Ancient pastoralism and landscape change in south central Jordan:
Are older survey data reliable for human-environment interaction studies?

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Introduction

Older survey data are a very important source of data for archaeologists working in the Near East. These data are especially important in areas where recent agricultural and urban development have impacted the landscape, and where previously recorded sites may have been destroyed. The spatial record of older data, especially the recorded coordinates of sites, may not be accurate enough for use in settlement pattern, site catchment, human-environment interaction, and site predictive modeling studies. As part of the ongoing Wadi Hasa Ancient Pastoral (WHAP) project, this paper investigates the the accuracy of site coordinates recorded by the 1979-1982 Wadi Hasa Survey (MacDonald 1988), and the 1992 Wadi Hasa North Bank Survey (Coinman 1998), and compiled into a computerized database by Hill (2002).

Background

The WHAP project aims to better understand pastoralist-landscape interactions east of the Jordan Rift during the Neolithic and Chalcolithic periods. The WHAP project is focused on the Wadi al-Hasa drainage in south-central Jordan in large part because of the large body of extant data available from these older surveys. A large portion of the 2008 pilot field season focused on the reinvestigation of previously discovered potential pastoralist sites in the Wadi al-Hasa, and the assessment of the accuracy of the site location data available from the WHS and WHNBS projects.

Because the sophisticated GIS techniques that the WHAP project will use to analyze human-landscape interaction will require highly accurate site coordinates, it is extremely important to assess the degree of error associated with the site coordinates included in the extant database. To that end, the site coordinates as recorded in the database were compared with both GPS coordinates from a small sample of relocated sites, as well as with a sample of site points captured by digitization from georectified scanned images of the original survey maps. The goal of this procedure is to discover, understand, and quantify the types of error present in the data, and to separate potentially correctable errors—such as systematic errors such as cartographic displacement or rounding error) from uncorrectable errors—such as misplotting, transposition, observer bias, and random error.

Problem Statement

During the short pilot season, the WHAP project was only able to rediscover 5 of 16 targeted sites (plus two previously undocumented sites), in large part due to inaccuracies in the locational data present in the survey database. This made clear that a primary preliminary goal of the WHAP project must be to assess the accuracy of extant spatial data, identify any correctable error in the extant data, and to ascertain the amount of new field work that will be necessary calibrate the older data. Three questions drive this research:

- *Are the coordinates as recorded in the site database different than those as read from the map, and if so, how are they different?*
- *How accurate were sites plotted on the survey maps?*
- *Are there any potentially correctable Cartesian errors (datums, spheroids, etc.)?*

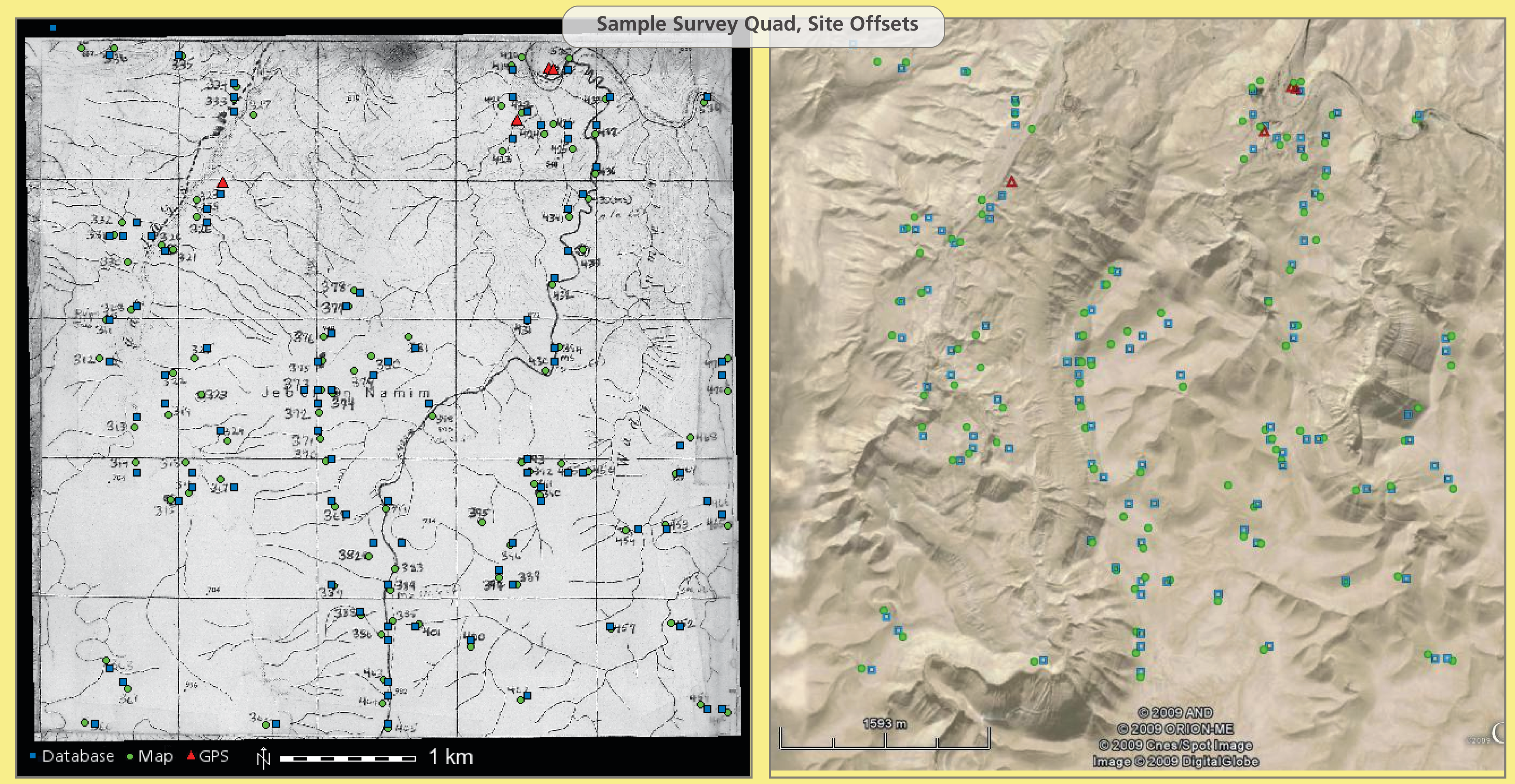
Data History

-1961 1:50,000 scale and 1953 1:25,000 scale Ministry of Economy Palestine Grid topo maps Sites plotted in the field by triangulation from landmarks.

-Site coordinates read off the map to the nearest hundred meters, and recorded onto site record forms (MacDonald 1988).

-Later, site records were encoded into a comprehensive electronic database (Hill 2002), and site coordinates converted into UTM coordinates.

Sample Survey Quad, Site Offsets



Phase I: Survey Database Accuracy

Methods

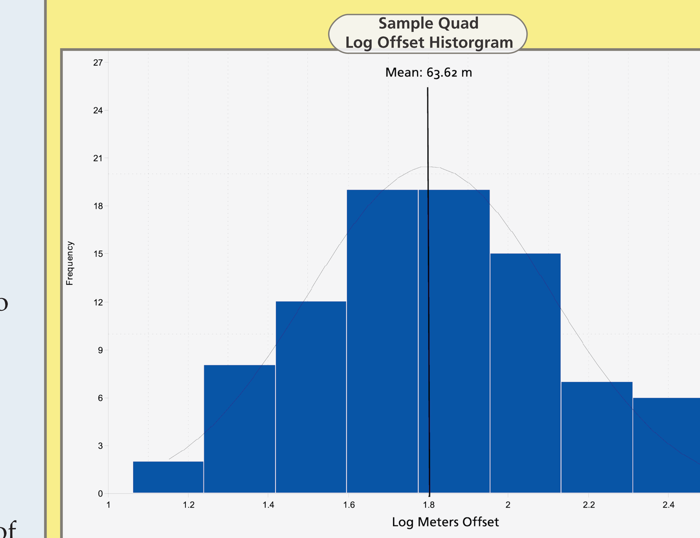
- Convert coordinates from site database to vector points map
- Scan and georectify original field map quads
- Digitize all sites (n=94) from one sample quad into a vector points map
- Calculate the angular and linear offset from the map coordinates to the database coordinates
- Identify and trim gross outliers
- Statistical analysis of offsets

Results

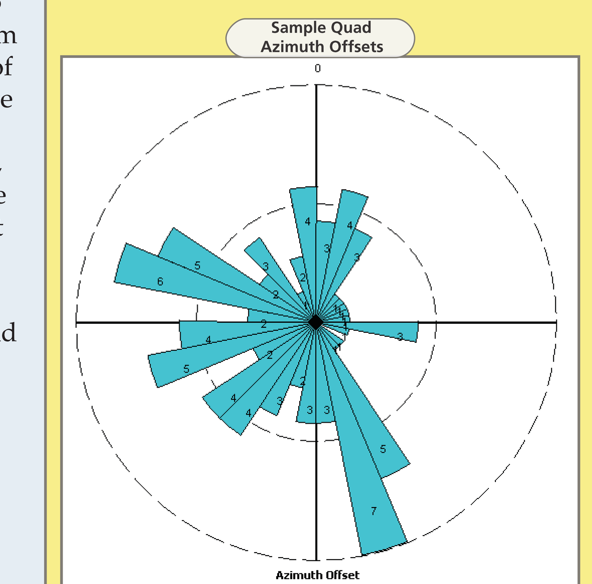
A visual comparison shows significant displacement of the set of site coordinates recorded in the survey database from the set of site coordinates digitized from the georectified scanned survey map quad. Moreover, some offsets seem regularized, whereas others seem more random. After the removal of 6 gross outliers (leaving a total of 88 points), statistical analysis showed that the total population of site offsets in the quad are make up a log-normal distribution with geometric mean 63.62, and geometric standard deviation 2.03. Thus, most offsets cluster well around the geometric mean. Analysis of the azimuth of offsets shows that there is no standard direction of offset among the sample of offsets.

To assess the amount of error due to rounding, each digitized map point was rounded to the nearest hundred meters, and then compared with the coordinates from the database. Of the 88 sample points, only 34 of the database coordinates (38.6% of total) exactly matched their counterpart rounded digitized map point. Of the remaining 54 points, however, 45 points (51.1% of total) had x and/or y coordinates that were within an extra 100 meters of what the rounded coordinate should have been. These points were likely displaced due to “over-rounding” during data encoding Finally, 15 points (17% of total) were off by more than 100 meters in the x and/or y directions. The coordinates for these 15 points were either grossly misread, or some digits were transposed during encoding.

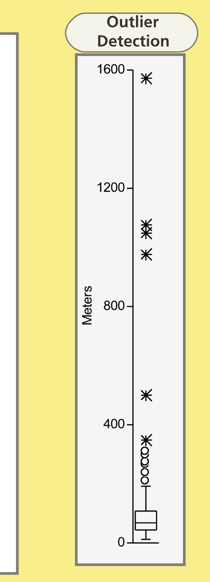
Sample Quad Log Offset Historgram



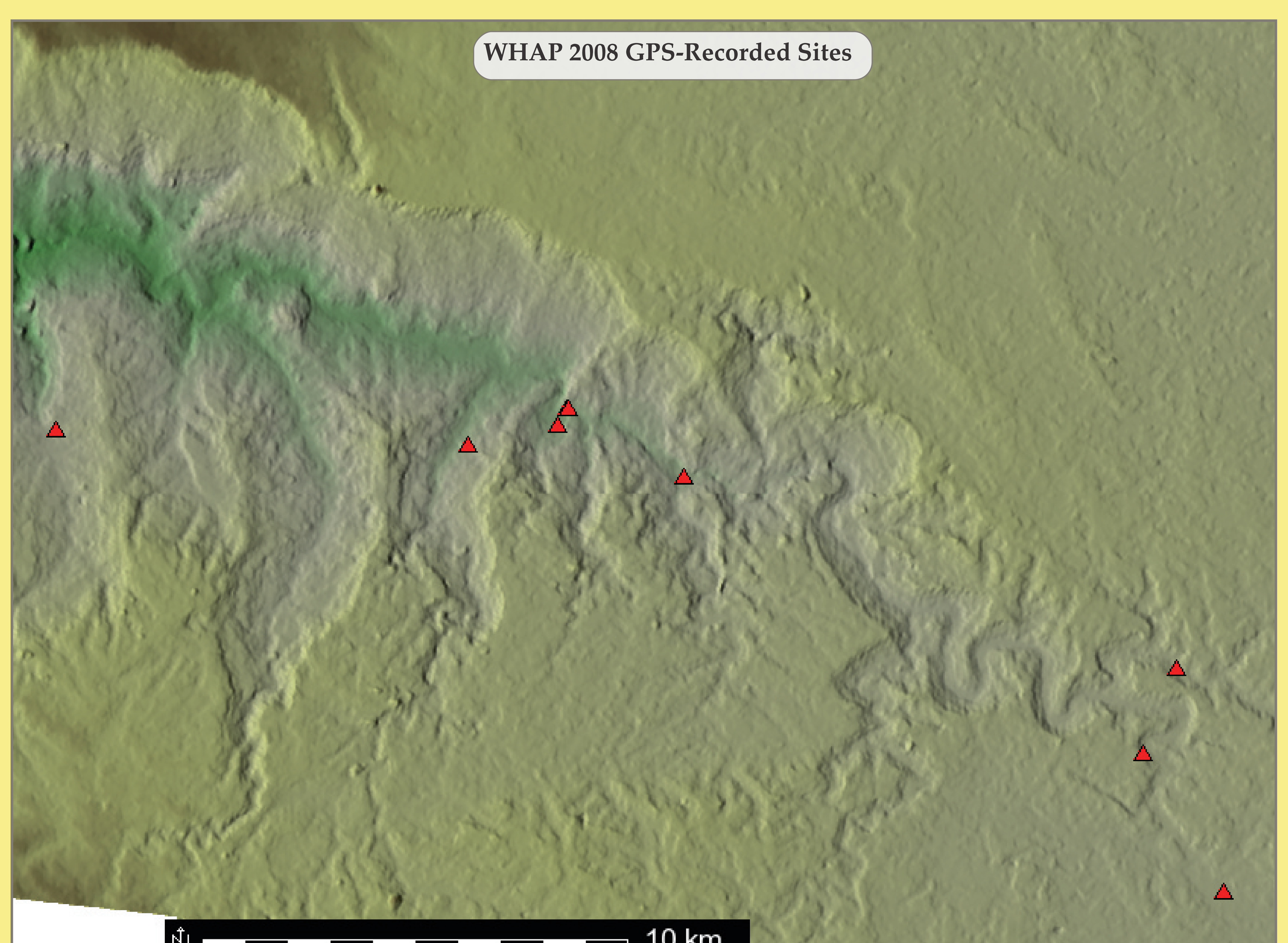
Sample Quad Azimuth Offsets



Outlier Detection



WHAP 2008 GPS-Recorded Sites



Phase II: Survey Map Accuracy

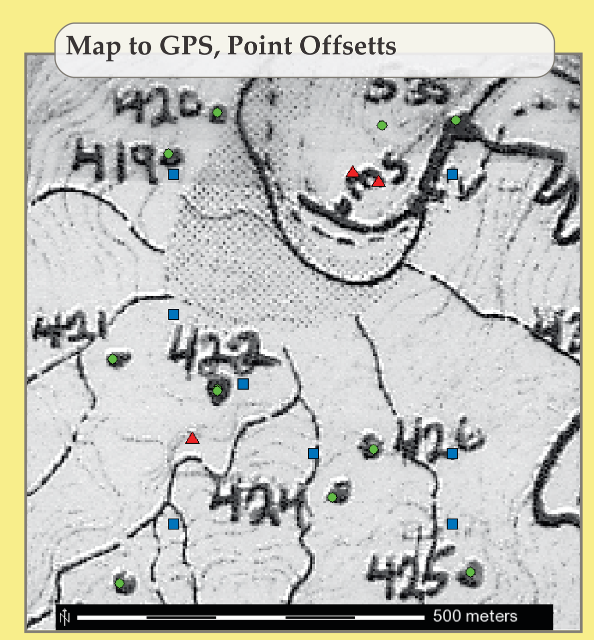
Methods

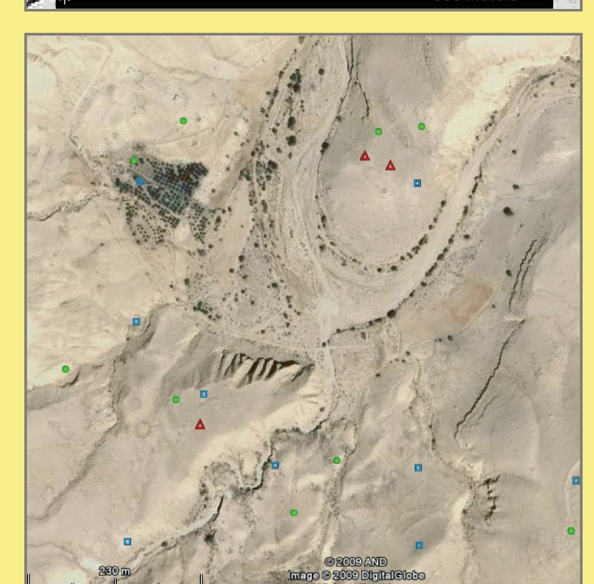
- Use database coordinates and site description to relocate a sample of known sites (n=5, plus two previously undocumented sites)
-Record site locations with a hand-held GPS unit, and import as vector points
- Digitize the coordinates of the known sites from the georectified versions original field maps as vector points i
- Estimate location of newly discovered sites on original field maps by triangulation from landmarks, and digitize as vector points
- Calculate the angular and linear offset from the map coordinates to the GPS coordinates
- Statistical analysis of offsets

Results

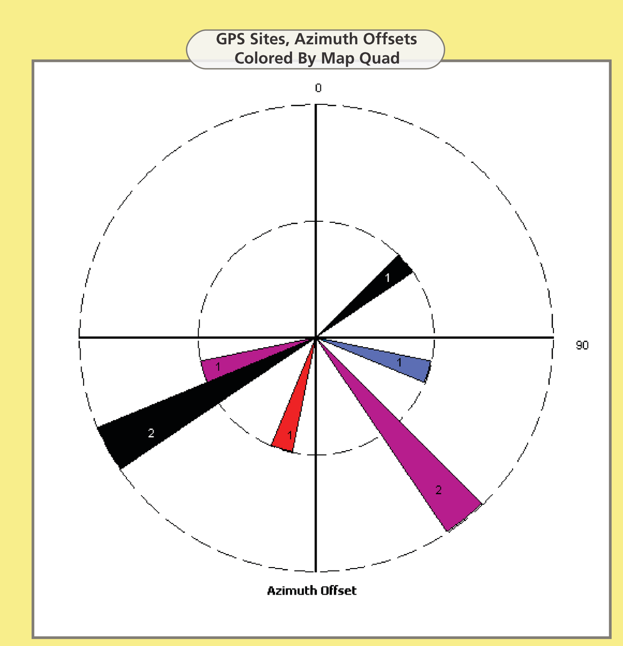
None of the digitized map coordinates for the 7 sample sites exactly matched the GPS recorded coordinates, although one site—site 525—was only 12 meters off. Overlaying the two sets of points on high resolution aerial imagery showed that some sites were simply misplotted, but most were systematically displacemed. This is likely due to some sort of Cartesian error inherent to the original 1:25000 and 1:50000 survey maps. Moreover, it seems that each quad has a unique Cartesian offset. A principle components analysis of the distance and azimuth offset for each site and a rose diagram of azimuth offsets—both color-coded by survey quad—show that the offsets of accurately plotted sites cluster by quad map. The sites that do not cluster are those sites that seem to have been misplotted by the surveyors. In general, misplotted sites are mostly offset to varying distances along natural features such as ridge lines or terraces, rather than in a standard direction.

Map to GPS, Point Offsets

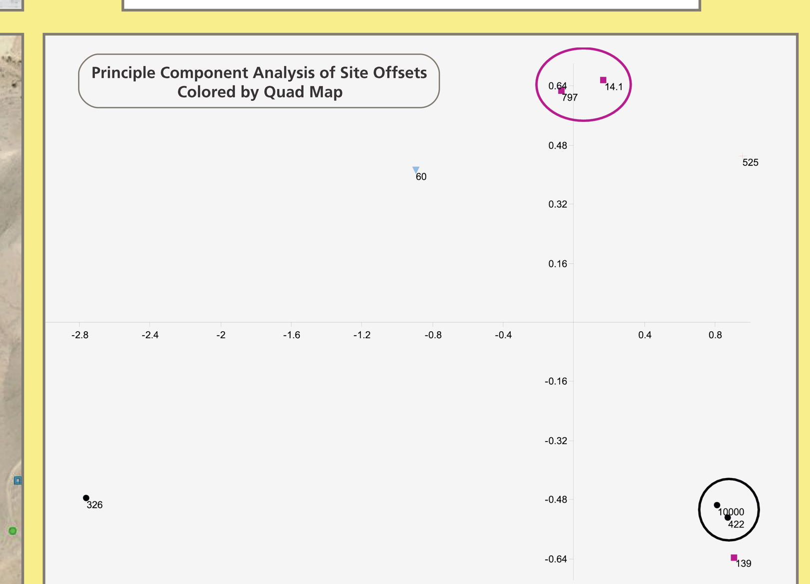




GPS Sites, Azimuth Offsets Colored By Map Quad



Principle Component Analysis of Site Offsets Colored by Quad Map



Conclusions and Future Directions

This study has shown that there are significant problems involved with using older survey data, as-is, in high-accuracy GIS analysis. The accuracy of these data are largely dependent upon the scale and quality of the available maps, as well as the the presence or absence of easily identifiable nearby landmarks in the survey area for triangulation. Additionally, this study has made clear that one must examine the entire chain of procedures that occurred between the time the original surveyors marked a dot on a map to the time the coordinates are entered into a GIS. Error occurs and accrues each time the data are manipulated; and, as the number of manipulations grows, it becomes increasingly hard to account for the accumulated error.

In the case of the WHS and WHNBS survey data, I have determined that the amount of rounding, over-rounding, and transposition errors that have accumulated in the extant site database are too great and too unpredictable to be corrected. As such, the site coordinates as entered in the extant database cannot be use for high-accuracy GIS applications. A majority of sites in the admittedly quite small GPS-referenced sample seem to have been accurately plotted on the survey quads, and re-encoding site coordinates by digitization from georectified scans of the original survey quads should provide more accurate coordinates. Unfortunately, the unique Cartesian offset each survey quad must be corrected before site locations can be digitized, but a larger sample of GPS-referenced sites is needed to properly calibrate these correction factors.

Correcting offsets for sites originally misplotted on the original survey map is more difficult. One promising technique could be to use high resolution aerial imagery and tools such as Google Earth to check site locations against landmarks recorded in the survey database. Such corrections methods are somewhat arbitrary, but could at least help identify and separate potentially misplotted sites.

Modern technology, especially hand-held GPS units, have greatly reduce the error associated with collection of site coordinates. However, many sites recorded by earlier surveys have been wholly or partly destroyed. In addition, it may no longer be possible to access certain areas due to permit issues, changes in property rights, or regional conflict. In these situations, we must rely on older spatial data that was necessarily collected with less accurate methods. The WHS and WHNBS survey data have been used and are currently being used in several diachronic studies of human land-use in the region (Hill 2002; Hill 2004; Hill 2006; Arikan 2009; Clark et al. 1987; Clark et al. 1992; Coinman 1998; Ullah et al. n.d). Many of the arguments made in these studies require precise and accurate site locations. This study develops an avenue to provide such accuracy, and at the very least, provides a measure of the error associated with the use of extent site coordinates.

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