Proceedings Society of Hawaiian Archaeology Conference, Maui, HI

2001

ENVIRONMENTAL FACTORS INHIBITING GPS ON TUTUILA ISLAND, AMERICAN SAMOA: STRATEGIES FOR GIS DATA INTEGRATION WHERE GPS CANNOT GO

Taylor Houston, Pacific Cooperative Studies Unit - RCUH
Epi Suafo'a, Archaeologist, National Park of American Samoa

ABSTRACT

Archaeological research at the National Park of American Samoa has identified an array of feature types such as star mounds, adze quarries, habitation and grave sites on high mountain ridges. Most of these features are located in deep valleys or along narrow and rough ridgelines, beneath a dense paleo-tropical rainforest. Field archaeologists have sought to use new technology, such as global positioning system (GPS) hardware, and geographic information system (GIS) software to document Samoan archaeological features. The Samoan landscape and environment, however, present special problems for GPS and the integration of field data into a GIS. The high ridges of Samoa, a thick forest canopy, and high humidity are factors that conspire against GPS field use. This paper will discuss how new mapping strategies incorporate new technologies with "older" field methods to overcome these environmental conditions, aiding in the modern documentation of the archaeological record represented within the National Park of American Samoa.

INTRODUCTION

American Samoa is located 65 miles east of Upolu, Western Samoa and more than 200 miles north of the Tonga archipelago (Figure 1). Stipulated by Territorial Law, non-American Samoans cannot purchase in American Samoa. As an agent for the National Park Service, the United States government leases 6,820 acres on Tutuila Island from the villages of Afono, Vatia, Pago, and Fagasa (Figure 2). An additional 2,550 acres are leased from the villages of Fiti'uta, Faleasao, and Ofu on the Manu'a Islands. Cultural preservation and conservation in the National Park of American Samoa is mandated under Public Law 100-571 enacted in 1988.

The islands that compose American and Western Samoa were first settled by Polynesians two to three thousand years ago. Over the past 50 years, several archaeological investigations have been conducted in the Samoan archipelago. Jack Golson initiated the first systematic survey in Samoa on Savai'i Island, Western Samoa, describing classifications of field monuments. Golson suggests that early settlements occurred inland, followed by later settlement of the coastal zone (Golson 1969). Roger Green and Janet Davidson of the Polynesian Archaeology Program at the University of Aukland, led a number of excavations on Savai'i and Upolu, Western Samoa. The artifactual data collected by Green and Davidson contributed to the overall goal of the New Zealand program, a settlement pattern approach to the Samoan archaeological record (Green and Davidson, 1965). These projects were the ground-work for investigations in American Samoa.

The first survey conducted for the National Park of American Samoa was made by Janet Frost, with excavations at seven sites on the eastern portion of Tutuila Island. The NPS and the US Army Corps of Engineers contracted out additional small scale surveys throughout the 1970's. The American Samoa Historic Preservation Commission in 1980 conducted several surveys on Tutuila and Manu'a Islands. Interdisciplinary research since the early 1990's has revealed landscape transformation from climatic change, as well as from human induced causes. The fragility of island environments in the face of human interactions have been emphasized by Hunt and Kirch (1987, 1993, and 1997) on Ofu Island. Numerous other studies have demonstrated the significance of direct and indirect human induced landscape transition of island environments. Results of these surveys suggest a Polynesian presence in Samoa dating back to at least two to three thousand years B.P.

The Cultural Resources Management program, led by archaeologist Epi Suafo'a, at the National Park of American Samoa continues with investigations within the Park. As part of Public Law 100-571, CRM staff were charged with surveying along a proposed trail along Sauma, Vatia, and Mauga Loa Ridges. The original tasks of the CRM staff from Hawai'i was to help with Section 106 compliance for the trail and collect GPS data on the features.

GIS and Archaeology

Computerized mapping of archaeological sites has long been utilized for small-scale large area site mapping. Archaeologists with some computer savvy adopted CADD and AutoCADD software typically for maps at 1:1000 or smaller scales. Although the excitement of producing computer maps was novel, the limitations were apparent—poor graphic capabilities produced "sterile" maps, and customizing the map was made difficult by the rigid confines of the software. This was software tailored more for engineering and architectural design, and cartographers and archaeologists had to wait for software more appropriate for stylistic mapping.

Graphic design software was used to create maps, but accurate placement of positional data was by approximation, due to the software not allowing for user input coordinates. The archaeologist using computer cartography to accurately display field data was trapped between engineering software and the artistic world of graphic design.

In 1969, Environmental Systems Research Institute (ESRI) was awarded a contract to use early GIS methods in highway corridor location. Since then, ESRI software has been adopted by most governmental agencies for their GIS needs. For those agencies involved in the management of cultural resources, ArcView software is typically used. Since the mid-1990's, GIS software have allowed the user to have greater control of the layout through increased graphics capability, and linking of databases with positional and feature information to a map. Aerial photographs, satellite imagery, historical maps, or USGS quadrangles can be overlayed with data collected in the field. Current technology allows for photo-documentation, feature information (feature forms), field notes, and feature maps to all be linked together in a geo-spatial database. This is the current aim of most cultural resource management programs.

GPS technology was developed primarily for military purposes, and the Department of Defense deliberately distorted the signals to decrease accuracy. This practice, known as selective availability stopped on May 1, 2000, inabling hand held GPS units an accuracy within 10 meters. Differential correction systems provided a higher order of accuracy, under 0.5 meters. These systems combine the field receiver data (rover data) with signals received at a fixed receiver base station (base station data). This process filters out errors and increases the accuracy and precision of the position.

GPS receivers afforded to a high level of accuracy can enhance survey methodology. Rather than gathering a single point to represent an archaeological feature, archaeologists can actually "trace" around a feature. The antenna acts as a pen, and the processed data is an outline the feature. This can allow for rapid individual feature mapping. Taken a step further, multiple feature maps can then be georeferenced into a smaller scale overview map (see Moniz-Nakamura, et al, 2001).

GPS and GIS in Pacific Cultural Resource Management Programs

Kaloko-Honokohau National Park was the first national park in the Pacific to use differential GPS for cultural resource management purposes. Followed quickly by Hawai`i Volcanoes National Park, and Haleakala National Park, cultural resources were inventoried using GPS and integrated into a GIS. GIS programs were initiated by Melia Lane-Kamahele and Tom Fake at the Pacific Regional Office in Honolulu and Sandy Margriter at the Pacific Regional Node Office on Hawai`i Island. The base map information, support, and training greatly benefited Pacific Parks.

National Park archaeologists directly benefited from these efforts. Old base maps were georeferenced, which allowed for GPS data to be over-layed. Archaeologists could plot features and see their relationship to roads, trails, infrastructure, and natural features such as lava flows, surface hydrology, and contours.

Field Use of GPS in National Park of American Samoa

In August of 2000, HVNP-CRM staff Dr. Jadelyn Moniz-Nakamura and Taylor Houston joined NPSA archeologist Epi Suafo'a for a two week project along Sauma and Mauga Loa Ridges on Tutuila Island, American Samoa. On the computer end of the project, priorities were given to configuring NPAS's existing GPS hardware and GIS software, field use of the GPS unit, the incorporation of existing tape and compass data into a GIS, and reconfiguration of the base station receiver on Tutuila Island.

Suafo'a, Moniz-Nakamura and Houston quickly were faced with daunting environmental factors inhibiting GPS field use in Samoa. Big Island CRM staff had used GPS primarily in environments favorable to the technology. These areas included the open dry areas of Kaloko and Honokohau *ahupua'a*, the *ahupua'a* of Kapapala in the Ka'u Desert, Kealakomo *ahupua'a* at Kealakomowaena, and the 13,600-foot summit of Mauna Loa. These areas hold in common a relatively dry troposphere, little or zero canopy, and no tall buildings or ridges.

On Tutuila Island, however, these factors are ubiquitous. Humidity often hovers at or below 90%, and a high moisture content will diffuse signal strength from the satellite and cause reflection of the signal from surrounding areas to the GPS antenna. A thick tree canopy will block the signals entirely. Mauga Loa Ridge raises the horizon at some points by 30 – 60 degrees. Any satellites below the ridge will be blocked, which compound another error-- satellite geometry. If satellites are grouped too close together in space, the position calculation algorithm will be less accurate. The algorithm is similar to triangulation, and if large objects block a few satellite signals, the receiver can only pick up signals from a tighter window.

Due to the humidity, thick canopy, high ridges, and satellite geometry, GPS operation at individual features proved impossible. Solutions were sought to compensate for the environmental factors. Tree climbing with the antenna was met with marginal success. Purchasing additional coaxial cable from a local marine navigation supply company increased the antenna height to approximately 15 meters, and the antenna was hoisted with pole extensions through the tree canopy. This allowed for more signals to reach the antenna, and proved more practical than climbing trees with a four thousand dollar GPS, not to mention the risk of a broken neck.

Methodology for Converting Polar Coordinates to Universal Transverse Mercator

Tape, compass, and inclinometer measurements were collected by Suafo'a and her staff along the proposed trail up Sauma Ridge and Mauga Loa. Feature maps were drawn of archaeological features on or near the route. This traditional method of mapping trails produced a large body of data, which were entered into a database. Within this database, algorithims were programmed in to convert the tape, compass, and inclinometer data (polar coordinates) into northing and easting UTM coordinates (cartesian).

Basically, a polar coordinate is represented by two values, a distance and a bearing (d, O). Cartesian coordinates are the (x,y) values that define a point (Figure 3).

A simple trigonometric function will convert a point defined by a distance and bearing into a cartesian coordinate. In classical geometry, which measures an angle from the x-axis, the sin function of an angle is the y value (opposite side to the angle) divided by the length of the hypotenuse of a right triangle. Likewise, the cosine function is the x value (adjacent non-hypotenuse side) over the hypotenuse. In cartography, however, a bearing is not measured from the x-axis, but from the North-South or y-axis.

Therefore, a point measured from the origin will have a distance *(D)* and bearing (□) from the north axis, which can be represented as a right triangle where the distance is the hypotenuse, and the angle is the bearing from north. To convert these values into the y value for cartesian coordinates, this formula is used.

$$D\cos\theta$$

And for the x value

$$D\sin\theta$$

UTM coordinates are essentially x and y coordinates, where y is the northing value and x is the easting value. If the polar coordinates are measured from a GPS location in UTM coordinates, these equations will reveal the new UTM point.

$E1 + D\sin\theta$, for the easting
$N1 + D\cos\theta$, for the northing

Successive points can be treated as vectors, and added together to produce a set of UTM coordinates (Figure 4).

These algorithms were incorporated into a Microsoft Excel Spreadsheet, so that the large set of tape and compass data that Suafoa collected in the field could be easily converted into UTM coordinates. Coordinates were then fed into the ArcView GIS software. Once the tape and compass field data were converted to UTM coordinates, the positions could be fully integrated with base map or other spatial data within a GIS. Using these algorithms, and if inclinometer readings are available, then a three-dimensional can be generated.

NPAS staff have identified an array of feature types such as star mounds, adze quarries, habitation and grave sites on the high mountain ridges. Based on the distance and bearing data the NPAS team collected, the overall trail could be mapped (Figure 5). The HAVO team then drafted and georeferenced the individual feature maps (Figures 6), and placed them in the proper scale and position along the trail (Figure 7).

CONCLUSION

UTM coordinates from GPS along the Sauma, Vatia, and Maunga Lao Ridges were not successfully taken in the field during the August 2000 survey. After numerous failed attempts to facilitate satellite signals to reach the GPS receiver, the survey crew relied upon the tape and compass data supplied by Suafo'a and her staff. A few signals were collected, however. Current GIS software cannot directly accept polar coordinate data. It was possible to convert a large body of positional data into UTM coordinates. Therefore, despite environmental factors that inhibit GPS on Tutuila Island, GIS software can still be relied upon for the modern documentation of cultural resources.

There are several ways to cope with environmental factors common to Tutuila Island and similar environments. Many GPS packages provide a utility to check the satellite availability and satellite geometry for specific times of the day. Trimble, the preferred GPS of the NPS, offers a "Quick-Plan" utility. This allows the user to maximize GPS time in the field when GPS conditions are good or to avoid times of poor satellite conditions. Manipulation of the receivers configuration can allow for more signals to be logged. By changing PDOP and SNR default masks, the receiver becomes less particular about the quality of the satellite signal. A decrease in accuracy, however, should be expected. Resource managers should establish survey control points, or use existing survey markers, throughout a land unit. GPS positions can be tested against these known points for accuracy. Humidity adversely effects positional accuracy, so dry field days or even seasons should be used for field GPS survey. Multipath errors can be minimized by standing away from large objects, such as tree trunks or cliff faces (Graves, 2001, personal correspondence).

In a tropical environment with a highly variable topography, conditions for GPS use are not ideal. Despite the inhibiting factors that Tutuila Island and other similar environments present, careful project planning coupled with a knowledge of GPS technology limitations can produce accurate field data for a GIS. This can only be accomplished through a creative approach to field mapping, and avoiding an over-reliance upon GPS technology.

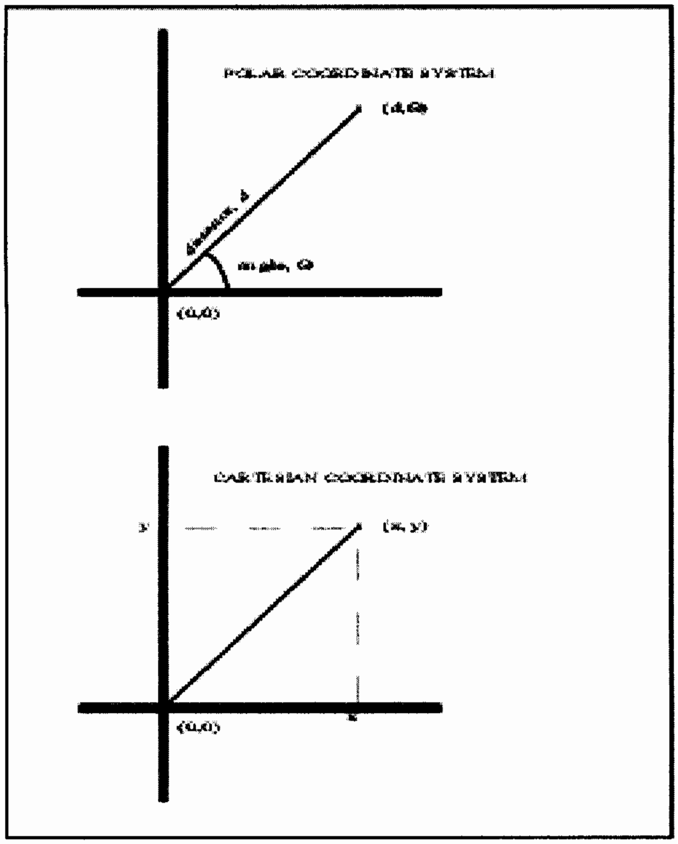


Figure 3. Polar and Cartesian Coordinate Systems

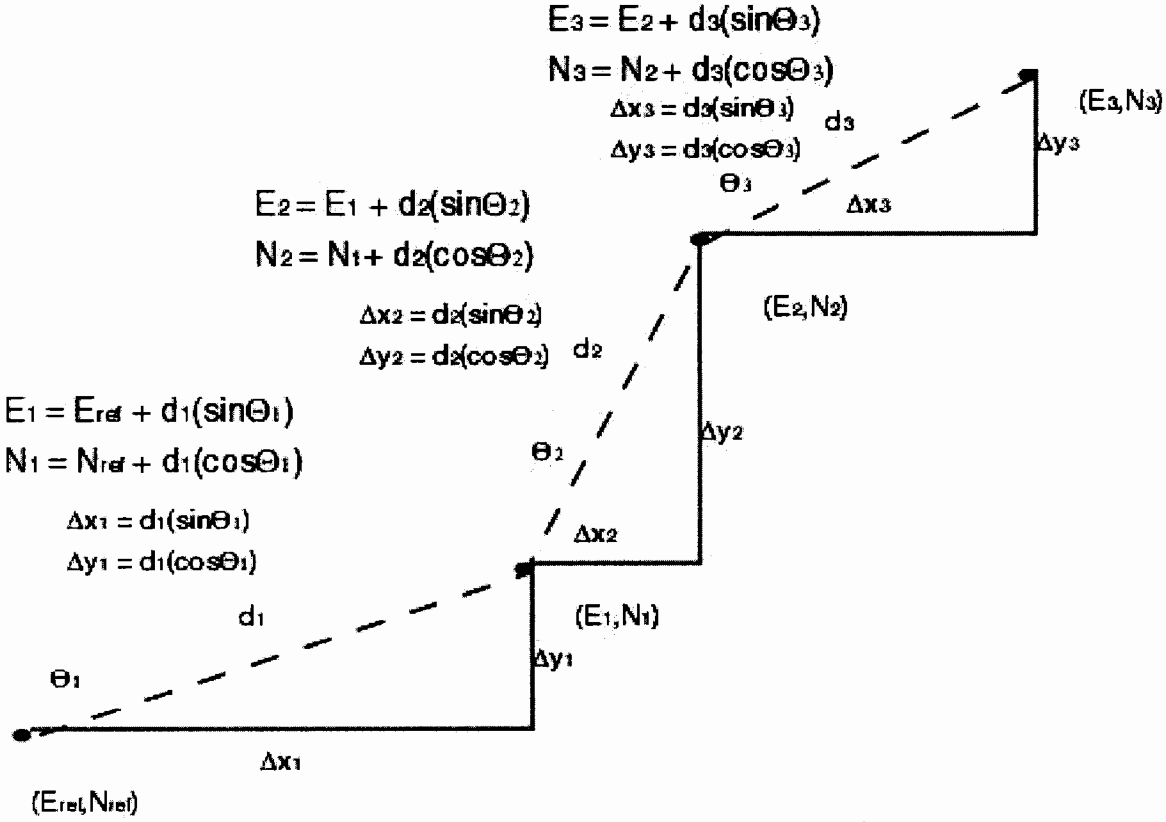


Figure 4. Converting Successive Vectors to UTM Coordinates

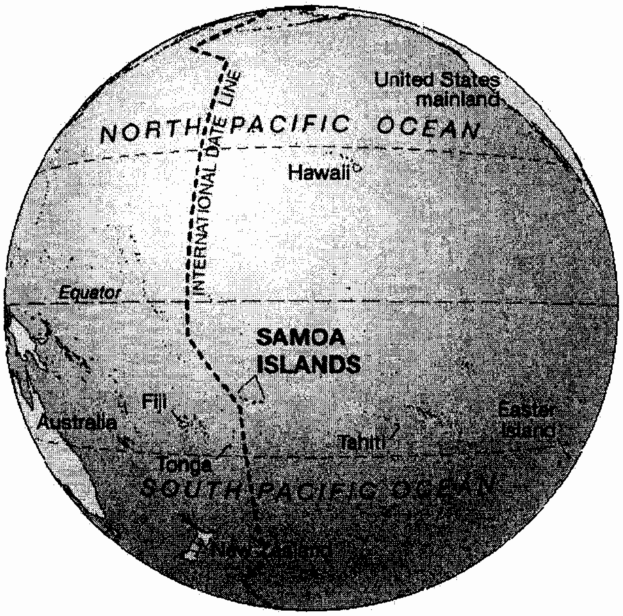


Figure 1. Location of the Samoa Islands

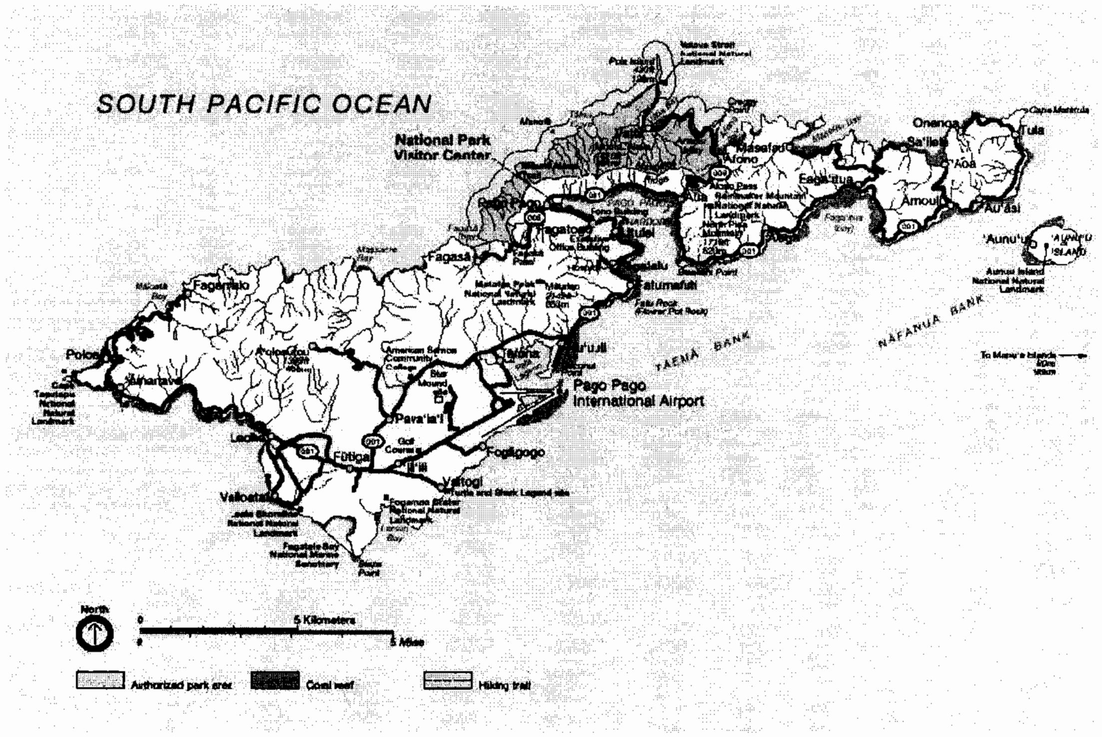
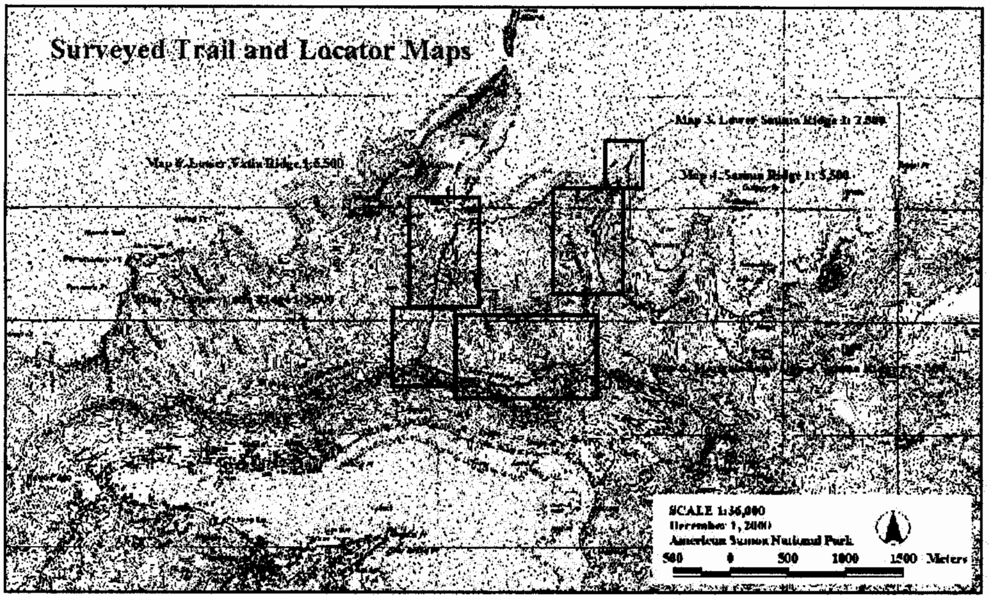


Figure 2. Tutuila Island, American Samoa



Map 2. Location of surveyed trails along Sauma Ridges, Maugaloa, and Vaita Ridge.

Figure 5. Trail data overlayed onto basemap.

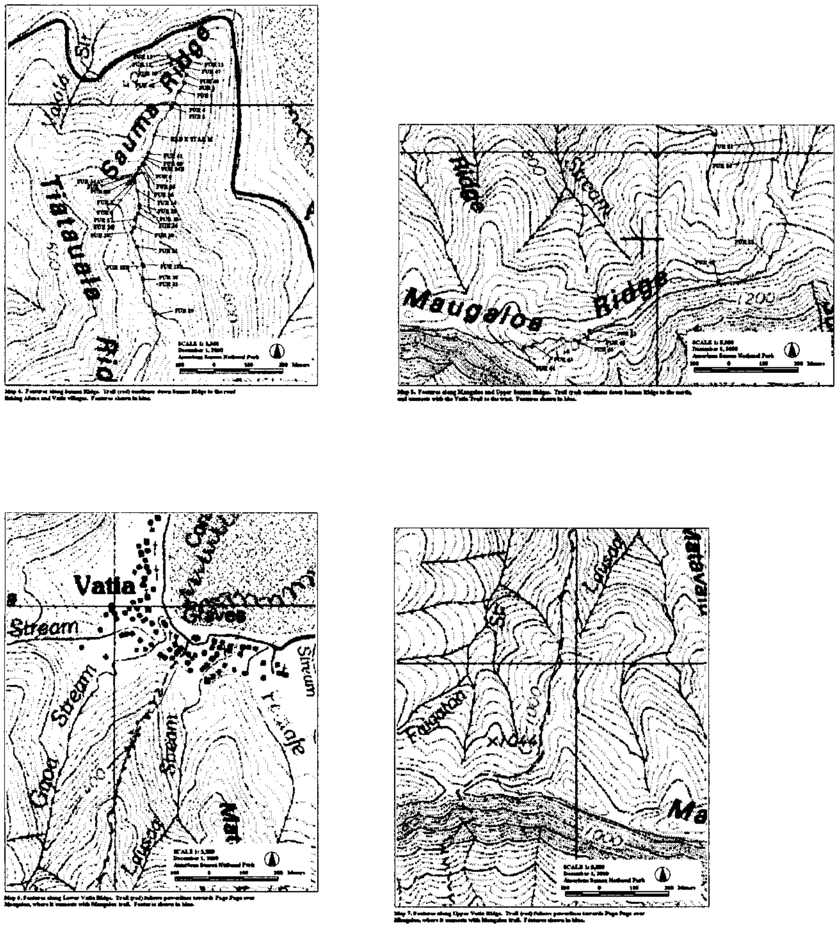


Figure 6. Archaeological feature positions integrated with trail data.

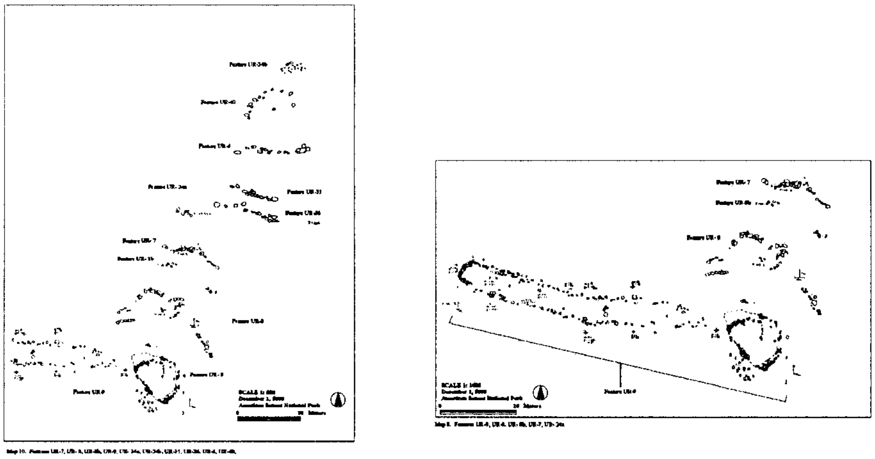


Figure 7. Georeferenced feature map of archaeological features along the trail.

REFERENCES

Coastal Zone Management

1981 *Atlas of American Samoa.* Honolulu: U.S. Office of Coastal Zone Management, American Samoa Government, and the Department of Geography, University of Hawaii.

Frost, Janet O.

1978 Archaeological Investigations on Tutuila, American Samoa. Unpublished, Ph.D. dissertation, Univeristy of Oregon.

Golson, J.

1969 Preliminary Research: Archaeology in Western Samoa, 1957. In R. Green and J. Davidson, eds., *Archaeology in Western Samoa,* Volume 1, pp. 14 – 20. Aukland: Bulletin of the Aukland Institute and Museum, Number 6.

Graves, Allison

2001 GIS Coordinator for the National Park of American Samoa, Personal Communication

Green, Roger C., and Janet M. Davidson

1965 Radiocarbon Dates from Western Samoa. *Journal of the Polynesian Society*74: 63-69.

Hunt, Terry L., and Patrick V. Kirch

1987 Archaeological Survey of the Manu'a Islands, American Samoa. *Journal of the Polynesian Society* 97: 153 – 183.

1993 *The To'aga Site: Three Millenia of Polynesian Occupation in the Manu'a Islands, American Samoa.* Archaeological Research Facility Contribution, Number 51. Berkeley: University of California at Berkley.

1997 *Historical Ecology of the Pacific Islands.* New Haven, Conn.: Yale University Press.

Moniz-Nakamura, J., W. Costa, R. Gmirkin, T. Houston, C. Quiseng, J. Waipa

2001 Tradition and Technology: Adapting to New Mapping Tools in Archeology. *Cultural Resource Management.* Volume 24, No. 2.