area.

2.3 ATST Project Description

2.3.1 Construction, Maintenance, and Operation of the ATST

The new facility is proposed for construction on an approximately 0.7-ac (0.3-ha) site consisting of cinder, lava, and ash deposits. The completed observatory enclosure will be a maximum of 142.7 ft (43.5 m) high and 84 ft (25.6 m) in diameter (Figure 8). The attached support and operations building will be several stories high in order to accommodate a large receiving bay, large platform lift, offices, and laboratories. The utility building will provide space for mechanical and electrical equipment including a generator, very-low-temperature chiller, ice storage tanks, a 10-ton heat pump condenser unit and uninterruptible power supply units. There will be a utility and ventilation tunnel connecting the utility building to the support and operations building. Additional support structures will include a subsurface grounding field for observatory equipment that also includes lightning protection, a wastewater treatment plant and infiltration well, and a storm water management system designed to provide potable water to the facility (NSF, 2009).

Figure 8. ATST construction site.

Project Schedule
Construction is scheduled to begin as early as the end of 2010 and will occur in various phases including site preparation and foundation work. Construction of the exteriors of the buildings and enclosures is anticipated to be completed within five years. Interior work and telescope integration, testing, and commissioning will then be completed within the subsequent two year period. The telescope is then scheduled for operation and use through the year 2060, which would span two complete 22-year solar sunspot cycles.

Demolition
The existing Mees Solar Observatory driveway, parking area and rock wall borders, the underground cesspool, and other selected items at the Mees Solar Observatory utility area will be demolished and removed. Demolition will be staged and will occur throughout the construction period. Demolition will require the use of bulldozers, dump trucks, bobcats, and other heavy machinery. Demolition work will occur for approximately 60 days of the construction timeline.

Grading and Leveling
The construction will require the creation of a level pad at least 20 ft (6 m) wider, in all directions, than the footprint of the telescope enclosure and the support and operations building. The grade cut will be made at approximately the 9,980 ft (3,042 m) contour elevation, the removal of a maximum of approximately 10 ft (3 m) of material from the highest portions of the site. This will be done using a bulldozer, backhoe, trencher, hoe ram, dump trucks, and other heavy equipment. No digging, trenching, or other type of earth removal work, associated with the grounding and lightning protection system[1], will be done within 40 ft (12 m) of any occupied Hawaiian petrel burrow. An estimated eight vehicles will travel to and from the site on a daily basis during a one-month period to complete this activity.

Excavation and Soil Retention
Initial major excavation will include a total removal of approximately 4,650 cubic yards (3,555 cubic meters) of rock and soil to accommodate the foundation systems for the proposed structures. This work will be done using bulldozers, backhoe, trencher, a truck-mounted auger for drilling down to bedrock, and a hydraulic hammer or jackhammers to break up large rock formations. A relatively undisturbed rocky site will be graded and leveled to approximately 2 ft (0.6 m) above the floor elevation of the Mees building (shown in the background in Figure 8) to accommodate construction of the ATST enclosure and concrete apron. Additional excavation will be needed in order to trench for utility lines, all of which will be installed underground. The major structural excavation is expected to follow the leveling work and take approximately two months to complete. The rock and soil removed from the construction site will be deposited in designated soil placement areas (Figure 9 and 10).

Soil Placement Area. The primary site for locating excavated material would be within the HO boundary, most likely below the Faulkes Telescope Facility. The material removed in the initial site leveling and structural excavation for the proposed ATST Project would be deposited in this location to a maximum thickness of about 6 feet at the east end, tapering down to be level with the existing site at the west end of HO property near the Federal Aviation Administration (FAA) facility. This new fill would be configured to maintain the established stormwater management

[1] A series of shallow trenches would be dug that extend peripherally around the entire facility and branch out to form a grounding field in the area to the south of the S&O Building. Trenches would be approximately 1 foot wide by 2 feet deep.

flow paths for HO. An alternative location for excavated material would be on HO property northwest of the ATST site on the slope above the infiltration basin that serves to contain stormwater runoff. This area has been disturbed numerous times, beginning in 1963, with grading for the Maui Space Surveillance Complex (MSSC). No biological or archaeological resources have been identified in this portion of HO during any of the surveys conducted throughout the last two decades. Appropriate grading would be employed to maintain the current slope angle into the basin, so that stormwater runoff paths and rates within HO would remain the same. Sand and silt in the basin would need to continue to be removed periodically, as it is at present, to maintain the capacity and percolation of the basin.

Alternate Soil and Rock Placement Strategies. A significant percentage of the material that would be excavated from the site is expected to be in the form of large intact pieces of rock. Subject to approval by IfA, other HO tenants, and the Cultural Specialist, these large rocks may be placed at locations around the HO property. As an additional strategy for beneficial use of on-site soil material, sand and silt may be taken from the infiltration basin area to be utilized for backfill around the proposed ATST structures. This could potentially eliminate the need for imported backfill material and would also augment periodic removal of sand and silt.

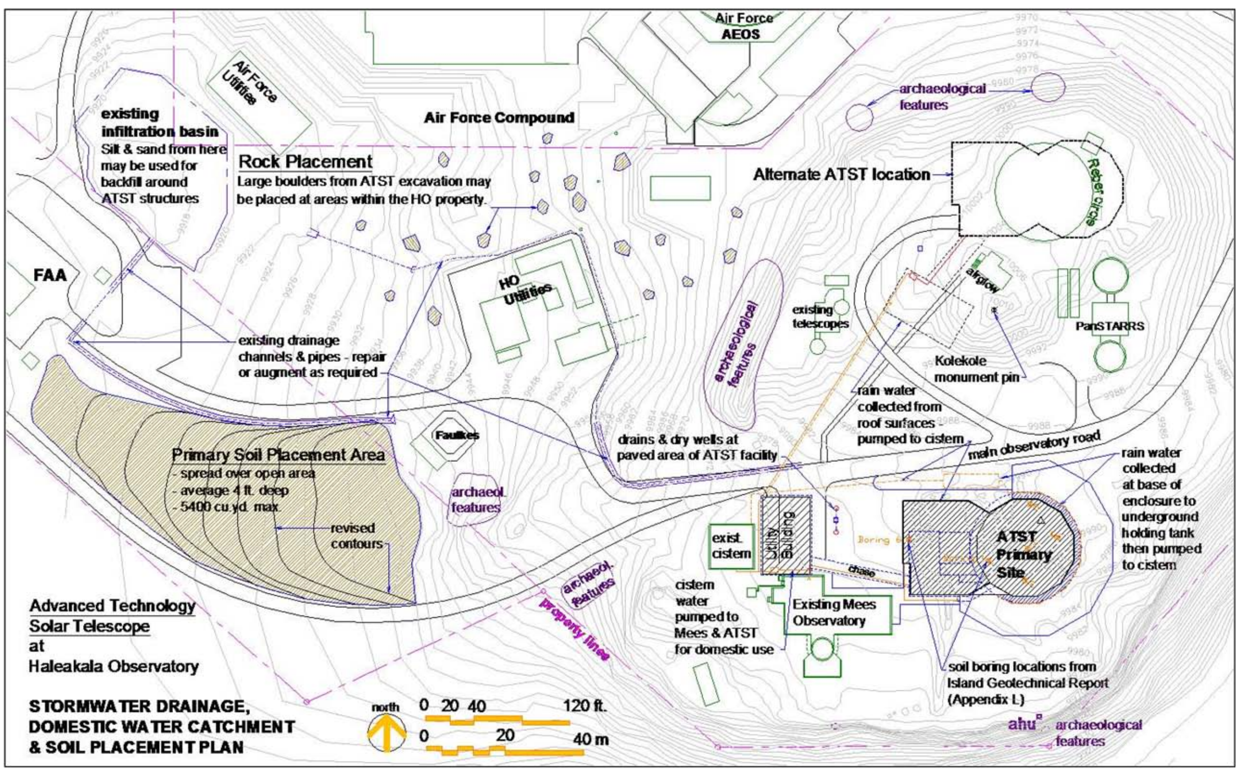

Figure 9. Most Efficient Soil Placement Plan for Stormwater, Erosion Control, and Water Catchment.

Figure 10. Primary proposed soil placement Area A, which will also serve as the equipment staging area is a previously disturbed site.

Caisson Drilling

Approximately 21 holes will be drilled to a maximum depth of 20 ft (6 m) to reach basalt bedrock so that caissons (support structures) can be poured to support concrete mat foundations below the telescope and enclosure (Figure 11). Caisson drilling will be restricted to periods outside the Hawaiian petrel breeding season, after burrow entrance camera information indicates all fledglings have left their burrows and before any prospecting birds have returned for the next breeding season. In addition, all caisson drilling will be completed the first winter of construction (Table 4). The support and operations and utility buildings, by contrast, will be built on simple concrete pads laid on top of the volcanic rock and gravel of the upper site strata.

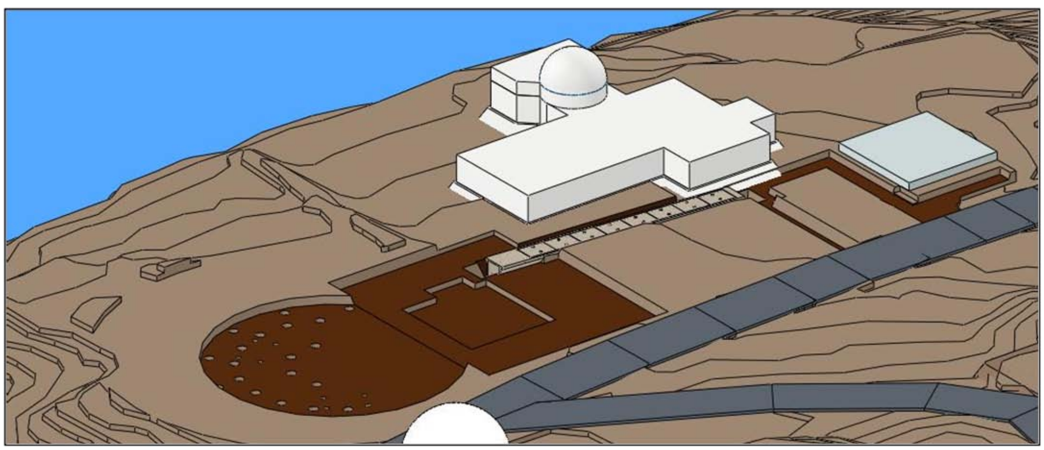

Figure 11. Excavation and caisson drilling will be completed in preparation for building fabrication.

Table 4. Schedule of construction activities.

Activities	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Years 7 & 8
Clear & Demo; Site level; Reroute Utilities & Services							
Major Earthwork							
Foundations & Caissons							
Facilities Buildings: Utility, Support and Operations, Pier, Lower							
Enclosure & Mechanical							
Telescope & Interior outfitting; Apron							
Construction complete; Telescope commissioning							

Construction Cranes

During the five years of building construction, a construction crane will be located just north of the telescope enclosure, between the enclosure and the access road (Fein, 2006c, personal communication) (Figure 12). A smaller crane will be used on all sides of the telescope structure to maneuver materials to a height of approximately 100 ft (30 m).

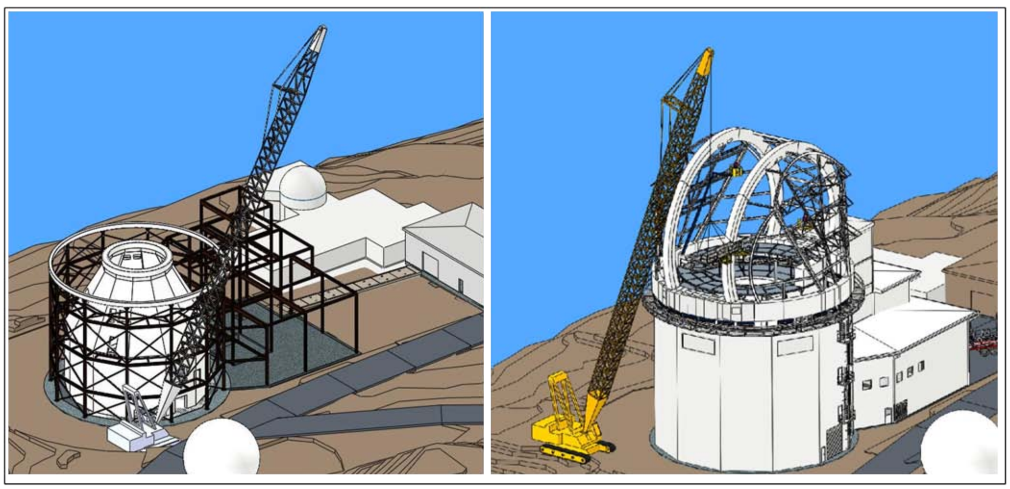

Figure 12. Framing for the telescope pier and support and operations building and the telescope enclosure will be pre-painted white prior to installation. (Diagrams do not accurately represent the size of the smaller construction crane.)

Building Fabrication

During fabrication of the telescope pier, upper enclosure, and support and operations building there will be periods in which the frame of the structures is exposed. The framing materials, which range in size from approximately eight in (20 cm) to approximately 24 in (61 cm) in diameter, will be pre-painted white prior to installation (Figure 12). ‘Storyboards’ provided by ATST engineers indicate the timing of framing and other construction activities (ATST 2009a, 2009b). These ‘storyboards’ were originally based on a July 2010 construction start date.

Vibration during Construction
Ground vibration will be monitored with seismographic equipment that utilizes sensitive geophones appropriate to detect vibration between 0.001 in/sec and the 0.12 in/sec peak particle velocity (PPV) burrow safety threshold. ATST project engineers conducted inspections of the burrows adjacent to the ATST project site to determine probability of burrow collapse due to vibration. They determined that the angular interlocking of separate rock segments which has allowed the borrows to survive seismic events, erosion and other potentially damaging forces over many years would enable them to withstand vibrations with peak particle velocities (PPV) of 0.12 in/sec without damage (Barr, unpublished 2006). PPV is the measure of the strength of ground vibration which is most often used to gauge the stress experienced by structures. The sources of maximum vibration during ATST construction are shown in Table 5. Ground vibration estimates in Table 2 were calculated based on the attenuation of ground vibration resulting from geometric damping alone. Due to a combination of geometric damping and additional attenuation of vibration as it moves through the soil, vibration levels at all petrel burrows are expected to remain well below the 0.12 in/sec damage thresholds throughout all stages of ATST construction.

Table 5. Maximum calculated ground vibration expected at various distances from construction equipment.

Equipment or Activity	Maximum Vibration Expected (PPV in/sec)			
	25 ft* (7.6 m)	50 ft (15.2 m)	100 ft (30.5 m)	200 ft (61 m)
Caisson drilling, large bulldozer, hoe ram	0.089	0.022	0.006	0.001
Loaded trucks	0.076	0.019	0.005	0.001
Jackhammer	0.035	0.009	0.002	0.001
Small Bulldozer	0.003	0.001	0.000	0.000

*U.S. DOT, Federal Transit Administration, 2006.

Vehicular Activities - Construction, Maintenance, and ATST Staff
It is estimated that during the seven-year construction, integration, and commissioning phases of the project, a total of approximately 25,000 round-trips by construction vehicles (primarily trucks) will be taken to the site. To minimize impacts to nesting Hawaiian petrels, no truck traffic within the Park and no construction activities at the ATST site will occur during the time-frame from 30 minutes after sunset to 30 minutes prior to sunrise. Vehicle lights are not permitted at any time within the HO site.

Infrastructure Maintenance
When ground disturbance activities are necessary to, for instance, maintain ATST infrastructure such as the lightning protection, wastewater treatment, and storm water management systems, the site will be surveyed to ensure the no listed species will be disturbed as a result of the project.

2.4 Assessment of Potential Effects

Table 6 summarizes the primary adverse impacts addressed in this HCP in addition to measures NSF proposes to avoid, minimize, and offset or mitigate for these effects. Take is expected because of (1) birdstrike to observatory structure prior to completion, (2) disturbance from general proximity to construction reducing breeding frequency / productivity, and (3) burrow collapse (ESRC meeting notes 16th Nov 2009). Appendix A includes an analysis of the estimated take expected from the ATST project. Appendix B includes a subsequent analysis summarizing population modeling results designed to identify when net benefit may be realized under different project scenarios. The results of these analyses are incorporated into this section and supplemented by other focused studies, as referenced in Section1.1.

The take license is inclusive of all project activities related to both construction and mitigation coverage. NSF believes that the allotted take of 35 ‘ua’u is a conservative estimate and will also be sufficient to cover unanticipated take from fence strikes and implementation of predatory control measures.

Table 6. Summary of effects of the project to the Hawaiian petrel addressed during the formal Section 7 consultation process.

Project Effects	Measures Adopted to Avoid, Minimize, and Offset Impacts
Collision of Hawaiian petrels with equipment and buildings	Framing lattice structures will be pre-painted white, construction crane will be lowered at night and marked with white visibility polytape or approved alternative. Polytape will be incorporated into conservation fencing. All completed structures will be painted white or an approved alternative will be used. Outdoor lighting will not be used.
Burrow collapse from construction vibration and trampling	Engineers set ground vibration threshold for burrow collapse. Vibration will be monitored and restricted to minimize the likelihood of burrow collapse.
Reductions in breeding attempts and reproductive success resulting from disturbance to adult birds	328-ac (133 ha) mitigation area surrounding HO will be fenced and managed with predator and ungulate control measures to achieve project net recovery benefit for the Hawaiian petrel.
Predator population increase	Trash will be contained. Predator control efforts.
Transport of invasive species to Haleakalā	Cargo will be thoroughly inspected for introduced non-native species. All ATST facilities and grounds will be thoroughly inspected for introduced species on an annual basis and any introduced species found will be eradicated.
Incidental live trapping of Hawaiian petrels in predator traps	Mammal traps will be monitored every other day. Any incidental captures will be released unharmed within 24 hours of capture.
Reduction of Hawaiian petrel population	Installation and maintenance of fencing and predator control measures to facilitate development of the Hawaiian petrel population within a 328-ac (133 ha) conversation area.

2.4.1 Collision with Buildings, Equipment, and Fences

There is a risk that Hawaiian petrel injury or mortality can occur due to collision with the equipment, and buildings, associated with the ATST Project. Collision with structures such as poles, buildings, vehicles, and lights, accounted for the death of 37 Hawaiian petrels (accounting for 26 percent of all detected Hawaiian petrel mortality, and the death of an average of 1.1 bird/year), in the vicinity of the Park and HO between 1964 and 1996 (Hodges and Nagata, 2001).

Birdstrikes to Conservation Fences

Bailey (2006b, personal communication) attributes the death of 26 of those birds to fences containing barbed wire, constructed to exclude ungulates from the Park in the 1980s. After two years, the barbed wire was removed from the fences. No birds have been found along those stretches of Park fence from which barbed wire has been removed (Bailey, 2010, personal communication). Significant levels of birdstrike and entanglement occurred on Park fences in the 1980s because the fences contained barbed wire. Park fences have been checked approximately once per month and, since the barbed wire was removed no downed birds have been seen in the vicinity of the Park fences. Because the proposed conservation fences will be marked with white polytape (Figure 13), Hawaiian petrels are believed to be less likely to strike the proposed conservation fencing. Based on the results of monitoring continuing through project construction, mitigation will be adaptively managed to allow improvements to the use, location, monitoring, or look of the conservation fence. Adaptive management and related reporting are discussed further in Chapter 6, HCP Implementation.

Research conducted by Swift (2004) and unpublished observations by Penniman and Duvall 2006 and Penniman (2009, personal communication) indicate that Hawaiian petrels avoid collision when objects are visible. Both the Swift (2004) and Penniman and Duvall (2006) applications of visibility marking found that the incorporation of strips of white, non-reflective electric fence polytape or similar material into fences reduced the risk of Hawaiian petrel collision. Before the installation of white visibility tape, birds were heard colliding with a new ungulate exclusion fence in the vicinity of a Hawaiian petrel colony on Lanaʻi on two occasions. Since the white electric fence polytape was installed (Figure 13), no bird collisions with the fence have been heard (Penniman, 2009, personal communication). Swift (2004) noted that birds appear to exhibit late avoidance behaviors when approaching marked fences, which they did not display when approaching unmarked fences, indicating that the apparent 100 percent successful collision avoidance marked fences is due to the birds' visual detection of the white tape.

Figure 13. Electric fence polytape improves visibility of lattice structures (photograph by Jay Penniman, Hawai'i Department of Land and Natural Resources, Division of Forestry and Wildlife, 2006).

Birdstrike to Buildings and Equipment

During the construction phase of ATST, the exposed materials and equipment present a potential strike risk to Hawaiian petrel. Ornithological radar and visual data collected during 2004 and 2005 (Day and Cooper 2004a, Day and Cooper 2004b, and Day, *et al.*, 2005) indicate that the ATST construction site is located within the flight path used by Hawaiian petrels. The ornithological radar data does indicate that birds tend to fly along the sides of the cliffs and through saddles on either side of the proposed ATST construction site, although they do also fly over the top of the peak, where the ATST is proposed for construction (Figure 14). Airspace used by Hawaiian petrels in the immediate vicinity of HO burrows will increase in the long term as a result of increases in population size resulting from mitigation activities implemented as a result of this and other projects.

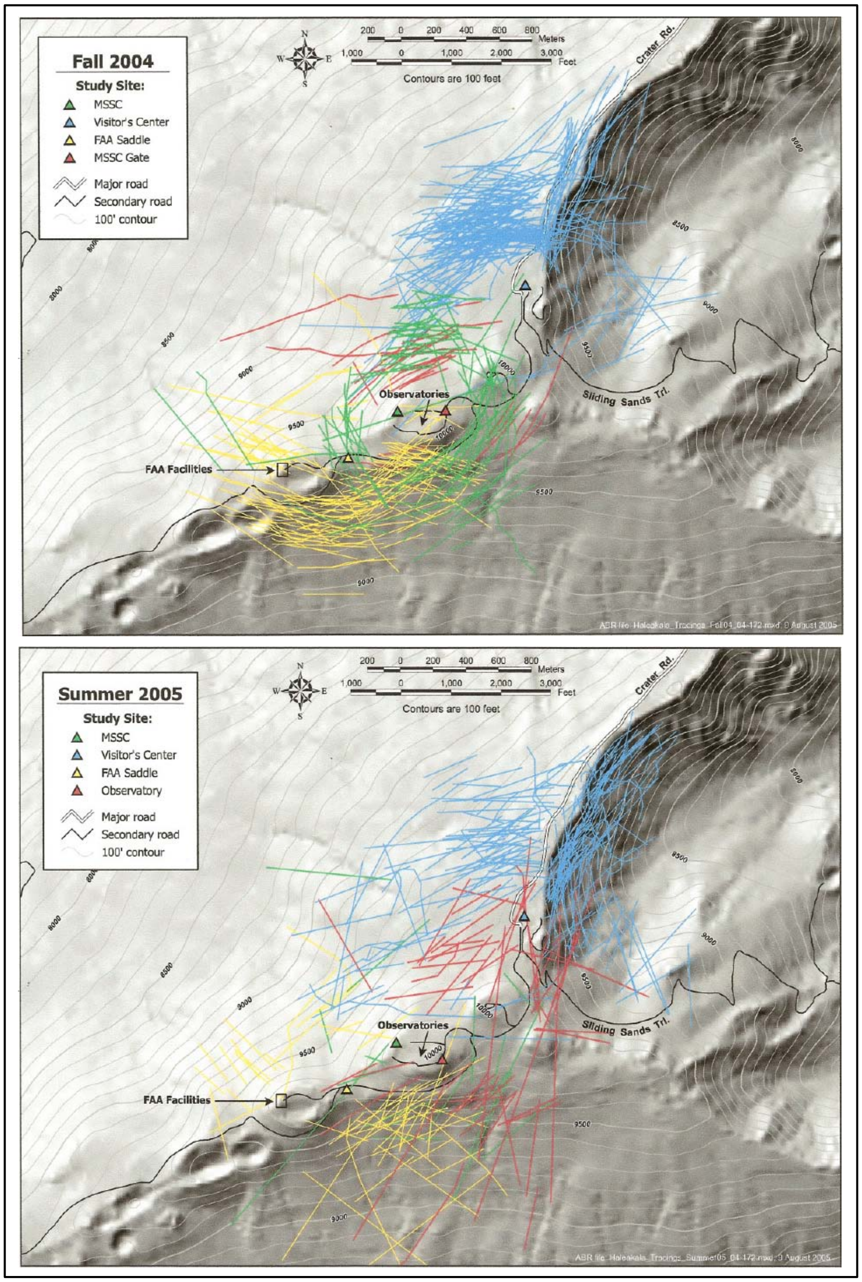

Figure 14. Diagrams from Day, *et al*., 2005, indicating Hawaiian petrel flight paths documented in the vicinity of the observatories site (the proposed ATST will be located south of the red triangle in the left picture; the red triangle in the right picture is located at the ATST site).

A Hawaiian petrel struck a small utility building which at the time had an outdoor light, in a topographic saddle in the vicinity of the ATST site (Bailey, 2006b, personal communication). The light has been removed to minimize potential attraction of seabirds. Additional Hawaiian petrel mortality has resulted during the fledging period, when fledglings collide with structures and rock outcroppings on their first flight to down to sea (Bailey, 2006b, personal communication).

Summary of Birdstrike Calculations of Direct and Indirect Mortality

Flight passage and avoidance rates were modeled based on the best available information. Mortality resulting from birdstrike will be monitored and direct take will be calculated based on observed carcasses and adjustments for carcass removal rate, percentage of the area searched, and searcher efficiency rate. If, for instance, a carcass removal factor of 0.1 were to be the case, 0.3 of the total search area is not covered, and searcher efficiency rate is 0.9, one carcass found is adjusted to an actual birdstrike of 1.5 birds. Indirect take will be calculated to incorporate reduced breeding success of the nest the struck bird would have attended to during the breeding season.

Calculations of Flight Passage and Through ATST Airspace and Avoidance Rates

Although building frame material will be pre-painted white to increase visibility to Hawaiian petrels, the large frame structures are likely to pose a flight hazard to the birds. To assess this risk, we first determined the passages rate and interaction through the airspace of the large structures (flight passage rate) and, second, estimated the likelihood they would avoid the object if it blocked their flight path (avoidance rate).

Flight Passage Rate Calculations

The Service previously estimated flight passage rate (Service, 2009, unpublished) through the three major structures of the ATST airspace (support and operations building, lower enclosure, upper enclosure) using ornithological radar data from Cooper and Day (2005) and Day, *et al*. (2005), and based on equations developed by Tucker (1996).

The Tucker (1996) model is based on interactions with turbine structures, and subsequent modification of this model as done so by Cooper and Day (2005). The application of this model to generate interaction probabilities and subsequent fatality rates for ATST has several limitations, including but not limited to the following:

1) The model is designed to determine interaction with solid albeit low visibility objects (towers), whereas the ATST construction will not be a solid object, but rather a conglomeration of several solid low visibility objects (e.g., metal framework). Determining the risk of each of these objects with the duration they are exposed is not practical with current information.

2) The model only uses data from a limited number of survey nights, with little assessment of variation in flight behavior during different weather conditions. For example, Hawaiian petrels and Newell's shearwaters will fly lower when fog or low cloud is present (Ainley, *et al*., 1995).

These data suggest that 15.3 birds per year fly through the airspace occupied by the lower and upper enclosure each and 15.0 birds per year fly through airspace to be occupied by the support and operations building. The figures and subsequent fatality estimates should not be considered a comprehensive assessment of take during the ATST construction, but rather they are the best available information used to calculate anticipated levels of take for this analysis and to inform the level of take to be authorized by the ITL.

Avoidance Rate Calculations

Determining a potential birdstrike or avoidance rate during ATST construction with minimization procedures in place is problematic because of a lack of suitable comparative data. Ideally species-specific and site-specific data should be used when assessing collision and avoidance rates (Fox, *et al*., 2006; Chamberlain, *et al*., 2006). There is a lack of data on the avoidance and collision of Hawaiian petrels with structures (Podolsky, 2004; Cooper, *et al*., 2007; Sanzenbacher and Cooper, 2008, 2009), and importantly a lack of comparative studies with colonial breeding bird species where the mechanism of strike occurs within 328 ft (100 m) of a breeding site, as the ATST construction will (NSF, 2009). The following summarizes knowledge to date.

Birdstrike rates determined from construction phases of previously built observatories at Haleakalā would provide site-specific comparative data; and while opportunistic observations suggest no strike occurred (Bailey, 2010, personal communication), it appears that no formal monitoring was undertaken during these construction periods, and thus no empirical data is available on the strike rate (KWP, 2006; Bailey, 2009, personal communication). Notably, opportunistic observations suggest no birdstrike has occurred at the Haleakalā Visitor Center, where the nearest burrow is approximately 3 m away (Bailey, December 29, 2009, personal communication). Habituation to the visitor center building may play a key role in this observation, given this building was constructed in the 1930s when only 15 burrows where known from the immediate area, and subsequent recruitment has occurred with this building occupying Hawaiian petrel airspace.

Using a comparative strike rate of zero from taped (visible) fences around Hawaiian petrel colonies on Lana‘i and Hawai‘i Island (Swift, 2004; unpublished observations by Penniman and Duvall, 2006) may underestimate birdstrike during ATST construction because these fences are rarely greater than 8 ft (2.4 m) in height, and on Lana‘i fence height is likely negated by adjacent vegetation, two conditions that will not be met by the ATST construction. Similarly, using comparative strike rate data from Hawaiian petrel interactions power lines on the island of Kaua‘i for decades (Cooper and Day, 1998; Podolsky, *et al*., 1998) may overestimate birdstrike because of the low visibility of these objects.

Wind turbine and meteorological tower studies in Hawai‘i include models for estimating annual Hawaiian petrel fatality based on nightly and annual movement rates (based on ornithological radar results) and exposure rates (based on the dimensions of the object presenting a strike hazard) (Table 7). Notably the avoidance rates used in these studies were estimated only and the authors note no empirical data exist to justify these numbers (Cooper, *et al.*, 2007; Sanzenbacher and Cooper, 2008; Sanzenbacher and Cooper, 2009; Podolsky, 2004).

Since development of these models, the duration of KWP-I (42 months) and the Lana‘i meteorological tower operation (2 years), offer limited testing of these avoidance estimations. In 42 months, total Hawaiian petrel strike at the KWP-1 wind farm is calculated to be 2.61 birds (Sanzenbacher and Cooper, 2009), equaling approximately 0.75 birds/year as corrected take (scavenging rate, searcher efficiency), and suggesting a 95 percent avoidance rate based on projected mortality from Cooper and Day (2004b). Notably, Podolosky (2004) suggests that a 50 percent avoidance rate used in Cooper and Day (2004b) is unrealistically conservative for Hawaiian petrels given the ecological context of their inherent flight and collision avoidance behavior, and used 90, 95, and 99 percent avoidance rates to present worst, moderate and best case birdstrike rates for KWP-II, albeit with a different model to estimate take. No birdstrike was recorded from the Lana'i meteorological towers after two years of operation (Sanzenbacher and Cooper, 2009).

Table 7. Hawaiian petrel estimated collision based on hypothetical avoidance rates from select sites in which actual passage rates were measured.

Study	Site	Annual movement rate bird/yr	Structure	Annual exposure rate bird/yr	Avoidance rate %	Hawaiian petrel fatality/yr
Cooper and Day, 2004a	USCG tower Haleakalā	191	30 m tower	1.64	57	0.67
Cooper and Day, 2004b	Kaheawa Wind Power (KWP) I	267/km	20 x 55 m turbines	12-90	50 95 99	1.46- 10.77 0.15-1.08 0.03-0.22
Podolsky, 2004	KWP I		20 x 55 m turbines	54 31 8	90 95 99.5	4.44 0.61 0.001
Cooper, *et al*., 2007	Lana'i Met towers, Upper Kuahoa	11,250	50 m met tower	80.83	0 50 95 99	76.1 38.4 3.8 0.8
Sanzenbacher and Cooper, 2008	KWPII	454	55 m guyed met tower	1.8	50 95 99	0.857 0.086 0.017
Sanzenbacher and Cooper, 2009	KWPII	348	100 m turbines	0.4-2.4 bird/yr	90 95 99	0.036 0.018 0.004

Like other nocturnal Procellariformes, Hawaiian petrels have evolved with a highly sensitive sense of vision and neuro-motor system to allow high speed flight (>30-50 mph) under nocturnal light conditions, all contributing to a degree of collision avoidance under natural conditions (Cooper and Day, 1998; Podolsky, 2004). The limited data from KWP-I and the Lana'i meteorological towers, plus the ecological context of this species' flight capabilities, suggest that Hawaiian petrels have a high potential to avoid structures encountered in their airspace. Ultimately, application of avoidance rates generated from power lines, fence, meteorological towers and wind turbines, to the ATST construction will be limited because:

1) the difference in *spatial airspace* that these objects occupy compared to the ATST;

2) the *visibility* will be markedly different for these objects compared to the ATST;

3) these strike / avoidance rates were generated in *flight paths* of Hawaiian petrels, as opposed to immediately *adjacent to a breeding site* as the ATST will be; and,

4) strike / avoidance rates generated for these objects were done so considering *objects static in the environment*. ATST construction will present a *changing strike hazard* as the horizontal, vertical and 'through' visibility for the total object changes during the construction process. This likely negates the possibility that birds may become habituated to the ATST framework, as habituation requires exposure to a consistent stimulus (Hinde, 1966; Mazur, 1998).

With these considerations in context, plus the apparent high avoidance rates of Hawaiian petrels, a range of avoidance rates are presented here to inform a selection of anticipated levels of birdstrike resulting from the ATST Project (Table 8).

Table 8. Estimated annual Hawaiian petrel fatality rate using Service biologists' (2009, unpublished) calculated passage rates.

Exposed Structure	Annual Estimated Fatality Avoidance Rate		
	90%	**95%**	**99%**
Lower Enclosure	1.46	1.46	1.42
Upper Enclosure	0.73	0.73	0.71
S&O Building	0.15	0.15	0.14

The following discussion of duration of birdstrike risk, summary of birdstrike risk analysis, and indirect take due to nest failure resulting from birdstrike may be found in Appendix A.

Duration of Birdstrike Risk

The duration of Hawaiian petrel birdstrike risk was assessed based on construction 'storyboards' provided by ATST contractors and engineers (ATST 2009a, 2009b). The schedules provided assumed a July 2010, start date which enabled caisson drilling to be conducted in the first winter of construction. In addition, three time schedules were assessed based on combinations of 5- or 6-day work weeks, and the use of a black-out period during Hawaiian petrel incubation (ATST 2009c). Birdstrike risk was considered if lattice, framework, or other structures were present with 'through' visibility (the ability to see through the structures) during each of the major construction tasks identified.

This Hawaiian petrel birdstrike risk assessment differs significantly from previous assessments of static or existing structures, including wind farms, power lines, and meteorological towers (Podolsky, *et al*., 1998; Sanzenbacher and Cooper 2008, 2009; Tetra Tech 2008). ATST construction is a dynamic process, and thus, birdstrike risk will change over time accordingly. This temporal variation was accounted for by assessing key construction tasks separately for each of the three major structures to be built (support and operations buildings, which includes the pier and lower enclosure, and the upper enclosure). No birdstrike is expected from the Utility Building construction as it is blocked by the Mees building from predominant flight paths (Cooper and Day, 2005). Risk of birdstrike from the completed structures is expected to be very low because of their size and white, visible color.

This duration of risk assessment is considered appropriate, based on the materials provided, but should be considered an overestimation for practical take considerations. For example, a maximum spatial (object airspace) and temporal (period of time exposed to the potential hazard) birdstrike risk is assumed during the task titled 'Pour Interior Elevated Slabs in S&O Bldg'. From a practical perspective, the total object airspace showing 'through' visibility, and the time exposed, will be progressively reduced on the support and operations buildings as each wall panel is fitted during the construction task. This scenario is analogous to most tasks and activities included in the dynamic construction process and suggest that the current risk assessment should be considered an overestimation for relevant take considerations.

A total birdstrike risk duration for each building's framing structures, based on a 6-day work week with no break during the incubation period, is as follows: the telescope pier structure/lower enclosure will be exposed for a total of 1.36 breeding seasons; the telescope enclosure/upper enclosure frame will be exposed for 1.22 breeding seasons before it is completed; and the support and operation building's frame will be exposed for 0.86 breeding seasons (Holmes, 2009).

Summary of Birdstrike Risk Analysis

Total anticipated observed birdstrikes, based on duration of birdstrike risk, passage rate calculations for airspace of each exposed structure, and a range of avoidance rates are shown in Table 9. The 99 percent avoidance rate was considered the most appropriate rate for this analysis based on results from the Lana‘i meteorological tower (Tetra Tech, 2008) and KWP (KWP, 2006) monitoring projects.

Table 9. Total anticipated birdstrikes based on duration of birdstrike risk, passage rate information, and a range of avoidance rates for 6-day schedule with no incubation break.

	Avoidance Rate		
Exposed Structure	**90%**	**95%**	**99%**
Lower Enclosure	2	1	0.2
Upper Enclosure	1.8	0.9	0.2
S&O Building	1.2	0.6	0.1
Total Birdstrikes	5	2.5	0.5

Monitoring is not expected to detect all birdstrikes due to carcass removal by predators and searcher efficiency, so anticipated birdstrikes shown in Table 10 are not expected to be directly detected. The Project Description outlines the measures that will be taken to determine appropriate adjustments to observed mortality which will be made to report levels of birdstrike occurring during project implementation. When a single carcass is detected, the total birdstrikes the carcass represents will be calculated to adjust for unobserved take (due to carcass removal, searcher efficiency, and search area correction described in the Project Description). The factors which will be used to adjust for unobserved take will be determined based on trials conducted at the site. If a carcass removal factor of 0.1 were to be the case, 0.3 of the total search area is not covered (see discussion of Area B in Section 5.2-Monitoring Impacts of the Project on the Hawaiian Petrel), and searcher efficiency rate is 0.9, one carcass found is adjusted to an actual birdstrike of 1.5 birds.

Indirect Take Due to Nest Failure Resulting from Birdstrikes

Selecting an appropriate level of anticipated take (Table 11) resulting from birdstrike requires adjustment for reduced breeding success of the nest the struck bird would have attended to during the breeding season. For Procellariformes, adult mortality while breeding will also result in chick mortality because both adults are required to provision sufficient food for successful chick rearing (Warham, 1990). Thus, Hawaiian petrel strike take must be adjusted for this potential chick mortality by the following factors:

1) A breeding bird versus a prospecting bird (breeding status: 50 percent) (Simons, 1984).

2) If a breeding bird, the probability that those birds did breed (breeding probability: 89 percent) (Simons, 1984).

3) If the bird did breed, the probability of successfully rearing a chick to fledging (fledging success: 66 percent) (Simons 1984).

Using these documented average rates, we calculated anticipated reductions to nest productivity to calculated total levels of take resulting from birdstrike (Table 10) using the following formula:

Adjusted Take = Total Direct Take x (Breeding Status x Breeding Probability x fledging success)

Or adjusted take for one Hawaiian petrel killed as a result of birdstrike =

$$1 + (BS \times BP \times FS) = \text{Adjusted Take}$$

Whereby,

TDT = Total Direct Take
BS = Breeding status (breeder or non-breeder)
BP = Breeding probability (if breeder, likelihood of breeding that year)
FS = Fledging success (if bred, likelihood of successfully raising a chick)
Using the formula and average levels noted above, adjusted take for one Hawaiian petrel killed as a result of birdstrike is 1.29

$$1 + (0.5 \times 0.89 \times 0.66) = 1.29$$

In other words, for each adult killed as a result of birdstrike, 0.29 fledglings will not successfully fledge. Observed direct take, unobserved take, total direct take, and adjusted take will be calculated and reported.

Table 10. Total anticipated direct and indirect take resulting from birdstrike to buildings.

Exposed Structure	Avoidance Rate		
	90%	**95%**	**99%**
Lower Enclosure	2	1	0.2
Upper Enclosure	1.8	0.9	0.2
S&O Building	1.2	0.6	0.1
Total Birdstrikes	5	2.5	0.5
Indirect Take (Reduced Nest Success)	1.5	0.7	0.1
Total Anticipated Take (Direct and Indirect)	6.4	5	0.6

2.4.1 Analysis of Burrow Collapse Due to Vibration and Crushing

ATST Project engineers conducted inspections of the burrows adjacent to the ATST Project site to determine probability of burrow collapse due to vibration. Physical crushing may also occur as a result of trampling or other physical disturbance. Holmes (2010) analysis indicated the two closest burrows (numbers 21 and 40, shown in Figure 15) were most at risk of collapse due to vibration and measures taken to avoid trampling burrows would be in place. Burrows 21 and 40 will be approximately 40 ft from excavation activities and 60 ft from caisson drilling sites.

Figure 15. Burrow entrances closest to the construction site: burrow 21 and the left and right entrances to burrow 40 (toothpicks shown are used by the Park to monitor burrow activity).

We compared the anticipated vibration levels at burrow numbers 21 and 40 to the level engineering assessments and additional information indicate they would be able to withstand. Project engineers determined that the angular interlocking of separate rock segments which has allowed the borrows to survive seismic events, erosion and other potentially damaging forces over many years would enable them to withstand vibrations with peak particle velocities (PPV) of 0.12 in/sec without damage (Barr, unpublished 2006). PPV is the measure of the strength of ground vibration which is the most often used to gauge the stress experienced by structures. Seismographs are used to measure PPV (Figure 16). The most fragile historic structures can be exposed to PPV of 0.12 in/sec without being damaged (U.S. Department of Transportation, Federal Transportation Administration, 2006).

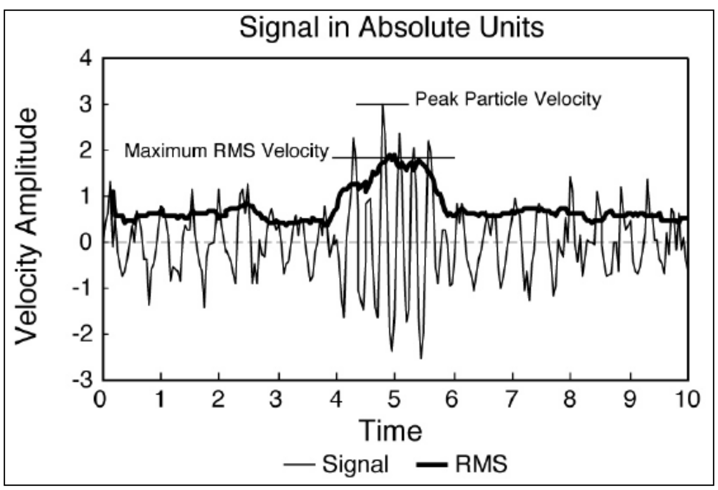

Figure 16. Peak particle velocity example (excerpt from U.S. Department of Transportation, Federal Transportation Administration 2006).

Although it was not thoroughly studied, anecdotal information collected during the October 15, 2006, 6.8 magnitude earthquake which had a measured PPV of 3.4 in/sec at a seismograph located adjacent to HO indicate the Hawaiian petrel burrows can withstand significant vibration. The earthquake's strongest vibration lasted for 15 to 20 seconds and reduced vibration lasted one minute (U.S. Geological Survey, unpublished). Many buildings and bridges were damaged or destroyed by the earthquake (Honolulu Advertiser, 2007). None of the 27 Hawaiian petrel burrow entrances in the ATST site vicinity that were being monitored by burrow cameras during the earthquake collapsed or showed any signs of instability. Bailey (2009, personal communication) detected one burrow collapse within the Park attributed to the earthquake, but emphasized that there likely were undetected collapses. Partial collapse of burrow tunnels was not monitored. However, burrows may be as long as 12 feet and a collapse anywhere along the burrow's length could result in take.

Although calculations based on geometric dampening of vibration of construction equipment (Federal Transit Administration, 2006) indicate caisson drilling would produce vibrations that are less than 0.12 in/sec at the closest burrows (Figure 17), ATST engineers agreed to relegate all use of rock drill equipment to the December through mid-February season when the Hawaiian petrels are absent from the site. Rock drills are the equipment used to drill holes for caisson pouring. Jeff Barr (January 31, 2007, unpublished) produced a map (Figure 17) which indicates caisson drilling will not be conducted within 60 ft (18 m) of Hawaiian petrel burrows. Excavation activities will be conducted at a distance of approximately 40 ft (12 m) from the closest burrow.

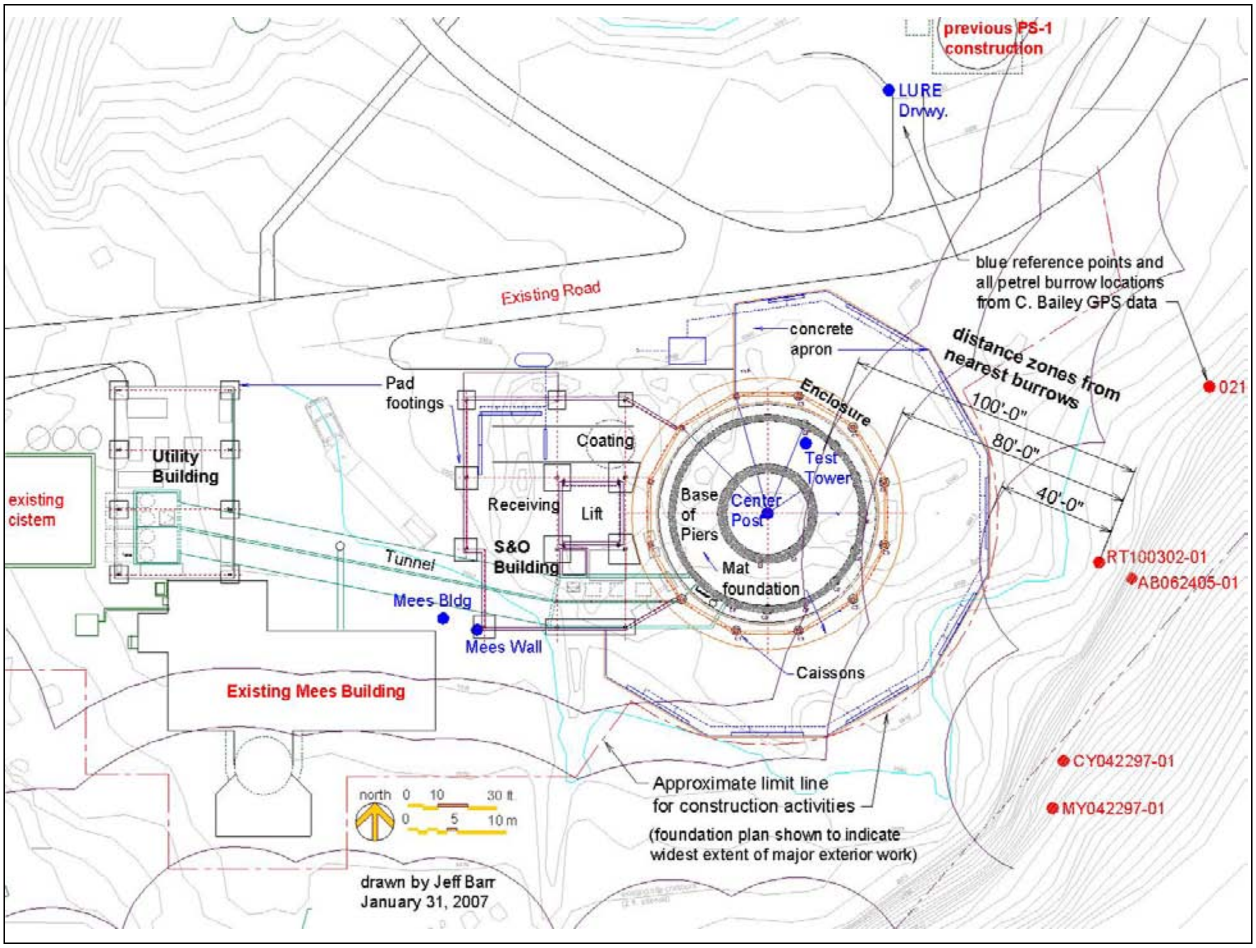

Figure 17. Hawaiian petrel burrows (bright red dots) in relation to the ATST construction site, including caisson drilling locations.

Vibration attenuation in local soils has been measured in two projects. In one project (Jenson, 1993), actual levels of vibration were lower than those predicted in Table 12 and in the other (Phelps 2009), vibration levels were higher than predicted levels. Jenson (1993) measured vibration of between 0.0009 in/sec and 0.0025 in/sec, 75 ft (23 m) from large trucks and tour buses driving on a road on Haleakalā, as being approximately four times lower than the vibration values listed in Table 12. The lower observed vibration is likely due to soil attenuation. Phelps (2009) found when excavators and hammers struck solid rock during demolition of a facility close to the ATST construction site, vibration was transmitted farther than soil damping calculations (see Table 5) predict (Figure 18). Presumably, this is because the solid volcanic substrate hit by the equipment transmitted vibration efficiently. However, even the highest levels of vibration measured at this demolition site attenuated, over a distance of 40 ft (12 m), to levels below the 0.12 in/sec burrow vibration safety threshold.

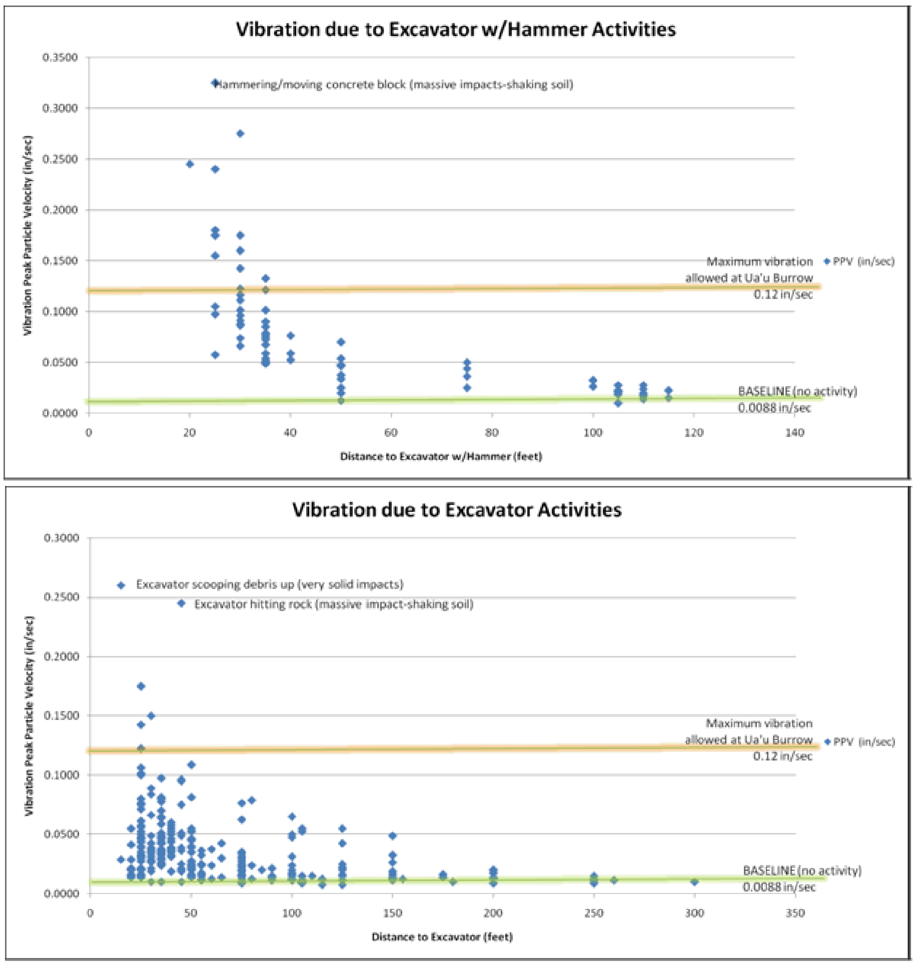

Figure 18. Phelps (2009) found vibration from excavators and hammers striking solid rock near to the ATST construction site was sometimes transmitted farther than soil damping calculations suggest it should have been.

Because Phelps' (2009) measurements indicate spikes in vibration it is reasonable to conclude that although on-site vibration monitoring and vibration restrictions which will be implemented during construction, will significantly minimize the duration of vibrations in excess of 0.12 in/sec, it may not be possible to avoid vibration spikes exceeding that threshold, particularly at the two closest burrows (numbers 21 and 40), because the vibration spike may occur without warning, if they hit solid rock. In summary, because only one collapsed burrow entrance was noted at the Park after the 6.8 magnitude earthquake (which had a measured PPV of 3.4 in/sec at a seismograph located adjacent to HO) the 0.12 in/sec PPV threshold set by Barr (2006, unpublished) appears to provide sufficient protection to the burrows. On-site real-time vibration monitoring and vibration restrictions will minimize the likelihood burrows will be exposed to vibrations greater than 0.12 in/sec PPV. However, unanticipated spikes in vibration, which may dislodge rocks within the nest cavity, may occur without warning. Because the greatest vibration risk is to the two burrows in Zone 1 (burrows 21 and 40), and because these burrows are effectively assumed to fail to produce fledglings during the years of project construction, for the purposes of take estimates (take, resulting from the anticipated lack of reproductive success of these Zone 1 burrows is accounted for in the next section), burrow collapse would not further reduce the anticipated project impacts to eggs or fledglings in these burrows. However, burrows 21 or 40 could be occupied by an adult or adult at the time of an unanticipated and unavoidable spike in vibration. Because only one adult is likely to be in each burrow, we anticipate that no more than two adult Hawaiian petrels may be killed as a result of partial or complete burrow collapse resulting from this project.

2.4.2 Summary of Anticipated Construction Noise Levels

Effect of the proposed construction noise on Hawaiian petrels can be inferred based on our knowledge about petrels, and from studies that addressed the effects of noise to other avian species. The birds' sensitivity to the sounds generated by the proposed project are likely to be associated with factors including the energy level and duration of the sound, how it reacts with topography and burrows, ambient sound levels and individual bird tolerance to sounds due to habituation. Sound energy level at various frequencies is measured in decibels (dB). For many purposes, sound measurements are A-weighted (dBA) to emphasize the middle portion of the entire sound frequency range, where humans and birds have the greatest sensitivity. The Hawaiian petrel vocalizations are sharp squeaks and nasal clucks (Simons 1985) which are within the central frequency range expressed by dBA sound measurements. This species is not known to use particularly high or low frequency hearing to search for prey or for other life history functions. Because Hawaiian petrels vocalize to each other within the human hearing frequencies, the A-weighted dBA scale was appropriate for application to the petrel. Therefore, the dBA sound estimates presented in the FEIS (NSF, 2009) were considered adequate for our analysis of the effect of construction noise on the Hawaiian petrel. The physics of noise attenuation with distance and terrain shielding presented here can also be applied at other frequency levels. It is important to note that sound (dBA) measurements are always associated with a distance from the source. The standard distance for sound measurements, referred to in this document is 50 ft (15 m) from the source. Noise levels of ATST construction equipment and vehicles (at 50 ft (15 m)), compared with familiar noise levels, based frequencies humans hear (dBA) are shown in Table 11.

Table 11. Noise levels of ATST construction equipment and vehicles (at 50 ft (15 m)), compared with familiar noise levels, based frequencies humans hear (dBA).

	Noise Source	Decibel (dBA) at 50 feet from source	Reference
1	Limit to human hearing	0 dBA	US DOT FHA 2006
2	Closed audiometric booth / bottom of Haleakala Crater	10 dBA	US DOT FHA 2006, NPS unpublished
3	Rustling leaves, tall grass in a light to moderate wind, and typical daytime urban residential area away from major streets	35 to 55 dBA	Resource Systems Group,. Inc., 2006
4	Ambient noise in front of Hawaiian petrel burrow at Haleakala Observatories Hawaiian petrel colony with 5 mph wind	55 to 68 dBA	Fein, unpublished 2007 data
5	Office, Restaurant, Library, toilet refilling its tank, air conditioning unit	60 dBA	Wikipedia
6	Passenger car, traveling at 30 mph	65 dBA	Resource Systems Group,. Inc., 2006
7	Large barking dog	70 dBA	Acoustical Solutions, unpublished
8	Passenger car, van, jeep at Haleakala	71 to 75 dBA	Fein, unpublished 2007 data
9	Tour buses at Yosemite National Park	58 to 77 dBA	NPS unpublished
10	City bus	80 dBA	FTA 1995
11	Tour buses at Haleakala	77 to 91 dBA	Fein, unpublished 2007 data
12	Backhoe, earth movers	80 dBA	FTA 1995, NSF 2006
13	Crane	82 dBA	NSF 2006
14	EPA maximum permissible truck noise level	83 dBA	Bearden 2000
15	Bulldozer	82 to 85 dBA	FTA 1995, NSF 2006
16	Jackhammer	97 dBA	NSF 2006
17	Rockhammers / drills	99 dBA	NSF 2006

Noise measurements conducted by Fein (unpublished data) indicate noise attenuation in the landscape surrounding the ATST construction site as a result of significant terrain shielding provides significant dampening of noise levels for burrows below the terrain drop-off approximately 160 ft (48 m) from the center of the construction site (Table 12). Although the noise was distinguishable below the terrain drop-off, noise levels did not exceed ambient levels as a result of the noise generator (Fein, 2009, personal communication).

Table 12. Terrain provides noise shield to burrows below the steep drop-off, south of the ATST construction site.

LOCATION	dBA	dBC	Ambient dBA/dBC
SOURCE	120	120	54/52
25'	95	93	54/52
50'	89	88	54/52
75'	79	78	54/52
100'	63	62	54/52
160' (edge of S.drop-off)	62	61	54/52
SC12	<50	<50	<50
SC15	<50	<50	<50
SC18	<50	<50	<50
SC19	<50	<50	<50
SC21	55	<50	<50
SC29	<50	<50	<50
SC30	<50	<50	<50
SC31	<50	<50	<50
SC33	<50	<50	<50
SC34	<50	<50	<50
SC35-L	<50	<50	<50
SC36	<50	<50	<50
SC37	<50	<50	<50
SC38	<50	<50	<50
SC39-R	<50	<50	<50
SC40	55	<50	<50
MY042297-01	<50	<50	<50
MY042297-02L	<50	<50	<50
RK062705-03L	<50	<50	<50
RT061397-01	<50	<50	<50
SKYLINE DRIVE	<50	<50	<50

2.4.3 Construction Impacts to Hawaiian Petrel Breeding Attempts and Reproductive Success

There is a risk of take resulting from breeding birds not initiating, or abandoning, breeding attempts during the breeding season because of construction activity (noise, vibration, etc.) and general proximity to the ATST construction, and a loss of productivity in those fledglings produced. Fewer fledglings and higher mortality would both be responsible for take. Impacts of vibration, noise and other construction-related disturbances to Hawaiian petrel reproduction will be greatest in the burrows located closest to the ATST construction site. Hawaiian petrels nesting in burrows adjacent the ATST construction site will be more sensitive to construction and traffic noise than the birds occupying burrows along the Park road, where they are exposed to ongoing traffic disturbance. The ATST site's Hawaiian petrel colony was divided into three zones of risk, as shown in Figure 19 and anticipated reductions in breeding attempts and reproductive success were estimated based on the best available information. This assessment was then used to calculate anticipated reductions in breeding success anticipated to result from the ATST Project.

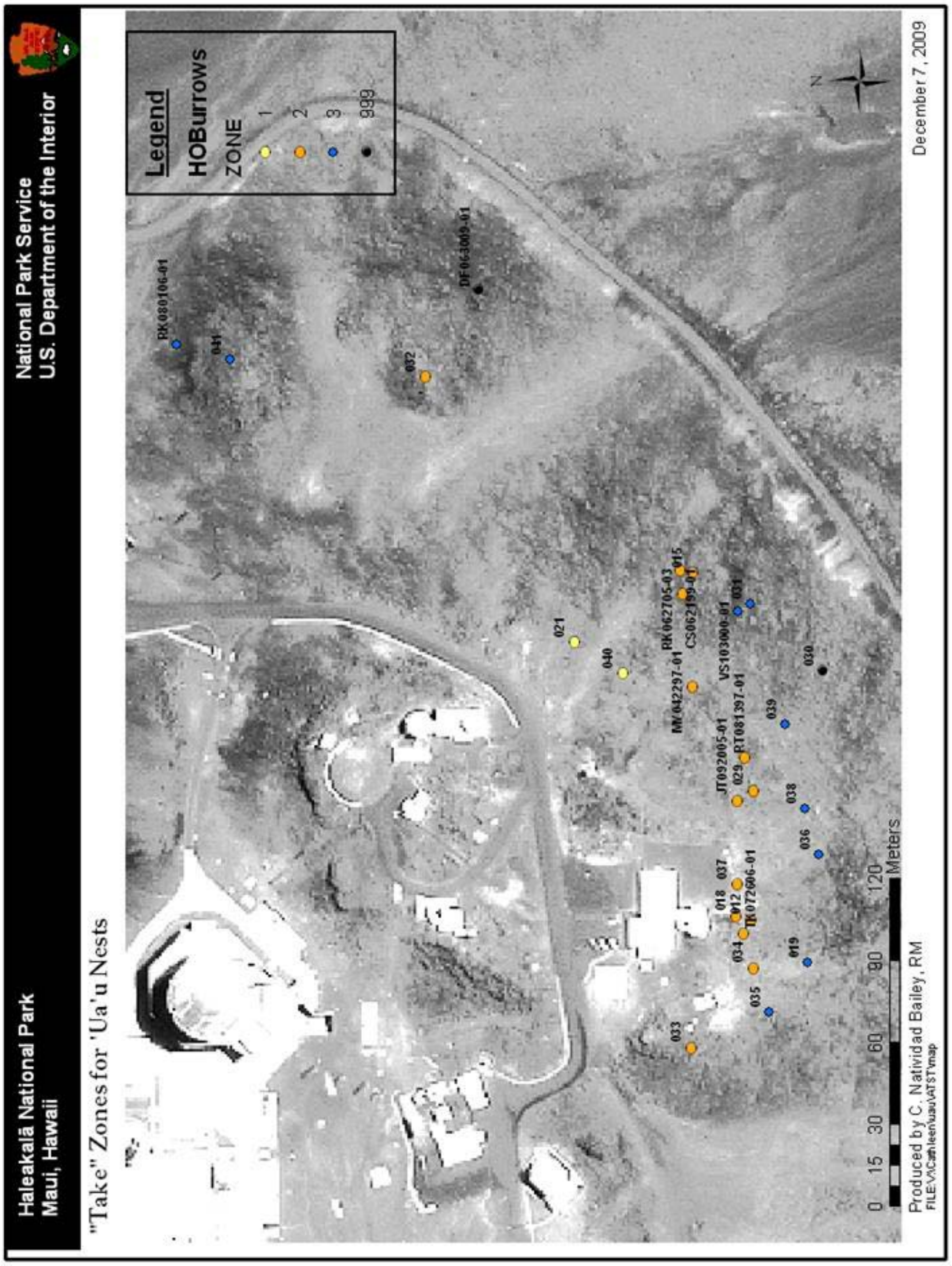

Figure 19. Risk zones and associated burrows for ATST construction process.

Wildlife responses to human activity are known to vary based on a variety of factors including previous exposure to human activity (Keller, 1989; Dunlop, 1996), species (Rodgers and Smith, 1997; Fernández-Juricic, *et al*., 2002; Blumstein *et al*., 2003) and stimulus type (Burger, 1986; Lord, *et al*., 2001). The timing of disturbance plays a key role in how wildlife will respond. Amongst seabird and waterbirds, greater sensitivity has been reported in earlier stages of breeding, (Götmark 1992; Knight and Cole, 1995; Yorio and Quintana, 1996; Bolduc and Guillemette, 2003). Animals act to maximize their lifetime reproductive output (Drent and Dann, 1980). Birds adjust their commitment to each breeding attempt to reflect the level of investment they have already made to the attempt (Trivers, 1972; Andersson, *et al*., 1980). The further a breeding pair progresses through a breeding season and the more it has invested in producing progeny, the greater the ‘cost’ of abandoning that particular breeding attempt becomes (Trivers, 1972; Andersson, *et al*., 1980). This information suggests the Hawaiian petrels would be more likely to abandon their nests during pre-egg laying/prospecting or incubation periods than after eggs have hatched; the birds would be less likely to abandon the nest as their investment in the nest increases.

Few studies exist investigating the effects of construction adjacent to burrowing petrel colonies. When a road paving project, which occurred during the incubation period, was done on the Park road, a 25 percent decrease in Hawaiian petrel reproductive success was observed (Bailey, 2009, personal communication). A search of the ISI Web of Science Database revealed no peer-reviewed articles for the search terms of petrel + noise / vibration / construction. In the absence of this information, measurements of these proximate mechanisms associated with disturbance (noise and vibration levels) were determined. Anticipated levels of noise and vibration were assessed cumulatively with other construction-related disturbance.

Overview of Disturbance Sensitivity of Incubating Hawaiian petrels

Construction activities that will produce daily prolonged loud noises, vibration, and other disturbance are scheduled to coincide with the incubation period. Male and female birds alternate incubation attendance. Eliminating the first and last incubation shifts, which are shortened by the events surrounding egg-laying and hatching, the overall average shift length is 16.47 days (+/-4.19 days). The adult’s incubation shift is relieved when the other parent returns to the nest after an extended foraging trip at sea. Incubating adult Hawaiian petrels in undisturbed environments spend almost 95 percent of their time sleeping (Simons, 1985). Given weight loss measurements by Simons (1985), undisturbed birds lose 1.54 percent of their initial body weight per day when incubating an egg. Simons (1985) estimated that a male petrel which he found taking a 23-day incubation shift in an undisturbed area may have lost 35.5 percent of its body weight during the shift. Egg temperature and evaporative water loss are controlled by the incubating adult. Because the metabolism of awake, resting birds is almost twice that of sleeping birds (Simons, 1985), disturbance of incubating birds’ sleep as a result of construction noise and vibration is likely to result in more rapid weight loss and an inability of the adult to stay on the egg until its mate relieves it.

Periods of egg neglect occur naturally and are usually associated with intermittent incubation resulting from asynchronous mate shift in inexperienced breeders, or in the general population during years of variable oceanic conditions which affect feeding success (Warham, 1990). Therefore, eggs may be able to survive exposure for some period. In fork-tailed storm-petrels (*Oceanodroma furcata*), chicks have been observed to hatch successfully from eggs that were left unattended for as long as seven consecutive days (Boersma, *et al.*, 1980), although the success of egg-hatch as well as nestling mortality was significantly lower for eggs which experienced lack of attendance. A Hawaiian petrel egg, neglected for three days during the middle of the incubation period, did successfully hatch. However, the extent to which eggs of this species can tolerate the absence of the incubating adult is not known (Simons, 1985). As a result of construction disturbance, egg neglect periods longer than three days are expected because incubating adults will leave the nest in self-preservation to avoid severe loss of body mass.

Disturbance resulting from construction equipment, vehicles, and workers is expected to increase startle, alarm, and alert behavior and disturb the day time sleep incubating adults occupying burrows within the three disturbance zones delineated by Bailey and Holmes. The closest burrow entrance is approximately 40 ft (12 m) from the outer edge of the construction site. The noise level at a point 40 ft (12 m) away from an operating crane is 84 dBA when the crane is operating, and 101 dBA when the rock hammer is in use. Topographical shielding between the line-of-sight view of the construction site and the burrow entrance cuts sound level at the burrow entrance (see Table 12). Sound attenuation of 0.625 dBA per inch of burrow depth (Fein, unpublished) would result in a some additional noise dampening; however noise levels within the burrow nest chambers is expected to be high.

No studies of the sensitivity of sleeping Hawaiian petrel to noise have been conducted. Human sensitivity to being awakened from sleep varies among individuals, as shown in Figure 20 (Federal Interagency Committee on Noise, 1992; Finegold, *et al.*, 1993, 1994; Finegold, 2007, personal communication). Based on this dose response curve, 5.34 percent of sleeping humans would be awakened by a noise event of 48 dBA. The hearing range of birds is expected to be very different than the human range of hearing, given that humans and birds belong to different taxonomic classes. Because knowledge of bird hearing is more limited than that known for humans, human hearing information is presented as it constitutes the best available information.

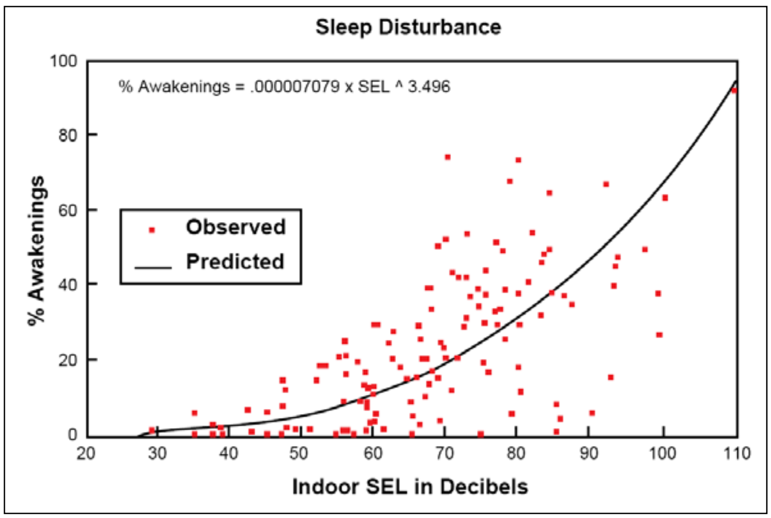

Figure 20. Percent of human awakenings at various dBA single event noise exposure levels (SEL) (Finegold, *et al.*, 1993, 1994; Federal Interagency Committee on Aviation Noise, 1997).

Birds occupying zone 1 (see Figure 19) will be exposed to the loudest noises; birds occupying burrows in zones 2 and 3 are will also be exposed to noise levels which we expect to be loud enough to disturb sleeping birds. During construction, sound levels are expected to be markedly higher than 48 dBA within nest chambers. However we assume incubating birds that occupy the burrows outside Zone 3 are not likely to abandon their eggs as a result of telescope construction activities.

Overview of Disturbance Sensitivity during Other Periods

The noise generated by construction equipment and vehicles are expected to increase startle, alarm, and alert behavior and disturb the day time sleep of Hawaiian petrels occupying zones 1 through 3. The closest burrow entrance is 40 ft (12 m) from the outer edge of the construction site. The noise level at a point 40 ft (12 m) away from an operating crane is 84 dBA when the crane is operating, and 101 dBA when the rock hammer is in use. Topographical shielding between the line of sight view of the construction site, and the burrow entrance, cuts sound level at the burrow entrance down to below 89 dBA. Sound attenuation of 0.625 dBA per inch of burrow depth (Fein, unpublished) would result in a maximum noise level of 82 dBA within the nest chamber of the burrow closest to the construction site.

Potential consequences of construction noise and vibration could include increased metabolism, nest abandonment, and temporary damage to auditory cells. Juvenile Hawaiian petrels in close proximity to the construction site are expected to respond to loud noises and vibration with increased activity and decreased incidence of sleep, therefore their food demands are expected to increase. Rat pups exposed to 80 dBA and 100 dBA noises for 3 hours per day for 30 days were found to have increased incidence of grooming, play, locomotion behavior, and decreased incidence of sleep. No indication of a noise-induced stress reaction, such as changes in adrenal gland weight or stomach ulceration were found in the 15- to 45-day old rats, compared to the control groups (Smiley and Wilbanks, 1982). Forty percent of people would be awakened by a sound of 85 dBA. The people who would not be awakened by such a loud sound are those who have habituated to the loud sound (Finegold, *et al.*, 1994). Adult Hawaiian petrels feed chicks at night, when construction activity will not be occurring. Parents continue to feed chicks, driven primarily by the chick's demands for food (Simons, 1985). If a chick has an increased need for food resulting from increased daytime activity, increased parental feeding is expected. A potential consequence of increased noise and vibration could be nest abandonment by Hawaiian petrels. We do not expect Hawaiian petrel chicks to abandon their nest, where they are fed, due to the noise and vibration associated with the ATST construction activities. Hawaiian petrel chicks, exposed to noise and vibration associated with the Park road and past construction projects on Haleakalā have not resulted in a documented decrease in chick survival or in chick nest abandonment. In September 2001, a 30-foot deep excavation for the Faulkes Telescope North facility began during the Hawaiian petrel breeding season and continued through the months when the birds were absent from the colony. Although the closest petrel burrow to this telescope was 100 ft (30 m), the 2001 project did not appear to have a negative impact on the nestlings (NPS, 2003).

We were concerned the adults and nestlings may be exposed to sound levels that are known to cause permanent hearing loss in mammals. Sound levels over 85 dB are considered harmful to inner ear hair cells, 95 dB is considered unsafe for prolonged periods (Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, unpublished). Nestlings may be outside the burrows closest to the loud construction equipment (66 ft (20 m)) during the day and exposed to 101 dBA sounds which may be loud enough to damage ear hairs. A review of avian hearing loss was conducted and it was determined that hearing loss in birds is difficult to characterize because birds, unlike mammals, regenerate inner ear hair cells, even after substantial loss (Corwin and Cotanche, 1988; Stone and Rubel, 2000). Therefore, we do not expect permanent hearing loss in Hawaiian petrels to result from the proposed action.

Construction Disturbance Risk Assessment

On November 11, 2009, Bailey and Holmes visited the site and delineated four zones of anticipated disturbance impacts around the ATST construction site (see Figure 19). Petrels occupying burrows in Zone 1 would be most exposed to disturbance and the risk of project disturbance-related reductions in breeding are insignificant and discountable in zone four. A 2010 census of the area (Bailey, 2009, personal communication) indicates there are 27 active burrows in the Hawaiian petrel colony adjacent to the ATST construction site (see Figure 19).

Construction-related disturbance impacts will be greatest to the burrows closest to the construction site. Three zones of risk (and the fourth zone within which risk was considered to be insignificant and discountable) were developed by Bailey and Holmes (Holmes, 2010a) based on proximity to the construction site, noise shielding by landscape features and topography, site-specific noise attenuation information provided by NSF (Fein, 2010, personal communication), and expert familiarity with impacts of various types of disturbance to Hawaiian petrel reproduction.

1) Two burrows (numbers 40 and 21) occur in zone 1. Zone 1 burrows will be exposed the highest noise and vibration levels and these burrows were given an adjustment of multiplier score of 1 (100 percent loss of nest success). These burrows are on the plateau the ATST is to be built on, and are within 40 ft (12 m) from the edge of ATST apron.

2) There are currently 14 active burrows in zone 2. Zone 2 burrows are given a multiplier of 0.5 (50 percent reduction in breeding success due to construction disturbances) given they are on the slopes immediately below construction and afforded some protection by topographic shielding and distance from the construction site.

3) Nine active burrows are located within zone 3. Zone 3 burrows are given a multiplier score of 0.1 (10 percent reduction in breeding success resulting from construction disturbances). They are furthest from the construction site on the slopes below.

Calculations of Anticipated Reductions in Breeding Attempts and Reproductive Success
Known breeding probabilities and fledging success rates for active burrows in undisturbed areas were used to adjust the zone multipliers to develop a factor for use calculating anticipated reductions in reproductive success resulting from project disturbance. This calculation adjusts for the probability that a bird would have bred that year (89 percent), and that the pair would have been successful (66 percent, Simons 1984). Adjusting for the probability that some of these pairs may have been non-breeders prospecting (i.e., breeding status) is problematic because the difference between failed breeders (a bird that did lay an egg) and prospecting non-breeders often is not distinguishable (Bailey, 2009, personal communication). Thus, we consider all active burrows identified in Table 4 to be breeders at some point during the 6 years of ATST construction.

Thus:

Anticipated Take = Take risk (Zone multiplier) x (breeding probability 89 percent x fledging success 66 percent)]

Or anticipated take for **one** active Hawaiian petrel burrow in **zone 1** =

(1.0) x (0.89 x 0.66) = **0.59**

Anticipated take for **one** active Hawaiian petrel burrow in **zone 2** =

(0.5) x (0.89 x 0.66) = **0.29**

Anticipated take for **one** active Hawaiian petrel burrow in **zone 3** =

(0.1) x (0.89 x 0.66) = **0.06**

Summing the anticipated take levels, factored by the number of active burrows in each zone (.59 x 2 + .29 x 14 + .06 x 9) we estimate a total of 5.78 fewer fledglings will be produced per year as a result of construction disturbance than would have been produced in the absence of the ATST Project. Table 13 is a summary of covered take based on the above calculations.

Table 13. Summary of covered take.

	Source	
	Disturb	**Collision**
Adult	5	3.2
Juvenile	30	0
Total	35	3.2

Duration of construction activity take

Duration of disturbance from construction activity is considered for the duration of the entire ATST Project. A total disturbance risk duration of 5.4 breeding seasons was estimated based on the 6-day work week with no blackout period during the Hawaiian petrel incubation period. This duration assessment overestimates the total period in which disturbance will occur, because it does not account for variation in activity likely to occur during that time. Given a total construction duration risk of 5.4 breeding seasons, we estimated that 31 fledglings are unlikely to be produced as a result of construction disturbance.

2.5 Cumulative Effects

Cumulative effects are those impacts of future state and private actions that are reasonably certain to occur within the area of action subject to consultation. Cumulative effects include the impacts of future state, local, or private actions that are reasonably certain to occur in the action area considered in this HCP. Future federal actions that are unrelated to the proposed action are not considered in this section because they require separate consultation pursuant to Section 7 of the ESA.

The cumulative impacts for this project include the incremental environmental impacts of the ATST Project when added to other “past, present, and reasonably foreseeable future actions, regardless of what agency (federal or non-federal) or person undertakes such other actions.” Cumulative impacts can result from individually minor, but collectively significant, actions taking place over time.

To identify other proposed projects within the action area, the HO Long Range Development Plan and information from the Park was used. In November 2005, and again in February 2009, agencies known to have facilities and operations within the action area were contacted with a request to provide information on current and planned activities that could occur within the reasonably known future and contribute to cumulative impacts when considered with the proposed ATST Project at HO (KCE, 2005, 2009). The agencies were:

1) County of Maui Police Department, Telecommunications
2) Department of Energy
3) Federal Aviation Administration
4) Federal Bureau of Investigation
5) Haleakalā National Park

6) Hawaiian Telcom
7) State of Hawaiʻi Department of Accounting and General Services Public Works, Information and Communications Services Division
8) Maui Electric Company, Inc.
9) DLNR Maui Na Ala Hele
10) National Weather Service/National Oceanic and Atmospheric Administration (NOAA)
11) Raycom Media, Inc.
12) Sandia Laboratories
13) U.S. Coast Guard, Civil Engineering Unit
14) U.S. Air Force Research Laboratory

3.0 MINIMIZATION AND AVOIDANCE

3.1 Minimization During Construction

A number of measures will be employed during construction to minimize potential impacts on Hawaiian petrels and petrel burrows. (These measures are also summarized in Table 6.)

During the pre-consultation process, state and NSF worked cooperatively to develop avoidance and minimization measures to reduce impacts of the project to the Hawaiian petrel. NSF incorporated conservation measures into the proposed action to minimize the impacts of the project and to avoid incidental take of Hawaiian petrel based on analysis compiled by NSF-contracted seabird biologist Nick Holmes. Avoidance and minimization measures include building frame equipment and fence visibility markings, construction scheduling, Hawaiian petrel monitoring and research, and predator control and invasive species interdiction and control (see Table 4).

Caisson Drilling
Caisson drilling will be restricted to periods outside the Hawaiian petrel breeding season, after burrow entrance camera information indicates all fledglings have left their burrows and before any prospecting birds have returned for the next breeding season.

Construction Cranes
During construction, a crane will be used on all sides of the telescope structure to maneuver materials to a height of approximately 100 ft (30 m). To ensure this crane does not crush any Hawaiian petrel burrows when it moves away from the existing road, the project site manager will install temporary marking to delineate the maximum extent of the crane's operation. To minimize and avoid the collision risk to birds between February 1 and November 30, the cranes' lattice structures will be lowered along the paved roadway each night, to rest no higher than 14 ft (4.3 m) from the ground, and the booms will be painted white or marked at night with visible white electric fence polytape. If the boom structures are not painted white, then white, non-reflective electric fencing polytape will be secured in some way to the all sides of the entire boom portion of the crane each night. The polytape strips would form a grid, with vertical and horizontal strips of polytape running a minimum of every 12 in (30.5 cm). The specific method of attachment would be finalized after consultation with the crane contractor. The polytape grid might be sewn to a canvas fabric to be thrown over the crane boom at night, a sewn matrix of tape might be pulled over the boom, or another method may be employed to secure the grid of polytape to the crane.

Birdstrike to Buildings and Equipment
To minimize the likelihood of birdstrike to buildings and equipment, building frame materials and the lattice structure of construction cranes will be painted white or marked with white polytape, as described in the Project Description. A large construction crane, which will be at the construction site for approximately five years, and a smaller crane and other equipment could pose a flight obstacle to the fast-flying Hawaiian petrels during breeding season. In order to minimize the flight risk to birds, the cranes' lattice structures will be lowered each night, to a height of 14 ft (4.3 m) or less, along the paved access road and the booms will be painted white or draped with visible white electric fence polytape.

The white polytape visibility flagging which will be secured over the ATST construction crane at night between February 1 and November 30 will contain a five times greater density of flagging than the flagging used in the Lana'i fences studied by Swift (2004) and Penniman (2009, personal communication) described above. Therefore, we anticipate that the crane will be visible to Hawaiian petrels flying in the area. Measures to increase visibility of the ATST cranes and other structures via taping and white paint are outlined in Section 2.3-ATST Project Description; however, these structures will still retain some through visibility during construction and heavy clouds and fog may reduce the visibility of the structures and equipment.

3.2 Invasive Species Interdiction and Control

To reduce the risk of transporting non-native species or seeds to the project site, NSF has proposed the following measures. The HO Long Range Development Plan for the prevention of introduction of invasive exotic weed species will be followed during the construction, maintenance, and use of the ATST. The eight Specific Alien Arthropod Control Measures listed below, which are modified versions of the alien arthropod control measures in the existing plan, will be implemented to minimize impacts to native species and habitats, as well as minimizing attraction of predators.

As part of the Special Use Permit (SUP) process with the Park, minimization measures will be developed which will include the following conditions. In order to ensure that destructive, non-native species are not introduced to the Park, HO, and adjacent areas, the ATST Project site manager will cooperate with the Park in developing and implementing a construction worker education program that informs workers of the damage that can be done by unwanted introductions. Satisfactory fulfillment of this requirement will be evidenced by successful completion of a test approved by the Park and administered by the contractor under Institute for Astronomy supervision. All workers bringing vehicles into HO will be required to complete the training and pass the test before beginning work on the site. In addition, all construction vehicles will be steam-cleaned to remove all organic matter and insects before alien invasive species are transported into the Park. Any equipment, supplies, and containers with construction materials originating from outer islands, the mainland, or an international port, will be checked for infestation by unwanted species by a qualified biologist or agricultural inspector prior to departure from that port and again prior to unloading at Kahului Harbor or Airport (University of Hawai'i, 2005).

The following measures will also be taken to prevent introduction of invasive exotic species to the project area: documentation of all inspections, including the name and contact information for the inspector will be maintained with each load. The ATST Project site manager will ensure that the Park is provided with advance notice about the arrival of each load in order to facilitate load inspections prior to vehicles reaching the Park entrance. In addition, ATST facilities and grounds within 100 ft (30 m) of the buildings will be thoroughly inspected on an annual basis for introduced species that may have eluded the cargo inspection processes. This annual inspection will be conducted by a qualified biologist. Any newly-discovered non-native, invasive plant or animal will be photo documented, mapped, and described. Any introduced species found inside or within 100 ft (30 m) of the ATST buildings will be exterminated as soon as they are identified. The resource biologist for ATST will employ appropriate control methods that will include the use of available herbicides and pesticides, in accordance with established practice at HO and pursuant to label requirements.

3.3 Specific Alien Arthropod Control Measures to be Taken

Alien arthropods can arrive at the site by two general pathways. First, alien species already on Maui can spread to new locations. Second, alien species can arrive on the island with construction materials in or on shipping crates and containers. In order to block the first pathway, heavy equipment, trucks, and trailers will be pressure-washed before being moved to the ATST construction site. The following specific alien arthropod control measures, adapted from those already required pursuant to the HO Long Range Development Plan will be implemented to further minimize the spread and establishment of alien insects. These six specific alien arthropod control measures are as follows:

1) Earthmoving equipment will be free of large deposits of soil, dirt and vegetation debris that could harbor alien arthropods.

   a. Pressure-wash to remove alien arthropods: Earthmoving equipment and large vehicles and trailers often sit at storage sites for several days or weeks between jobs. Most of these storage sites are located in industrial areas and usually support colonies of ants and other alien arthropods. These species often use stored equipment as refuges from rain, heat, and cold. Ants may colonize mud and dirt stuck on earthmoving equipment and could then be transported to uninfested areas. Pressure-washing of equipment before it is transportation to the site will be thorough enough to remove dirt and mud and to wash away ants, spiders and other alien arthropods, thereby reducing the chances of transporting these species to the site area.

   b. As required by the HO Long Range Development Plan, large trucks, tractors, and other heavy equipment will be inspected before entering the Park. Inspection will be recorded in a log book kept at the site.

2) All construction materials, crates, shipping containers, packaging material, and observatory equipment will be free of alien arthropods when it is delivered to the site.

   a. Inspect shipping crates, containers, and packing materials before shipment to Hawaiʻi: Alien arthropods can be transported to Hawaiʻi via crates and packaging. Therefore, only high quality, virgin packaging materials will be used when shipping supplies and equipment to the ATST Project site. Pallet wood will be free of bark and other habitat that can facilitate the transport of alien species. Federal and Hawaiʻi State agricultural inspectors do not currently check all imported non-food items for alien arthropods. ATST construction management will communicate to shippers and suppliers the environmental concerns regarding alien arthropods, and inform them about appropriate inspection measures to ensure that supplies and equipment shipped to Hawai'i are free of alien arthropods at the points of departure and arrival.

b. Shipping containers will be inspected and any visible arthropods will be removed. Construction of crates immediately prior to use will prevent alien arthropods from establishing nests or webs. Cleaning containers just prior to being loaded for shipping will also be done to minimize the transport of alien arthropods.

c. After arrival in Hawai'i, crates or boxes to be transported to the site will be inspected for spider webs, egg masses, and other signs of alien arthropods. Arthropods are small and easily overlooked during hectic assembly and packaging activity off-island. Many arthropods could escape detection during shipping inspections. Re-inspection prior to transport to the site will be completed to reduce the potential for undetected arthropods to reach the construction site. Arrangements will be made stipulating mandatory use of the Maui Alien Species Action Plan (ASAP) building for complete inspection of all possible items. This will prevent /or best allow for alien species interdiction on arriving materials.

i. Inspect construction materials before entering the Park: Alien arthropods already resident in Hawai'i are capable of hitchhiking on construction material such as bricks and blocks, plywood, dimension lumber, pipes, and other supplies. Precautions will be taken to ensure that alien arthropods are not introduced to the HO site.

ii. Construction materials will be inspected before transport to the construction site. If any alien arthropods are discovered, the infestation will be removed prior to transport. Infestations of ants can be removed using pressure-washing. Infestations of spiders can be removed using brooms, vacuum cleaners, or other similar methods. Pesticide use on materials to be transported to the site should be avoided.

3) Sanitary control of food and garbage will prevent access to food resources that could be used by invading ants and yellowjackets. Outdoor trash receptacles will be secured to the ground, have attached lids and plastic liners, and their contents will be collected frequently to reduce food availability for alien predators. Heavy, hinged lids will be used to prevent wind dispersal of garbage. Refuse will be collected on a regular basis to ensure containers do not become full or overflow. This could entail collection several times a week, particularly in eating areas and during periods of heavy use of the area. Containers will be regularly washed using steam or soap to reduce odors that attract ants. Plastic bag liners will be used in all garbage containers receiving food to contain leaking fluids.

4) Ensure construction waste and debris is secured to ensure it is not dispersed.

a. Construction activity may generate a considerable amount of waste debris. Typically construction debris is disposed of in "roll-off" containers that are periodically picked up and emptied at a landfill. Large "roll-off" containers can accommodate debris generated over several days of construction. Debris disposed of in these containers consists of wood, scrap insulation, packaging material, waste concrete, and various other construction wastes.

b. High winds at the site can disperse construction debris from the containers and disperse the material into adjacent arthropod habitat. Unsecured building materials and equipment at the site are also susceptible to wind dispersal. Construction trash and building material is not believed to significantly impact native arthropod species, but collection of the wind-blown material could potentially disturb their habitat (e.g., Howarth, *et al*., 1999).

c. Construction trash containers will be tightly covered to prevent construction wastes from being dispersed by wind. This will be accomplished during construction of ATST pursuant to the best management practices described in the HO Long Range Development Plan.

Covering containers will decrease the amount of construction debris that could be blown onto adjacent native arthropod habitat. "Roll off" containers can be equipped with tarps held securely with cables. Containers will be collected on a regular basis before they are completely full or overflowing. This could entail collection several times a week, particularly during periods of heavy use.

5) Invasive species detection and interdiction will be the responsibility of the resource biologist for ATST and supporting avian biologist. Detection and interdiction will be conducted routinely by these personnel to ensure that new introductions are controlled.

a. A biological monitor will be employed during construction and programmatic arthropod sampling will be done in accordance with the schedule described within Section 2.3-ATST Project Description. Monitoring for new alien arthropod introductions will be conducted during construction activities and any populations detected will be eradicated. Monitoring for alien populations is relatively easy and inexpensive to conduct. Baited traps have been shown to detect alien populations before they reach damaging proportions.

b. Ant eradication: Sticky traps designed to capture ants will be deployed immediately after any ants are detected. Persistence of ant detections are indicative of larger infestations, and will prompt a search for and eradication of colonies. Bait and chemical control will be employed only when absolutely necessary and only by a certified pest control professional.

c. Alien spider eradication: Any alien spider webs detected will be removed. Native lycosid wolf spiders do not make webs. Native sheet-web spiders make tiny webs under the cinder surface. Only alien spiders would make large spider webs at HO. Sweeping such webs away with a broom disrupts alien spider food capture success and destroys egg masses. Follow-up measures will be developed and implemented to control alien spiders when they are detected.

6) Construction materials stored at the site will be covered with tarps, or anchored in place, and will not be susceptible to movement by wind. Securing materials will reduce the

chances of debris being dispersed from the site into native arthropod habitat. Construction materials and supplies will be prevented from being blown into native arthropod habitat by covering them with heavy canvas tarps, using steel cables, attached to anchors that are driven into the ground. Construction materials at the site will be tied down or otherwise secured during high winds and at close of work each day. If construction materials and trash are blown into native arthropod habitat, they will be collected with a minimum of disturbance to the habitat.

3.4 Avoidance: Activities for Which Take is Not Expected

The proposed Satellite Laser Ranging station, known as SLR 2000, is a small, one story pre-fabricated building that will house an autonomous and eye-safe photon-counting Satellite Laser Ranging station. It is to be installed at HO within an existing footprint of a concrete pad on the southwestern side of the Mees Solar Observatory (MSO) (Figure 21). The SLR 2000 is also described in the HO Long Range Development Plan (UH IfA, 2005) and the FEIS (NSF, 2009).

The impact of the SLR 2000 was examined together with the impacts from past, present, and reasonably foreseeable activities within the action area for endangered species. The cumulative effects of this proposed project on endangered or threatened species is described in detail in the FEIS (NSF 2009, Section 4.17.6). As summarized in the FEIS (NSF 2009), the incremental effect of this project on all biological resources would be minor, adverse, and long-term during individual construction and negligible during operations.

The SLR 2000 poses some risk to Hawaiian petrels, since the pad that SLR 2000 would occupy is within 50 ft (15 m) of the nearest burrow at Kolekole. Only minimal use of motorized equipment would, however, be necessary to assemble the building, and even though the project would only take a few days, it would be done during the non-nesting season to limit the potential for incremental impacts to minor, adverse, and short-term.

Figure 21. Location of proposed SLR 2000.

4.0 MITIGATION

4.1 Proposed Hawaiian Petrel Mitigation Site Location

A 328-ac (133-ha) proposed mitigation area surrounding HO, adjacent to the western perimeter of Haleakalā National Park, will be fenced and managed (Figure 22). All land within the conservation area is unencumbered land owned by the state. The site is within Maui County Tax Map Key (TMK) 2-2-2-007-005 and -006, which surrounds and contains other smaller parcels, including the 18.2-ac HO site, along with the former General Broadcasting Area, which was restored to its undeveloped condition in early 2009. One parcel (HO site) is managed under Executive Order 1987 by the University of Hawaiʻi. Two other properties are managed by federal agencies, the FAA and the Department of Energy. The State of Hawaiʻi is in the process of implementing appropriate administration for fencing and Hawaiian petrel management (F. Duvall, 2010, personal communication). The site includes all observatories, broadcast facilities, communication towers, and other structures sometimes collectively known as "Science City", plus the portion of Skyline Trail dissecting the site from the northeast to southwest. Culturally significant sites exist in the region and have been extensively analyzed by NSF, as reflected in its FEIS for the ATST (NSF, 2009). Adjacent lands include the Kula Forest Reserve, Kahikinui Forest Reserve, NPS, DHHL, and private land (Figure 22). The mitigation site contains a number of cinder cones, of which Puʻu Kolekole is the highest in elevation. This cone is about 0.3 mi (0.5 km) from the highest point on the mountain, Puʻu ʻUlaʻula (Red Hill) Overlook, which is in the Park and outside of the unencumbered state lands. The Kolekole cinder cone lies near the apex of the southwest rift zone of the mountain. The rift zone forms a spine which separates the Kula Forest Reserve from the Kahikinui Forest Reserve.

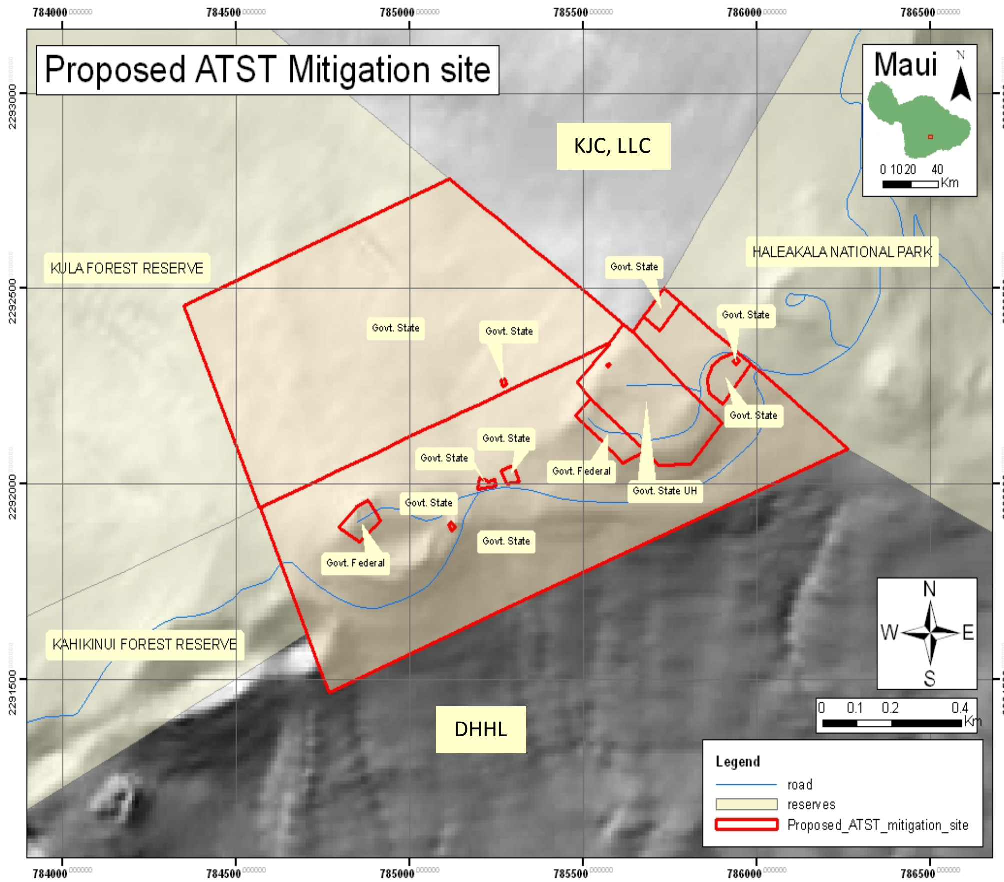

Figure 22. Proposed ATST Hawaiian petrel mitigation site (bounded by outer red perimeter lines) vicinity land ownership.

4.2 Mitigation Site Habitat Quality and Number of Hawaiian Petrel Burrows

The mitigation site includes 131 known Hawaiian petrel burrows (NPS, unpublished data), 61 identified as active, including the 25 burrows adjacent to the ATST construction site. This is not a complete census and more burrows may exist in the area. Obtaining a complete census of burrows in the proposed mitigation area will enable a more thorough assessment of potential benefits of proposed mitigation.

Hawaiian petrel burrow density in the mitigation site is likely to be lower than burrow densities found inside the Park because the site has not previously been protected from ungulates and predators. Hawaiian petrel burrows are typically under large rocks on steep slopes in the vicinity of shrub cover (Brandt, *et al*., 1995). The majority of known Hawaiian petrel burrows are located along the western rim of the Haleakalā Crater, where this type of habitat is most abundant and where predator control is in place (Natividad-Hodges and Nagata, 2001). Survey data collected between 1990 and 1996 indicates average burrow density in the vicinity of the mitigation area (and including a portion of the mitigation area) ranges from 5 to 15 burrows per hectare, compared to 15 to 30 burrows per hectare along the western crater rim, (Natividad-Hodges and Nagata, 2001). Similarly, in 2004 and 2005, Hawaiian petrel passage rates, collected using ornithological radar, were four to seven times greater, during summer and fall, at the Visitor's center (western rim) than in the vicinity of HO (Day, *et al*., 2005), suggesting bird numbers are lower in the vicinity of the mitigation area. The increasing Hawaiian petrel population at

Haleakalā (Natividad-Hodges and Nagata, 2001; NPS, unpublished data), may also serve as a source for recruitment of additional birds into this site.

4.3 Proposed Mitigation Project

The proposed mitigation activity focuses on removal of predators and habitat protection, key activities that are demonstrated to increase the reproductive rate and adult survivorship of Hawaiian petrels (Simons 1984, Natividad-Hodges and Nagata 2001). The proposed mitigation includes:

a) Census of burrows within mitigation area;
b) Ungulate (goat *Capra* sp.) fencing around the mitigation boundary, connecting with existing National Park boundary, and ungulate removal;
c) Predator control, including trapping and removal of known predators *Felis catus* and Indian mongoose *Herpestes* sp., and baiting of rats *Rattus* sp.;
d) Social attraction project and artificial burrow placement, to encourage recruitment into the site;
e) Burrow and habitat searching outside the mitigation site to identify i) suitable spatial control site and ii) potential back-up mitigation site; and
f) Mitigation success monitoring;

Ungulate Proof Fence Location and Ungulate Removal

An approximately 328-ac (133-ha) proposed mitigation area surrounding the ATST construction site (Figure 23) will be fenced with ungulate exclusion fencing such as hog wire. The fence will be located as close to the TMK boundary as possible. Surveys will be conducted to ensure the fence will be situated to avoid take of Haleakalā silversword plants, other listed species, or other sensitive resources. Approximately 14,107.6 ft (4,300 m) of ungulate proof fence would be installed around the project boundary, connecting to the existing 2,296.6 ft (700 m) of fence at the western edge of the National Park. The fence will be similar in structure to existing Park fences which are approximately 5 ft (1.5 m) in height, hog wire with no barbed wire strands. Fence installation costs are projected to be approximately $75/m (total=$322,500). A cattle guard will be installed to prevent ingress of ungulates on the Skyline Trail at the western end of the site. Ungulate removal shall occur immediately after fence installation and, to ensure integrity, regular inspection of the fence will be required.

Three strands of twisted polytape or alternative approved by the agencies will be integrated into the fence to increase visibility and minimize the potential for birdstrike. This HCP addresses impacts of the fence given that white polytape is installed. Fences without polytape in the vicinity of seabird colonies may be a flight hazard to these birds. NSF may investigate alternate fence marking designs to determine if an adequate alternative to white polytaping, such as use of black polytape, can be developed to minimize fence marking impacts to the viewshed while still protecting seabirds.

NSF will ensure the fence is maintained, the conservation area is managed for zero tolerance of ungulates, and predator control measures are implemented within the conservation area, as detailed below, for a period of no less than six years following completion of the fence and removal of all ungulates, or the duration of the construction activities, whichever is longer. Mitigation shall continue for up to four subsequent years (year's seven to ten) should monitoring indicate that the first six years did not produce a net recovery benefit as discussed in Section 5.3 Methods for Modeling Changes In Population Size Resulting from Proposed Actions, given observed levels of take, to the Hawaiian petrel.

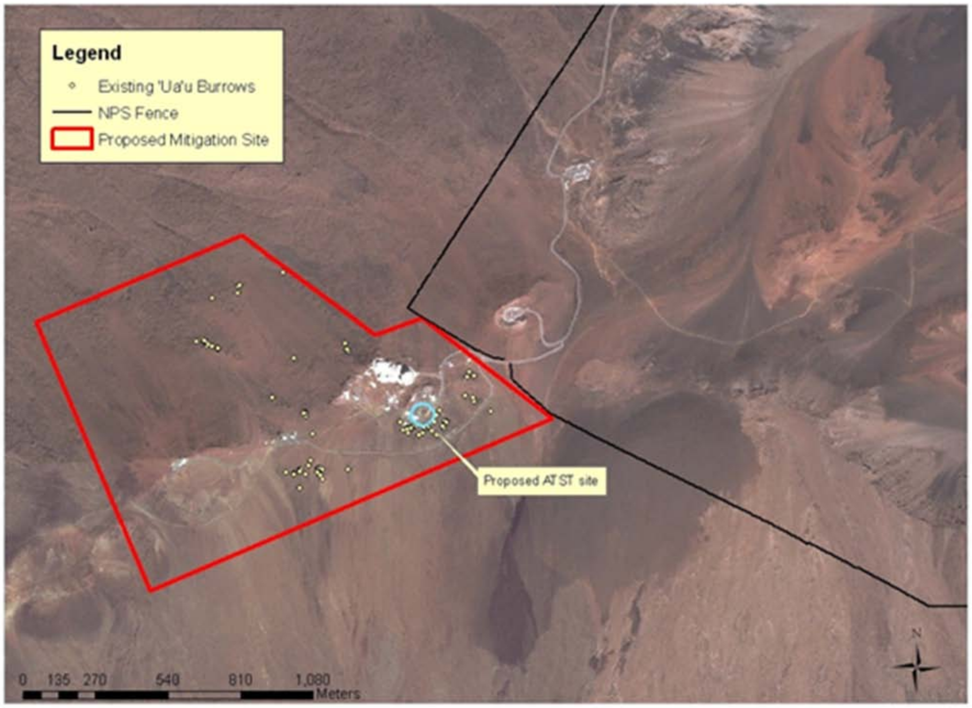

Figure 23. Proposed ATST Hawaiian petrel mitigation area.

Short-Term Predator Control in the Mitigation Area

Short-term predator control will remain in place prior to and throughout the Hawaiian petrel breeding season (February to October). Protocols, methods, and design, of the predator control operations shall utilize all legal means available and shall be subject to approval by the agencies. Only diphacinone labeling is available for use for rodent reduction/elimination for conservation purposes in the State of Hawai‘i. The label outlines what is legal and how the application can proceed.

Traps should be checked every other day, and animals disposed of consistent with ethics protocols required by the State. The placement of traps is to be determined based on topography and outcomes of burrow searching. Approximately two technicians will be necessary to undertake the predator control operations in addition monitoring the activities. Checking the trap lines in the mitigation area is expected to take a full day. Throughout the course of the project, it is estimated that approximately one Hawaiian petrel will be caught in the live traps per year, although traps will be set to avoid capturing Hawaiian petrels and any that are caught will be released unharmed. If a Hawaiian petrel is captured in a trap, the trap will be resituated to minimize the likelihood of any additional capture. If an injured 'ua'u is identified, DOFAW will provide short-term rehabilitation through local Maui veterinarians.

Social Attraction to Encourage Recruitment

Encouraging recruitment into the mitigation site can be achieved by utilizing social attraction equipment. Social attraction is a common tool used for conservation of colonially breeding seabirds to either a) bolster existing colonies, b) restart historic breeding sites or c) facilitate an entirely new colony. The basis for social attraction lies in manipulating seabird calling activity to promote pair establishment at a selected site through sexual advertisement. For the ATST project, this would include installation of social attraction equipment at a site determined to have suitable habitat but low breeding occupancy (Holmes, 2010b).

Long-Term Rodent Control in the Immediate Vicinity of the ATST
The NSF will install and maintain, during the 50 years of this project, a permanent 24c State Conservation Label rodenticide bait station grid around the HO Hawaiian petrel colony. Forty-nine bait stations will be installed and maintained approximately 164.50 ft (50 m) apart (Figure 24), as required by label. Bait stations will be placed on previously disturbed areas along edges of buildings, roads, and trails throughout the HO petrel colony area. The rodent bait station grid extends approximately 656 ft (200 m) around the petrel colony in all directions except to the southeast and directly to the west. In order to prevent predation of petrel eggs, rodent bait stations will be stocked with fresh rodenticide as needed, in accordance with label requirements, year-round. The permanent rat bait station grid around the HO Hawaiian petrel colony will ensure that the rat population does not increase during construction and operation of ATST. In addition, rodent control will be maintained throughout all ATST structures.

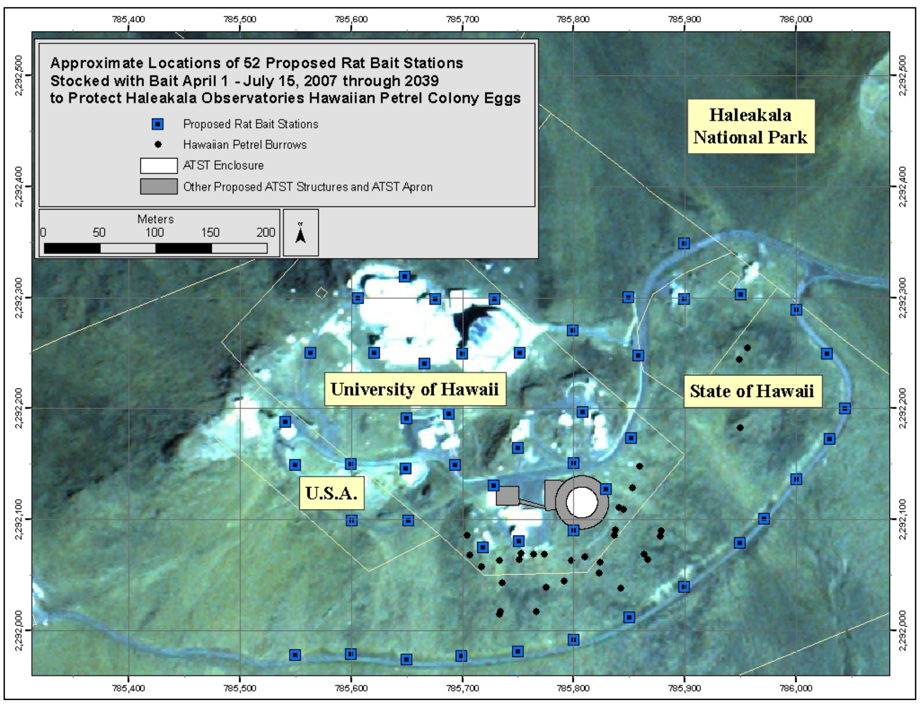

Figure 24. Approximate locations of rat bait stations to be maintained to protect the HO Hawaiian petrel colony burrows.

Identification of a suitable spatial control
A suitable spatial control will be required in order to adequately determine the success of this mitigation project. This will allow comparison of reproductive success of mitigation burrows to burrows not receiving any management activity, and will allow for control of year-to-year variability in breeding success due to food availability or other factors (Warham, 1990). As much as possible, the control site will be subject to the same conditions as the mitigation site, to reduce the likelihood of differences occurring between sites beyond the management activities. Surveys

will be conducted in year 1 to identify a suitable control site. Areas likely to yield potential controls sites (Figure 25), pending landowner approval, and pose the least administrative requirements to allow searching, are: (1) Kula and Kahikinui Forest Reserve west of the mitigation site; (2) KJC LLC c/o West Maui Financial Svc, north of the mitigation site; and, (3) possibly Dept. of Hawaiian Homelands to the south of HO.

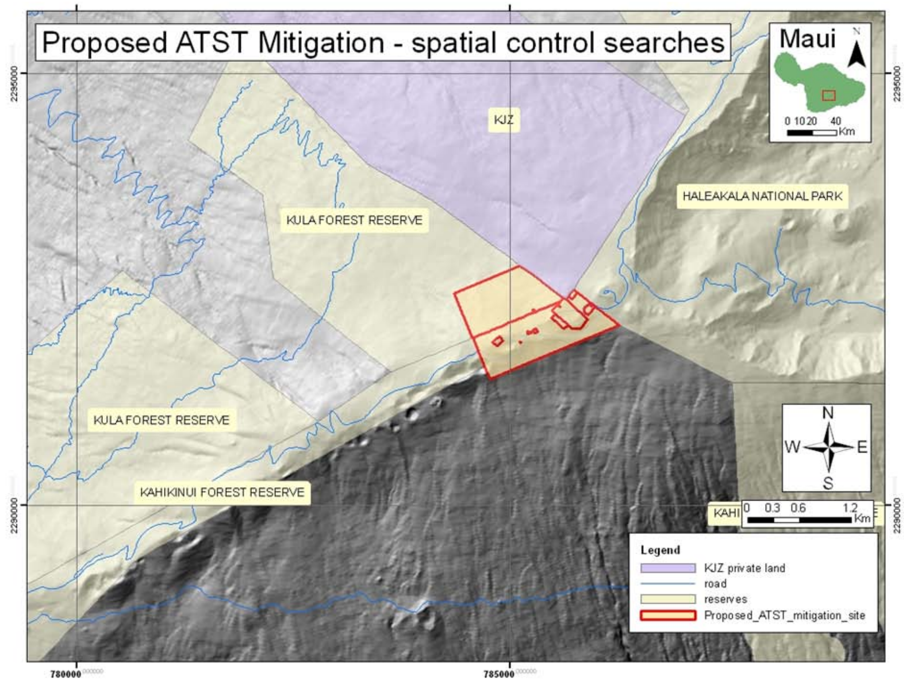

Figure 25. Proposed search areas for spatial control site for ATST Hawaiian petrel mitigation site.

A large number of active burrows within the control site will better ensure differences in reproductive success resulting from mitigation will be detected and determinations when net recovery benefit is achieved can be substantiated. Approximately five technicians will search these areas for approximately three months to identify the extent of the control site. Timing of surveys will be based on existing NPS protocol, including diurnal searching for petrel signs along transects, and will be undertaken during the period of highest detectability during incubation and early chick rearing.

Mitigation Success Monitoring

Monitoring is required to demonstrate the effect of management activities for the proposed mitigation and to determine when net recovery benefit is achieved. Construction may reduce the number of burrows that are actively used for breeding and reduce the likelihood active burrows will successfully fledge offspring. Mitigation is expected to offset this reduction by increasing the likelihood of reproductive success of Hawaiian petrels breeding within the mitigation area. Monitoring methods, analysis procedures, and protocols currently exist for the Park, including a "Standard Operating Procedure for Surveying 'Ua'u Burrows" (NPS) (Natividad, 1994; Natividad-Hodges, 2001). Nests at both the mitigation site plus proposed mitigation control site will be monitored at least twice per month for direct and indirect signs of activity and fledgling, based on standard definitions provided in this document.

Estimated Mitigation Duration

The timeline and budget for the proposed mitigation project are provided pursuant to HRS 195D in Table 14. The duration of the mitigation shown in this table is based on a six-year period, beginning upon completion of the fence and indication of no ungulates within the enclosure and overlapping with the period of construction. Termination of the mitigation project after the six-year period may be approved by the state following satisfactory annual report and review that demonstrates mitigation goals and net recovery benefit have been met, assuming all construction activities are complete at that time.

Mitigation would continue for up to the next subsequent four years (year's seven to ten) should monitoring demonstrate that the first six years did not produce a net recovery benefit to the Hawaiian petrel. Net recovery benefit is measured as net increase in the number of adults and fledglings produced relative to the respective number subject to take as a result of project activities, and it is based on demographic monitoring.

Table 14. Timeline for proposed Hawaiian petrel conservation and landscape-scale mitigation activity.

Objective	Activity	Year					
		1	2	3	4	5	6
Determine breeding numbers in mitigation site	Burrow searches	A	A	A	A	A	A
Protect habitat	Construct fence	A	N/A	N/A	N/A	N/A	N/A
	Remove ungulates	A	N/A	N/A	N/A	N/A	N/A
	Fence inspection and maintenance	A	A	A	A	A	A
Predator control	Place cat / mongoose traps	A	N/A	N/A	N/A	N/A	N/A
	Cat /mongoose trapping	A	A	A	A	A	A
	Rat bait station placement	A	N/A	N/A	N/A	N/A	N/A
	Rat baiting	A	A	A	A	A	A
Identify spatial control and potential mitigation backup	Burrow searches in Kahikinui	A	N/A	N/A	N/A	N/A	N/A
	Burrow searches in TMK 230050020000	A	N/A	N/A	N/A	N/A	N/A
Monitoring	Monitor burrows within mitigation site	A	A	A	A	A	A
	Monitor burrows at control site	A	A	A	A	A	A

A = activity during the year; N/A = no activity

Contingency for Mitigation Action

In the event that the mitigation area is not available or suitable, an appropriate alternative shall be implemented of similar scope and cost upon approval of the state. For example, an appropriate site has been identified at HAVO, in which ungulate and predator control may be implemented with similar expected results (S. Fretz and D. Hu, personal communication).

4.2 Anticipated Benefits of Fencing and Predator Control Within 328-ac Mitigation Area

Future numbers of Hawaiian petrels occupying burrows in the mitigation site were modeled to assess impacts of construction, success of mitigation, and when net benefit to the site's population may be achieved (Holmes, 2010b). The model assumptions, approach, and results are summarized in Section 5.3 and discussed in detail in Appendix B.

5.0 MONITORING

5.1 Monitoring During Construction

Vibration Restrictions and Monitoring

The monitoring equipment will be a MiniSeis 8G, 4-channel seismograph manufactured by LARCOR/White Seismology (http://www.whiteseis.com/Seismographs.html), which are appropriate for monitoring vibration from heavy construction equipment. At least two units will be deployed adjacent to the entrances to the Hawaiian petrel burrows nearest to the source of the vibration. The units will be operational and archiving data during all periods of construction when ground disturbance work is being done, including caisson drilling and excavation. When only concrete pouring and fabrication of the telescope buildings is being done, vibration will not be monitored. Sensors will be equipped with an auto-call feature for reporting events that meet or exceed a defined trigger level. The auto-call feature would send an alert by cell phone or telephone, and e-mail to the ATST project site manager if the sensors register a vibration of 0.08 in/sec. This would provide the project site manager with an early warning that the on-site activity was causing vibration which warrants close monitoring. A vibration of 0.12 in/sec or greater is not expected to occur at any Hawaiian petrel burrow as a result of ATST construction activity. Any vibration of 0.12 in/sec or greater, measured at a Hawaiian petrel burrow would be reported in writing to the state within one week. The report will include a physical assessment of burrows 21 and 40 (if they are believed to be free of Hawaiian petrels and Hawaiian petrel eggs) as well as a description of additional measures to be taken to minimize the likelihood future site work will cause the vibration threshold to be exceeded.

Construction Noise Monitoring

To correlate observed Hawaiian petrel behavior with construction noise, a minimum of two microphones or other type of sound level (dBA) meters will be installed adjacent to Hawaiian petrel burrow 40. One will be installed within five meters of burrow number 40 at a location where it has a direct line of sight view of the ATST construction site. The other will be installed at the opening to burrow number 40. This is the closest burrow to the construction site and therefore it is the most likely to be impacted by construction disturbance. The noise monitoring equipment will archive sound data during all years of ATST construction.

Video surveillance in place at this burrow entrance may also enable assessment of changes in Hawaiian petrel behavior resulting from noise events. Motion-triggered digital infrared and visible spectrum cameras have been mounted at the entrances to the burrows in the HO site colony, adjacent to the ATST construction site. Most of the burrow cameras are mounted outside burrow entrances so that the bird is visible only when it is at the entrance. Several of the cameras are mounted in the burrows, so that the nesting activity of the birds can be monitored. Pre-construction data was gathered beginning in 2006 and during each successive year.

5.2 Monitoring Impacts of the Project on the Hawaiian Petrel

Birdstrike Monitoring

Birdstrike monitoring protocols for the ATST Project, described below, were developed based on the birdstrike monitoring protocols recently developed for wind power generation turbines at the Kaheawa Wind Power (KWP) site on Maui (KWP, 2006) and meteorological towers site at the Lana‘i meteorological towers (Tetra Tech 2008). The KWP currently includes 20 GE 1.5-megawatt 180-ft (55-m) tall wind turbines rotating at speeds of 11 to 20 revolutions per minute. The Lana‘i meteorological towers project is composed of seven 165-ft 50-m) tall towers secured with four sets of guy wires.

Because Hawaiian petrels fly at speeds of over 30 miles/hour (48 km/hour) (Day and Cooper, 1995) birdstrike to any structure and equipment associated with the ATST Project would be likely to result in mortality. Research by Orloff and Flannery (1992), Higgins, *et al*. (1996) (as cited in Young, *et al*., 2003; Johnson, *et al*., 2002) and others, indicates birds killed as a result of striking objects are found at maximum distances of about 1.25 times the height of the object. Based on a search area 1.25 times the height of the objects associated with the construction of the ATST, a 180-ft perimeter boundary search area extending from the perimeter of the site, the support and operations building, and the lower and upper enclosures was delineated. This search area covers 4.7 ac (1.9 ha).

Within this search area, two zones are identified (Figure 26). Area A (3.3 ac (1.3 ha)) lies on the ATST plateau and includes other observatories. This area includes roads, pathways and roofs of buildings, plus open rocky habitat with little obstructions for detecting bird carcasses. No restrictions on this search area exist. These open and bare areas are likely to yield high searcher efficiency, similar to the 100 percent obtained at KWP in bare ground habitat (KWP, 2006). Area B (1.4 ac (0.6 ha)) lies on the slopes south and east below the ATST plateau and includes rocks and boulders of various sizes that would obstruct simple observation of bird carcasses. This area is in existing Hawaiian petrel habitat and frequent access for birdstrike monitoring is not recommended because it would degrade breeding habitat there.

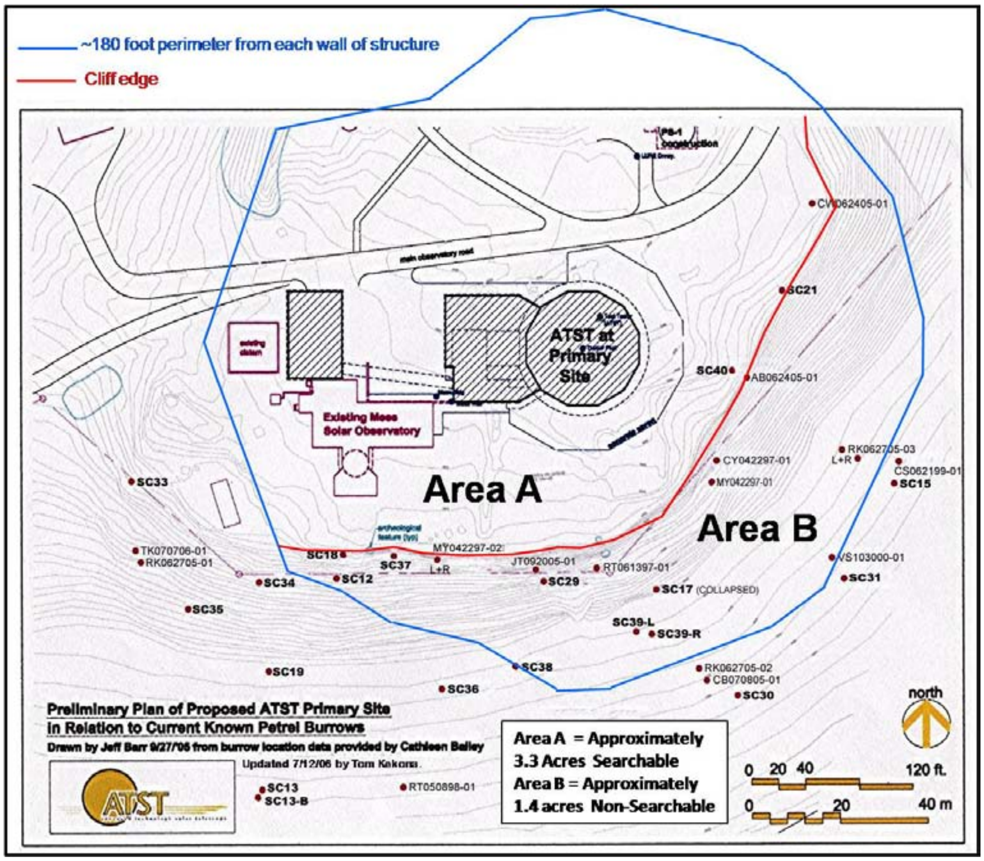

Figure 26. Birdstrike monitoring search area, including searchable (Area A) and unsearchable (Area B) zones.

However, searchers will be able to access the edge of the cliff at the demarcation between Area A and Area B, and be able to visually inspect the Area B from the Skyline Trail road below. Using careful visual scanning (binocular-assisted) of Area B from both Area A and the Skyline Trail road is feasible; however, take will be adjusted for Area B, which cannot be covered adequately enough to accurately count downed birds. Visual scanning will, however, be useful in detecting and recovering any downed birds in the open, so that they do not become a predator attraction.

ATST technical staff or third-party contractors who have been trained by the responsible ATST biologist will conduct observatory/bird interaction studies. Criteria for selecting third-party contractors will be developed in coordination with and approval by the state. Searcher efficiency and carcass removal (i.e., scavenging) trials will be conducted each year. To be consistent with other projects, a minimum of three carcass removal trials will be conducted each year.

Searcher Efficiency Trials
Searcher efficiency trials (SEEF) will be undertaken to determine the probability of detection of birdstrike mortalities and to provide for an index and index the calculation of adjusted take. Searcher efficiency trials to be conducted in the vicinity of the ATST Project shall include:

Searcher efficiency trials will be undertaken to determine the percentage of birdstrike mortalities that are identified. Key elements of the searcher efficiency trials to be conducted in the vicinity of the ATST Project include:

- Carcass removal (CARE) and searcher efficiency trials will be conducted with sufficient replication to produce statistically reliable results. Experimental design will follow protocols developed by and subject to approval by DOFAW.

- Wedge-tailed shearwaters or other approved species will be used as surrogates. Arrangements will be made to collect carcasses from sources other than the state, if the state is not able to provide them. Wedge-tailed shearwaters or other seabird carcasses are needed for the CARE trials to provide the appropriate odor, but are not necessarily needed for the SEEF trials if a suitable, visually appropriate alternative is approved by DOFAW.

- A variable number of carcasses will be used (1-3) so searchers are unaware of total carcasses used in each trial.

- Carcasses will be placed at times other than known search periods and at locations marked using GPS (+/-1 m) so as to be distinguished from actual birdstrike.

- Carcasses will be placed at dawn, and recovered at dusk – no carcasses will be left overnight, as this may encourage scavenger and predator activity near the adjacent Hawaiian petrel breeding colony.

- Carcasses will be placed in a variety of positions including exposed (thrown) and hidden to simulate a crippled bird and partially hidden.

- Birdstrike searchers will be trained in active searching.

- Searchers will be unaware of trials being implemented; trials will be implemented and monitored by the lead ATST Project biologist.

Carcass Removal Trials

Carcass removal trials are undertaken to determine the scavenging rate by cats, rats and mongoose or other scavengers of any birds killed via birdstrike. This information is used to guide search intervals for birdstrike monitoring. These trials will include:

- Trials will be undertaken in spring, summer and fall to obtain a measure of seasonal variation in scavenging rate.

- Wedge-tailed shearwaters will be used as a surrogate species; arrangements will be made to collect carcasses from sources other than the state, if not available from the state.

- Carcasses will be placed in an area outside the search area (with similar habitat and predator control) and away from known Hawaiian petrel breeding areas to avoid encouraging scavenger and predator activity near breeding sites.

- Carcasses will be placed in locations marked using GPS (+/-1 m).

- Carcasses will be placed in a variety of positions including exposed (thrown) and hidden to simulate a crippled bird and partially hidden.
- Carcasses will be checked every 7 days until the 28th day, when they will be removed.
- The experimental design of the carcass removal trials will comply with DOFAW guidelines and be subject to approval by DOFAW.

Birdstrike Monitoring Study Design and Reporting

Birdstrike monitoring study design incorporates practical considerations, including the most cost- and time-efficient method to determine actual birdstrike numbers and measures to minimize impacts to sensitive resources. Initial monitoring will be undertaken along transects 32.8 ft (10 m) apart, extending through Area A, plus active searches of the perimeter of all buildings, and roofs of flat-topped buildings. One sample per week will be conducted during the first two breeding seasons after which the state will review any proposed schedule modifications. Searches will be conducted from February to October during the Hawaiian petrel breeding season only. Systematic searches will be completed under the direction of a project biologist. The frequency of searches will ensure that a variety of conditions are included. For example, days after moonless, cloudy, or stormy nights are of particular interest, because the ATST would be least visible and the risk of collision would presumably be greater, especially during peak fledgling periods. Intensive searches will be conducted for the first two years, after which it is expected that the approach will be reduced to a sampling method based on the results obtained up to that point. Search intervals will be adjusted seasonally based on the results of carcass removal trials. Modifications to the intensive search schedule will be made with the approval of the state.

Detected carcasses will be used to calculate take by factoring in rates of searcher efficiency, search interval, carcass removal rate, and percentage of birdstrike monitoring area covered in searches of Area A only (while using a factor for unsearched Area B). Loss of the bird's nest (indirect take) will be calculated based on average breeding status, breeding probability, and fledgling success from the literature. In the absence of updated information, 50 percent of downed birds will be considered to be breeders. Breeder's probability of breeding will be assumed to be 89 percent, and fledgling success of breeding birds will be 66 percent (Simons, 1984).

Take resulting from birdstrike will be calculated and reported by adjusting observed carcass numbers by factors to account for carcasses that were not found in searches. This is because it is assumed that not all birds that do suffer birdstrike will be found, either because they were not located during required monitoring, or because the carcass was removed by scavengers, thus requiring adjustment of the take estimate. Importantly, carcass removal and searcher efficiency data are estimated only here, and would required data from studies specific to the ATST site, thus adjusting the equation below. For the purposes of estimating adjusted take, the following figures are used.

No carcass searching efficiency data exists for the ATST area, but it is assumed that because of the open terrain, and dry climate that searcher efficiency would be high in Area/Zone A and, in this example, estimated at 90 percent (ESRC meeting notes November 16, 2009). By comparison, searcher efficiency at KWP-I was anticipated to be 100 percent on bare ground (KWP, 2006). Carcass removal rate also is expected to be low because of terrain blocking and

low levels of scavenger (rat, mongoose, cat) presence at the site, as a result of predator control measures to be implemented by NSF.
Monitoring efforts for the ATST Project will result in identification of "observed" mortality, which would represent a statistical sampling of all mortality directly attributable to ATST construction and initial operations. Identifying total mortality (or "total direct take") requires accounting for individuals that may be killed, but that will not be found by searchers for various reasons, including terrain blocking and/or CARE. The calculation for estimating total direct take is:

Total Direct Take = Observed Direct Take + Unobserved Direct Take

SEEF and CARE trials will be conducted to arrive at estimates of Observed Direct Take.

While numerous estimators have been developed for the calculation of Unobserved Direct Take, the most recent estimator by Huso (2008) has several improvements that appear to be less susceptible to bias than earlier calculations. Although it was designed primarily for use with wind turbines, it could serve as a useful tool for estimating Unobserved Direct Take for the ATST Project. The estimator by Huso is defined as:

$$\hat{m}_{ij} = \frac{c_{ij}}{\hat{r}_{ij}\hat{p}_{ij}\hat{e}_{ij}}$$

- **m_{ij}** = estimated total direct take at turbine *i* over interval *j*
- **c_{ij}** = observed direct take
- **r_{ij}** = estimated proportion of carcasses remaining after scavenging
- **p_{ij}** = estimated searcher efficiency (proportion of carcasses found)
- **e_{ij}** = effective search interval

This or other estimator approved by DOFAW will be used for this HCP.

Calculated levels of Total Direct Take will be further adjusted to account for reduced breeding success of the nest the struck bird would have attended to during the breeding season. For Procellariformes, adult mortality while breeding will also result in chick mortality because both adults are required to provision sufficient food for successful chick rearing (Warham, 1990; F. Duvall, unpublished). Thus Hawaiian petrel strike take must be adjusted for this potential chick mortality by the following factors:

1) A breeding bird versus a prospecting bird (breeding status: 50 percent) (Simons, 1984).

2) If a breeding bird, the probability that those birds did breed (breeding probability: 89 percent), (Simons, 1984)

3) If the bird did breed, the probability of successfully rearing a chick to fledging (Fledging success: 66 percent) (Simons, 1984).

Breeding status, breeding probability, and breeding success are unlikely to be known for a detected Hawaiian petrel mortality unless it was a banded bird and the associated burrow was being monitored that year. Therefore, adjusted take will be calculated and reported using the best available information regarding average levels for the species such as those shown above. Thus:

Adjusted Take = Total Direct Take (TDT) + (TDT x Breeding Status x Breeding Probability x Fledging Success)

Whereby,

TDT = Total Direct Take
BS = Breeding status (breeder or non-breeder)
BP = Breeding probability (if breeder, likelihood of breeding that year)
FS = Fledging success (if bred, likelihood of successfully raising a chick)

Using the formula and average levels noted above, adjusted take for one Hawaiian petrel killed as a result of birdstrike is 1.29:

$$1 + (0.5 \times 0.89 \times 0.66) = 1.29$$

In other words, for each adult killed (TDT) as a result of birdstrike, 0.29 fledglings will not successfully fledge. Observed direct take, unobserved take, total direct take, and adjusted take will be calculated and reported.

Monitoring Burrow Collapse

A biological technician has measured the depths of all 41 of the Hawaiian petrel burrows, leading to 33 nest chambers, located within 262.5 ft (80 m) of the ATST construction site. The technician will use a burrow scope capable of making measurements in winding burrow tunnels. Each winter following any periods of construction, when birds are absent from the site, the burrow tunnels will be re-measured and a report will be submitted to the state summarizing any changes in burrow configuration.

Monitoring Impacts to Reproductive Success

Real-time monitoring of Hawaiian petrels, noise, and vibration will be continuously conducted at the HO colony to detect effects of construction on the status of burrow activity and active burrow reproductive success. Noise and vibration monitoring procedures are described previously in this project description. In addition, reproductive success of Hawaiian petrels within the mitigation site and the control site will be monitored.

Any take documented by monitoring during the license period will be adjusted for search efficiency and carcass removal by scavengers, and increased by indexes from best known available data to account for indirect take that results from the probable loss of reproductive success for any adults taken.

Indexes for searcher efficiency and carcass removal will be obtained from ongoing trials through the duration of the license. Because of terrain, searcher efficiency is expected to be high and due to ongoing predator control in this area, carcass removal is expected to be low for the project area for the reasons discussed above.

Noise and ground vibration data will be compiled for statistical comparisons with behavior and reproductive success data. NSF will fund a research biologist and a biological technician to complete the monitoring data collection and analysis. Real-time monitoring will ensure that any changes in behavior and any Hawaiian petrel mortality associated with the ATST construction project disturbance are detected and reported to the state. Several university and contract research biologists are expressing interest in participating in the burrow camera noise disturbance study and NSF will make accommodations to support that interest. All appropriate state and federal permits will be obtained for this work.

During the year(s) of heavy excavation and external building construction, Hawaiian petrel fledglings will be monitored in real-time for mortality and fledging date. Hawaiian petrel behavior may also be monitored with cameras at a control site, although control site camera monitoring is not necessary and may not be practical. In addition to monitoring construction impacts to Hawaiian petrel behavior, the reproductive effort, reproductive success, and survival of birds nesting in the vicinity of the construction site will be rigorously compared to that of birds at a comparably situated site with no construction disturbance.

Two metrics will be used to assess levels of take resulting from the project: burrow breeding status (active versus inactive) and fledging success. Current methods employed by Park biologists to capture these metrics will be used (Natividad Hodges, 1994; Simons, 1984, 1985). The Park's methods will be validated and the accuracy of assessments of levels of burrow activity and fledging success will be increased with the use of the burrow entrance cameras.

It will be critical to compare the treatment data (ATST burrow productivity during construction) to suitable control data. These control data will include:

1) Previously collected fledgling success data from the ATST site. Approximately 8 years of data exist for this site (C Bailey, 2009, personal communication). Because these data will primarily come from the same individuals that will be impacted by the ATST process, they reduce any error associated with individual-to-individual variation and increase the likelihood of detecting a difference due to the ATST construction;

2) Breeding productivity from one or more control sites within the same years of ATST construction. Breeding success is inherently variable from year to year due to food availability and other factors (Warham, 1990). Same-year control data reduces the year-to-year variation and increases the likelihood of detecting a difference due to ATST construction. Control sites used to detect effects of ATST construction will have the same level of management as the ATST site (trapping, etc.) to avoid introduction of unwanted sources of error and will come from within the Park. This control is separate from that required to demonstrate the effects of mitigation, which will require comparison to a site not receiving management.

Statistical methods for comparing sites are established in Natividad Hodges (1994) and Simons (1985) and may include Chi square analyses or other appropriate statistical methods. NPS and/or NFS will obtain a state scientific collecting permit for all work that is not within the Park.

5.3 Methods for Modeling Changes in Population Size Resulting From Proposed Actions

A population modeling exercise was undertaken to identify when net benefit would be achieved from the proposed mitigation project. This required determining a baseline population, identifying losses from ATST construction, and benefits from mitigation. The model approach, assumptions and results are summarized here and further discussed in detail in Appendix B.

Models used were deterministic demographic matrix models, based on Leslie (1945). The modeling approach used required a statistical assumption of a closed population because it was not possible to estimate immigration or emigration with the larger Haleakalā population. Impacts from immigration into the mitigation site would decrease the time to meet net benefit because more adults would supplement the breeding population. Conversely, emigration away from the mitigation site would increase the time to meet net benefit. A second assumption used was that the population at year one was stable. Again, this is unlikely because these birds are part of the larger Haleakalā population, and birds attending the mitigation site will be part of larger population dynamics. For example, with the larger increasing trend known for the population, it may be that birds attending this site are primarily younger adults in the process of recruiting to a new site. These results should not be considered a comprehensive assessment of net benefit from this mitigation, but rather a starting point for selecting an appropriate mitigation investment.

Several significant parameters that will limit its biological relevance could not be included in this model. In addition to an assumption of a stable population and closed population, no allowance was made for increased reproductive success with age or annual variation in reproductive success. The mitigation benefit outcomes used in these modeling efforts were somewhat conservative, with increases in reproductive success limited to 6, 9 and 12 percent and adult survivorship by 2, 3, and 4 percent. By comparison, the combined predator control and habitat protection efforts at Haleakalā have increased reproductive success by as much as 20 percent annually in some cases (Natividad-Hodges and Nagata 2001; Holmes 2010b).

These results provide a starting point for selecting an appropriate mitigation investment. Given it is likely that more burrows exist in the site, and given the conservative mitigation benefits used in the model, mitigation for the duration of the construction (6 years) may cover the requirements for the ATST project (Holmes 2010b).

Results

Five modeling efforts were run under each of the following ten scenarios:

1	Baseline	No ATST construction and no mitigation with 61 active burrows.
2	Baseline	No ATST construction and no mitigation with 100 active burrows.
3	MIT-0	ATST construction and no mitigation with 61 active burrows.
4	MIT-0	ATST construction and no mitigation with 100 active burrows.
5	MIT-1	Increased reproductive success of 6 percent and increased adult survivorship of 2 percent with 61 active burrows.
6	MIT-1	Increased reproductive success of 6 percent and increased adult survivorship

		of 2 percent with 100 active burrows.
7	MIT-2	Increased reproductive success of 9 percent and increased adult survivorship of 3 percent with 61 active burrows.
8	MIT-2	Increased reproductive success of 9 percent and increased adult survivorship of 3 percent with 100 active burrows.
9	MIT-3	Increased reproductive success of 12 percent and increased adult survivorship of 4 percent with 61 active burrows.
10	MIT-3	Increased reproductive success of 12 percent and increased adult survivorship of 4 percent with 100 active burrows.

Figure 27 shows the population growth curves for each of the 10 scenarios modeled. A decreasing population trend is evident for all scenarios but the most productive mitigation option (MIT 3). Figure 28 shows the time to reach net recovery benefit in adult population size and cumulative production of fledglings for each of the ten model simulations. Annual increase in adult survivorship from mitigation is expected to be greater than take during years of construction, and net recovery benefit is to the adult population size is expected to begin accruing in year four for MIT-1 at 61 active burrows. Net recovery benefit is expected to begin accruing in year one for all other mitigation scenarios. Stopping mitigation in year 2, however, would begin a net loss again for these 5 scenarios. Model results indicate annual loss of reproductive success will be greater than the mitigation benefit in the first few years of construction. Assuming maximum allowable take is realized, with only 61 active burrows, it takes 19, 11 and 8 years (given the three modeled increases in reproductive success: six, nine, and 12 percent) to begin accruing net recovery benefit in fledgling production. With 100 active burrows, it would take 8, 3 and 1 years under the three reproductive success scenarios.

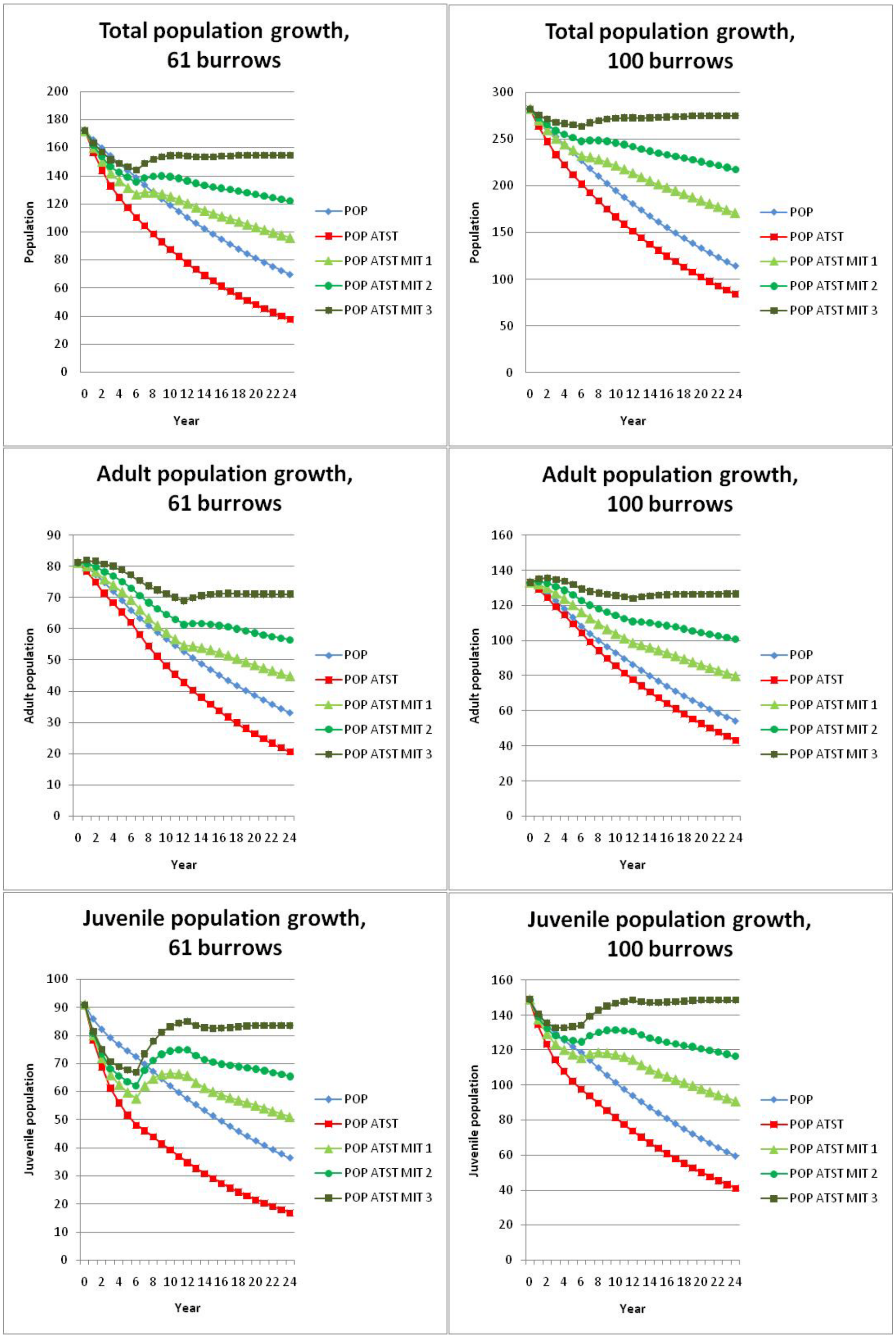

Figure 27 Population growth rates with and without ATST construction, and three levels of mitigation benefit

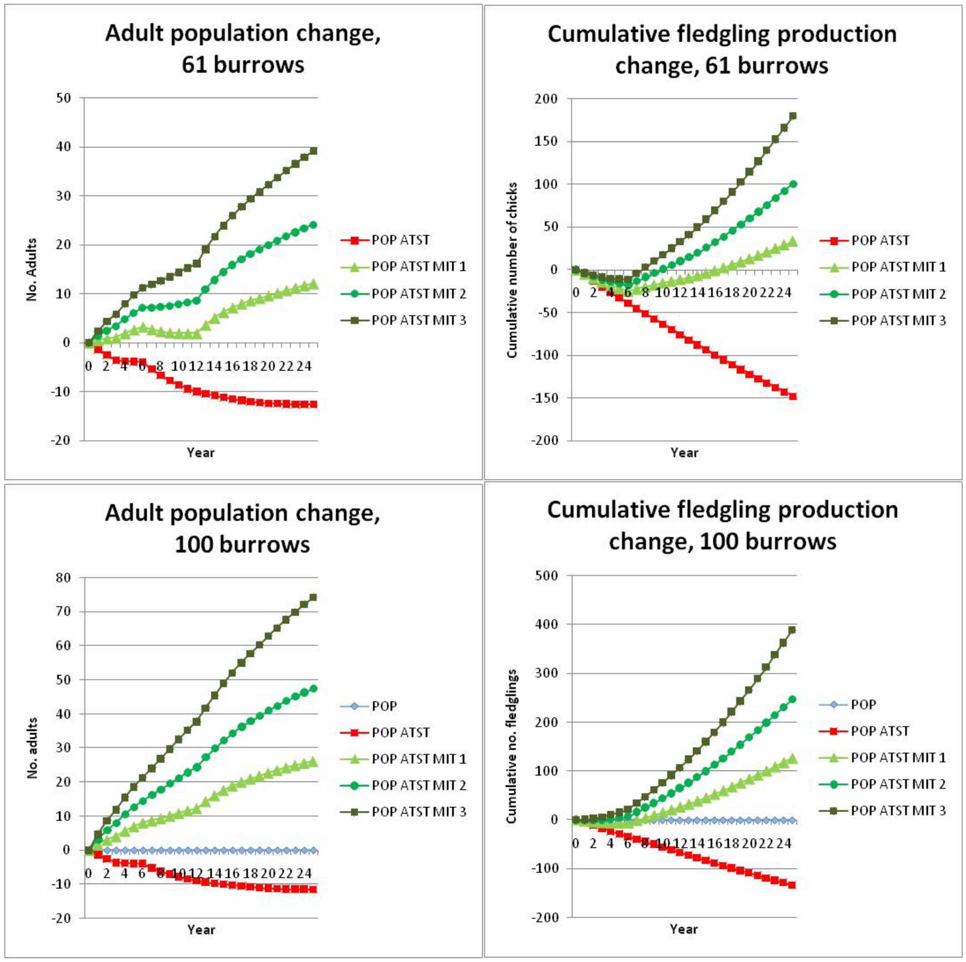

Figure 28. Time to begin accruing net recovery benefit in adult populations and cumulative chick production under varying assumptions (Numbers above zero indicate net recovery benefit).

5.3.1 Potential Burrowing Habitat Modification

GIS assessment of the ATST project site location indicates that 0.77 ac (0.31 ha) of unoccupied, potential burrowing habitat would be lost due to the construction of the ATST facilities. Burrowing habitat quality varies throughout the ATST Project site, but stable rocks with loose material suitable for burrow excavation are available for future petrel colony expansion within the area which will be disturbed by the proposed project. The ATST Project activities will make the site unsuitable for burrowing due to changes in soil structure or access. Impact areas include the telescope enclosure, apron, support and operations building; the portion of utility building and new wastewater treatment plant and infiltration well which will be constructed on ground not previously developed; areas disturbed for the radial field of grounding conductors; and the areas to be excavated for staging areas and equipment use. No stormwater or grey water erosion is expected to be associated with the project. The soil deposition areas were previously disturbed; therefore, no potential burrowing habitat loss will occur in these areas.

6.0 HCP IMPLEMENTATION

Table 15 is a summary of the measures and costs to implement the HCP for the ATST Project in 2010 dollars. Costs provided are estimates. Actual costs for items may vary and costs may be adjusted in the future.

Table 15. Summary of costs and measures for proposed mitigation activity.

	HCP Action	No. Staff	Full-time Equivalent	Per Year	Estimated No. Years[(1)]	Total[(2)]
Personnel						
Coordinator (resource biologist)	Minimization; Mitigation; Monitoring: Take, Mitigation and Compliance	1	1	$80,000	6	480,000
Monitoring and predator control technicians	Monitoring: Take, Mitigation and Compliance	2	1	$65,000	6	$390,000
Technicians to identify control site	Mitigation	5	1	$65,000	0.4	$26,000
DLNR	Compliance monitoring			$15,000	6	$90,000
Travel: Fuel	Monitoring: Take, Mitigation and Compliance			$3,000	6	$18,000
Equipment: Rat baiting equipment and supplies	Minimization, Mitigation			$500.00	6	$3,000
Fixed costs including capital						
Fence materials, heliops, construction labor (4.3 km)	Mitigation			$75/m		$322,500
Environmental review, HRS 343 compliance	(Contractor already procured)					$204,000
Polytape (8.6 km), two strands per meter	Mitigation			$0.70/m		$6,020
Cat trapping equipment	Minimization					$20,000
Predator control, monitoring and control site identification vehicle	Monitoring: Mitigation and Compliance					$40,000
Field equipment	Monitoring: Take, Mitigation and Compliance					$7,500
Burrow scope	Monitoring: Take, Mitigation and Compliance					$7,500
Equipment maintenance	Monitoring: Take, Mitigation and Compliance					$2,000
Ongoing quarterly fence maintenance	Monitoring: Take, Mitigation and Compliance					$15,000
					Total[(3)]	$1,585,520

(1) It is anticipated that the full net recovery benefit will be achieved in 6 years or less. During the construction phase, an evaluation will be conducted to determine the number of take, if any, and the effectiveness of the mitigation measures. Depending upon the outcome of this evaluation, the monitoring and mitigation costs may be adjusted.
(2) Costs are provided as estimates only and guides for provision of assurance of funding under HRS 195D. Actual costs may vary.
(3) Total cost is calculated in 2010 dollars. Adjustments for economic variables will be employed using standard accounting indices.

6.1 Responsibilities

NSF is legally responsible for all aspects of the HCP implementation. In addition, NSF, through its awardee, AURA/NSO, shall provide funding to the state sufficient to monitor compliance of the HCP (HRS 195D). NSF, through its awardee, AURA/NSO, will deploy personnel or contractors that are qualified and subject to approval by DOFAW. The fence contractor shall be approved or procured by the agencies.

NSF recognizes that effective monitoring of potential take resulting from project activities, in compliance with the terms of the HCP, is essential. Per HRS 195D, in the event that the ESRC determines, upon annual review, that NSF is not in compliance with regard to take monitoring, NSF, through its awardee, AURA/NSO, shall provide funding to the state that is sufficient to support personnel and expenses to conduct the monitoring.

The HCP will be administered by a qualified biological specialist contractor (criteria to be developed by NSF in cooperation with the state) funded by the Applicant (NSF), through its awardee, AURA/NSO, as part of the ATST Project, with additional guidance from the state (pursuant to the implementation of the HCP). Other experts may be consulted as needed, including biologists from other agencies (such as the Park), conservation organizations, consultants, and academia. HCP-related issues may also be brought before the ESRC for formal consideration when deemed appropriate by the NSF and the state.

As part of the mitigation activities for the ATST, a qualified biologist, functioning as lead researcher, with two additional trained biological technicians (equivalent to the position of a State of Hawaiʻi Wildlife Technician Level 3 to 4 will monitor birdstrike occurrence in addition to burrow activity and reproductive success of burrows in the vicinity of the ATST construction site, within the mitigation site, and within the control site. The lead researcher will be responsible for compiling project reports addressing construction and mitigation impacts to the Hawaiian petrel.

The Applicant or designated biological specialist will meet at least semi-annually with the state. Additional meetings/conferences may be called by any of the parties at any time to address immediate concerns. The purpose of the regular meetings will be to evaluate the efficacy of monitoring methods, compare the results of monitoring to the estimated take, evaluate the success of mitigation, and develop recommendations for future monitoring and mitigation. Regular meetings will also provide opportunities to consider the need for adaptive management measures. In addition, the Applicant will meet annually with the ESRC to provide updates to monitoring, mitigation, and adaptive management, and to solicit input and recommendations for future efforts. Additional meetings may be requested by the ESRC at any time to address immediate questions or concerns.

NSF, through its awardee, AURA/NSO, is responsible for providing the identified funds to implement the mitigation measures expressly described in this HCP. NSF, through its awardee, AURA/NSO, will manage the funds required to cover the costs associated with the HCP mitigation measures and will maintain a detailed report that accounts for the money spent to implement the mitigation activities and will provide annual reports that summarize the results of mitigation and monitoring activities.

Through its biological specialist, NSF will provide annual reports to the state that summarize the results of the construction mortality monitoring and any take that has occurred. These reports will also be provided to the ESRC. NSF is responsible for implementation of the HCP and actions described in the Project Description and shall have completed its involvement for this project once the stipulations identified in this HCP are fulfilled. NSF will not be responsible for any additional actions or costs that are not identified in the HCP Project Description section, as long as the HCP is properly implemented and functioning.

This HCP is designed to address the authorized take of one listed wildlife species. The take level requested is 35 Hawaiian petrels. Direct take, and associated anticipated indirect take, will be compensated through the mitigation plan. (NSF believes that the allotted take of 35 ‘ua‘u is a conservative estimate and is thus also sufficient to cover unanticipated take from fence strikes and implementation of predator control measures.)

6.2 HCP Scope and Duration

NSF proposes to enter into the HCP to cover the potential take of this listed species as a result of construction and operation of ATST. The term of the HCP is for a period of 6 years, through September 1, 2016. The HCP and ITL may be amended or extended if necessary, up to a total period of 10 years.

6.3 HCP Monitoring

Monitoring project impacts to the Hawaiian petrel will be conducted as described in Section 5.0-Monitoring. Monitoring is required at both the ATST construction site and out to potential “casualty” areas to ensure that the authorized levels of take are not exceeded, and that the effects of take are minimized and mitigated to the extent possible.

There are several mortality mechanisms for Hawaiian petrels that are of concern during ATST construction and operations—birdstrike, vibration, noise, and general stress from other factors related to construction activities. There is also a risk of take for breeding birds not initiating, or abandoning, breeding attempts during the breeding season because of construction activity (noise, vibration, etc.) and general proximity to ATST construction and a loss of productivity in those fledglings produced (see Section 2.4-Assessment of Potential Effects).

Monitoring and reporting by the Applicant will address both compliance with and effectiveness of monitoring and mitigation measures. Compliance monitoring will verify the Applicant’s implementation of the conservation/mitigation measures in the HCP Project Description. Annual reports and other deliverables as described in the Project Description will be provided to the state to enable verification that the Applicant has performed all of the required activities and tasks on schedule. Monitoring will document take relative to authorized levels and the success of the HCP mitigation program. The monitoring will involve surveys to make sure the authorized level of take is not exceeded, and that minimization and mitigation measures are sufficient and successful.

HCP Reporting

Semi-annual meetings with the state will be held to provide brief progress reports and summarize the findings of scavenging, searcher efficiency trails and results of mitigation efforts. Written progress reports and electronic copies of HCP-related data will be submitted no less frequently than once per year to the state. These annual reports will be tied to the state's fiscal schedule such that information from the period July 1 through June 30 will be summarized and submitted no later than August 1 of each year. Take limits will be reviewed and changed circumstances or adaptive management measures will be discussed with the state as appropriate. In addition, an incident report will be submitted to the state within 48-hours of any documented take (i.e., injury or fatality) of Covered Species.

HCP Performance and Success Criteria

In addition to semi-annual meetings, the ATST Project biological specialist will coordinate monthly with the state and the Park during the first two years of construction or two full nesting cycles of the petrels regarding the status of mitigation activities, in order to measure the effectiveness of the proposed conservation fencing.

An EA for the proposed conservation fencing and other conservation measures not already analyzed in the FEIS has been funded by NSF, through its awardee, AURA/NSO, and will be completed in 2010, so the mitigation efforts can begin in 2010. A minimum of $322,500.00 (Total Costs) will be provided by NSF as part of the ATST award to be used for the construction of the conservation fencing at the earliest possible date, if approved.

6.4 HCP Project Funding

Sufficient funding will be made available by NSF through the ATST award to ensure that the proposed measures and actions in the HCP are undertaken in accordance with the schedule. The funding provided allows for the costs of the proposed conservation fencing, the options of state compliance monitoring and reporting in addition to outside contractors and ATST technical staff, and contingency costs for mitigation that could be pursued in the event fencing and predator control are not as effective as anticipated. A summary of costs and measures for proposed mitigation activity is presented in Table 17. Assurance of funding will be provided by bond or other arrangement in compliance with HRS 195D.

As currently proposed, NSF will provide funding through the ATST award in the amount of $1,585,520.00, which will be available to fund the primary proposed mitigation and associated monitoring costs. Costs provided in Table 17 are estimates and actual costs for items may vary. NSF, through its awardee, AURA/NSO, will provide funding to DLNR to cover the costs of monitoring compliance under HRS 195D.

6.5 Changed Circumstances Provided for in the HCP

Changed circumstances are circumstances that occur during the life of an HCP that can reasonably be anticipated and planned for. These circumstances occur independent of the proposed project. For ATST, possible changed circumstances that are anticipated and planned for include:

1) Disease outbreaks in any of the listed species;

2) Hurricanes or other major storms that may affect the project site or mitigation sites;

3) Changes in the price of raw materials and labor;

4) De-listing of any species covered in the HCP; and

5) Listing of one or more species that already occur on site, or fly over the site, not currently covered in the HCP.

The procedures to provide for these scenarios are described below:

1) **Disease Outbreaks in Listed Species.** The most prevalent disease for the seabirds covered in the HCP is avian botulism (Service, 2005). Avian botulism is caused by a toxin produced in stagnant water by the anaerobic bacteria *Clostridium botulinum* type C_a. If such outbreaks should occur at the chosen mitigation site(s), ATST will assist the state in implementing measures to prevent or reduce the severity of the outbreaks at the mitigation sites as appropriate under the monitoring and reporting budget established for the mitigation expenses.

   Hawaiian petrels have not been documented to have disease outbreaks. Disease is considered one of the lesser threats to the persistence of petrels covered in the HCP. Should the prevalence of disease become indentified as a major threat the survival of this species by the state, NSF will consult with the state to determine if changes in monitoring, reporting, or mitigation are necessary to provide assistance in documenting or reducing the impact of disease. Any changes prompted by disease outbreaks in the species covered in the HCP will be performed under the budget established for monitoring and reporting.

2) **Hurricanes and Storms**. Throughout recorded history, severe storms have occasionally impacted the Hawaiian Islands. Petrels are not known to be particularly susceptible to habitat destruction from severe storms, but in the event that Hawaiian petrel burrows at the project site or within the mitigation site are damaged or adults or fledglings suffer injury or mortality due to storm activities, NSF will contribute to measures to rehabilitate injured individuals and restore their damaged habitat as deemed appropriate by the state and the Park.

3) **Changes in the Price of Raw Materials and Labor.** Annual reviews will be performed to analyze the costs in the previous years' budget for mitigation expenses and cumulative costs. Annual expenses for subsequent years will be adjusted to meet projected costs based on the previous years' expenditures and cumulative spend to date.

4) **De-listing of Covered Species.** Should the species covered in the HCP be de-listed during the tenure of the permit, it is expected that the mitigation efforts provided by NSF will contribute to the de-listing of the species. However, mitigation actions for the species will continue to be performed in accordance with the HCP, unless and until the state agree that such actions may be discontinued.

5) **Listing of One or More Species that Already Occur on Site.** In the event that the species that occur on site are listed pursuant to the ESA, NSF will evaluate the degree to which the species is (or are) at risk of being incidentally taken by project operations. If

take of the species appears possible, NSF will then assess whether the mitigation measures already being implemented provide conservation benefits to the newly listed species and if any additional measures are needed to provide a net conservation benefit to the species. NSF would then seek coverage for the newly listed species under an amendment to the HCP if it is determined that the coverage would benefit both NSF and the species.

6.6 Changed Circumstances Not Provided for in the HCP

If changed circumstances occur that are not provided for in Section 6.5 (funding) and the HCP is otherwise being properly implemented, the state will not require any conservation and mitigation measures in addition to those provided for in the HCP without the consent of NSF. NSF would seek reinitiation of formal consultation with the state, as appropriate, pursuant to 50 CFR § 402.16.

6.7 Notice of Unforeseen Circumstances

The state will have the burden of demonstrating that unforeseen circumstances exist, using best available scientific and commercial data. The state will notify NSF in writing should the State believe that any unforeseen circumstance has arisen.

6.8 Incidental Take License/Take Permit Duration

This HCP for NSF is written in anticipation of the issuance of an ITL to cover the entire construction, integration period of the project, in addition to 3 years of subsequent ATST operations, for a total duration of 10 years. Birdstrike to structures is covered for a period of 10 years.

6.9 HCP Amendment Procedure

Different procedures are present that allow for the amendment to the ITL. However, the cumulative effect of any amendments must not jeopardize any listed species. The state must be consulted on all proposed minor and formal amendments, listed below.

Minor Amendments
Minor amendments include routine administrative revisions, time extensions to the ITL, changes to surveying or monitoring protocols that do not decrease the level of mitigation or increase take. A request for a minor amendment to the HCP may be made with written request to the state and implemented upon receiving concurrence from the agencies that the modification provides protection equal to or greater than the level provided by the Project Description. Request for minor amendment should be made no less than 180 days prior to the expiration of the ITL.

Formal Amendments
Formal amendments are required when the Applicant wishes to significantly modify the project, activity, or conservation program already in place or when a net adverse effect on the Hawaiian petrel is significantly different than that considered in the original HCP. For example, a formal amendment would be required if the documented level of take exceeds that covered by the state's ITL. A formal amendment would also be required if another listed species is found to occur in the project area and could be adversely affected by project activities or in the event of unforeseen circumstances. An amendment to the ITL requires written notification to the state requesting an

amendment to the HCP addressing the new circumstance(s). The need for a formal amendment must be determined at least one year before ITL expiration, as a formal amendment may require additional baseline surveys and data collection, additional or modified minimization or mitigation measures, additional or modified monitoring protocols, ESRC, agency, and additional public review, and approval by the BLNR.

6.10 Renewal and Extension of the HCP

This HCP proposed by NSF may be renewed or extended, and amended if necessary, beyond its initial term with the approval of the state by minor or formal amendment. A written request will be submitted to the state that will certify that the original information provided is still current and conditions unchanged or provide a description of relevant changes to the implementation of the HCP that will take place. The request will also provide species-specific information concerning the level of take that has occurred during the HCP implementation.

6.11 Other HCP Implementation Measures

An Implementing Agreement stipulating the HCP terms and conditions in contractual form will be signed by NSF and the state to provide assurances that the HCP will be implemented.

7.0 REFERENCES

ABR, Inc. 2005. “Movements of Hawaiian Petrels Near USAF Facilities Near the Summit of Haleakalā, Maui Island, Fall 2004 and Spring 2005”. Prepared for USAF AFRL. September 2005.

Adams, J., D. G. Ainley, H. Freifeld, J. F. Penniman, F. Duvall, J. Tamayose, C. Bailey, N. Holmes, and M. E. Laut, G. Spencer 2006 Summer movements of ‘Ua’u (Hawaiian dark-rumped petrel Pterodroma phaeophygia sandwichensis) nesting on Haleakalā and Lana‘i: can we use satellite tracking to gain new information and advise conservation management? Poster, The Wildlife Society Hawai‘i Chapter, Seabird Conservation and Management in the Hawaiian Islands Workshop, October 26-27.

Advanced Technology Solar Telescope. 2009a. Storyboard of utility building, support and operations building and lower enclosure construction process (sb_bldgs2.ppt). Unpublished PowerPoint, 25 pp.

Advanced Technology Solar Telescope. 2009b. Storyboard of upper enclosure construction process (sb_enc2.ppt). Unpublished PowerPoint, 14 pp.

Advanced Technology Solar Telescope. 2009c. ATST Construction time schedule (Bird Analysis Calendar). Unpublished PDF, 8pp.

AFRL [U. S. Air Force Research Laboratory]. April 2005. “Draft Environmental Assessment: Proposed Advanced Electro-Optical System (AEOS) Mirror Coating Facility at the Maui Space Surveillance Complex (MSSC), Haleakalā, Maui, Hawai‘i”. Prepared by Belt Collins.

Ainley, D. G., Podolsky, R., de Forest, L., Spencer, G. and Nur, N. 1995. Kaua‘i Endangered Seabird Study Volume 2. The ecology of Dark-rumped Petrels and Newell’s Shearwater on the island of Kaua‘i, Hawai‘i. Final Report prepared for Electric Power Research Institute, Palo Alto, California. (ed^(eds, pp. 74. Prepared by Point Reyes Bird Observatory, Stinson Beach, California.

Andersson, M., Wiklund, C.G. and Rundgren, H. 1980. Parental defense of offspring: a model and an example. Anim. Behav. 28: 536-542.

Attwell, P.B. and Farmer, I.W. 1973. Attenuation of ground vibrations from piles. Ground Engineering 6(4):26-29.

Awbrey, F.T. and D. Hunsaker. 1997. Effects of fixed-wing aircraft noise on California gnatcatchers. U.S. Navy and Marine Corps Symposium, Effects of Noise on Passerines. January 15, 1997. Hubbs-Sea World Research Institute.

Bailey, C. pers. comm. 2006a. Patrice Ashfield, Dawn Greenlee, and Charlie Fein met with NPS Hawaiian petrel biologists Cathleen Bailey and Joy Takemoto, at the HALE offices. The Service solicited input from the biologists regarding minimization measures which will reduce impacts of the project to Hawaiian petrels. August 29, 2006.

Bailey, C. pers. comm. 2006b. Gina Shultz, Patrice Ashfield, Holly Freifeld, Dawn Greenlee, from the Service met with Park Hawaiian Petrel Biologist Cathleen Bailey to discuss various aspects of the proposed ATST Project and measures which will minimize the impacts of the project to the Hawaiian petrel and nēnē. October 25, 2006.

Bailey, C. pers. comm. 2006c. Park Hawaiian Petrel Biologist Cathleen Bailey Emailed Service Biologist Dawn Greenlee with information regarding vehicle use of the Park and Hawaiian goose mortality on the road. November 21, 2006.

Bailey, C. pers. comm. 2006d. Bailey, C. pers. comm. 2006c. Park Hawaiian Petrel Biologist Cathleen Bailey provided Service Biologist Dawn Greenlee with information regarding the number of active Hawaiian petrel burrows on Haleakalā. November 22, 2006.

Bailey, C. pers. comm. 2007. Park Hawaiian Petrel Biologist Cathleen Bailey told Service Biologist Dawn Greenlee that in her 20 years at Haleakalā, she had not seen a Hawaiian petrel burrow collapse as a result of an earthquake. March 20, 2007.

Barr, J. unpublished. November 30, 2006. Response to Draft Vibration Avoidance Section of Biological Opinion. Jeffrey D. Barr. Project Architect, Advanced Technology Solar Telescope, 950 N. Cherry Ave, Tucson, AZ 85726.

Barr, J. unpublished. January 31, 2007. Engineering map of construction site and closest petrel burrows. Jeffrey D. Barr, Project Architect, Advanced Technology Solar Telescope, 950 N. Cherry Ave, Tucson, AZ 857261

Beardsley, J.W. 1966. Investigations of Nysius spp. And other insects at Haleakalā, Maui during 1964 and 1965. Proceedings of the Hawaiian Entomological Society 19(2):187-200. (*See* FEIS Appendix C(2) Supplemental Arthropod Sampling, March 2007.)

Blumstein, D.T., Anthony, L.L., Harcourt, R. and Ross, G. 2003. Testing a key assumption in wildlife buffer zones: is flight initiation distance a species-specific trait? Biol. Conserv. 110: 97-100.

Boersma, P.E., N.T. Wheelwright, M.K. Nerini, and E.S. Wheelwright. 1980. The breeding biology of the fork-tailed stork-petrel (*Oceanodroma furcata*) Auk, 97: 268-282.

Bolduc, F. and Guillemette, M. 2003. Human disturbance and nesting success of Common Eiders: interaction between visitors and gulls. Biol. Conserv. 110: 77-83.

Bonaccorso, F. pers. comm, 2009. Opeapea (Hawaiian Hoary Bat) Workshop, May 12, 2009. U.S. Fish and Wildlife Service Pacific Islands Fish and Wildlife Office.

Brandt, C. A., Parrish, J. K. and Hodges, C. N. 1995. Predictive approaches to habitat quantification: Dark-rumped petrels on Haleakalā, Maui. Auk, 112, 571-579.

Brooke, M. 1978. Sexual differences in the voice and individual vocal recognition in the Manx Shearwater Puffinus puffinus. Anim. Behav. 26: 622-629.

Burger, J. and M. Gochfeld. 1981. Discrimination of the threat of direct versus tangential approach to the nest by incubating herring and great black-backed gulls. J. Comp. Physiol. Phychol. 95(5): 676-684.

Burger, J. 1986. The effects of human activity on shorebirds in two coastal bays in northeastern United States. Environ. Conserv. 13: 123-130.

Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, unpublished. Preventing occupational hearing loss, a practical guide. http://www.cdc.gov/niosh/docs/96-110/appF.html

Chamberlain, D. E., M. R. Rehfisch, A. D. Fox, M. Desholm, and S. J. Anthony. 2006. The effect of avoidance rates on bird mortality predictions made by wind turbine collision risk models. Ibis 148: 198–202.

Conant, S. and Stemmermann Kjargaard, 1984. "Annotated Checklist of Birds of Haleakalā National Park, Maui, Hawai'i", Western Birds Vol 15, No 3.

Conomy, J. T., J. A. Dubovsky, J.A. Collazo, and W.J. Fleming. 1998. Do black ducks and wood ducks habituate to aircraft disturbance. J. Wildl. Manage. 62(3): 1135-1142.

Cooper, B. A. and Day, R. H. 2004. Estimated mortality of Hawaiian petrels at a proposed USCG tower on Haleakalā, Maui Island. Unpublished report prepared for the U.S. Coast Guard by ABR, Inc., Fairbanks, AK and Forest Grove, OR. 12 pp.

Cooper, B.A. and Day, R.A. 2005. Estimated mortality of Hawaiian petrels at a proposed USCG tower on Haleakalā, Maui Island. Prepared for USCG Engineering Unit Honolulu HI, 12pp.

Cooper, B.A., Day, R.A. and Plissner, J.H. 2007. Radar and audiovisual studies near Hawaiian petrels at proposed meteorological towers and wind turbines on Northwestern Lana'i Island, May-July 2007.

Corwin, J. T. and Cotanche, D. A. 1988. Science. 240: 1772-1774.

Day, R.A., Gall, A. E., Burgess, R. M. and Parrett, J.P. 2005. Movements of Hawaiian petrels near USAF facilities near the summit of Haleakalā, Maui Island, Fall 2004 and Spring 2005. Prepared for USAF AFRL c/o Boeing LTS, Kihei, Hawai'i. 34. Pp.

Delaney, D.K., T.G. Grubb, P. Beier, L.L. Pater, and M. Hildegard Reiser. 1999. Effects of helicopter noise on Mexican spotted owls. J. Wildl. Manage. 63(1): 60-76.

Drent, R. 1972. The natural history of incubation. Pages 262-311 in D.S. Farner (Ed) Breeding Biology of Birds. Washington, D.C. National Academy of Science.

Drent, R.H. and Dann, S. 1980. The prudent parent: energetic adjustments in avian breeding. Ardea 68: 225-252.

Dunlop, J. N. 1996. Habituation to human disturbance by breeding Bridled Terns Sterna anaethetus. Corella 20: 13-16.

ESI Engineering unpublished. Brief technical notes on vibration monitoring and control. ESI Engineering. Minneapolis, MN. http://www.esi-engineering.com/V9701.PDF

Federal Interagency Committee on Aviation Noise. 1992. Federal Agency Review of Selected Airport Noise Analysis Issues. http://www.fican.org/pdf/nai-8-92.pdf 119 pp.

Fein, C. pers. comm. 2006a. Representatives from the Service (Patrice Ashfield and Dawn Greenlee) and KC Environmental, Inc. (Dr. Charlie Fein, Tom Kekona, George Redpath) visited Haleakalā Observatories to tour the ATST construction site, view burrow entrances in the vicinity, and examine the petrel monitoring camera system. August 29, 2006.

Fein, C. pers. comm. 2006b. Via email, Dr. Fein provided the Service with the results of video monitoring of burrows during the October 15, 2006, earthquake, which indicated that none of the burrows were damaged and none of the petrel chicks appeared to respond to the strong ground vibration. October 26, 2006.

Fernández-Juricic, E., Jimenez, M.D. and Lucas, E. 2002. Factors affecting intra- and inter-specific variations in the difference between alert distances and flight distances for birds in forested habitats. Canadian Journal of Zoology-Revue Canadienne De Zoologie 80: 1212-1220.

Finegold, L. S., C. S. Harris, and H.E. Von Gierke. 1993. Applied acoustical report: criteria for assessment of noise impacts on people. Submitted to Journal of the Acoustical Society of America, June, 1992.

Finegold, L. S., C. S. Harris, and H.E. Von Gierke. 1994. Community annoyance and sleep disturbance: updated criteria for assessing the impacts of general transportation noise on people. Noise Control Eng. J. 42(1) 25-30.

Fox, A. D., M. Desholm, J. Kahlert, T. K. Christensen, and I. K. Petersen. 2006. Information needs to support environmental impact assessment of the effects of European marine offshore wind farms on birds. Ibis 148: 129–144.

Frasher, Heather, V. Parker-Geisman and G. R. Parish. 2007. "Hawaiian Hoary Bat Inventory in National Park on the Island of Hawaiʻi, Maui and Molokai." Technical Report 140. Pacific Cooperative Studies Unit, University of Hawaiʻi, Honolulu, Hawaiʻi. 25 pp. (unpublished data).

Götmark, F. 1992. The effects of investigator disturbance on nesting birds. In Power, D.M. (ed.) Curr. Ornithol.: 63-104. Vol. 9. New York: Plennum Press.

Hinde, R., 1966. Animal Behaviour. A Synthesis of Ethology and Comparative Psychology. McGraw-Hill Book Company, New York.

Hodges, C. S. 1994. Effects of introduced predators on the survival and fledging success of the endangered Hawaiian Dark-rumped Petrel (*Pterodroma phaeo-pygia sandwichensis*). M.S. thesis, Univ. of Washington, Seattle.

Hodges, C. S. N. and R.J. Nagata Sr. 2001. Effects of predator control on the survival and breeding success of the endangered Hawaiian dark-rumped petrel. Studies in Avian Biology 22:308-318.

Holmes, Nick. 2010a. Pacific Rim Conservation. *Impacts of the Advanced Technology Solar Telescope Construction on Hawaiian petrels* Pterodroma sandwichensis, *Haleakala: Recommendations for take estimation and monitoring.* (Appendix A). January.

Holmes, Nick. 2010b. *Impacts of the Advanced Technology Solar Telescope Construction on Hawaiian petrels* Pterodroma sandwichensis, *Haleakala: Recommendations for mitigation.* (Appendix B). March.

Honolulu Advertiser 2007. Quake victims struggle to rebuild. Sunday February 11, 2007 http://the.honoluluadvertiser.com/article/2007/Feb/11/ln/FP702110354.html

Hood, G. M. 2009. PopTools version 3.1.1. Available on the internet. URL http://www.cse.csiro.au/poptools

Howarth, F.G. and Hoch, H.1999. Multiple cave invasions by species of the planthopper genus Oliarus in Hawaiʻi (Homoptera: Fulgoroidea: Cixiidae). *Zoological Journal of the Linnean Society*. 127(4): 453-475.

Huso, M., 2008a Estimators of wildlife fatality: a critical examination of methods in Procedings of the NWCC Wind Wildlife Research Meeting VII. Milwaukee, WI. October 28-29, 2008. Prepared for the Wildlife Workgroup of the National Wind Coordinating Collaborative by RESOLVE, Inc., Washington D.C., Susan Schwartz, ed. 116 pp.

Huso, M., 2008b. Estimators of wildlife fatality: a critical examination of methods PowerPoint Presentation. Available at: http://www.nationalwind.org/pdf/HusoManuela, pdf.

Jensen, T.E. 1993. Ground Vibration Measurements During Soil Cement Test Paving, MSSS Access Road, Haleakalā, Maui, Hawaiʻi, Haleakalā, Maui, Hawaiʻi, Prepared by Dames and Moore, Honolulu, Hawaiʻi. 22pp.

Johnson, G. D., W. P. Erickson, M.D. Strickland, M.F. Shepherd, D. A. Shepherd and S. A. Sarappo. 2002. Collision mortality of local and migrant birds at a large-scale windpower development on Buffalo Ridge, Minnesota. Wildlife Society Bulletin, 30:879-887.

KCE [KC Environmental, Inc.] 2005. Letter from KCE sent to agencies with facilities at Haleakalā summit, regarding “Cumulative Impact Analysis for Project on Haleakalā, Maui, HI.” November 9, 2005.

KCE [KC Environmental, Inc.] 2009. Follow-up phone calls to agencies with facilities at Haleakalā summit, regarding "Cumulative Impact Analysis for Project on Haleakalā, Maui, HI" February 2009.

Keller, V. 1989. Variations in the response of Great Crested Grebes Podiceps cristatus to human disturbance - A sign of adaption? Biol. Conserv. 49: 31-45.

Kithil, J. unpublished. Effect of lightning upon burrowing and tunneling bird birds and mammals near ATST. National Lightning Safety Institute. 891 N. Hoover Ave, Louisville, CO. 2 pp.

Knight, R.L. and Cole, D.N. 1995. Factors that influence wildlife responses to recreationists. In Knight, R.L. and Gutzwiller, K. (eds.) Wildlife and Recreationists. Coexistence through Management and Research: 71-79. Washington D.C.: Island Press.

KWP [Kaheawa Wind Power LLC.] 2006. Kaheawa Pastures Wind Energy Generation Facility Habitat Conservation Plan, TMK Nos. 4-8-001: 001 and 3-6-001: 014, Ukumehame, Maui, Hawai‘i.

Liebherr, J.K. and E.C. Zimmerman 2000. Hawaiian Carabidae (coleopteran), Part 1 Introduction and Tribe Platynini. Volume 16. University of Hawai‘i Press, Honolulu. 494 pp.

Lord, A., Waas, J. R., Innes, J. and Whittingham, M. J. 2001. Effects of human approaches to nests of Northern New Zealand Dotterels. Biol. Conserv. 98: 233-240.

Mazur, J. A. 1998. Learning and Behaviour, 4th edn. Prentice-Hall, Upper Saddle River, New Jersey.

Mock, P.J. and Tavares, R. 1997. Noise effects on least Bell's vireo: studies of military helicopter activity, auto traffic, and light rails. U.S. Navy and Marine Corps Symposium, Effects of Noise on Passerines. January 15, 1997. Hubbs-Sea World Research Institute.

Natividad Hodges, C. 1994. Effects of Introduced Predators on the Survival and Breeding Success of the Endangered Hawaiian Dark-rumped Petrel. MS Thesis, University of Washington, Seattle, WA.

Natividad-Hodges, C. N. and Nagata, R. J. 2001. Effects of predator control on the survival and breeding success of the endangered Hawaiian dark-rumped petrel. Studies in Avian Biology, 22, 308-318.

Natividad Bailey, C. 2009. Technical Report 164. "Seabird Inventory at Haleakalā National Park, Maui, Hawai‘i. February 2009".

NPS [National Park Service] 2003. Hawaiian Petrels Near the Haleakalā Observatories: A Report to the K.C Environmental, Co. Inc. for Preparation of a Long-Range Development Plan. Cathleen Natividad Bailey, Wildlife Biologist, Endangered Species Management. 9 pp.

NSF [National Science Foundation] 2006. Draft Environmental Impact Statement for the Advanced Technology Solar Telescope Haleakalā, Maui, Hawai‘i. September 2006. 241 pp.

NSF [National Science Foundation] 2009. Final Environmental Impact Statement for the Advanced Technology Solar Telescope. July 2009.

Penniman, J. and F.P. Duvall. 2006. ‘Ua‘u on Lanaihale: History and current status. The Wildlife Society 2006 Workshop: Seabird Conservation and Management in Hawai‘i. October 26 – 27, Honolulu, HI.

Penniman, J. pers. comm. Service Biologist Dawn Greenlee corresponded with Hawai‘i Department of Land and Natural Resources, Division of Forestry and Wildlife Biologist Jay Penniman via telephone and email regarding the success of the white electric fence polytape at reducing Hawaiian petrel collisions. February 27 through March 20, 2007.

Penniman, pers. comm. 2010. April 9, 2010, email correspondence providing updated status of Lana‘i Hawaiian petrel colony.

Phelps, L. unpublished. Acoustic Evaluation of the ATST Mechanical Equipment Building. July 2005. 10pp.

Phelps, L. 2009. Study of Vibration due to Construction Activities on Haleakalā. Unpublished report to ATST, 32.pp.

Podolsky, R., D. G. Ainley, *et al*. 1998. Mortality of Newell's Shearwaters caused by collisions with urban structures on Kaua‘i. Colonial Waterbirds 21 (1): 20-34.

Podolsky, R. H. 2005. The use of decoys and sound systems to attract marine birds to restored habitat. Spoken paper. 2nd Regional workshop on dredging, beach nourishment, and bird conservation. Islip, Long Island, NY, Oct 6-7.

Resource Systems Group, Inc., 2006. The RSG Noise Primer. 12pp. http://www.rsginc.com/pdf/RSGNoisePrimer.pdf

Rodgers, J. A. and Smith, H. T., 1997. Buffer zone distances to protect foraging and loafing waterbirds from human disturbance in Florida. Wildl. Soc. Bull. 25: 139-145.

Saether, B. E. 1990. Age-specific variation in reproductive performance of birds. Current Ornithology 7:251–283.

Sanzenbacher, P.M and Cooper, B.A. 2008. Radar and visual studies of seabirds at the KWP I and II Wind Energy Facilities, Maui Island, Hawai‘i: Use of 2008 data to model annual collision fatalities at meteorological towers. Draft Report. Prepared for First Wind, Newton Massachusetts, 21 pp.

Sanzenbacher, P.M and Cooper, B.A. 2009. Radar and visual studies of seabirds at the proposed KWPII Wind Energy Facility, Maui Island, Hawai‘i: Use of 2008 data to model annual collision fatalities at proposed wind turbines. Prepared for First Wind, Newton Massachusetts, 28 pp.

Service. [U.S. Fish and Wildlife Service] 1998. "Terrestrial Mammal, 'Ōpe'ape'a or Hawaiian Hoary Bat, Lasiurus cinereus semotus. Species Status: Federally listed as Endangered, State listed as Endangered, State recognized as Indigenous (at the species level and Endemic at the subspecies level) Nature Serve Heritage Rank G2/T2 –Species secure/Subspecies imperiled, Recovery Plan for the Hawaiian Hoary Bat– Service 1998".

Seto, N.W.H. 1994. Effects of Rat (Rattus rattus) predation on the reproductive success of the Bonin Petrel (Pterodroma hypoleuca). MS Thesis. University of Hawai'i. 96pp.

Seto, N.W.H. and S. Conant. 1996. Effects of rat (Rattus rattus) predation on the reproductive success of the Bonin Petrel (Pterodroma phypleuca) on Midway Atoll. Colonial Waterbirds 19(2): 171-185.

Simons, T.R. 1983. Biology and conservation of the endangered Hawaiian Dark-rumped Petrel (*Pterodroma phaeopygia sandwichensis*). National Park Service, Cooperative Park Studies Unit, University of Washington, CPSU/UW83-2, Seattle.

Simons, T.R. 1984. A Population Model of the Endangered Hawaiian Dark-rumped Petrel. Journal of Wildlife Management 48: 1065–1076.

Simons, T.R. 1985. Biology and behavior of the endangered Hawaiian Dark-rumped Petrel. Condor 87: 229–245.

Simons, T.R., and C. N. Hodges. 1998. Dark-rumped Petrel (*Pterodroma phaeopygia*). *In* The Birds of North America, No. 345 (A. Poole and F. Gill, eds.). The Birds of North America, Inc., Philadelphia, PA.

Simons, T. R., and C. Natividad Hodges. 1998. "Dark-rumped Petrel". The Birds of North America, No. 13 (A. Poole and F. Gill, eds.). Academy Natural Sci., Philadelphia, and Amer. Ornith. Union, Washington, D. C.

Smiley, C.S. and W.A. Wilbanks. 1982. Effects of noise on early development in the rat. Bull. Psychon. Soc. 19(3):181-183.

South San Francisco Ferry Terminal Project. 2003. San Francisco Water Transit Authority. Final Program Environmental Impact Report: Expansion of Ferry Transit Service in the San Francisco Bay Area. June 2003. http://www.watertransit.org/pubs/eir/Section5.11_Noise.pdf

Stone, J.S. and E.W. Rubel. 2000. Cellular studies of auditory hair cell regeneration in birds. Proceedings of the National Academy of Sciences. 22: 11714 -11721.

Swift, R. 2004. Potential effects of ungulate exclusion fencing on displaying Hawaiian petrels (*Pterodroma sandwichensis*) at Hawai'i Volcanoes National Park. Master of Science Thesis. Oregon State University. 72pp.

Tetra Tech EC. 2008. DRAFT Habitat Conservation Plan for the construction and operation of Lana'i met towers, Lana'i, Hawai'i (Revised February 8, 2008, TTEC-PTLD-2008-080).

Unpublished report by Tetra Tech EC, Honolulu, HI for Castle and Cooke LLC, Lana‘i City, HI. 52 pp. + appendices. Available at: http://www.state.hi.us/dlnr/dofaw/pubs/Lana'i_Met_Towers_HCP.pdf .

Trivers, R.L. 1972. Parental investment and sexual selection. In Campbell, B. (ed.) Sexual selection and the descent of man, 1871-1971: 136-179. Chicago: Aldine-Atherton.

Tucker, V.A. 1996. A mathematical model of bird collisions with wind turbine rotors. Journal of Solar Energy Engineering 118: 253-262.

Turunen-Rise, I.H., Brekke, A., Harvik, L., Madshus, C., and Klaeboe, R. 2003. Vibration in dwellings from road and rail traffic. Part I. A new Norwegian measurement standard and classification system. Applied Acoustics, Vol. 64 (1), pp. 71-87.

UH IfA [University of Hawai‘i, Institute for Astronomy]. 2005. “Haleakalā High Altitude Observatory Site Long Range Development Plan (LRDP)”. KC Environmental, January 2005. 190 pp. Web site: http://www.ifa.hawaii.edu/haleakala/LRDP/.

UH IfA [University of Hawai‘i, Institute for Astronomy]. 2005a. “Haleakalā High Altitude Observatory Stormwater Erosion Report”. Prepared by Tetra Tech, Inc., July 2005.

U.S. Department of Interior, Geological Survey. 2009. The National Map LANDFIRE: LANDFIRE Hawai‘i Existing Vegetation Type layer. 2009, July - last update. U.S. Department of Interior, Geological Survey. [Online]. Available: http://gisdata.usgs.net/website/landfire/.

U.S. Geological Survey. Unpublished. http://earthquake.usgs.gov/eqcenter/shakemap/global/shake/twbh_06/

U.S. DOT (Department of Transportation) Federal Transportation Administration. 2006. Transit noise and vibration impact assessment. Noise and Vibration Manual. http://www.fta.dot.gov/documents/FTA_Noise_and_Vibration_Manual.pdf

Warham, J. 1990. The petrels: their ecology and breeding systems. Academic Press. New York, NY. 440 pp.

Yorio, P. and Quintana, F. 1996. Effectos del disturbio humano sobre una colonia mixta de aves marinas en patagonia. Hornero 14: 60-66.

Yuen, George A. L. and Associates. 1990. “Water Resources Protection Plan Volumes I and II. Commission on Water Resource Management Department of Land and Natural Resources State of Hawai‘i. June 1990”.

Young, D.P. Jr., W. P. Erickson, R. E. Good, M.D. Strickland,, and G.D. Johnson. 2003. Avian and bat mortality associated with the initial phase of the Foote Creek Rim Windpower Project, Carbon County, Wyoming: November 1998 – June 2002. Technical Report prepared by WEST, Inc. for Pacificorp, Inc., Sea West Windpower, Inc. and Bureau of Land Management. 35 pp.

Appendix A

Impacts of the Advanced Technology Solar Telescope Construction on Hawaiian Petrels, *Pterodroma sandwichensis,* Haleakalā: Recommendations for take estimation and monitoring

Impacts of the Advanced Technology Solar Telescope Construction on Hawaiian petrels *Pterodroma sandwichensis*, Haleakala: Recommendations for take estimation and monitoring.

Nick Holmes, nick.holmes@hawaii.edu Pacific Rim Conservation

January 2010

Summary

The following describes modeling approaches to determine approximate take associated with the ATST project as a basis for determining a biologically reasonable tier of take. Take was considered for a) birdstrike, b) disturbance from construction activity (noise, vibration, exhaust, dust, etc.) on burrows, and c) burrow collapse from vibration.

Three work schedules were assessed for 6-day work week (incubation black out period), 5-day work week (no incubation black out) and 6-day work week (no incubation work week). A 6-day work week with no incubation break equated to the least overall take, and based on advice from NSF, was subsequently used in remaining take estimations.

Birdstrike risk was calculated for the Site and Operations Building, and Lower and Upper enclosures separately. Total adjusted take for birdstrike equated to 0.5, 2.5 and 5 Hawaiian petrels for 99, 95 and 90% avoidance rates, for the total duration of the project.

A total disturbance risk duration of 5.4 breeding seasons was estimated, equating to 31.4 fledglings as take.

Take from burrow collapse was recommended at 2 adults for the duration of the project.

Table of Contents

1 Introduction

The proposed construction of the Advanced Technology Solar Telescope (ATST) project at Haleakala has the potential to negatively impact on the Hawaiian petrel *Pterodroma sandwichensis* population breeding at the site Haleakala. Under State of Hawaii Statute 195D, and Section 7 of the US Endangered Species Act, these negative impacts are considered 'take' – defined as "harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct". Determining the amount of take is required for State and Federal laws to determine if the proposed activity will place the population in jeopardy, and if no jeopardy is likely, the amount of subsequent mitigation required providing for net benefit of the Hawaiian petrel population.

Developing a exact model predicting the level of Hawaiian petrel take for ATST construction (vibration, noise, exhaust, etc.) is likely impossible at this stage because there is insufficient information about the specific, and cumulative, effects of these novel proximate mechanisms on Hawaiian petrel behavior and subsequent reproductive success. Ideally, each of these mechanisms, and their cumulative impact, would be tested using rigorous experimental research design. However given the proposed timeframe of the ATST project, and likely permitting challenges for such experiments, this is unachievable.

There should, however, be sufficient information to develop approximate estimates of Hawaiian petrel take, based on expert biological opinion, approximately comparative studies and observational studies. These can be used to produce tiers of take, e.g. 1-5 birds, 6-20 birds, etc. These tiers would subsequently be tested against the known demographic parameters for the population at Haleakala to assess the impact on the broader population, and also to produce modeling scenarios for each of the proposed mitigation options, and their capacity for mitigation benefit against take.

The following describes modeling approaches to determine approximate take associated with the ATST project as a basis for determining a biologically reasonable tier of take. A conservative approach towards estimating take is deliberately employed, erring on the side of overestimation. This is because Hawaiian petrels are an endangered species facing considerable threats across their breeding range, and Haleakala is one of the most important colonies for the survivorship of the species. Importantly, overestimating take provides the ATST applicants (National Science Foundation) with a safety barrier so they are unlikely to break State and Federal endangered species law.

1.1 Take mechanisms

Table 1 outlines the potential impacts and associated minimization and avoidance procedures for the ATST project (D Greenlee pers comm. Nov 2009). Take is expected for 1) birdstrike to observatory structure prior to completion, 2) disturbance from general proximity to construction reducing breeding frequency / productivity 3) burrow collapse (ESRC meeting notes 16th Nov 2009).

Potential Negative Impact		Summary	Minimization & Avoidance Measures
Bird Strike (New information suggests take likely to occur in foggy conditions.)	Observatory structure - prior to completion	Six years: 142-ft tall/84-ft wide (plus 60-ft tall 60-ft wide support building).	
	Completed Structure (Fledgling/Juvenile/Adult)	44 Years: 142-ft tall/84-ft wide (plus 60-ft tall 60-ft wide support building)	White Color
	Construction Crane (Fledgling/Juvenile/Adult)	5 years: Located on north side of telescope building	Feb 1 - Nov 30 crane will be lowered each night and marked with white polytape
	Construction Site Equipment	Six years - heavy equipment, trucks, dumpsters, signs in staging area and construction site.	
	25 Wide Loads (Fledgling/Juvenile/Adult)	If all loads are taken during the day	
		Each load would take 5 hrs to drive up to the site (driving 2 mph). Trucks would drive down during daylight.	? Turn off large headlights, ? White Polytape on trucks/loads?
Light Attraction	Seabird Fallout	Night-time activity is limited to 25 round-trip wide loads on NPS road	? Turn large truck headlights off?
Noise/Vibration	Reduced Breeding Frequency/Egg Laying	33 burrows within 328 feet (100 meters) of construction site (closest burrow 66 feet (20 meters)	With the exception of 25 wide load deliveries, all construction will occur during the day.
	Egg Neglect	Incubation period: Noise restricted at construction site/road to two truck and 8 passenger vehicle round-trips per day. Construction site noise severely limited such that burrow entrance noise will not exceed ambient noise levels.	
	Burrow Collapse (Egg/Nestling/Juvenile/Adult)	Park road burrows occur where they have not collapsed from previous vehicle vibration. Construction vehicle vibration is not greater than previous vibration exposure along Park road. Vibration resulting from slow-moving wide loads will be lower than fast-moving loaded trucks. At the construction site vibration at closest burrows will remain 20 times less than 0.12 inches/second vibration threshold (set by NPS engineers).	Caisson drilling will only occur December through mid-February (petrels absent from site).
	Reduced Nestling Survival to fledging	Construction noise and vibration may increased nestling metabolism (requiring extra feeding visits), cause temporary damage to auditory cells, and nestling may abandon nest.	
	Reduced Fledgling Survival at sea		
Habitat loss	Excavation and construction	Loss of 0.77 acres (0.31 ha) unoccupied potential burrowing habitat	
Invasive Species	Introduced invertebrate, plant impacts to reproductive success		NPS training/testing of all drivers. Steam cleaning of all construction vehicles before transported through the Park. Agricultural inspector/biologist inspections of loads at ports in addition to NPS load inspections. Annual inspection of construction site for non-native plants and animals with extermination within six months of detection.
Other:			
Predators	Predation	New staging area may further increase trash at construction site	Trash will be contained in secure bins to prevent trash access by predators. Rat bait station grid will be implemented.

.

Table 1-1 **Hawaiian petrel impacts from ATST Construction (Dawn Greenlee, FWS, 16 Nov 2009)**

2 Take from birdstrike

During the construction phase of the ATST the exposed materials and equipment present a potential strike risk to Hawaiian petrel. Hawaiian petrel strike with fences (Swift 2004, unpublished observations by Penniman and Duvall 2006) suggest strike is more likely with objects that have low object visibility and 'through' visibility, whereby birds can see through the object. Reducing birdstrike risk is achieved by increasing visibility of the object (e.g. fence taping, Swift 2004) and reducing 'through' visibility. Ultimately solid objects present the least strike risk (i.e. completed buildings). Minimization procedures to increase visibility of the ATST crane and other structures via taping and white paint are outlined in NSF (2009), however scaffolding, framework and other exposed structures will still retain some through visibility throughout parts of construction (ATST 2009a,b). Thus, ESRC biologists perceive it is unwise to assume 'zero' risk of birdstrike (ESRC meeting notes, 16 Nov 2009).

2.1 Flight passage and avoidance rates through ATST airspace

Determining birdstrike rate requires 1) determining the passages rate and interaction through the airspace the object occupies, and 2) determining the likelihood of avoiding the object (avoidance rate).

2.1.1 Flight passage rate

FWS (2009) previously estimated flight passage rate through the three major structures of the ATST airspace (Site and Operations Building, Lower Enclosure, Upper Enclosure) using ornithological radar data from Cooper and Day (2005) and Day et al. (2005), and based on equations developed by Tucker (1996). A summary of this estimation is provided in Appendix 1.

The Tucker (1996) model is based on interactions with turbine structures, and subsequent modification of this model as done so by Cooper and Day (2005). The application of this model to generate interaction probabilities and subsequent fatality rates for ATST has several limitations, including but not limited to:

- The model is designed to determine interaction with solid albeit low visibility objects (towers), whereas the ATST construction will not be a solid object, but rather a conglomeration of several solid low visibility objects (e.g. metal framework). Determining the risk of each of these objects with the duration they are exposed is not practical with current information
- The model only uses data from a limited number of surveys nights, with little assessment of variation in flight behavior during different weather conditions. For example, Hawaiian petrels and Newell's shearwaters will fly lower when fog or low cloud is present (Ainley et al. 1995).

These data suggest that 15.3 birds per year would fly through the airspace occupied by the Lower and Upper Enclosure each, and 15.0 birds per year through the S&O building. The figures, and subsequent fatality estimates, should not be considered a comprehensive assessment of take during the ATST construction, but rather a starting point for selecting an appropriate tier of take.

2.1.2 Avoidance rate

Determining a potential birdstrike or avoidance rate during ATST construction with minimization procedures in place is problematic because of a lack of suitable comparative data. Ideally species-specific and site-specific data should be used when assessing collision and avoidance rates (Fox et al. 2006, Chamberlain et al. 2006). There is a lack of data on the avoidance and collision of Hawaiian petrels with structures (Podolsky 2004, Cooper et al. 2007, Sanzenbacher and Cooper 2008, 2009), and importantly a lack of comparative studies with colonial breeding bird species where the mechanism of strike occurs within 100 m of a breeding site, as the ATST construction will (NSF 2009). The following summarizes knowledge to date.

Birdstrike rates determined from construction phases of previously build Haleakala observatories would provide site-specific comparative data, and while opportunistic observations suggest no strike occurred (NSF Meeting Notes, December 9), however it appears that no formal monitoring was undertaken during these construction periods, and thus no empirical data available on the strike rate (KWP 2006, ESRC Meeting notes 16 Nov 2009). Notably, opportunistic observations suggest no birdstrike has occurred at the Haleakala Visitor's center, where the nearest burrow is ~3m away (C. Bailey pers. comm. 29 Dec). Habituation to this building may play a key role in this observation, given this building was constructed in the 1930's when only 15 burrows where known from the immediate area, and subsequent recruitment has occurred with this building occupying Hawaiian petrel airspace.

Using a comparative strike rate of zero from taped (visible) fences around Hawaiian petrel colonies on Lanai and the Big Island (Swift 2004, unpublished observations by Penniman and Duvall 2006) may underestimate birdstrike during ATST construction because these fences are rarely greater than 8 feet in height, and on Lanai fence height is likely negated by adjacent vegetation, two conditions that will not be met by the ATST construction. Similarly, using comparative strike rate data from Hawaiian petrel interactions powerlines on the Island of Kauai for decades (Cooper and Day 1998, Podolsky et al. 1998) may overestimate birdstrike because of the low visibility of these objects.

Wind turbine and met tower studies in Hawaii include models for estimating annual Hawaiian petrel fatality based on nightly and annual movement rates (based on ornithological radar results) and exposure rates (based on the dimensions of the object presenting a strike hazard) (Table 2). Notably the avoidance rates used in these studies were estimated only and the authors note no empirical data exist to justify these numbers (Cooper et al 2007, Sanzenbacher and Cooper 2008, Sanzenbacher and Cooper 2009, Podolsky 2004).

Table 2-1: Hawaiian petrel avoidance rates estimated for Met Tower and Wind Turbines projects in Hawaii.

Study	Site	Annual movement rate bird/yr	Structure	Annual exposure rate bird/yr	Avoidance rate %	Hawaiian petrel fatality/yr
Cooper and Day 2004a	USCG tower Haleakala	191	30 m tower	1.64	57	0.67
Cooper and Day 2004b	KWP I	267/km	20 x 55 m turbines	12-90	50	1.46-10.77
					95	0.15-1.08
					99	0.03-0.22
Podolsky 2004	KWP I		20 x 55 m turbines	54	90	4.44
				31	95	0.61
				8	99.5	0.001
Cooper et al. 2007	Lanai Met towers, Upper Kuahoa	11250	50m met tower	80.83	0	76.1
					50	38.4
					95	3.8
					99	0.8
Sanzenbacher and Cooper 2008	KWPII	454	55m guyed met tower	1.8	50	0.857
					95	0.086
					99	0.017
Sanzenbacher and Cooper 2009	KWPII	348	100m Turbine	0.4-2.4 bird/yr	90	0.036
					95	0.018
					99	0.004

Since development of these models, the duration of KWP I (33 months) and the Lanai Met tower operation (2 years), offer limited testing of these avoidance estimations. From 33 months of operation 1 Hawaiian petrel strike (1.2 birds as corrected take) was collected from KWP I (Sanzenbacher and Cooper 2009), aligning with a 95% avoidance rate from Cooper and Day (2004b). Notably, Podolosky (2004) suggests that a 50% avoidance rate used in Cooper and Day (2004b) is unrealistically conservative for Hawaiian petrels given the ecological context of their inherent flight and collision avoidance behavior, and used 90, 95 and 99% avoidance rates to present worst, moderate and best case birdstrike rates for KWP II, albeit with a different model to estimate take. No birdstike was recorded from the Lanai Met towers after two years of operation (Sanzenbacher and Cooper 2009).

Like other nocturnal procellariformes, Hawaiian petrels have evolved with a highly sensitive sense of vision and neuro-motor system to allow high speed flight (>30-50 mph) and under nocturnal light conditions, all contributing to a degree of collision avoidance under natural conditions (Cooper and Day 1998, Podolsky 2004). The limited data from KWP I and the Lanai Met towers, plus the ecological context of this species' flight capabilities, suggest that Hawaiian petrels have a high potential to avoid structures encountered in their airspace.

Ultimately, application of avoidance rates generated from powerlines, fence, met towers and wind turbines, to the ATST construction is limited because:

a) the difference in *spatial airspace* that these objects occupy compared to the ATST;

b) the *visibility* will be markedly different for these objects compared to the ATST;

c) these strike / avoidance rates were generated in *flight paths* of Hawaiian petrels, as opposed to immediately *adjacent to a breeding site* as the ATST will be; and

d) strike / avoidance rates generated for these objects were done so considering *objects static in the environment*. ATST construction will present a *changing strike hazard* as the horizontal, vertical and 'through' visibility for the total object changes during the construction process. This likely negates the possibility that birds may become habituated to the ATST framework, as habituation requires exposure to a consistent stimulus (Hinde 1966, Mazur 1998).

With these considerations in context, plus the apparent high avoidance rates Hawaiian petrels, a range of avoidance rates are presented here to inform a selection of tier of take (Table 2.2).

Table 2-2: Estimated Annual Hawaiian petrel fatality rate using FWS (2009) passage rates.

		Annual Estimated Fatality		
		Lower Enclosure	Upper Enclosure	S&O Building
Avoidance rate	80%	2.91	2.91	2.84
	90%	1.46	1.46	1.42
	95%	0.73	0.73	0.71
	99%	0.15	0.15	0.14

2.2 Duration of take from birdstrike

The duration of Hawaiian petrel birdstrike risk was assessed based on 'storyboards' provided by Advanced Technology Solar Telescope (ATST) contractors and engineers (ATST 2009a, 2009b). In addition, three time schedules were assessed based on combinations of 5 or 6 day work weeks, and the use of a black-out period during Hawaiian petrel incubation (ATST 2009c). Birdstrike risk was considered present if lattice, framework, or other structures were present with 'through' visibility (the ability to see and/or fly through the structures) during each of the major construction tasks identified. The total months, and total proportion of breeding season, which each task and structure presents a birdstrike risk is summarized in Appendix 2.

This Hawaiian petrel birdstrike risk assessment differs significantly from previous assessments of static or existing structures including Windfarms, Powerlines and Meteorological Towers (Podolsky et al. 1998; Sanzenbacher & Cooper 2008, 2009; Tetratech 2008). ATST construction is a dynamic process, and thus, birdstrike risk will change over time accordingly. This temporal variation was accounted for by assessing key construction tasks separately, for each of the three major structures to be built (Site and Operations Buildings, which includes the Pier and Lower Enclosure, and the Upper Enclosure). No birdstrike is expected from the Utility building construction as it is blocked by the Mees building from predominant flight paths (Cooper and Day 2005).

This duration of risk assessment is considered is appropriate, based on the materials provided, but should be considered an overestimation for practical 'take' considerations. For example, a maximum spatial (object airspace) and temporal (period of time exposed to the potential hazard) birdstrike risk is assumed during the task titled 'Pour Interior Elevated Slabs in S&O Bldg'. From a practical perspective, the total object airspace showing 'through' visibility, and the time exposed, will be progressively reduced on the Site & Operations Buildings as each wall panel is fitted during the construction task. This scenario is analogous to most tasks and activities included in the dynamic construction process and suggest that the current risk assessment should be considered an overestimation for relevant 'take' considerations.

A total birdstrike risk duration for each building is provided below.

Table 2-3 **Birdstrike duration (breeding seasons) risk for each major structure of the ATST.**

	Lower Enclosure	Upper Enclosure	Site and Operations Building
Incubation break, 6-day schedule	1.75	1.61	1.11
Incubation NO break, 5-day schedule	1.67	1.25	1.08
Incubation NO break, 6-day schedule	1.36	1.22	0.86

2.3 Adjusting take – indirect take

For *Procellariformes*, adult mortality while breeding will also result in chick mortality because both adults are required to provision sufficient food for successful chick rearing (Warham 1990). Thus Hawaiian petrel strike take must be adjusted for this potential chick mortality by the following factors:

1. A breeding bird versus a prospecting bird (breeding status: 50%) (Simons 1984).

2. If a breeding bird, the probability that those birds did breed (breeding probability: 89%), (Simons 1984)
3. If the bird did breed, the probability of successfully rearing a chick to fledging (Fledging success: 66%) (Simons 1984).

Adjusting indirect take values beyond these probabilities (i.e. based on actual direct take evidence) would be difficult. Breeding status could be potentially assessed by determining presence of a brood patch, however non-breeding birds can also present with this characteristic. Breeding probability and breeding success are unlikely to be known for any mortality unless it was a banded bird, and the associated burrow was being monitored that year.

Thus

Indirect take = direct take x (breeding status 50% x breeding probability 89% x fledging success 66%)

Or adjusted take of **one** Hawaiian petrel =

DT x (0.5BS x 0.89BP x 0.66FS) = **1.29**

Whereby

DT= Direct take
BS = Breeding status (breeder or non-breeder)
BP = Breeding probability (if breeder, likelihood of breeding that year)
FS = Fledging success (if bred, likelihood of successfully raising a chick)

And Direct Take = 1 adults, and Indirect Take = 0.29 fledglings.

Table 2-4 shows the direct take (adults) and indirect take (fledglings) and adjusted take for the avoidance rates identified and the range of work schedules provided.

Table 2-4 **Adjusted based on duration of birdstrike risk, FWS (2009) passage rate information, and a range of avoidance rates.**

Schedule	Avoidance rate	Total Fatality (Take) Lower Enclosure	Upper Enclosure	S&O Building	TOTAL	Indirect take	ADJUSTED TAKE
Incubation break, 6-day schedule	80%	5.1	4.7	3.2	12.9	3.8	**16.7**
	90%	2.5	2.3	1.6	6.5	1.9	**8.4**
	95%	1.3	1.2	0.8	3.2	1.0	**4.2**
	99%	0.3	0.2	0.2	0.6	0.2	**0.8**
Incubation NO break, 5-day schedule	80%	4.9	3.6	3.1	11.6	3.4	**15.0**
	90%	2.4	1.8	1.5	5.8	1.7	**7.5**
	95%	1.2	0.9	0.8	2.9	0.8	**3.7**
	99%	0.2	0.2	0.2	0.6	0.2	**0.7**
Incubation NO break, 6-day schedule	80%	4.0	3.6	2.4	10.0	2.9	**12.9**
	90%	2.0	1.8	1.2	5.0	1.5	**6.4**
	95%	1.0	0.9	0.6	2.5	0.7	**3.2**
	99%	0.2	0.2	0.1	0.5	0.1	**0.6**

2.4 Consideration of unobserved take

Selecting an appropriate tier of take requires consideration of unobserved direct take. This is because it is assumed that not all birds that do suffer birdstrike will be found, either because they were not located during required monitoring, or because the carcass was removed by scavengers, thus requiring adjustment of the take estimate. Importantly, carcass removal and searcher efficiency data are estimated only here, and would required data from studies specific to the ATST site, thus adjusting the equation below. For the purposes of estimating adjusted take the following figures are used.

No carcass searching efficiency (SE) data exist for the ATST area, but it is assumed that because of the open terrain, and dry climate that SE would be high and is thus estimated at 90% (ESRC meeting notes 16th Nov 2009). By comparison, SE at KWP I was 100% on bare ground (KWP 2006). Carcass removal rate also is expected to be low because of terrain and scavenger (rat, mongoose, cat) presence and control at the site, and is thus estimated at 10% (ESRC meeting notes 16th Nov 2009). A final correction factor is the amount of area that can be searched. Approximately 30% of the area in which a birdstrike could fall (Section 2.5) lies within the rocky slopes of the Hawaiian petrel breeding colony and must be discounted from the total area searched.

Thus

Unobserved take = Direct take x (carcass removal rate 10% + searcher efficiency rate 90% + search area correction 30%)

Or unobserved take of **one** Hawaiian petrel =

DT + [(DT x 0.1CR) + (DT x (1-0.9SE)) x (DT x 0.3SA)] = **0.5**

Whereby

DT= Direct take
UT = Unobserved take
CR = Carcass removal rate
SA = Search area not covered
SE= Searcher efficiency rate

This consideration of unobserved take has practical implications when an appropriate tier of take for the ATST construction project. For every 1 adult found (direct take) an additional 0.5 birds (unobserved take) would be added to this take observation. When considering a 95% avoidance rate, and a 6-day schedule and no incubation break, the estimated adult take equals 2.5 adults, meaning take would be exceeded once the second bird is found (2 birds direct take + 1 bird unobserved take). When considering the 90% avoidance rate, estimated take is 5 adults, and take would be exceeded when the fourth bird is found (3.3 birds direct take + 1.7 birds unobserved take)

2.5 Recommendations for Birdstrike Monitoring

Similar birdstrike monitoring study design and protocols exist for turbines (KWP 2006) and meteorological towers (Tetratech 2008) in Hawaii and provide a basis the ATST.

2.5.1 Monitoring area

Birdstrike is considered to result in mortality given Hawaiian petrels travel at 30-50 mph. This dictates a monitoring area based on the distance a killed bird would travel after striking the ATST. Based on a calculation of 1.25 the height of the ATST (see Tetratech 2008), this creates a 4.7 ac area within 180 feet extending from the perimeter of the Site and Operations building, and Lower and Upper Enclosure (Figure 2-1).

Within this search area two zones are identified. Area A (3.3 ac) lies on the ATST plateau and includes other observatories. This area includes roads, pathways and roofs of buildings, plus open rocky habitat with little obstructions for identifying bird carcasses. No restrictions on this search area exist. These open and bare areas are likely to yield high searcher efficiency, similar to the 100% obtained at KWP in bare ground habitat (KWP 2006).

Area B (1.4 ac) lies on the slopes South and East below the ATST plateau, and includes rocks and boulders of various sizes that would obstruct simple identification of bird carcasses. This area is amongst existing Hawaiian petrel habitat and frequent access for birdstrike monitoring is not recommended because it would degrade breeding habitat there.

However, searchers will be able to access the edge of the cliff at the demarcation between Area A and Area B. Using careful visual scanning (binocular assisted) of Area B from Area A may be feasible. A protocol for obtaining birds/carcasses of downed birds s detected in Area B by visual scanning should be developed, including searcher efficiency.

2.5.2 Searcher efficiency trials

Searcher efficiency trials are undertaken to determine to percentage of birdstrike mortalities that are identified. Key elements of the searcher efficiency trials include:

- Trials should be undertaken in Spring, Summer and Fall to obtain a measure of seasonal variation in scavenging rate;
- A minimum of three trials per season to obtain a mean and standard deviation in searcher efficiency;
- Wedge-tailed shearwaters *Puffinus pacificus* should be used as a surrogate species, and should be obtained via coordination with State of Hawaii Division of Forestry and Wildlife and US FWS;
- A variable number of carcasses should be used (1-3) so searchers are unaware of total carcasses used in each trial;
- Carcasses should be placed outside known search periods, and locations marked using GPS (± 1 m) so as to be distinguished from actual birdstrike;
- Carcasses should be placed dawn, and recovered at dusk – no carcasses should be left overnight given this may encourage scavenger and predator activity near to the adjacent Hawaiian petrel breeding colony.
- Carcasses should be placed in a variety of positions including exposed (thrown), hidden to simulate a crippled bird and partially hidden;
- Birdstrike searchers should be trained in active searching, and be familiar with seabird and birdstrike ecology;
- Searchers should be unaware of trials being implemented;

2.5.3 Carcass removal trials

Carcass removal trials are undertaken to determine the scavenging rate by cats, rats and mongoose of any birds killed via birdstrike. This information is used to guide search intervals for birdstrike monitoring, with a search intervals at 50% of the mean carcass removal rate. Considerations for these trials include:

- Wedge-tailed shearwaters *Puffinus pacificus* should be used as a surrogate species, and should be obtained via coordination with State of Hawaii Division of Forestry and Wildlife US FWS;
- Carcasses should be placed in an area outside the search area (with similar habitat), and away from known Hawaiian petrel breeding areas, to avoid encouraging scavenger and predator activity near to breeding sites.
- Carcasses should locations marked using GPS (± 1 m);
- Carcasses should be placed in a variety of positions including exposed (thrown), hidden to simulate a crippled bird and partially hidden;
- Carcasses should be checked every 7 days until 28th day, whereby removed.
- A minimum of 30 carcass removal trials should be undertaken.

2.5.4 Study design

Birdstrike monitoring study design should be summation of practical considerations, plus the most cost and time efficient method to determine true birdstrike numbers.

For the ATST, initial monitoring should be undertaken using transects 10 m apart extending through Area A, plus active searches of the perimeter of all buildings, and roofs of flat-topped buildings. Weekly sampling should be sufficient until Carcass removal trials are completed. Searches to be conducted from February to October during the Hawaiian petrel breeding season only.

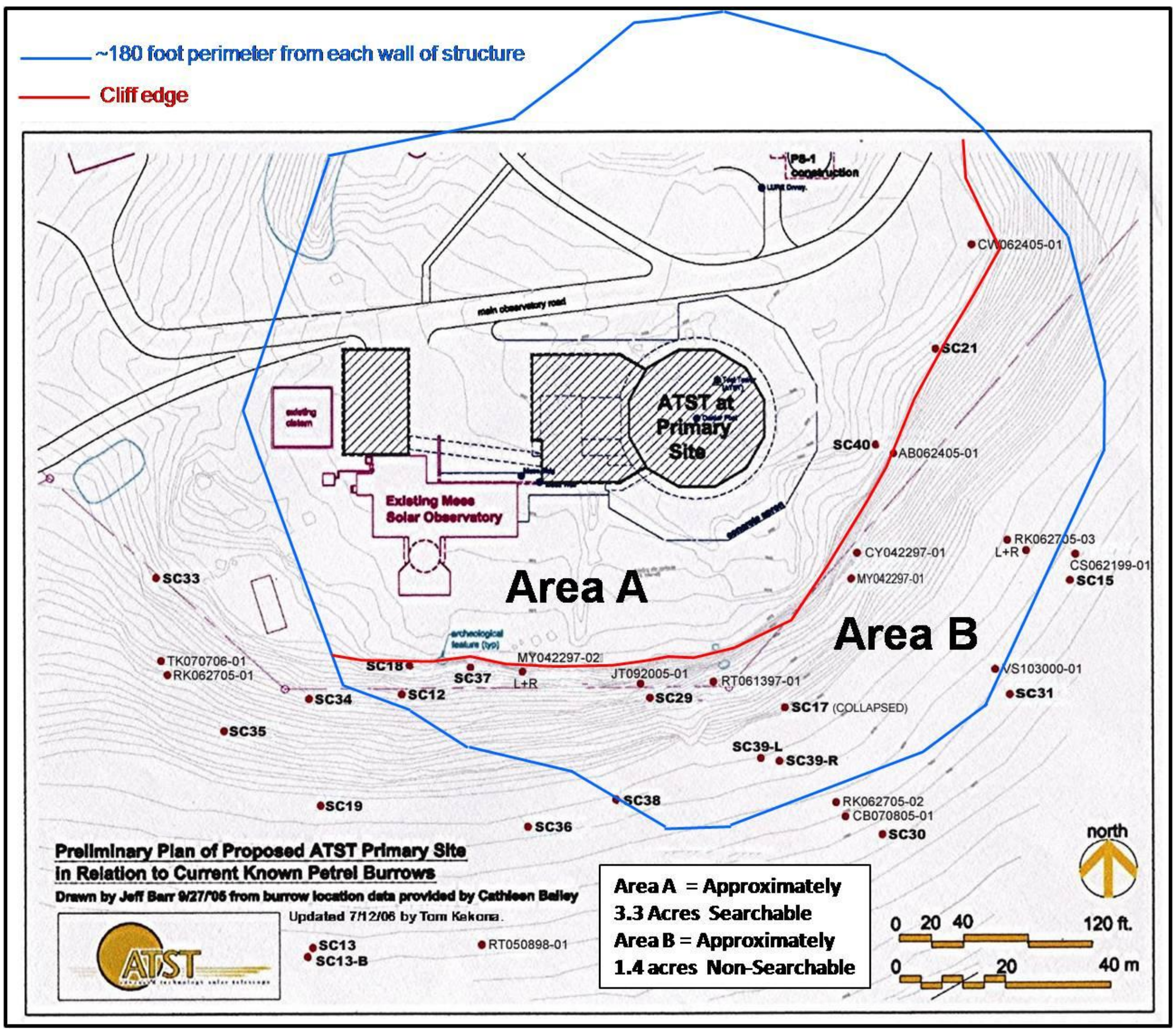

Figure 2-1 Birdstrike monitoring search area, including searchable (Area A) and unsearchable (Area B) zones.

3 Take from disturbance because of construction activity and general proximity to ATST construction site during breeding

There is a risk of take for breeding birds not initiating, or abandoning, breeding attempts during the breeding season because of construction activity (noise, vibration, exhaust, construction worker activity, etc.) and general proximity to the ATST construction, and a loss of productivity in those fledglings produced (Table 1.1).

Wildlife responses to human activity are known to vary based on a variety of factors including previous exposure to human activity (Keller 1989, Dunlop 1996), species (Rodgers & Smith 1997, Fernández-Juricic et al. 2002, Blumstein et al. 2003) and stimulus type (Burger 1986, Lord et al. 2001). These suggest that Hawaiian petrel responses to noise, vibration and general proximity to the ATST construction site are likely to be species and situation specific.

The timing of disturbance plays a key role in how wildlife will respond. Amongst seabird and waterbirds, greater sensitivity has been reported in earlier stages of breeding, (Götmark 1992, Knight & Cole 1995, Yorio & Quintana 1996, Bolduc & Guillemette 2003). Life history theory demands that animals act to maximise their life time reproductive output (Drent & Dann 1980). As such, within a single breeding effort, birds will adjust their commitment to a breeding attempt to reflect the level of investment they have already made (Trivers 1972, Andersson *et al.* 1980). The further a breeding pair progresses through a breeding season the more it has invested in producing progeny, therefore the 'cost' of abandoning that particular breeding attempt will increase over time (Trivers 1972, Andersson *et al.* 1980). This suggests that greater Hawaiian petrel sensitivity to abandonment can be expected during prospecting and incubation during ATST construction.

Few studies exist investigating the effects of construction adjacent to burrowing petrel colonies. During previous road paving work at Haleakala, a 25% decrease in Hawaiian petrel reproductive success was observed (C. Bailey pers. comm. Nov 2009). A search of the ISI Web of Science Database revealed no peer-reviewed articles for the search terms of petrel + noise / vibration / construction. In the absence of this information, measurements of these proximate mechanisms associated with disturbance have been investigated. Phelps (2009) assessed the vibrations associated with a demolition project at Science city in 2009. They determined that construction equipment similar to that required for ATST (excluding Caisson drilling) was unlikely to exceed a 0.12 PPV in/sec threshold for burrows beyond 30 feet of source point. Sound attenuation from the site has also been measured at the site with consideration of an incubation black out period (NSF 2009) and more recently with no consideration of a black out period (Appendix 3). These three studies suggest that there would be little effect of noise and vibration at the burrow site. Key limitations of these approaches are that they not experimental with their effect on Hawaiian petrels, and there is no consideration of the cumulative effects.

Because of these limitations, and because there is no empirical evidence of the effect of this type of construction adjacent to Hawaiian petrels, ESRC biologists perceive it is unwise to assume 'zero' risk of disturbance (ESRC meeting notes, 16 Nov 2009). The following describes an approach for selecting a biologically reasonable tier of take.

3.1 Noise and Vibration zones

There were 27 active burrows in the vicinity of the ATST construction site considered at risk from this mechanism of take, and this number is considered a census of the area (C. Bailey pers. comm. November 2009). Risk of take is not uniform to those burrows potentially affected, and we consider there to be three zones of risk based on proximity to the construction site, associated landscape feature / topography and expert biological opinion of the potential risk.

- Zone 1 yields the highest potential risk and is given a adjustment of multiplier score of 1, given these burrows are on the plateau the ATST is to be built on, and are within 40 feet from the edge of ATST apron. We consider these burrows have a score of 1 with or without a black-out period during incubation

- Zone 2 burrows are given a multiplier of 0.5 given they are on the slopes immediately below construction and afforded some protection, and no black-out during incubation. With a black-out during incubation this we apply a score of 0.4

- Zone 3 burrows are given a multiplier score of 0.1 given they are furthest from the construction site on the slopes below, and no black-out during incubation. With a black-out during incubation this we apply a score of 0.05

Figure 1 shows these zones and burrow locations on a map.

3.2 Indirect and adjusted take

Take from construction activity disturbance is considered indirect take because adult mortality is not expected. This estimate needs to be adjusted for probability that a bird would have bred that year (89%), and that the pair would have been successful (66%, Simons 1984). Adjusting for the probability that some of these pairs may have been non-breeders prospecting (i.e. breeding status) is problematic because failed breeders (a bird that did lay an egg) and prospecting non-breeders can often not be distinguished apart (C. Bailey pers. comm. Nov 2009). Thus we consider all active burrows identified in Table 1 to be breeders at some point during the 6 years of ATST construction.

Thus:

Indirect take = Take risk (Zone multiplier) x (breeding probability 89% x fledging success 66%)]

Or adjusted take of **one** Hawaiian petrel in **zone 1** =

$$IT \times (1.0Z_1) \times (0.89BP \times 0.66FS)] = \mathbf{0.59}$$

Adjusted take of **one** Hawaiian petrel in **zone 2** =

$$IT \times (0.5Z_2) \times (0.89BP \times 0.66FS)] = \mathbf{0.29}$$

Adjusted take of **one** Hawaiian petrel in **zone 3** =

$$IT \times (0.1Z_3) \times (0.89BP \times 0.66FS)] = \mathbf{0.06}$$

Whereby

IT= Indirect take
Z = zone 1, 2 or 3: take risk as a function of proximity to construction and landscape feature
BP = Breeding probability (if breeder, likelihood of breeding that year)
FS = Fledging success (if bred, likelihood of successfully raising a chick)

Thus, there is a total modeled take of 5.72 fledglings per year for these burrows should work occur during incubation, and 5.01 fledglings per year should no work occur during incubation. Monitoring of burrows to determine adjust for actual take would require a control set of burrows to adjust for breeding probability and breeding success for that year.

3.3 Duration of construction activity take

Duration of disturbance from construction activity is considered for the duration of the entire ATST project. A total disturbance risk duration of 6.3, 6.0 and 5.4 breeding seasons was estimated for the three schedules of 6-day work week (incubation black out period), 5-day work week (no incubation black out) and 6-day work week (no incubation black out work week). This duration assessment should be considered an overestimation of the total period in which disturbance occurs, because it does not account for variation in activity during that time.

Using these durations, this equates to 31.7, 34.3 and 31.4 fledglings as take, respectively.

3-1 Take estimations for three ATST schedules for disturbance at the burrow from noise, vibration and proximity to human activity. Beginning activity defined as Demolition and Clearing (Excludes Cess Pool Removal). Final activity defined as Install Enclosure Apron (Tie into Rainwater Collection).

Schedule	begin	end	months of noise / vibration	number of years affected	number of seasons affected	Fledglings as take per year	Total fledglings as take
6-day work week, incubation break	16-Jul-10	16-Sep-16	75	7	6.3	5.01	31.7

5-day work week, no incubation break	16-Jul-10	1-Jun-16	72	7	6.0	5.72	34.3
6-day work week, no incubation break	16-Jul-10	3-Nov-15	65	6	5.4	5.72	31.4

3.4 Recommendations for monitoring take from construction disturbance

Consideration of the metrics used to determine take are important here as they must be achievable to monitor during the construction process. The primary metric for monitoring take is from construction activity disturbance is active / inactive burrow status and fledgling success. The current methods employed by the Haleakala National Park biologists capture this metric (C Bailey pers comm. NPS unpublished data; Natividad Hodges 1994, Simons 1984, 1985) and can be increased in accuracy by using the existing cameras methodology (FEIS 2009) to verify these metrics and independently calibrate the NPS methods.

It will be critical to compare the treatment data (ATST burrow productivity) to suitable control data. These control data should include:

a) Previously collected fledgling success data from the ATST site. Approximately 8 years of data exist for this site (C Bailey, pers. comm. Nov 2009). Because these data will primarily come from the same individuals that will be impacted by the ATST process, they reduce any error associated with individual-to-individual variation, and increase a likelihood of detecting a difference due to the ATST construction;

b) Breeding productivity from control sites within the same years of ATST construction. Breeding success is inherently variable from year to year due to food availability (Warham 1990). Same year control data reduces the year-to-year variation an increase the likelihood of detecting a difference due to ATST construction. Importantly, these control sites should have the same level of management as the ATST site (trapping, etc.) so as not to introduce unwanted sources of error, so ideally should come from within the park. Importantly, this control is separate to that required to demonstrate the effects of mitigation, which will require comparison to a site not receiving management.

Statistical methods for comparing sites are established in Natividad Hodges 1994 and Simons (1985), and include Chi square analyses.

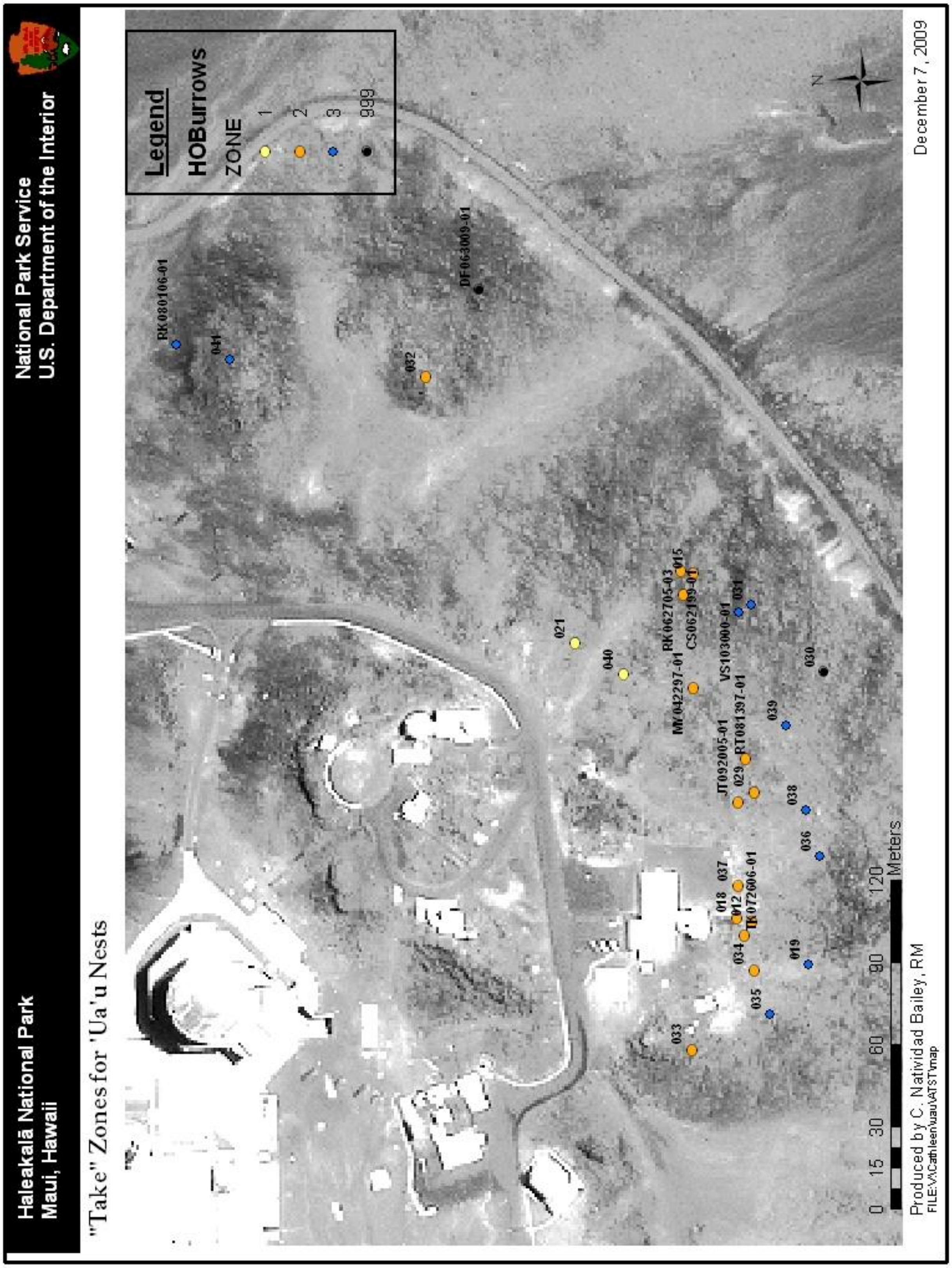

Figure 3-1 **Risk zones and associated burrows for ATST construction process.**

Burrow	Zone	Breeding status	Take score no incubation black out	Take Score Incubation black-out	Camera on bird	Comment
12	2	active	0.29	0.24	y	
15	2	active	0.29	0.24	y	
18	2	active	0.29	0.24	y	
19	3	active	0.06	0.24	y	
21	1	active	0.59	0.59	y	
29	**2**	active	0.29	0.24	y	
30	**999**	active	n/a	n/a	y	not expected to have an impact
31	3	active	0.06	0.03	y	
32	2	active	0.29	0.24	n	
33	2	active	0.29	0.24	y	
34	2	active	0.29	0.24	y	
35	3	active	0.06	0.03	y	
36	3	active	0.06	0.03	y	
37	2	active	0.29	0.24	y	
38	3	active	0.06	0.03	y	
39	3	active	0.06	0.03	y	
40	1	active	0.59	0.59	y	
CS062199-01	2	active	0.29	0.24	n	
DF063009-01	**999**	active	n/a	n/a	n	not expected to have an impact
IE040207-01	2	active	0.29	0.24	n	
JT092005-01	2	inactive	n/a	n/a	y	
MY042297-01	2	active	0.29	0.24	y	
RK062705-3	**2**	active	0.29	0.26	y	
RK080106-01	3	active	0.06	0.03	n	
RT081397-01	2	active	0.29	0.24	y	
TK072606-01	2	active	0.29	0.24	n	
VS103000-01	3	active	0.06	0.03	n	

Table 3-2 Burrows, breeding status and take score location within each risk zone.

4 Take from burrow partial or full collapse

Vibration could potentially case full or partial burrow collapse resulting in loss of habitat and mortality if during the breeding season. Hawaiian petrels, like all burrowing *Procellariformes* show site and mate fidelity in returning to the same burrow each year. Loss of the burrow or mate can result in reduced breeding probability that year, or reduced success if with a new mate (Warham 1990, Brooke 2004). This risk is considered for burrows 21 and 40 only, given their location on the ATST plateau and proximity to ATST construction.

Determining the likelihood of burrow collapse is inherently problematic. Notably, because of the cryptic nature, extreme length and multiple passages associated with many of the Haleakala burrows, detecting a partial collapse inside the burrow (whereby the entrance remains intact) would be unlikely given limitations of burrow scoping the full length of most burrows (C Bailey pers comm. Nov 2009).

Phelps (2009) assessed the vibrations associated with a demolition project at Science city in 2009. They determined that construction equipment similar to that required for ATST was unlikely to exceed a 0.12 PPV in/sec threshold for burrows beyond 30 feet of source point. The limitations of this report for determining burrow collapse risk are that a) it does not include results from caisson drilling, the technique expected to cause the most vibration (FWS 2007), b) each technique is considered separately and no assessment is made of cumulative vibration (SOH 2009), and c) there may be localized rock structures and strata specific to ATST site that are not reflected by the Phelps (2009) results.

4.1 Fledgling take from burrow collapse

Should ATST construction cause burrow collapse outside of the breeding season, once breeders returned to their burrow in the spring they would be forced to obtain a new burrow, and potentially a new mate, and there is a risk this would induce loss of breeding attempt, or reduced breeding success should they partner with a new mate. Should a pair be forced to leave a burrow, it would be unlikely that either individual would ever be located or their breeding outcome determined, unless they relocate to within the study area. Because burrow 21 and 40 are expected to have reduced breeding productivity each year due to noise and vibration disturbance (Section 3), this does not require any additional take to be considered

4.2 Adult take from burrow collapse

Should a full or potential burrow collapse occur during the breeding season this could result in the potential mortality of one or both of the parents, in addition to the loss of the chick (section 4.2). In a worst case, and highly unlikely, scenario this would result in 4 adults killed, should both parents be present in both burrows at the same time.

ESRC biologists perceive it is unwise to assume zero risk from burrow collapse (ESRC meeting notes, 8 Dec 2009). Given the a) limitations of determining burrow collapse, b) likelihood that adult take form birdstrike is likely an overestimation, c) that should a burrow collapse it would only kill the occupants once, and d) the impracticalities of identifying impact from partial collapse from a burrow, it was recommended that a take allowance of 2 adults from burrow collapse be used in selecting a tier of take.

5 References

Advanced Technology Solar Telescope (2009a) Storyboard of Utility Building, Site and Operations Building and Lower Enclosure construction process (sb_bldgs2.ppt). Unpublished powerpoint, 25 pp.

Advanced Technology Solar Telescope (2009b) Storyboard of Upper Enclosure construction process (sb_enc2.ppt). Unpublished powerpoint, 14 pp.

Advanced Technology Solar Telescope (2009c) ATST Construction time schedule (Bird Analysis Calendar). Unpublished pdf, 8pp.

Ainley, D. G., Podolsky, R., de Forest, L., Spencer, G. & Nur, N. (1995) Kauai Endangered Seabird Study Volume 2. The ecology of Dark-rumped Petrels and Newell's Shearwater on the island of Kauai, Hawaii. Final Report prepared for Electric Power Reserach Institute, Palo Alto, California. (ed^(eds, pp. 74. Prepared by Point Reyes Bird Observatory, Stinson Beach, California.

Andersson, M., Wiklund, C.G. & Rundgren, H. 1980. Parental defence of offspring: a model and an example. Anim. Behav. 28: 536-542.

Bolduc, F. & Guillemette, M. 2003. Human disturbance and nesting success of Common Eiders: interaction between visitors and gulls. Biol. Conserv. 110: 77-83.

Blumstein, D.T., Anthony, L.L., Harcourt, R. & Ross, G. 2003. Testing a key assumption in wildlife buffer zones: is flight initiation distance a species-specific trait? Biol. Conserv. 110: 97-100.

Burger, J. 1986. The effects of human activity on shorebirds in two coastal bays in northeastern United States. Environ. Conserv. 13: 123-130.

Chamberlain, D. E., M. R. Rehfisch, A. D. Fox, M. Desholm, and S. J. Anthony. 2006. The effect of avoidance rates on bird mortality predictions made by wind turbine collision risk models. Ibis 148: 198–202.

Cooper, B.A. & Day, R.A. (2005) Estimated mortality of Hawaiian petrels at a proposed USCG tower on Haleakala, Maui Island. Prepared for USCG Engineering Unit Honolulu HI, 12pp.

Cooper, B.A., Day, R.A. and Plissner, J.H. 2007. Radar and audiovisual studies near Hawaiian petrels at proposed meteorological towers and wind turbines on Northwestern Lana`i Island, May-July 2007.

Drent, R.H. & Dann, S. 1980. The prudent parent: energetic adjustments in avian breeding. Ardea 68: 225-252.

Day, R.A., Gall, A.E., Burgess, R.M. and Parrett, J.P. 2005. Movements of Hawaiian petrels near USAF facilities near the summit of Haleakala, Maui Island, Fall 2004 and Spring 2005. Prepared for USAF AFRL c/o Boeing LTS, Kihei, Hawaii. 34. Pp.

Dunlop, J.N. 1996. Habituation to human disturbance by breeding Bridled Terns Sterna anaethetus. Corella 20: 13-16.

Fernández-Juricic, E., Jimenez, M.D. & Lucas, E. 2002. Factors affecting intra- and inter-specific variations in the difference between alert distances and flight distances for birds in forested habitats. Canadian Journal of Zoology-Revue Canadienne De Zoologie 80: 1212-1220.

First Wind (2008) Kaheawa Pastures Wind Energy Generation Facility Habitat Conservation Plan. Year 1 HCP Implementation (Part II) January-June, 2007.

Fox, A. D., M. Desholm, J. Kahlert, T. K. Christensen, and I. K. Petersen. 2006. Information needs to support environmental impact assessment of the effects of European marine offshore wind farms on birds. Ibis 148: 129–144.

Götmark, F. 1992. The effects of investigator disturbance on nesting birds. In Power, D.M. (ed.) Curr. Ornithol.: 63-104. Vol. 9. New York: Plennum Press.

Hinde, R., 1966. Animal Behaviour. A Synthesis of Ethology and Comparative Psychology. McGraw-Hill Book Company, New York.

Kaheawa Wind Power LLC. (2006) Kaheawa Pastures Wind Energy Generation Facility Habitat Conservation Plan, TMK Nos. 4-8-001: 001 and 3-6-001: 014, Ukumehame, Maui, Hawai`i.

Keller, V. 1989. Variations in the response of Great Crested Grebes Podiceps cristatus to human disturbance - A sign of adaption? Biol. Conserv. 49: 31-45.

Knight, R.L. & Cole, D.N. 1995. Factors that influence wildlife responses to recreationists. In Knight, R.L. & Gutzwiller, K. (eds.) Wildlife and Recreationists. Coexistence through Management and Research: 71-79. Washington D.C.: Island Press.

Lord, A., Waas, J.R., Innes, J. & Whittingham, M.J. 2001. Effects of human approaches to nests of Northern New Zealand Dotterels. Biol. Conserv. 98: 233-240.

Mazur, J.A., 1998. Learning and Behaviour, 4th edn. Prentice-Hall, Upper Saddle River, New Jersey.

NSF (2009) Final Environmental Impact Statement for Advanced Technology Solar Telescope.

Phelps, L. (2009) Study of Vibration due to Construction Activities on Haleakalā. Unpublished report to ATST, 32.pp.

Podolsky, R., D. G. Ainley, et al. 1998. Mortality of Newell's Shearwaters caused by collisions with urban structures on Kauai. Colonial Waterbirds 21 (1): 20-34.

Rodgers, J.A. & Smith, H.T. 1997. Buffer zone distances to protect foraging and loafing waterbirds from human disturbance in Florida. Wildl. Soc. Bull. 25: 139-145.

Sanzenbacher, P.M & Cooper, B.A. 2008. Radar and visual studies of seabirds at the KWP I and II Wind Energy Facilities, Maui Island, Hawaii: Use of 2008 data to model annual collision fatalities at meteorological towers. Draft Report. Prepared for First Wind, Newton Massachusetts, 21 pp.

Sanzenbacher, P.M & Cooper, B.A. 2009. Radar and visual studies of seabirds at the proposed KWPII Wind Energy Facility, Maui Island, Hawaii: Use of 2008 data to model annual collision fatalities at proposed wind turbines. Prepared for First Wind, Newton Massachusetts, 28 pp.

Simons, T. R. 1984. A population model of the endangered Hawaiian Dark-rumped Petrel. Journal of Wildlife Management 48: 1065–1076.

Swift, R. 2004. Potential effects of ungulate exclusion fencing on displaying Hawaiian petrels (*Pterodroma sandwichensis*) at Hawaii Volcanoes National Park. Master of Science Thesis. Oregon State University. 72pp.

TetraTech EC. 2008. DRAFT Habitat Conservation Plan for the construction and operation of Lanai met towers, Lanai, Hawaii (Revised February 8, 2008, TTEC-PTLD-2008-080). Unpubl. report by Tetratech EC, Honolulu, HI for Castle and Cooke LLC, Lanai City, HI. 52 pp. + appendices. Available at: http://www.state.hi.us/dlnr/dofaw/pubs/Lana'i_Met_Towers_HCP.pdf .

Trivers, R.L. 1972. Parental investment and sexual selection. In Campbell, B. (ed.) Sexual selection and the descent of man, 1871-1971: 136-179. Chicago: Aldine-Atherton.

Tucker, V.A. 1996. A mathematical model of bird collisions with wind turbine rotors. Journal of Solar Energy Engineering 118: 253-262.

Yorio, P. & Quintana, F. 1996. Effectos del disturbio humano sobre una colonia mixta de aves marinas en patagonia. Hornero 14: 60-66.

Warham, J. 1990. The petrels: their ecology and breeding systems. Academic Press. New York, NY. 440 pp.

Appendix 1: Estimation of passage rate, interaction probability and fatality at ATST buildings using FWS model for tower structures (D. Greenlee pers. comm. Dec 09).

	December 22 update December 18, 2009 1:30 pm: Dawn Greenlee, Bill Standley, and Megan Laut (USFWS) met to discuss use of Day and Cooper 2005 (MSSC) data for estimating building strike rates on lattice of ATST structures. The table is designed for use with lattice tower/guy wire structures so may not be applicable to denser telescope buildings.	**Telescope Pier and Lower enclosure (23.1 m H x 12.8 m R)**	**Telescope Dome Upper Enclosure (20.15 m H x 12.8 m R)**	**S&O Building Framing (25 x 25 x 23 m)**	Dimensions from page 2-20 and 2-26 on FEIS for upper and lower enclosure
A	Movement Rate (targets/hr)	*6.2*	*6.2*	*6.2*	MSSSC site
B	Hours of darkness/nt	*6*	*6*	*6*	6 hours used to account for varying levels of intensity of flight over the night
C	Flock Size (Mean birds/target)	*1.02*	*1.02*	*1.02*	
D	Daily Movement rate (birds/day)	*37.944*	*37.944*	*37.944*	
ADDITIONAL 12% during other 5 hours of darkness	Additional Daily Movement rate (birds/day) (12% to add to the daily movement rate for the most active 6 hours)	*4.55328*	*4.55328*	*4.55328*	To account for the low frequency of bird flights during the less active 5 hours of darkness 12% added here.
E	Mortality domain (days/year)	*228*	*228*	*228*	228 Exposure days based on non-breeder and breeder attendance
F	Annual Movement Rate (birds/year)	*9689.37984*	*9689.37984*	*9689.37984*	
	Horizontal Interaction Probability				
G	Building height (m)	*23.1*	*20.15*	*23*	
H	Building radius (m)	*12.8*	*12.8*	*12.5*	
I	Maximal X-section of building((radius*building height/2)*2)(m2)	*295.68*	*257.92*	*287.5*	
J	X-sectional area of Radar (radar diam*tower height = sq.m)	*69,300*	*60,450*	*69,000*	
K	Horizontal Interaction Probability = (I/J)	*0.004266667*	*0.004266667*	*0.004166667*	
	Vertical Interaction Probability				
L	Proportion of birds below building height	*0.415000*	*0.415000*	*0.415000*	Cooper and Day (2005) identify 41.5% of targets recorded flew below 100 AGL from Surveys at Haleakala
	Exposure Rate				
M	Daily Exposure Rate =D*K*L	*0.067186176*	*0.067186176*	*0.0656115*	
N	Annual Exposure Rate =E*M	*15.31844813*	*15.31844813*	*14.959422*	
	Or (=F*K*L)	*17.1566619*	*17.1566619*	*16.75455264*	
	Fatality Probability				
O	Probability of Striking tower or guys if in airspace	*1.000000*	*1.000000*	*1.000000*	
P	Probability of fatality if striking tower or guys	*0.95*	*0.95*	*0.95*	
Q	Probability if an interaction	*0.95*	*0.95*	*0.95*	
	Annual Fatality (Take) Rate				
R	80% Avoidance	*2.910505144*	*2.910505144*	*2.84229018*	
S	90% Avoidance	*1.455252572*	*1.455252572*	*1.42114509*	
T	95% Avoidance	*0.727626286*	*0.727626286*	*0.710572545*	
U	99% Avoidance	*0.145525257*	*0.145525257*	*0.142114509*	

Appendix 2: Assessment of Birdstrike duration

Bird strike hazard assessment ***Information used*** sb_bldgs2.ppt, sb_enc2.ppt & Bird Calender Analysis.pdf

Schedule	**Calender**	**Source**
Incubation break	6-day	Bird Calender Analysis.pdf

Work	ppt	slide	begin	end	lower enclosure exposed	upper enclosure exposed	Site and Operations Building exposed	months of birdstrike risk	Proportion of season birdstrike risk	Comments
Pier Assembly - Construct Concrete Pier Walls	sb_bldgs2	12	4-Apr-12	29-Sep-12	yes	no	no	5.75	0.639	1
Steel Erection for S&O Bldg. and Lower Enclosure (Includes Cat..		13-17	1-Oct-12	15-Aug-13	yes	no	yes	7.5	0.833	
Pour Interior Elevated Slabs in S&O Bldg,		18-19	16-Aug-13	2-Sep-13	yes	no	yes	0.5	0.056	
Install Exterior Pre-cast Wall Panels		19-22	3-Sep-13	11-Nov-13	yes	no	yes	2	0.222	
Install Roof Panels		21	2-Nov-13	27-Dec-13	yes	no	no	0	0.000	
ENC Azimuth Track Assy and Test	sb_enc2	2	28-Dec-13	7-Mar-14	no	yes	no	1.25	0.139	2
ENC Carousel Fab, Assy and Test, ENC Carousel Drives Assy & Test @ Site, ENC Ancillary Mechanical Equipment Fab, Assy & Test @ Site		3-13	8-Mar-14	15-Jul-15	no	yes	no	13.25	1.472	
ENC Thermal systems Fab, Assy and Test		14-15	27-Jul-15	20-Feb-16	no	no	no	0	0.000	3

	lower enclosure	upper enclosure	Site and Operations Building
Months exposed	15.75	14.5	10
Seasons exposed	**1.750**	**1.611**	**1.111**

Comments

1. This involves a steelframework to lay concrete slobs onto (P. Eliason pers comm. 17 Dec 09)
2. there would be the exposed catwalks on upper sections during that process (H Marshall pers comm. 18 Dec 2009)
3. all internal (Heather Marshell pers com. 18 Dec 2009)

Bird strike hazard assessment ***Information used*** sb_bldgs2.ppt, sb_enc2.ppt & Bird Calender Analysis.pdf

Schedule	**Calender**	**Source**
Incubation NO break	5-day	Bird Calender Analysis.pdf

Work		**slide**	**begin**	**end**	**lower enclosure exposed**	**upper enclosure exposed**	**Site and Operations Building exposed**	**months of birdstrike risk**		**Comments**
Pier Assembly - Construct Concrete Pier Walls	sb_bldgs2	12	19-Apr-12	10-Aug-12	yes	no	no	3.75	0.417	1
Steel Erection for S&O Bldg. and Lower Enclosure (Includes Cat..		13-17	13-Aug-12	31-May-13	yes	no	yes	6.5	0.722	
Pour Interior Elevated Slabs in S&O Bldg,		18-19	3-Jun-13	21-Jun-13	yes	no	yes	0.5	0.056	
Install Exterior Pre-cast Wall Panels		19-22	24-Jun-13	17-Sep-13	yes	no	yes	2.75	0.306	
Install Roof Panels		21	18-Sep-13	12-Nov-13	yes	no	no	1.5	0.167	
ENC Azimuth Track Assy and Test	sb_enc2	2	13-Nov-13	13-Feb-14	no	yes	no	0.5	0.056	2
ENC Carousel Fab, Assy and Test, ENC Carousel Drives Assy & Test @ Site, ENC Ancillary Mechanical Equipment Fab, Assy & Test @ Site		3-13	14-Feb-14	3-Apr-15	no	yes	no	10.75	1.194	
ENC Thermal systems Fab, Assy and Test		14-15	6-Apr-15	18-Dec-15	no	no	no	0	0.000	3

Months exposed	15	11.25	9.75
Seasons exposed	**1.667**	**1.250**	**1.083**

Comments

1. This involves a steelframework to lay concrete slobs onto (P. Eliason pers comm. 17 Dec 09)
2. there would be the exposed catwalks on upper sections during that process (H Marshall pers comm. 18 Dec 2009)
3. all internal (Heather Marshell pers com. 18 Dec 2009)

Bird strike hazard assessment ***Information used*** sb_bldgs2.ppt, sb_enc2.ppt & Bird Calender Analysis.pdf

Schedule	**Calender**	**Source**
Incubation NO break	6-day	Bird Calender Analysis.pdf

Work		**slide**	**begin**	**end**	**lower enclosure exposed**	**upper enclosure exposed**	**Site and Operations Building exposed**	**months of birdstrike risk**		**Comments**
Pier Assembly - Construct Concrete Pier Walls	sb_bldgs2	12	4-Apr-12	5-Jul-12	**yes**	no	no	3	0.333	1
Steel Erection for S&O Bldg. and Lower Enclosure (Includes Cat..		13-17	4-Aug-12	25-Mar-13	**yes**	no	**yes**	5	0.556	
Pour Interior Elevated Slabs in S&O Bldg,		18-19	26-Mar-13	11-Apr-13	**yes**	no	**yes**	0.5	0.056	
Install Exterior Pre-cast Wall Panels		19-22	12-Apr-13	20-Jun-13	**yes**	no	**yes**	2.25	0.250	
Install Roof Panels		21	21-Jun-13	6-Aug-13	**yes**	no	no	1.5	0.167	
ENC Azimuth Track Assy and Test	sb_enc2	2	7-Aug-13	15-Oct-13	no	**yes**	no	2.25	0.250	2
ENC Carousel Fab, Assy and Test, ENC Carousel Drives Assy & Test @ Site, ENC Ancillary Mechanical Equipment Fab, Assy & Test @ Site		3-13	16-Oct-13	11-Sep-14	no	**yes**	no	8.75	0.972	
ENC Thermal systems Fab, Assy and Test		14-15	12-Sep-14	9-Apr-15	no	no	no	0	0.000	3

Months exposed	12.25	11	7.75
Seasons exposed	**1.361**	**1.222**	**0.861**

Comments

1. This involves a steelframework to lay concrete slobs onto (P. Eliason pers comm. 17 Dec 09)
2. there would be the exposed catwalks on upper sections during that process (H Marshall pers comm. 18 Dec 2009)
3. all internal (Heather Marshell pers com. 18 Dec 2009)

Appendix 3: Sound Attenuation at ATST construction site. C Fein pers. comm. Dec 09

Burrow Noise Measurement Notes:

Burrow noise measurements were taken using a Radio Shack 33-2055 Sound Pressure Level (SPL) Meter with a range of 50-126dB. Decibel (dB) readings were taken both in A-weighted (most sensitive at a range of 500-10,000 Hz, representing human hearing) and C-weighted (flat frequency range from 32-10,000 Hz).

Measurements were taken at 20 burrow locations, one location on Skyline Drive (Lat/Lon: 20*42’20.2”/156*15’21.7” 30.5ft EPE), and at distances of 25, 50, 75, 100 and 160 feet from the 120dB noise source (Car horn of a 2003 Nissan Xterra).

The source was positioned as close as was allowable to the center point of the proposed ATST Solar Telescope’s enclosure (Lat/Lon: 20*42’24.3”/156*15’22.0” 27.1ft EPE). The horn was pointed south with the burrows forming a rough semi-circle around it (see map).

Weather conditions were relatively calm with occasional passing light mists.
Wind speed varied from 0 to approximately 5mph at the noise source, at Burrows SC21 and SC40, and at the 25, 50, 75, 100 and 160 ft. locations. Wind speed at the remaining burrows and at the Skyline Drive location averaged approximately 0 to 2 mph. Wind direction was primarily from the west. The measurements were taken in the late afternoon/ early evening (spanning a time period of ~2:00 to ~6:00PM).

SPL readings were taken approximately ½ to 1 foot above the burrows and approximately 3 feet above ground at the other locations. In addition to the noise measurements, ambient SPL readings were also taken at each location. Care was taken to avoid what little wind noise there was.

BURROW NOISE MEASUREMENTS DEC 20th 2009			
LOCATION	dBA	dBC	Ambient dBA/dBC
SOURCE	120	120	54/52
25'	95	93	54/52
50'	89	88	54/52
75'	79	78	54/52
100'	63	62	54/52
160' (edge of S.drop-off)	62	61	54/52
SC12	<50	<50	<50
SC15	<50	<50	<50
SC18	<50	<50	<50
SC19	<50	<50	<50
SC21	55	<50	<50
SC29	<50	<50	<50
SC30	<50	<50	<50
SC31	<50	<50	<50
SC33	<50	<50	<50
SC34	<50	<50	<50
SC35-L	<50	<50	<50
SC36	<50	<50	<50
SC37	<50	<50	<50
SC38	<50	<50	<50
SC39-R	<50	<50	<50
SC40	55	<50	<50
MY042297-01	<50	<50	<50
MY042297-02L	<50	<50	<50
RK062705-03L	<50	<50	<50
RT061397-01	<50	<50	<50
SKYLINE DRIVE	<50	<50	<50

Appendix B

Impacts of the Advanced Technology Solar Telescope Construction on Hawaiian petrels *Pterodroma sandwichensis*, Haleakala: Recommendations for mitigation

Impacts of the Advanced Technology Solar Telescope Construction on Hawaiian petrels *Pterodroma sandwichensis*, Haleakala: Recommendations for mitigation.

Nick Holmes, nick.holmes@hawaii.edu Pacific Rim Conservation

Updated March 21st

Summary

The following outlines a basic description of a proposed ungulate fence and predator control mitigation project for Hawaiian petrels at Haleakala, including budget, timeline, and population modeling to identify when net benefit is recovered for the species.

Ten modeling simulations were run to determine the time to begin accruing net benefit for allocated take of 33 fledglings and 13 adults. These were based on two scenarios of 61 and 100 active burrows in the site, including a baseline (no ATST construction), no mitigation, and three mitigation options with conservative increases in reproductive success by 6, 9 and 12%, and increases in annual survival by 2, 3 and 4%, respectively.

Annual increase in adult survivorship from mitigation is greater than take during years of construction, so adult net benefit begins accruing in year one. Annual fledgling take is greater than the mitigation benefit in the first few years of construction. With only 61 burrows, it takes 19, 11 and 8 years to begin accruing net benefit in fledgling production. With 100 burrows, it takes 8, 3 and 1 years.

These results provide a starting point for selecting an appropriate mitigation investment. Given it is likely that more burrows exist in the site of the proposed mitigation, and given the conservative mitigation benefits used in the model, mitigation for the duration of the construction (6 years) may very well cover the requirements for the ATST project. A second tier of mitigation for the subsequent 4 years (years 7-10) could be applied should monitoring demonstrate that the first six years did not meet net benefit.

Table of Contents

1 Introduction

The proposed construction of the Advanced Technology Solar Telescope (ATST) project at Haleakala has the potential to negatively impact on the Hawaiian petrel *Pterodroma sandwichensis* population breeding at the site Haleakala. Under State of Hawaii Statute 195D, and Section 7 of the US Endangered Species Act, these negative impacts are considered 'take' – defined as "harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct". Impact from the ATST is not likely to constitute jeopardy to the species, and a full description of minimization procedures have been described elsewhere (FEIS 2009). A remaining task is to identify a mitigation project that will recover those adults and fledglings lost during construction, and provide a net benefit for the species.

Take from ATST construction considered in these models included: a) birdstrike at 5 adults + 1.5 fledglings as indirect take, b) 31.4 fledglings from disturbance from construction, and c) 2 adults from burrow collapse.

Adjacent to the ATST is Haleakalā National Park with the most effective habitat protection and predator control program for Hawaiian petrels in the State, and for the species. This offers a significant opportunity to employ proven protocols and methods to achieve the ATST net benefit requirement in accessible habitat. The following outlines a basic description of a proposed ungulate fence and predator control mitigation project for Hawaiian petrels at Haleakala, including budget, timeline, and population modeling to identify when a net benefit is recovered for the species.

2 Mitigation project description

2.1 Site description

The proposed mitigation project involves 327.2 ac located on Haleakala, adjoining and immediately west of the National Park (Figure 2-1). The boundary of the mitigation site is State Land and all parcels inside the mitigation site are owned by the state. One parcel is leased by the University of Hawaii (Science City) and two others by the Federal Government (Figure 2-2), and the State of Hawaii is in the process of implementing appropriate administration for fencing and HAPE management (F. Duvall pers. comm. 12 Jan 2010). The site includes all observatories known as Science City, plus the portion of Skyline road dissecting the site from the Northeast to Southwest. Culturally significant sites exist in the region and have been extensively analyzed by NSF as reflected in its Final Environmental Impact Statement for the ATST (FEIS 2009).

2.2 Habitat quality and number of burrows

The mitigation site includes 131 known burrows (NPS unpublished data), 61 identified as active, including all 25 Hawaiian petrel burrows affected by the ATST construction. Importantly, this is not a complete census and more burrows may exist in the area. Obtaining a complete census of burrows in the proposed mitigation area is recommended as a key task.

Hawaiian petrel burrow density in the mitigation site is likely to be lower than inside the park. Burrows are typically under large rocks on steep slopes in the vicinity of shrub cover (Brandt et al. 1995). The majority of known Hawaiian petrel burrows are located along the western rim of the Haleakalā crater, where this habitat is most abundant and also where predator control is afforded (Natividad-Hodges and Nagata 2001). Using survey efforts from 1990-1996, previous estimates of burrow density including part of the mitigation area range from 5-15 burrows per ha, compared to 15-30 burrows per ha along the western crater rim, (Natividad-Hodges and Nagata 2001). Similarly, in 2004 and 2005, Hawaiian petrel passage rates collecting using ornithological radar were 4 to 7 times greater during summer and fall at the Visitor's center (Western rim), when compared to Science City (Day et al. 2005), suggesting bird numbers are lower on the western slopes encompassing the mitigation site. Importantly, the population trend at Haleakalā is increasing (Natividad-Hodges and Nagata 2001, NPS unpublished data), suggesting that additional recruitment into this site is possible.

2.3 Proposed mitigation activity

The proposed mitigation activity focuses on removal of predators and habitat protection, key activities that are demonstrated to increase the reproductive rate and adult survivorship of Hawaiian petrels (Simons 1984, Natividad-Hodges and Nagata 2001). The proposed mitigation includes:

a) Census of burrows within mitigation area;
b) Ungulate (goat *Capra* sp.) fencing around the mitigation boundary, connecting with existing National Park boundary, and ungulate removal;
c) Predator control, including trapping and removal of known predators *Felis catus* and Indian mongoose *Herpestes* sp., and baiting of rats *Rattus* sp.;
d) Social attraction project and artificial burrow placement, to encourage recruitment into the site;
e) Burrow and habitat searching outside the mitigation site to identify i) suitable spatial control site and ii) potential back-up mitigation site; and
f) Mitigation success monitoring;

2.3.1 Ungulate proof fence and ungulate removal

Approximately 4300 m of ungulate proof fence would be installed around the project boundary, connecting to the existing 700 m of fence at the western edge of the National Park. Fence would have no barb wire strands and include an ungulate grid at the western end of skyline trail. Fence would be polytaped to increase visibility and reduce birdstrike. Installation would occur in the first year of the project at a cost of approximately $75/m ($322,500). Ungulate removal should occur immediately after the fence has gone up, and regular inspection of the fence will be required.

Birdstrike is a possible outcome of the fence and based on discussions with F Duvall and C Bailey, allowing for 6 mortalities is a reasonable first tier of take.

2.3.2 Predator control for cats, mongoose and rats

Predator control will be required prior to and throughout the Hawaiian petrel breeding season (Feb-Oct), and based on existing protocols used by the National Park. Traps should be checked every other day, and animals disposed of consistent with ethics protocols required by the State. The placement of traps is to be determined based on topography and outcomes of burrow searching. It is expected that two technicians will undertake the trapping, in addition to monitoring the activities outlined below. Checking the traplines in the mitigation area is expected to take a full day.

It is expected that throughout the course of the project, approximately one Hawaiian petrel will be caught in the traps per year, but will be released unharmed (F Duvall, C Bailey pers comm. Jan 2010). These birds are not considered in the mitigation modeling g because they do not result in mortality.

2.3.3 Social attraction to encourage recruitment

Encouraging recruitment into the mitigation site can be achieved by utilizing social attraction equipment. Social attraction is a common tool used for conservation of colonially breeding seabirds to either a) bolster existing colonies, b) restart historic breeding sites or c) b) facilitate an entirely new colony (Podolsky 2005). The basis for social attraction lies in manipulating seabird calling activity to promote pair establishment at a selected site through sexual advertisement (Brooke 1978). For the ATST project, this would include installation of social attraction equipment at a site determined to have suitable habitat but low breeding occupancy.

2.3.4 Identification of a suitable spatial control

To adequately determine the success of this mitigation project, a suitable spatial control will be required. This will allow comparison of mitigation burrows to burrows not receiving any management activity, and will allow for control of year to year variability in breeding success due to food availability (Warham 1990). As much as possible, the control site should be subject to the same conditions as the mitigation site, to reduce the likelihood of differences occurring between sites beyond the management activities. A suitable spatial control does not currently exist, and surveys will be required to identify this site in year 1. The two closest areas likely to yield potential controls sites, and pose the least administrative requirements to allow searching, are:

1) Kula and Kahikinui Forest Reserve west of the mitigation site; and
2) KJC LLC c/o West Maui Financial Svc, north of the mitigation site.

Greater numbers of burrows within the control site will increase the strength to statistically satisfy the demonstrable effect of the mitigation, and when net benefit is achieved. Approximately three months should be utilized to search for suitable mitigation in these areas, with 5 technicians. Timing of surveys should be based on existing NPS protocols, including diurnal searching for petrel sign by trained staff along transects, and undertaken during the period of highest detectability during incubation and early chick rearing.

2.3.5 Mitigation success monitoring

Monitoring is required to demonstrate the effect of management activities for the proposed mitigation, and when net benefit is achieved. The primary metric for take monitoring take is active / inactive burrow status and fledgling success. Existing monitoring methods, analysis procedures, and protocols exist for Haleakalā National Park, including a Standard Operating Procedure for Surveying \`Ua\`u burrows (NPS). Natividad (1994) and Natividad-Hodges (2001). Nests should be monitored at least twice per month for direct and indirect sign of activity and fledgling, based on standard definitions provided in this document.

2.3.6 Duration of mitigation and budget

A time line and budget of activities are provided in Table 2-1 and Table 2-2 based on a ten year project length. Less time may be required to achieve net benefit, as outline in the previous chapter, however this budget was put together as a guide only, and can be adjusted based on fixed and annual costs.

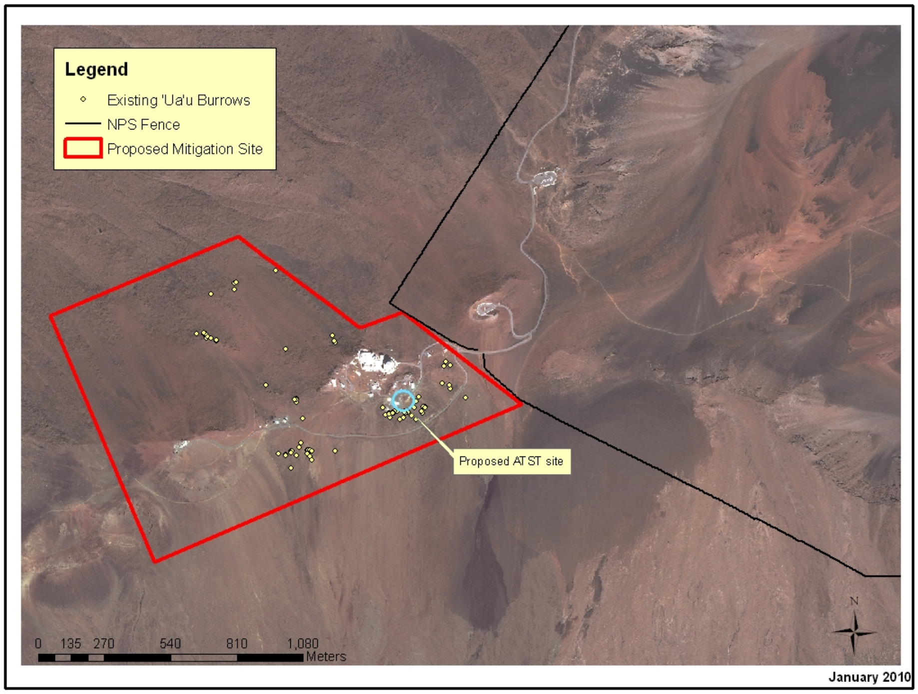

Figure 2-1: Proposed ATST Hawaiian petrel mitigation site

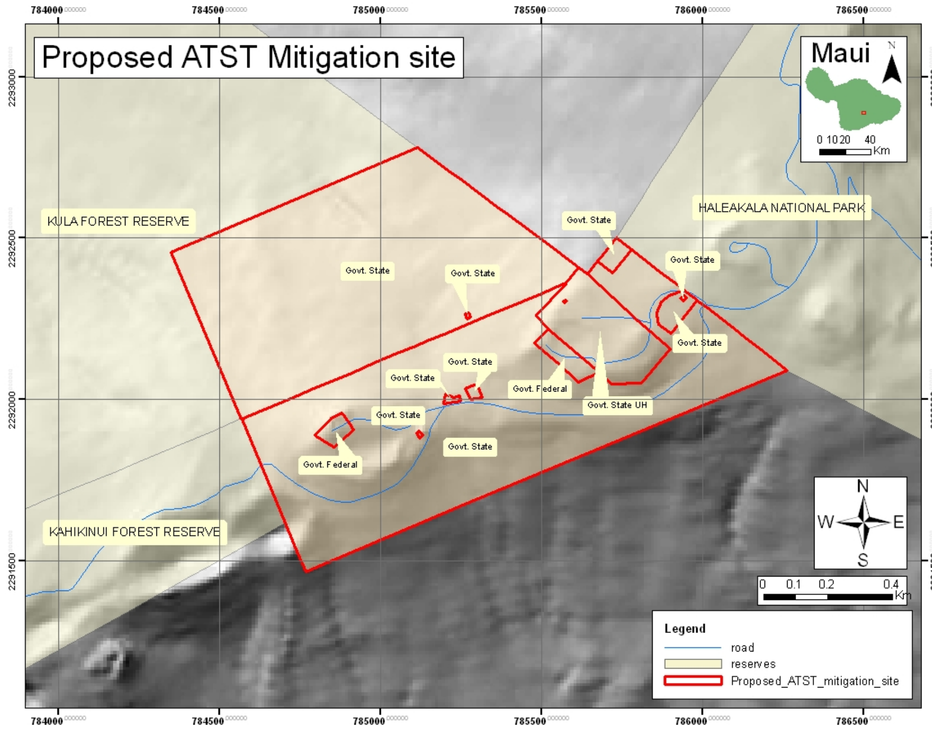

Figure 2-2: Land ownership at the proposed ATST Hawaiian petrel mitigation site

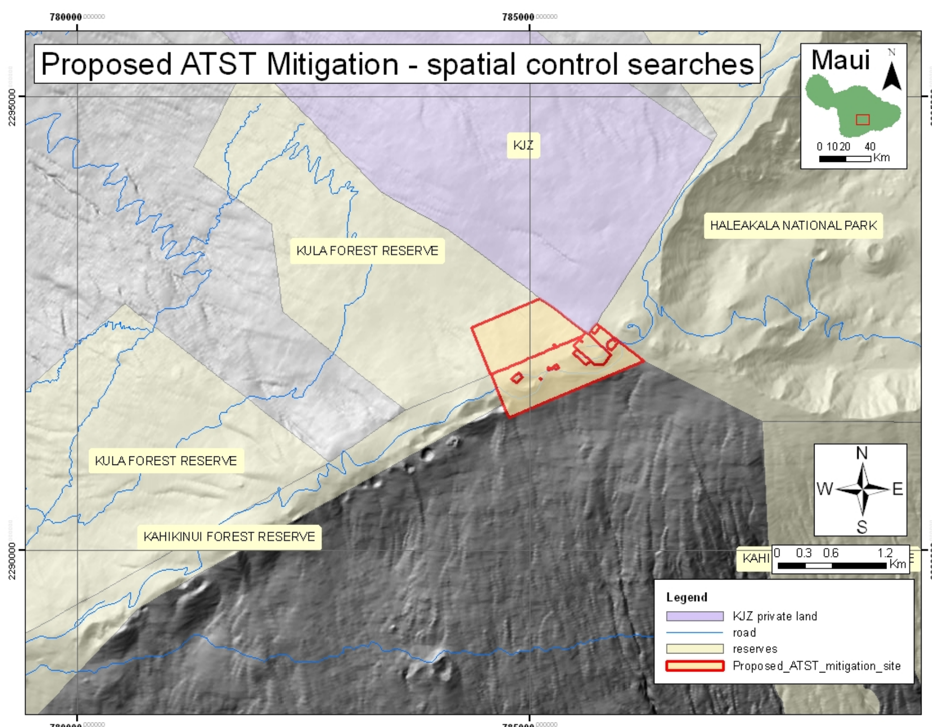

Figure 2-3: Proposed search areas for spatial control site for ATST Hawaiian petrel mitigation site

Table 2-1: Timeline for proposed mitigation activity

Objective	Activity	Year 1	2	3	4	5	6
Determine breeding numbers in mitigation site	Burrow searches	X					
Protect habitat	Construct fence	X					
	Remove ungulates	X					
	Fence inspection and maintenance	X	X	X	X	X	X
Predator control	Place cat / mongoose traps	X					
	Cat / mongoose trapping	X	X	X	X	X	X
	Rat bait station placement	X					
	Rat baiting	X	X	X	X	X	X
Encourage recruitment	Install social attraction project	X					
	Install artificial burrows	X					
Identify spatial control and potential mitigation backup	Burrow searches in Kahikinui	X					
	Burrow searches in TMK# 230050020000	X					
Monitoring	Monitor burrows within mitigation site	X	X	X	X	X	X
	Monitor burrows at control site	X	X	X	X	X	X

Table 2-2: Budget for proposed mitigation activity.

Personnel	Per Unit	Unit (yrs)	Total
1 x Coordinator (0.25 FTE)	$80,000	6	$120,000
2 x Monitoring and predator control technicians (1.0 FTE)	$65,000	6	$780,000
5 x Technicians to identify control site (1.0 FTE)	$65,000	0.4	$130,000
Travel			
Fuel	$3,000	6	$18,000
Equipment			
Fence materials and construction labor (4.3 km)	$75/m		$322,500
Polytape (8.6 km), two strands per m	$0.70/m		$3,000
Cat trapping and disposal equipment			$20,000
Rat baiting equipment and supplies	500	6	$3,000
Predator control and monitoring vehicle			$40,000
Vehicle rental to identify control site			$5,000
Field equipment			$7,500
Burrowscope			$7,500
Equipment maintenance			$2,000
TOTAL			**$1,458,500**

3 Mitigation modeling

A population modeling exercise was undertaken to identify when net benefit would be achieved from the proposed mitigation project. This required determining a baseline population, identifying losses from ATST construction, and benefits from mitigation. Models used were deterministic demographic matrix models, based on Leslie (1945)

The modeling approach used required a statistical assumption of a closed population because it was not possible to estimate immigration or emigration with the larger Haleakalā population. Impacts from immigration into the mitigation site would decrease the time to meet net benefit because more adults would supplement the breeding population. Conversely, emigration away from the mitigation site would increase the time to meet net benefit.

A second assumption used was that the population at year one was stable. Again, this is unlikely because these birds are part of the larger Haleakala population, and birds attending the mitigation site will be part of larger population dynamics. For example, with the larger increasing trend known for the population, it may be that birds attending this site are primarily younger adults in the process of recruiting to a new site.

These results should not be considered a comprehensive assessment of net benefit from this mitigation, but rather a starting point for selecting an appropriate mitigation investment.

3.1 Methods

3.1.1 Initial population and baseline

Two scenarios were run using 61 and 100 active burrows in the mitigation site. A complete census of burrows in the mitigation site has not yet been undertaken, and 61 active burrows represents the current knowledge of the site. The second scenario is a hypothetical increase in the number of active burrows, given it is highly likely that more exist in the site.

Age distribution was estimated assuming a stable population (Table 3-2), using Hood (2009), and life history parameters based on Simons (1984) and NPS (unpublished data) described in Table 3-1. This included age of first breeding at 6, maximum breeding age of 16, and juvenile survivorship of 0.8034. Adult survivorship was chosen at 0.87, assuming mild-moderate predation in the mitigation site (Table 3-1). No survivorship data exist for this site, and 87% was chosen because no protection is afforded to burrows currently in the mitigation site from predators. Initial population sizes were calculated based on initial numbers of active burrows (61 and 100), 59.89% active burrows laying eggs (NPS unpublished data, n=6 years), 89% breeding probability and 0.478 of the population are breeders (Simons 1984), equating to a total of 172 and 282 birds in the mitigation site as initial numbers.

3.1.2 Mitigation outcomes

Five modeling efforts were run under each of the following scenarios for 61 and 100 burrows:

1. Baseline: no ATST construction and no mitigation
2. MIT 0: ATST construction and no mitigation
3. MIT 1: Increased reproductive success of 6% and increased adult survivorship of 2%
4. MIT 2: Increased reproductive success of 9% and increased adult survivorship of 3%
5. MIT 3: Increased reproductive success of 12% and increased adult survivorship of 4%

Table 3-3 and Table 3-4 show the specific parameters used.

3-1 Life history parameters

Life history		*Source*
Reproductive rate (chicks fledged from eggs laid)		
Science city mitigation site	0.59	NPS unpub, n=6 yrs
HALE, no predation	0.66	Simons 1984
HALE, highest recorded	0.75	Simons 1984
Breeding probability	0.89	Simons 1985
Annual rate of active burrows w/ eggs laid in mitigation site	0.59	NPS unpub, n=6 yrs
Annual rate of active burrows w/ eggs laid, undisturbed	0.64	Simons 1984
Juvenile survival rate	0.8034	Simons 1984
%fledglings surviving to breed	0.2689	Simons 1984
Adult survival rate		
Undisturbed	0.93	Simons 1984
w/ mild predation	0.90	Simons 1985
w/ moderate predation	0.85	Simons 1986
w/ extreme predation	0.80	Simons 1984
Age of first breeding	6	Simons 1984

Table 3-2 Age distribution estimation

Age distribution 61 burrows

age class	age	% birds	# birds
juvenile	<6	0.522	89.7
adult	6-11	0.190	32.6
adult	12-17	0.123	21.1
adult	18-23	0.079	13.6
adult	24-29	0.052	8.9
adult	30-35	0.034	5.8

Age distribution 100 burrows

age class	age	% birds	# birds
juvenile	<6	0.522	147.0
adult	6-11	0.190	53.5
adult	12-17	0.123	34.6
adult	18-23	0.079	22.2
adult	24-29	0.052	14.6
adult	30-35	0.034	9.6

Table 3-3 Parameters for models, 61 burrows.

No ATST	ATST MIT 0	ATST MIT 1	ATST MIT 2	ATST MIT 3	
					Baseline Life history
0.89	0.89	0.89	0.89	0.89	Breeding probability
0.59	0.59	0.59	0.59	0.59	Reproductive rate (chicks fledged from eggs laid)
0.80	0.80	0.80	0.80	0.80	Juvenile survival rate
0.87	0.87	0.87	0.87	0.87	Adult survival rate
					Impact from ATST construction
	-0.1663	-0.1833	-0.1917	-0.2002	Reproductive rate adjustment: construction disturbance (6 years)
	-0.0137	-0.0137	-0.0137	-0.0137	Reproductive rate adjustment: indirect take from birdstrike (3 years)
	-0.0119	-0.0119	-0.0119	-0.0119	Juvenile survival rate adjustment: birdstrike (3 years)
	-0.0102	-0.0102	-0.0102	-0.0102	Adult survival rate adjustment: birdstrike (3 years)
	-0.0041	-0.0041	-0.0041	-0.0041	Adult survival rate adjustment: burrow collapse (6 years)
					Benefit from Mitigation
	0.000	0.060	0.090	0.120	Reproductive rate (chicks fledged from eggs laid)
	0.000	0.020	0.030	0.040	Adult survival rate

Table 3-4 Parameters for models, 100 burrows

No ATST	ATST MIT 0	ATST MIT 1	ATST MIT 2	ATST MIT 3	
					Baseline Life history
0.89	0.89	0.89	0.89	0.89	Breeding probability
0.59	0.59	0.59	0.59	0.59	Reproductive rate (chicks fledged from eggs laid)
0.80	0.80	0.80	0.80	0.80	Juvenile survival rate
0.87	0.87	0.87	0.87	0.87	Adult survival rate
					Impact from ATST construction
	-0.0828	-0.0912	-0.0954	-0.0996	Reproductive rate adjustment: construction disturbance (6 years)
	-0.0083	-0.0083	-0.0083	-0.0083	Reproductive rate adjustment: indirect take from birdstrike (3 years)
	-0.0072	-0.0072	-0.0072	-0.0072	Juvenile survival rate adjustment: birdstrike (3 years)
	-0.0062	-0.0062	-0.0062	-0.0062	Adult survival rate adjustment: birdstrike (3 years)
	-0.0025	-0.0025	-0.0025	-0.0025	Adult survival rate adjustment: burrow collapse (6 years)
					Benefit from Mitigation
	0.000	0.060	0.090	0.120	Reproductive rate (chicks fledged from eggs laid)
	0.000	0.020	0.030	0.040	Adult survival rate

3.1.3 Construction disturbance adjustment: reproductive success

Disturbance from construction required adjustment for the first 6 years of the population models. Of 61 and 100 active burrows, 37 and 60 were considered to have eggs laid. Note that the 25 burrows adjacent to ATST have all been previously determined to be breeders, and thus considered to have eggs laid (NPS unpublished data). See Table 3-5.

Table 3-5: Effect of construction disturbance on reproductive success

No ATST construction 61 burrows

zone	impact	#burrows					
			0.59	0.65	0.68	0.71	Reproductive rate (chicks fledged from eggs laid)
1	0%	2	1.2	1.3	1.4	1.4	
2	0%	15	8.9	9.8	10.2	10.7	
3	0%	8	4.7	5.2	5.4	5.7	
999	0%	12	6.8	7.5	7.8	8.2	
			21.6	23.7	24.8	25.9	Chick produced
			36.5	36.5	36.5	36.5	Eggs laid

ATST construction 61 burrows

zone	impact	#burrows	MIT 0	MIT 1	MIT 2	MIT 3	
			0.59	0.65	0.68	0.71	Reproductive rate (chicks fledged from eggs laid)
1	100%	2	0.0	0.0	0.0	0.0	
2	50%	15	4.4	4.9	5.1	5.3	
3	10%	8	4.2	4.7	4.9	5.1	
999	0%	12	6.8	7.5	7.8	8.2	
			15.5	17.1	17.8	18.6	Chick produced
			0.42	0.47	0.49	0.51	Adjusted reproductive rate (chicks fledged from eggs laid)
			0.166	**0.183**	**0.192**	**0.200**	**Loss in Reproductive success from ATST construction**

No ATST construction 100 burrows

zone	impact	#burrows					
			0.59	0.65	0.68	0.71	Reproductive rate (chicks fledged from eggs laid)
1	0%	2	1.2	1.3	1.4	1.4	
2	0%	15	8.9	9.8	10.2	10.7	
3	0%	8	4.7	5.2	5.4	5.7	
999	0%	35	20.6	22.7	23.7	24.8	
			35.3	38.9	40.7	42.5	Chick produced
			59.9	59.9	59.9	59.9	Eggs laid

ATST construction 100 burrows

zone	impact	#burrows	MIT 0	MIT 1	MIT 2	MIT 3	
			0.59	0.65	0.68	0.71	Reproductive rate (chicks fledged from eggs laid)
1	100%	2	0.0	0.0	0.0	0.0	
2	40%	15	5.3	5.9	6.1	6.4	
3	5%	8	4.5	4.9	5.2	5.4	
999	0%	35	20.6	22.7	23.7	24.8	
			30.4	33.5	35.0	36.6	Chick produced
			0.51	0.56	0.58	0.61	Adjusted reproductive rate (chicks fledged from eggs laid)
			0.083	**0.091**	**0.095**	**0.100**	**Loss in Reproductive success from ATST construction**

3.1.4 Birdstrike adjustment: adult and juvenile survivorship

Assuming 95% avoidance, a direct take of 2.5 plus indirect take of 1.25 birds was used (Holmes 2010), Table 3-6.

Table 3-6 Birdstrike adjustment for adult and juvenile survivorship

Birdstrike: adult and juvenile survivorship	61 burrows	100 burrows	Assumes 95% avoidance
Total direct take	5	5	Holmes 2010
breeder to non breeder rate	0.5	0.5	Simons 1984
Breeding seasons of birdstrike risk	3	3	Holmes 2010 (rounded)
Adult mortality per year	0.833	0.833	
Juvenile mortality per year	0.833	0.833	
adults in mitigation area year 1	82	135	
juveniles in mitigation area year 1	70	115	approximate only, exludes age zero birds (chicks)
Annual adult birdstrike rate	0.0102	0.0062	adult mortality / adults in mitigation area
Annual juvenile birdstrike rate	0.0119	0.0072	juv mortality / juv in mitigation area

3.1.5 Birdstrike adjustment: reproductive success

Assuming 95% avoidance, an indirect take of 1.1 chicks was used (Holmes 2010). This equated to 0.367 chicks per year given over three years of birdstrike risk (rounded). For 61 and 100 burrows, this equated to a decrease in reproductive success of 0.006 and 0.01, respectively (Table 3-7).

Table 3-7 Birdstrike adjustment for effect of indirect take on reproductive success

	61 burrows				**100 burrows**				
	No ATST construction				**No ATST construction**				
	0.59	0.66	0.69	0.72	0.59	0.66	0.69	0.72	Reproductive rate (chicks fledged from eggs laid)
	21.42	24.11	25.21	26.30	35.11	39.53	41.32	43.12	Chicks produced
	ATST construction				**ATST construction**				
	MIT 0	MIT 1	MIT 2	MIT 3	MIT 0	MIT 1	MIT 2	MIT 3	
	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	Loss of chicks (1.5 chicks / 3 years)
	20.9	23.6	24.7	25.8	34.6	39.0	40.8	42.6	Adjusted chicks produced years 1-3
	0.57	0.65	0.68	0.71	0.58	0.65	0.68	0.71	Adjusted reproductive success years 1-3
	0.014	**0.014**	**0.014**	**0.014**	**0.008**	**0.008**	**0.008**	**0.008**	**Loss in Reproductive success from ATST indirect birdstrike take**

3.1.6 Burrow collapse: adult survivorship

Adult survivorship of 2 adults from burrow collapse was used, equating to 0.3 burrows over six seasons (rounded). For 82 and 135 adults in the mitigation area this equaled a mortality rate of 0.0041 and 0.0025.

3.2 Results

Figure 3-1 shows the population growth curves for each of the 10 scenarios modeled. A decreasing population trend is evident for all scenarios but the most productive mitigation option (MIT 3).

Figure 3-2 shows the time to reach net benefit. Annual increase in adult survivorship from mitigation is greater than take during years of construction, so net benefit begins accruing in year four for MIT 1 at 61 burrows, and year one for all other mitigation scenarios. Stopping mitigation in year 2 would begin a net loss again for these 5 scenarios.

Annual fledgling take is greater than the mitigation benefit in the first few years of construction. With only 61 burrows, it takes 19, 11 and 8 years to begin accruing net benefit in fledgling production. With 100 burrows, it takes 8, 3 and 1 years.

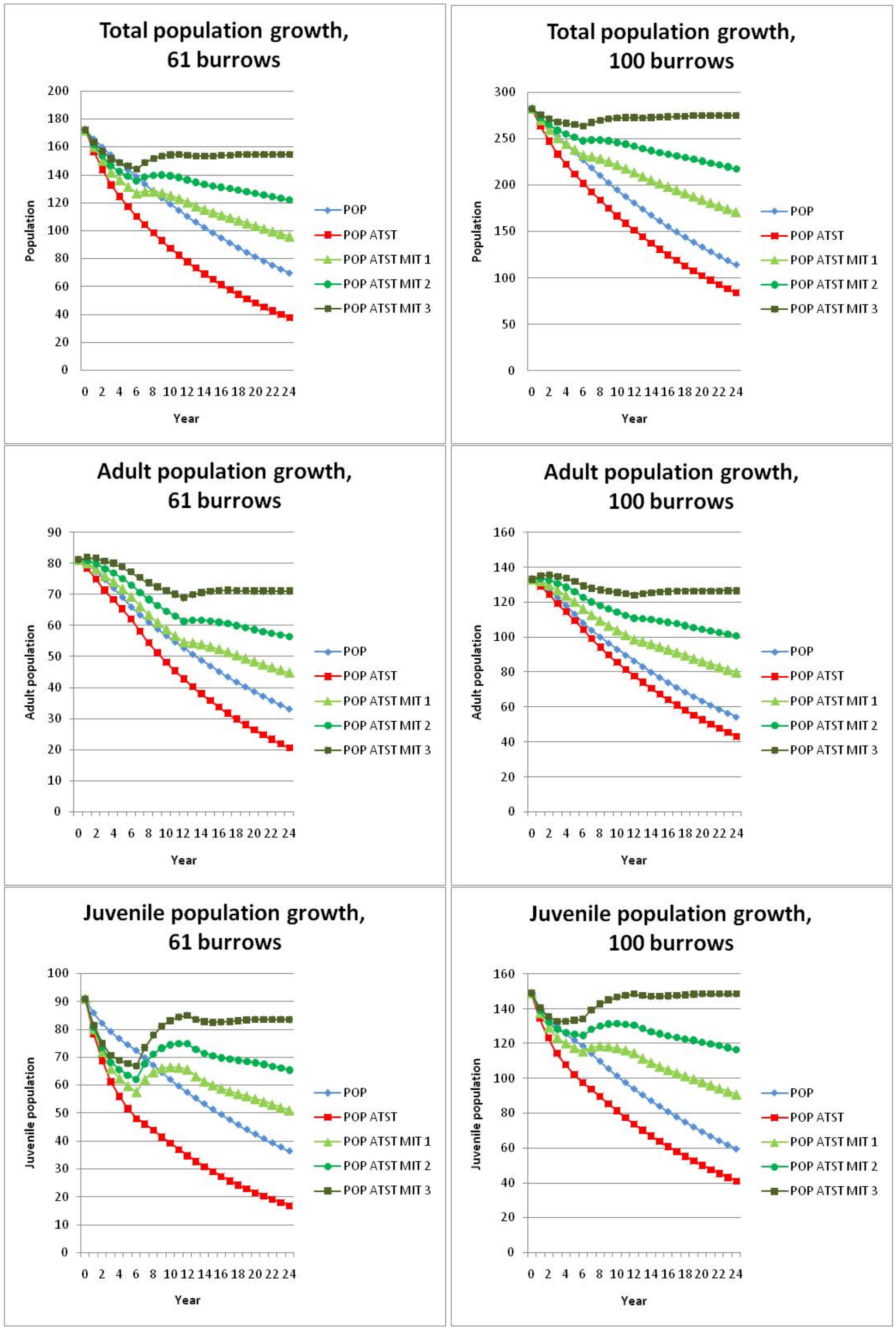

Figure 3-1 **Population growth rates with and without ATST construction, and three levels of mitigation benefit**

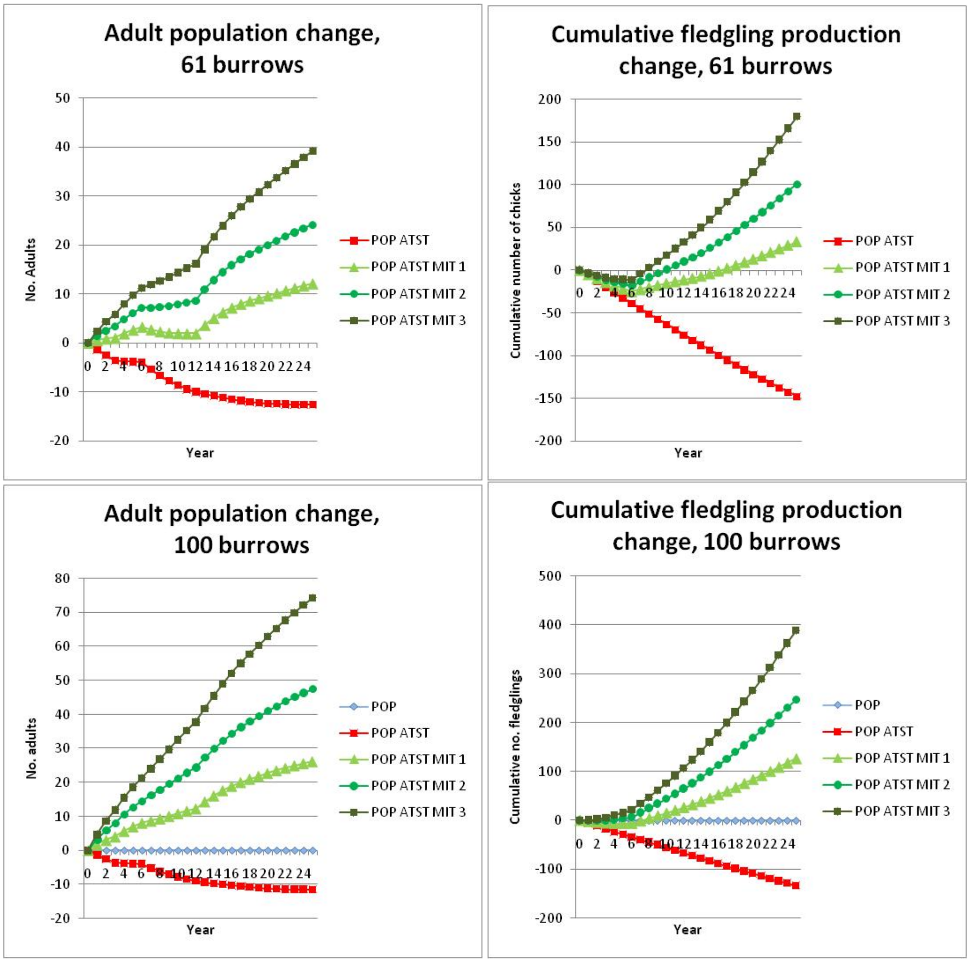

Figure 3-2 **Time to begin accruing net benefit in adult populations, and cumulative chick production. Lines crossing zero indicate net benefit.**

3.3 Discussion

Several significant parameters could not be included in this model that will limit its biological relevance. In addition to an assumption of a stable population and closed population, no allowance was made for increased reproductive success with age (Saether 1990) or annual variation in reproductive success (Warham 1990, Simons 1984). Nonetheless, it is noteworthy that sufficient parameters exist to even attempt these models, given the difficulty in obtaining specific key life history parameters of juvenile survivorship and breeding probability in long-lived seabirds.

Procellariformes, like other long-lived seabirds, are particularly sensitive to predation (Warham 1990, Simons 1994). In this exercise, even the mild-moderate predation effects modeled for adult survivorship put the population on a trajectory towards extinction. Only when reproductive success is increased by 12% per year and adult survivorship by 4% per year does the population approach a somewhat stable trajectory. The results from these models are similar to previous efforts (Simons 1984), whereby, without protection from predators, even minor effects on adult survivorship result in dramatic decreasing population trends.

The mitigation benefit outcomes used in these modeling efforts were somewhat conservative, with increases in reproductive success limited to 6, 9 and 12% and adult survivorship by 2, 3 and 4%. By comparison, the combined predator control and habitat protection efforts at Haleakala have increased reproductive success by as much 20% annually in some cases (Natividad-Hodges and Nagata 2001). Greater success can be expected for the Park when compared to the current mitigation proposal because it is well-established (>25 years), and losses from predators can be buffered with the significantly greater population size there. Regardless, the mitigation efforts proposed should allow ATST construction to meet their net benefit requirement within a practical timeframe.

These results provide a starting point for selecting an appropriate mitigation investment. Given it is likely that more burrows exist in the site, and given the conservative mitigation benefits used in the model, mitigation for the duration of the construction (6 years) may very well cover the requirements for the ATST project. A second tier of mitigation for the subsequent 4 years (years 7-10) could be applied should monitoring demonstrate that the first six years did not meet net benefit.

4 References

Brandt, C. A., Parrish, J. K. & Hodges, C. N. (1995) Predictive approaches to habitat quantification: Dark-rumped petrels on Haleakala, Maui. Auk, 112, 571-579.

Brooke, M (1978) Sexual differences in the voice and individual vocal recognition in the Manx Shearwater Puffinus puffinus. Anim. Behav. 26: 622-629.

Day, R.A., Gall, A.E., Burgess, R.M. and Parrett, J.P. 2005. Movements of Hawaiian petrels near USAF facilities near the summit of Haleakala, Maui Island, Fall 2004 and Spring 2005. Prepared for USAF AFRL c/o Boeing LTS, Kihei, Hawaii. 34. Pp.

Hood, G. M. (2009) PopTools version 3.1.1. Available on the internet. URL http://www.cse.csiro.au/poptools

Leslie, P. H. 1945 On the Use of Matrices in Certain Population Mathematics. Biometrika 33:83–212

Natividad Hodges, C.. 1994. Effects of Introduced Predators on the Survival and Breeding Success of the Endangered Hawaiian Dark-rumped Petrel. MS Thesis, University of Washington, Seattle, WA.

Natividad-Hodges, C. N. & Nagata, R. J. (2001) Effects of predator control on the survival and breeding success of the endangered Hawaiian dark-rumped petrel. Studies in Avian Biology, 22, 308-318.

National Science Foudation (2009) Final Environmental Impact Statement for Advanced Technology Solar Telescope.

Podolsky, R.H. 2005. The use of decoys and sound systems to attract marine birds to restored habitat. Spoken paper. 2nd Regional workshop on dredging, beach nourishment, and bird conservation. Islip, Long Island, Oct 6-7.

Sæther, B.E. 1990. Age-specific variation in reproductive performance of birds. Current Ornithology 7:251–283.

Simons, T. R. (1984) A POPULATION-MODEL OF THE ENDANGERED HAWAIIAN DARK-RUMPED PETREL. Journal of Wildlife Management, 48, 1065-1076.

Simons, T. R. (1985) Biology and behavior of the endangered Hawaiian Dark-rumped Petrel. Condor, 87, 229-245.

Warham, J. 1990. The petrels: their ecology and breeding systems. Academic Press. New York, NY. 440 pp.