



# FMP

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### New Techniques for 'Seeing' Hawaiian Petroglyphs: Photogrammetry at Mākua Military Reservation

By Jaime Raduenzel and Michael Desilets

**I**N ALMOST EVERY part of the world where humans have lived, they pecked or inscribed images—petroglyphs—into natural rock surfaces. These images last many hundreds of years and reflect the symbolic motifs and configurations important to a culture.

In comparison to other Polynesians, Hawaiians were especially prolific in the production of petroglyphs, or ki'i pohaku. Likely due to the abundance of exposed basalt on the relatively young islands, pre-Contact Hawaiians created extensive, heavily covered panels on the young flows of Hawai'i Island, and on suitable outcrops on all of the other islands, as well. Although widespread, petroglyphs are most often found on the dry, leeward sides and in open country near the shore.

In 1970, petroglyph experts in Hawai'i had concluded, perhaps prematurely, that "new sites are occasionally reported, but new discoveries are usually small, isolated occurrences and it is doubtful whether any major finds will be made that will add significantly to our present knowledge"<sup>1</sup>. At that time, only 10 cultural sites on the island of O'ahu were known to have petroglyphs. Beginning in 1999, Army archaeologists began discovering numerous petroglyphs in the ahupua'a (tra-

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ditional land divisions) of Mākua and Kahānahaiki in Mākua Military Reservation (MMR) on O'ahu's leeward side. The Army has currently recorded more than 22 sites that include petroglyphs in these two valleys—certainly enough to be considered a "major find."

MMR's first petroglyph discovery was made during an archaeological inventory survey of portions of Mākua. Ironically, this major panel was hidden in



Petroglyphs on this rock slab at Mākua are getting a "closer look" thanks to the use of close-range photogrammetry. (Photo by OACRP)

<sup>1</sup> Cox, J.H. and E. Stasack (1970). Hawaiian Petroglyphs. Bernice P. Bishop Museum Special Publication 60. Honolulu, HI.

plain sight at the makai end (ocean side) of the valley, in an area that had been heavily used for many decades. Now known as Feature 12 of Hawai'i State Site 50-80-03-5926 (Site -5962), the panel consists of a large, uplifted coral reef and sandstone slab that dominates an otherwise low area in a dry streambed (Figure 1). Dense kiawe (*Prosopis pallida*) had long concealed the large slab, which is nearly covered in petroglyphs. This particular sandstone slab is likely



Figure 1. Nicole Vernon, an archeologist with Garcia and Associates, photographs an upright slab covered with petroglyphs. (Photo by OACRP)

associated with nearby Kumuaku'opio Heiau, once thought to have been destroyed.

The Site -5926 images include primarily human figures and 'ilio, or dogs (Figure 2), which turn out to be quite common on Mākua petroglyphs. Recent investigators have attempted to understand the symbolic and cultural meanings of these figures through an analysis of Hawaiian traditional histories. Speaking of Mākua petroglyphs generally, they state:

"Mākua's petroglyphs often depict human-like figures and four-legged animals probably representing 'ilio, or dogs. The 'ilio is frequently represented in Hawaiian mythology and chants and was often kept as a pet and for food for chiefly feasts and ceremony. The 'ilio appears in creation myths, and in chants and legends as faithful guardians of humans and gods, and as a relative and friend of mo'ō or giant lizards. The 'ilio seen in Mākua's petroglyphs may suggest that it was an 'aumakua or guardian spirit for the residents of Mākua and Kahānahaiki."<sup>2</sup>

Following the dramatic discovery of Site -5926,



Figure 2. This 3D rendering of a portion of the Feature 12 petroglyph slab, contains images of 'ilio, or dogs, and human figures. (Photo by OACRP)

additional surveys in 2003 and 2004 identified 59 new archaeological sites, the majority of which are interpreted as having traditional Hawaiian affiliation. Eight of these newly identified sites contained petroglyphs, including both isolated images and multi-image panels. Once it was clear that these types of features were common in Mākua, other petroglyph discoveries followed. Alton Exzabe, an archaeologist with the O'ahu Army Cultural Resources Program, described the survey and the effort to locate petroglyphs. "Throughout the survey, we would investigate boulders that had smooth, almost canvas-like surfaces for petroglyphs. More often than not, sites that had these [types of] boulders had petroglyphs on them... at times when recording a petroglyph, the lighting would change and on the same boulder another petroglyph would reveal itself."

Thanks to the archaeologists' determination and keen eyesight, the Army eventually recorded numerous petroglyphs at 22 cultural sites at MMR.

Despite this great progress, however, clearly "seeing" individual images on boulders and outcrops remains challenging. This challenge has been met, in part, by applying recent advances in digital photography and photogrammetry—the practice of deriving geometric properties from data contained in photographic images.

### **Close-Range Photogrammetry**

Close-range photogrammetry (CRP) is the science of capturing three-dimensional information for near objects using suites of stereoscopically overlapping

<sup>2</sup>Robins, J., A. González and J. Peterson (2005). Archaeological Survey and Protection of Cultural Resources During UXO Clearance Activities, Mākua Military Reservation, Kahānahaiki and Mākua Ahupua'a, O'ahu Island, Hawai'i (Final). Kailua, HI.



Figure 3. Photogrammetry image of Site -5926, Feature 12 (Image by OACRP)

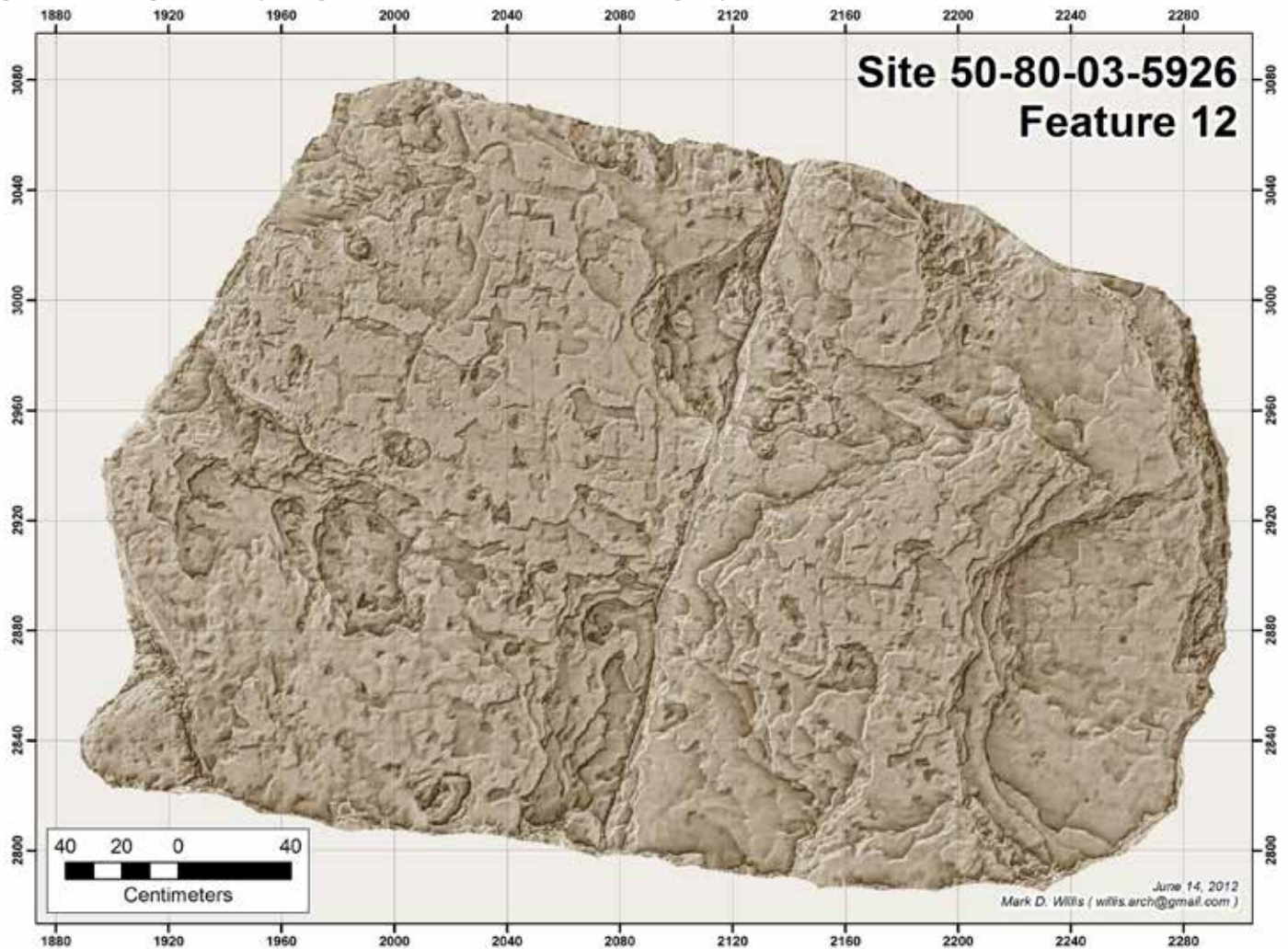
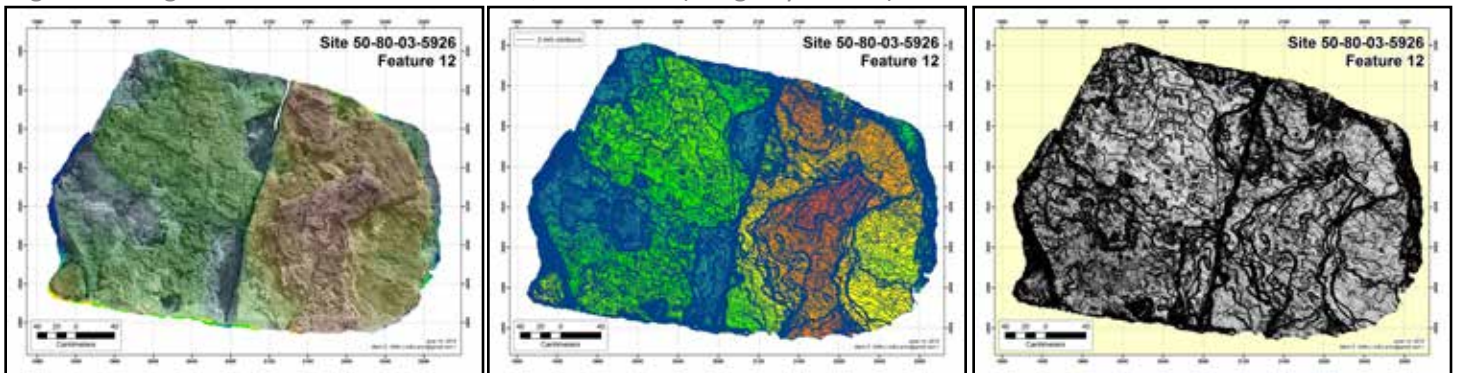


Figure 4. Image enhancements of Site -5926, Feature 12 (Image by OACRP)



digital photographs. The processing methods are closely akin to those used for more traditional aerial photogrammetry, which has been in use since the 1930s to create topographic and thematic maps of large landscapes. The newer CRP category generally refers to object distances of less than 300 meters and can be as close as camera focal distances will permit. Resolutions of 0.25 millimeters and spatial accuracies of 0.025 millimeters are now possible with today's high megapixel cameras.

Recent advances in digital camera resolution and open source processing software have greatly increased the ease and lowered the cost of photogrammetric processing. Consequently, photogrammetry has moved from the realm of highly specialized professionals into the public and business sectors. A wide range of professionals can now employ the technique. Archaeologists have found CRP to be a particularly important and useful application in the recordation and modeling of petroglyphs.

## Site 50-80-03-5926

In order to try to better define the number, types and patterns of individual petroglyphs at Site -5926, Feature 12, archaeologists from Garcia and Associates, under contract to U.S. Army Garrison Hawai'i, conducted a CRP analysis of the feature. The limestone slab was photographed with a series of 60% overlapping digital photos at 16 megapixels. Due to the height of the slab, three traverses across the face were required. A fine-increment ruler was placed on the slab, from which the final image could be scaled. Once the data set was collected, it was processed using open source software to create a high resolution, three-dimensional model of the face of the slab (Figures 2 and 3). A variety of color enhancements were employed to provide different perspectives and simulate different lighting conditions (Figure 4). The slab was then examined for previously unseen petroglyphs by Army archaeologists. Analysis is not yet complete, but initial findings indicate the presence of several, very shallow petroglyphs that were not previously visible. Of equal importance, CRP has provided archaeologists a high resolution image of the petroglyph panel that can be used to track changes and degradation over time with great precision.

Petroglyphs are long-lasting records of Hawaiian culture that may, with careful analysis, provide insight into the tradition of stone carvings and its meaning. While archaeologists may never truly understand the precise meaning of the petroglyphs at Mākua, they have undeniable cultural significance. Natural weathering and degradation of the soft, friable limestone surface of Site -5926, Feature 12 will doubtless continue, but accurate documentation can help to preserve the cultural and scientific information contained in the petroglyphs. The use of CRP is an exciting new technique for improved documentation and has contributed greatly to the conservation and analysis of these amazing creations. •

Jaime Raduenzel is an Outreach Specialist with the O'ahu Army Cultural Resources Program, and Michael Desilets is the Principal Investigator at Garcia and Associates.

## 2013 Lineup FOR MANUWAI

### MA'O HAU HELE

*Hibiscus brackenridgei*  
subsp. *mokuleianus*



### HĀHĀ

*Cyanea superba* subsp.  
*superba*



### ‘ŌHĀ WAI

*Delissea waianaensis*



### MANONO

*Kadua degeneri* var.  
*degeneri*



### MĒHAMEHAME

*Flueggea neowawraea*



### MA'ALOA

*Neraudia angulata* var.  
*dentata*



## A New Home in Manuwai

By Celeste Ventresca

Some of Hawai'i's rarest flora are enjoying their final preparations under the nurturing care of horticultural specialists at the O'ahu Army Natural Resources Program's (OANRP) rare plant nurseries. This year, six endangered plant species, including our state flower, the ma'o hau hele (*Hibiscus brackenridgei* subsp. *mokuleianus*) will be outplanted in a new location for the first time: Manuwai. Situated in the northern Wai'anae Mountains and part of Ka'ala Natural Area Reserve and Mokulē'ia State Forest Reserve, Manuwai is one of just a handful of places on the island where patches of native dry-mesic forest remain. The OANRP, charged with managing over 60 endangered plant and animal species on O'ahu, is pleased to finally begin planting in this location. Various preparations spanning a 13-year period have been made, and this remote forest area is now ready to host the endangered plants that the OANRP has cultivated.

The diverse floral community at Manuwai was first noted in the early 1920s by renowned botanist and Waialua resident Dr. Otto Degener (1899-1988), who developed an extensive collection of Hawaiian plant specimens throughout the 20th century. Later in the 1980s Manuwai





LEFT Hanging down from Pu'u Kamaohanui, Manuwai's steep cliffs are home to endangered plants like manono (*Kadua degeneri* var. *degeneri*) and nehe (*Melanthera tenuifolia*). BELOW Justin Luafalemana (left) and Dominic "Munsta" Souza (right), Natural Resource Fence Workers with the OANRP, use safety ropes to construct fence in steep areas in Manuwai. These fences protect native forests from pig and goat damage. (Photos by OANRP staff)

would again come under the radar of the scientific community, when botanical surveys revealed patches of rare "diverse mesic forest" habitat. One of the reasons Hawai'i is recognized as the "endangered species capital of the world" is due its severe loss of dry and mesic forest habitat. The classification "diverse mesic forest" denotes a forest that is neither wet nor dry and is "so evenly composed in its makeup that not one tree species dominates the community."<sup>1</sup> This type of habitat, though now extremely scarce, contains some of the richest representation of Hawai'i's rare plants.

The OANRP found this to be the case in 1999 when staff began to visit historical rare plant populations in Manuwai and survey for new populations. Staff steadily collected fruit and cuttings from endangered species in the area so that the plants could be grown under the care of program horticulturalists and eventually outplanted once threats were removed from the wild.

While Natural Resources Field Technicians will enjoy helicopter support to help transfer plants for this year's outplanting effort, getting to Manuwai on the ground is no easy feat, requiring access through a four-wheel drive dirt road and a long, steep, off-



trail hike into the forest.

Working in Manuwai isn't any easier than getting there. Much of the gulch boasts extremely steep terrain, making these areas inaccessible without the use of safety ropes. Rare plants like the endangered manono (*Kadua degeneri* var. *degeneri*) and nehe (*Melanthera tenuifolia*) have managed to "hang on" in the steepest sections, where natural topography has helped protect them from the impact of feral pigs and goats.

Today, however, rare and endangered species located in the more accessible areas of Manuwai are

<sup>1</sup> Sailer, Dan (2006). I Ho'ōla I Ka Nahele: To Heal a Forest, A Mesic Forest Restoration Guide for Hawai'i. Retrieved from [http://manoa.hawaii.edu/hpicesu/DPW/SAILER\\_2006/v01-08.pdf](http://manoa.hawaii.edu/hpicesu/DPW/SAILER_2006/v01-08.pdf)

benefitting from a fence that OANRP has built to protect native habitat from the damaging effects of feral pigs and goats. While snaring and hunting programs for goats had been in place for several years at Manuwai, the fence crew also began hunting pigs in 2011, when the fence was completed. The last pigs seen in the fenced area were removed in January 2013, making life a lot easier for the native Hawaiian plant community at Manuwai.

While the way has been paved for this year's outplantings, the battle to protect these species is far from over, as fire poses a constant threat to natural resources on O'ahu. A 2007 fire that started on fallow land near Kaukonahua Road burned a total of 5,655 acres, blazing its way high into the mountains over the course of seven days. The fire destroyed some area now protected by the Manuwai fence as well as many neighboring gulches, which were home to hundreds of endangered ma'o hau hele. The threat of pig and goat ingress is an additional challenge facing natural resources managers. While the OANRP field crews check fence integrity on a quarterly basis, just one downed tree from a storm or high wind event can create an opportunity for the prolific pig and goat communities that surround the fenced unit to enter and destroy the protected native habitat area. Controlling weeds in steep areas of Manuwai is also an ongoing challenge. OANRP staff currently focus control efforts in intact forest patches and around rare

taxa and are looking into ways to control canopy weeds across large areas of the management unit.

Nonetheless, given the careful management in this fenced unit, the time has never been better for endangered plants to spread their roots in the forest at Manuwai. This year the OANRP will be putting more than 3,100 endangered plants into the ground on Army, State, City and County and private land at Manuwai and 44 other sites across O'ahu. These efforts for endangered species will not only benefit the plants and their offspring, but all of the communities of life that surround them, including supporting the growing human population in Hawai'i. Like these plants, we also depend on forests for our existence, as they constitute our primary source for drinking water, capturing rainwater and recharging groundwater aquifers. While most of us will not be rappelling down the cliffs of Manuwai to visit endangered plants, we can rest assured with the knowledge that their keiki (children), along with our own, are better off as we mālama (care for) Manuwai. •

Celeste Ventresca is an Outreach Specialist with the O'ahu Army Natural Resources Program.

Camping in remote Manuwai allows OANRP staff to spend more time working within the management unit and less time getting there. (Photo by OANRP staff)





# 2012 Presidential Service Awardees

## Elaine Mahoney & David Danzeiser

O'AHU ARMY NATURAL RESOURCES PROGRAM VOLUNTEERS



This past year, O'ahu Army Natural Resources Program volunteers Elaine Mahoney and David Danzeiser earned the Presidential Volunteer Service Award at the Silver Level. The President's Volunteer Service Award, presented by the President's Council on Service and Civic Participation, honors the valuable contributions that volunteers are making in communities across the United States. Mahoney volunteers each week in the propagation laboratory, assisting staff with rare seed processing, watering and maintenance, in addition to spending one day per week helping horticultural staff at OANRP rare plant nurseries. Danzeiser volunteers his time maintaining the program's interpretive garden at Schofield Barracks. Both Mahoney and Danzeiser also help the program out in the field on numerous volunteer trips in the forests of the Wai'anae and Ko'olau mountains.

### HOW DO THEY DO IT?

#### ELAINE

##### Seed lab

2 hours per week

##### Rare Plant Nursery

6 hours per week

##### Volunteer Trips

9 per year

**457**  
TOTAL HOURS

#### DAVID

##### Interpretive Garden

4 hours per week

##### Volunteer Trips

23 per year

**268**  
TOTAL HOURS



## 'Tis the Season...

# W I N T E R

For the fragile Hawaiian mint, *Phyllostegia hirsuta*, to put forth beautiful floral spikes. The creamy white, fragrant flowers are likely pollinated by insects, although specific native pollinators are unknown.

Endemic to the island of O'ahu, this forest-dweller now exists in very small numbers and was added to the endangered species list in 1996. Small populations of *P. hirsuta* exist in wet forests in the northern Ko'olau mountains and in mid-elevation gulches along the Wai'anae range.

O'ahu Army Natural Resources Program staff protect remaining wild *P. hirsuta* by controlling ungulates and invasive weeds in its habitat. Cuttings have been collected from these small wild populations of *P. hirsuta* over the past ten years and plants are propagated in OANRP nurseries.

This outplanting season, several *P. hirsuta* will be leaving the OANRP nurseries and joining the wet forest community of Ka'ala. Prime planting sites were selected and follow-up visits scheduled to ensure these fragile mints thrive in their new top-of-the-island home.



The endangered *Phyllostegia hirsuta* is found only in the Wai'anae and Ko'olau mountains of O'ahu. (Photo by OANRP staff)

## VOLUNTEER *Opportunities*

The O'ahu Army Natural Resources Program offers monthly volunteer service trips to help protect populations of rare and endangered plants and animals on Army land. For information on how to get involved email [outreach@oanrp.com](mailto:outreach@oanrp.com) or call 656-7741.

### SIGN-UP INFORMATION

Already filled out your volunteer paperwork? Visit [www.oanrp.ivolunteer.com](http://www.oanrp.ivolunteer.com) to sign up for volunteer trips. Please note that volunteer spots are offered on a first come, first served basis.



# EMP *Bulletin*

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[http://www.garrison.hawaii.army.mil/sustainability/  
NaturalResources.aspx](http://www.garrison.hawaii.army.mil/sustainability/NaturalResources.aspx)

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