# From Pencil to Pentium: Digitizing the Classic Period Maya City of Chunchucmil, Yucatán, Mexico.

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**Abstract**

In this paper we present the large variety of techniques, tools, and technologies used for the recording, storage, processing, analysis, and visualization of the archaeological data of the Classic period Maya city of Chunchucmil, Yucatán, Mexico. From pencil and paper maps, drawn by pace and compass using traditional Yucatecan landmarks, to high-tech remote sensing, GIS, and 3D technology, the Pakbeh Regional Economy Project has integrated a series of age-old methods with some of the latest software, resulting in a robust body of GIS, remote sensing, and multimedia data products. At its apogee, AD 400–600, Chunchucmil grew to become a sprawling urban center that housed 31,000 to 43,000 residents over an area covering 20–25 km$^2$. Strategically located at the edge of several ecological zones, and only 27 km from the Gulf of Mexico, Chunchucmil became a specialized trading site and redistribution center for its region. Despite being located in an agriculturally stunted location (the driest portion of the entire Maya area, with limited soils), this city displayed the highest structural density of any Classic period Maya site. With hundreds of kilometers of boundary walls and more than a thousand residential groups (only counting the mapped portion of the site), the work of recording and analyzing the abundant features of Chunchucmil has been quite challenging. Fortunately, the location of Chunchucmil in the arid landscape of northwest Yucatán has allowed our project to successfully use both recent and historic aerial photographs, AIRSAR (airborne synthetic aperture radar), and diachronic multispectral satellite imagery from NASA's LANDSAT satellites to reveal a wealth of archaeological data which would otherwise remain undetected in the humid tropics. Two GIS databases were created: one with Intergraph GeoMedia Pro for intrasite features, and one in ArcGIS for the regional database of peripheral site locations and features. These GIS databases are used for the storage, analysis, and visualization of all the archaeological data collected at Chunchucmil. Finally, portions of the site were reconstructed using the Unreal Engine, a 3D visualization software, to create an immersive three-dimensional real-time walkthrough of both the major and minor features of the site. In this paper, we will present a review of the challenges and advantages of each low-tech and high-tech tool as well as their integration in the analysis of the city of Chunchucmil.

***Keywords***: *remote sensing, GIS, 3D technology*

## 1 INTRODUCTION

Chunchucmil, a large Classic Period city in the northern Maya lowlands (Yucatán, Mexico; see fig. B [for figures A, B, and C see the end of this paper]), was first noticed in the 1970s because of the high density of settlement, despite being located in a region with limited agricultural potential. Aerial photographs, taken when the region was cleared of vegetation for henequen cultivation (fig. 1a), revealed the unusual density of settlement and prompted the first investigations. Archaeologist David Vlcek[1] mapped a portion (c. 10 hectares) of the residential settlement 1.25–1.75 km north of the site center,[2] and with the help of aerial photographs, drew a map of the site center.[3] From 1993 to 2006 the Pakbeh Regional Economy Project (PREP), directed by Bruce Dahlin and later joined by codirectors Traci Ardren and Scott Hutson, began systematic investigations in the Chunchucmil region to address more thoroughly the question of how and why so many people were living at this city in such a marginal environment.

PREP adopted a two-pronged approach to answer this question. They first compared the agricultural carrying capacity of the region against the best estimate of population size to test whether Chunchucmil residents could have been supported by subsistence agriculture alone.[4] Second, they focused on gathering as much information as possible on the role of trade in the growth of Chunchucmil to compensate for agricultural

[1]David Vlcek, "Muros de Delimitación Residencial en Chunchucmil," *Boletín de la Escuela de Ciencias Antropológicas de la Universidad de Yucatán* 28 (1978): 55–63.

[2]Aline Magnoni, *Albarradas at Chunchucmil and in the Northern Maya Area* (BA thesis, Institute of Archaeology, University College London, 1995) figure 3.

[3]David Vlcek, Sylvia Garza Tarazona de Gonzalez, and Edward B. Kurjack, "Contemporary Farming and Ancient Maya Settlements: Some Disconcerting Evidence," in *Prehispanic Maya Agriculture*, ed. P. D. Harrison and B. L. Turner (Albuquerque: University of New Mexico Press, 1978) 211–223.

[4]Bruce H. Dahlin., Timothy Beach, Sheryl Luzzadder-Beach, David R. Hixson, Scott Hutson, Aline Magnoni, Eugenia Mansell, and Daniel Mazeau, "Reconstructing Agricultural Self-Sufficiency at Chunchucmil, Yucatán, Mexico," *Ancient Mesoamerica* 16 (2) (1995): 229–247

limitations.[1] A variety of specialists, including (among others) archaeologists, soil scientists, hydrologists, and a palynologist, spent thirteen field seasons gathering data at Chunchucmil. As members of the Pakbeh Project, Aline Magnoni (together with Bruce Dahlin and Scott Hutson) supervised the site center mapping, while David Hixson was responsible for remote sensing operations and the regional survey to the west of the site center. Together we used an array of techniques, tools, and technologies for the recording, storage, processing, analysis, and visualization of the abundant archaeological features at Chunchucmil.

The evidence gathered by the Pakbeh Project supports the notion that Chunchucmil developed as a late Early Classic (A.D. 400–600) specialized trading site that attracted a large population despite being located in an agriculturally marginal environment.[2] Exploiting a variety of local resources from the adjacent ecological areas, participating in maritime trade,[3] and functioning as a regional redistribution center, Chunchucmil grew to become a sprawling urban center that attracted vast numbers of people from the surrounding region. Because of its size and the lack of any competing site in the region, Chunchucmil must have provided all urban functions for its hinterland.[4] In the second part of the Early Classic period, so many people chose to settle in this city that Chunchucmil had the highest population density of any Classic period Maya site.[5] The economic opportunities provided by commerce and trade not only allowed it to overcome the agricultural limitations of the region, but also provided average Chunchucmil residents with considerable wealth, as shown by domestic assemblages at several excavated residential groups.[6]

## 2 Paper and Pencil Maps and Digitizing: From Low-Tech Mapping to GIS

Our initial efforts were aimed at mapping nearly 16 km$^2$ of the Classic period archaeological site, but given the high density of cultural features we managed to cover 11.77 km$^2$ (fig. B [end of this paper]). After experimenting with different mapping techniques (including standard theodolite, total station, and high accuracy GPS), mapping of archaeological features at Chunchucmil was carried out with the simple technique of pacing off a grid. This technique was chosen as the optimal compromise between accuracy and speed of mapping. Chunchucmil has the highest densities of cultural features for a Classic period Maya site[7] and extends over a large area (20–25 km$^2$). These factors would have necessitated using modern equipment to take numerous line-of-site points for thousands of structures and features. In addition, dense secondary vegetational growth prevented visibility, and cutting lines of sight would have slowed down the pace of mapping.

Since there are hardly any natural topographic changes in the region (any topographic rise greater than a meter is invariably a cultural feature), we chose to forgo the recording of natural topography with a total station or high accuracy GPS units, but we were still recording the heights of cultural features on our maps. The clearing of vegetation for mapping with a total station or the amount of work involved in post-processing to create maps from high resolution GPS would have severely limited our mapping coverage of a site with such density of archaeological features. Moreover, the use of expensive equipment, such as total stations and high-resolution GPS units, limits the mappers to the available equipment and consequently mapping coverage is reduced.

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[1]Bruce H. Dahlin and Traci Ardren, "Modes of Exchange and their Effects on Regional and Urban Patterns at Chunchucmil, Yucatan, Mexico," in *Ancient Maya Political Economies*, ed. Marilyn Masson and David Freidel (Walnut Creek: Altamira Press, 2002) 249–284.

[2]Bruce H. Dahlin, "Chunchucmil: A Complex Economy in NW Yucatan," *Mexicon* 25 (2003): 129–138; Dahlin and Ardren, "Modes of Exchange" (p. 217n1) 249–284.

[3]Bruce H. Dahlin, et al., "Punta Canbalam in Context: A Peripatetic Coastal Site in Northwest Campeche, Mexico," *Ancient Mesoamerica* 9 (1) (1998): 1–16.

[4]Bruce H. Dahlin et al., "In Search of an Ancient Maya Market," *Latin American Antiquity* 18 (4) (2007): 363–384; Aline Magnoni et al., "Estudios Arquitectónicos de Chunchucmil Prehispánico," in *Memorias del Congreso Internacional de Cultura Maya*, ed. R. Gubler and A. Barrera Rubio, (Mérida: CULTUR, CONACULTA-INAH, Universidad Autónoma de Yucatán, 2006) 49–61; Aline Magnoni et al., "Landscape Transformations and Changing Perceptions at Chunchucmil, Yucatán," in *Ruins of the Past: Use and Perception of Abandoned Structures in the Maya Lowlands*, ed. Travis Stanton and Aline Magnoni (Boulder: University of Colorado Press, 2008) 193–222.

[5]Aline Magnoni, "Population Estimates at the Ancient Maya City of Chunchucmil, Yucatán, Mexico," in *Digital Discovery: Exploring New Frontiers in Human Heritage. CAA 2006. Computer Applications and Quantitative Methods in Archaeology. Proceedings of the 34th Conference, Fargo, United States, April 2006*, ed. Jeffrey Clark and Emily Hagemeister (Budapest: Archaeolingua, 2007) 175–182; Scott R. Hutson, et al., "Site and Community at Chunchucmil and Ancient Maya Urban Centers," *Journal of Field Archaeology* 33 (1) (2008): 19–40.

[6]Scott R. Hutson et al., "The Archaeology of Urban Houselots at Chunchucmil, Yucatán," in *Lifeways in the Northern Maya Lowlands. New Approaches in the Yucatán Peninsula*, ed. Jennifer P. Mathews and Bethany A. Morrison. (Tucson: The University of Arizona Press, 2006); Scott R. Hutson et al., "House Rules? The Practice of Social Organization in Classic-Period Chunchucmil, Yucatan, Mexico," *Ancient Mesoamerica* 15 (2004): 73–90.

[7]Magnoni, "Population Estimates," 2007 (above, p. 218n5).

Our technologically simpler, yet sufficiently accurate mapping technique consisted of using a traditional Mesoamerican unit of measure known as a *mecate* (a 20 x 20 m measure of area). The modern *mecate* was once a widespread Mesoamerican unit to measure areas of land in early colonial and possibly pre-Hispanic times. The term *mecate* is a Hispanicization of a Nahuatl (Aztec) term. The Maya, however, had a similar term during the early colonial period (*k'àan*).[1] The Spanish incorporated this unit into their agricultural programs. Our project utilized and expanded an existing *mecate* grid which had been established by Yucatecan land owners of Spanish descent in nineteenth century henequen fields across the ruins of Chunchucmil. We used these grids as reference points to pace and map archaeological features. A compass was used when necessary and elevations of buildings were estimated or measured with a tape.[2] We did use a total station, however, to record more accurately elevation data, including natural topography, in the five intensively excavated groups.

The 20-meter-grid pacing method of mapping was facilitated by the presence of *mojoneras* (stone piles) at the corner of every *mecate*. These were originally created by the henequen hacienda owners to measure their land, their yields, and the productivity of their labor force. We cut lines of sight (*brechas*) through the vegetation to connect the *mojoneras*, thus creating a physical grid across the entire landscape of ancient Chunchucmil. Our mappers would then pace off the grid, mapping all features contained within each 20 x 20 meter block. Any mapping errors were therefore contained within each block and were not cumulative across the map. Features were located within each *mecate* with a precision of approximately 1 m. When the *mojoneras* were not present we laid our own 20 x 20 m grid using a theodolite. Despite the fact that using a theodolite to establish a grid was a slow process, this was still faster than using a total station or a high-resolution GPS to map all features contained within the same area. Once a grid was established, mappers would draw features at a scale of 1:1000 on individual sheets of graph paper, and later everything was traced onto a composite map drawn in pencil on mylar. In anticipation of the eventual print publication of this map, the mylar composites were then scanned and imported into Adobe Illustrator, where archaeological features and artifacts were transferred to vector format.

To this date, the Pakbeh Project has mapped a total of 11.77 km$^2$ of the archaeological site of Chunchucmil, consisting of a contiguous block of 9.4 km$^2$ plus five transects that extend beyond the central block.[3] Both the the hand-drawn and Adobe Illustrator 1:1000 maps are in many ways archaeological works of art, with amazing detail and filled with valuable information. If printed at the original scale, they would cover 11.77 m$^2$. Such large printed maps, however, are not easily analyzed or statistically queried. While the relative accuracy was approximately 1 m, the maps were essentially "floating" data without geographic control points. Therefore, the next step was to import these data into a Geographic Information System (GIS).

While the field mapping was completed in 2006 we are just now finishing the digitizing of every single feature into an intrasite GIS database designed in GeoMedia Professional (now version 6.1). The original hand-drawn map sheets were scanned into raster images, which in turn were georeferenced in ERDAS Imagine and/or ENVI using high resolution GPS points collected with a Trimble 4700 receiver. This receiver, differentially corrected with a secondary receiver, provided coordinates with an accuracy of 1 cm horizontally. Georeferenced maps were then imported into GeoMedia Professional, where archaeological, natural, and modern cultural features were digitized through "heads up digitizing" (i.e., digitizing vector data over the raster map images). Twenty-nine "Feature Classes" and corresponding attributes were defined to capture all the different types of archaeological remains and natural features (tables 1 and 2 [see the end of this paper]). Other attribute data, such as artifact databases from excavations, were entered in Excel and Access databases and attached as additional attribute tables that can be queried.

The GeoMedia Professional GIS database of Chunchucmil has been an indispensable tool for intrasite analysis,[4] and especially for mesospatial contexts (in relation to the internal structure of sites).[5] Intrasite GIS has been used to analyze the distribution of residential groups of the late Early Classic-Early Late Classic and Late-Terminal Classic across the site and their internal arrangements (e.g., presence/absence of certain types of structures, disposition of structures within house lots, measurements of structural versus non-structural areas, calculation of residential structures, distribution of natural resources such as fresh water wells and *sascaberas*, which are quarries with

[1]Ramon Arzapalo Marin, *Calepino de Motul: Diccionario Maya-Espanol* (Mexico City: Universidad Nacional Autonoma de Mexico, 1995) 408.

[2]For tall buildings such as pyramids a theodolite was used to calculate the height.

[3]Hutson et al., "Site and Community," 2008 (p. 218n5).

[4]Aline Magnoni, "Counting the Stones: GIS as an Indispensable Tool for Intrasite Analysis at the Ancient Maya City of Chunchucmil, Yucatán, Mexico," in *Beyond the Artifact: Computer Applications and Quantitative Methods in Archaeology, CAA 2004*, ed. Franco Nicolucci and Andrea D' Andrea (forthcoming).

[5]Aline Magnoni, *From City to Village: Landscape and Household Transformations at Classic Period Chunchucmil, Yucatán, Mexico* (Ph.D. diss., Tulane University, New Orleans, 2008).

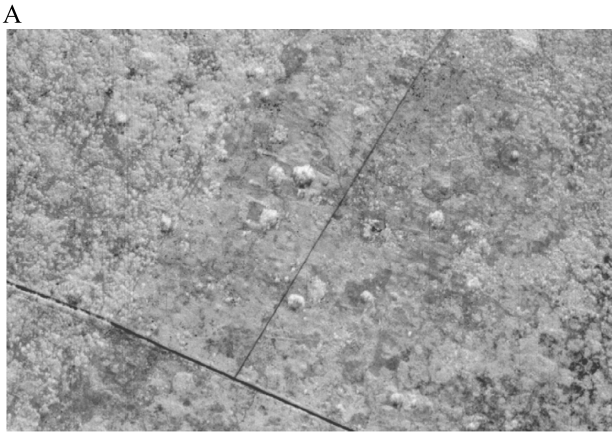
pockets of *sascab,* saprolitic limestone). Spatial analysis of the excavated artifacts from domestic contexts has been done with "queries" (searches by artifact type, time association, context of occurrence) within multiple databases to compare and characterize assemblages. These analyses were indispensable in identifying and defining the settlement pattern transformations over the centuries as well as the house lots' internal characteristics and their integration in the surrounding contemporaneous landscape. Moreover, intrasite GIS has helped in visualizing the contemporaneous settlement of each period, by removing "layers" of later occupations to understand how it functioned as an integrated unit at a given time.[1] An important intrasite GIS analysis presented at the 2006 CAA was the calculation of the structural density and population estimates for late Early Classic Chunchucmil. The study revealed that Chunchucmil had the highest structural and population density for a Classic period Maya site.[2]

## 2 Views from above: Aerial Photographs, Satellite Imagery, and AIRSAR

Two sets of aerial photographs have been used to guide our mapping strategies by indicating where settlement extended. In addition, these aerial photographs have also been used to check on the accuracy of what was being mapped and to measure specific features. As part of our GIS database, they have proven to be useful for checking the accuracy of the georeferencing of our hand-drawn maps. Low-altitude aerial photographs, taken in 1979 (by the *Atlas Arqueológico del Estado de Yucatán*) have a 1:5,000 scale and cover an area of ca. 32 km$^2$ (fig. 1a). These aerial photographs are not fully orthorectified and thus cannot be used for accurate measurements, but they are helpful in revealing many features that today are under vegetation, since they were taken when much of the land was still clear-cut for henequen production. A second set of lower resolution orthophotos at a scale of 1:20,000 taken in 1998 is available from INEGI (Instituto Nacional de Estadística, Geografía e Informática) (fig. 1b). These photographs have a digital resolution of 2 m per pixel, and cover an area of 23,000 km$^2$. Since the photographs have been rectified by INEGI with great precision, they can be used for measurements. They are especially useful for modern features, such as boundary walls of henequen fields, *tranvia* lines (raised beds for decauville railways used for transportation of henequen leaves across the fields), and modern villages, although large prehispanic architecture and some ancient boundary walls are also clearly visible.

In preparing for a regional survey of the wetlands, west of Chunchucmil, Hixson assembled an array of remotely sensed data, including the aerial photographs noted above, as well as diachronic multispectral satellite imagery from LANDSAT, SIR-C imaging radar data, and synthetic aperture radar from NASA's AIRSAR platform. While the ultimate purpose of these remotely sensed data was to survey for secondary archaeological sites outside of Chunchucmil, as with all remote sensing surveys, one must begin with the known universe and extrapolate beyond. Therefore we turned our attention first to the site center and worked our way outwards. Interestingly, the results of this exercise helped us realize that while Chunchucmil has fingers of habitation extending in various directions, there are certain properties that evidence a concentric settlement pattern within the ancient city.

A



B

**Figure 1**. *Aerial photographs of Chunchucmil's site center;* A) *low-altitude oblique photograph taken by the* Atlas Arqueológico del Estado de Yucatán project. B) *orthorectified imagery available through INEGI.*

[1]John Castleford, "Archaeology, GIS, and the Time Dimension: An Overview," in *Computer Applications and Quantitative Methods in Archaeology 1991*, ed. G. Lock and J. Moffett (Oxford: BAR International Series, vol. 577: 1992) 95–106; Trevor M. Harris and Gary R. Lock, "Multi-Dimensional GIS: Exploratory Approaches to Spatial and Temporal Relationships within Archaeological Stratigraphy," in *Interfacing the Past: Computer Applications and Quantitative Methods in Archaeology, CAA 95*, vol. 2, ed. H. Kamermans and K. Fennema (Leiden: University of Leiden, Analecta Praehistorica Leidensia 28, 1996) 307–316.

[2]Magnoni, "Population Estimates," 2007 (above, p. 218n5).

From our hand drawn georeferenced maps of the site center, we already understood that Chunchucmil's central core is defined by the convergent presence of large-scale architecture often connected by raised causeways (*sacbeob*). By overlaying our remotely sensed data upon the georeferenced maps in ArcGIS, we found that a more synoptic regional view can assist in defining the core zone, as well as other zones of architecture within ancient Chunchucmil. Figure 2 represents a digital elevation model that was produced using radar imagery from NASA's AIRSAR instrument, which flew over Chunchucmil in March of 2004. In this image, structures as small as four to six meters tall were clearly detectable in the low scrub forest that covers Chunchucmil, as well as larger pyramids that reach heights of up to 18.5 m. When all 2,000 $km^2$ of the AIRSAR data are viewed in a single image, the pyramidal structures of Chunchucmil appear tightly clustered within approximately the central 1 $km^2$. While other isolated pyramids can be found in the radar image, it is clear that Chunchucmil truly had a central nucleus of monumental architecture, which we can securely term the "site center." More importantly, we can say with a degree of certainty that no other site of this magnitude exists within that 2,000 $km^2$ AIRSAR coverage area, signifying the primacy of Chunchucmil within its supporting region.

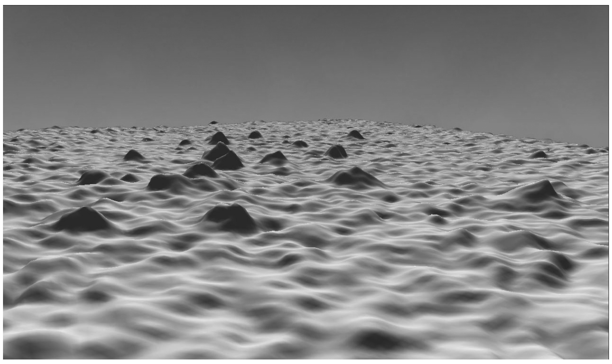


**Figure 2**. *Perspective view Chunchucmil's site center using the digital elevation model generated by NASA's AIRSAR platform.*

Moving beyond the site center, we refer to the next two zones of habitation as the "residential core" and the "residential periphery."[1] The first zone, the "residential core," is characterized by densely packed household groups. In this zone, *albarradas* (ancient stone boundary walls) are shared between neighboring household groups, often leaving enough space between them to form narrow pathways called *callejuelas*. The end result is a settlement pattern that appears like a honeycomb, with little or no empty space between residential groups. This zone exhibits fewer examples of monumental architecture, including a lower number of quadrangle groups that are sparsely placed and lack an interconnecting *sacbe* network. The second zone, "residential periphery," contains many of the same features, but empty space is left between the bounded residential groups so streets are no longer needed for traffic. Due to the increasingly dispersed architecture beyond these two zones, it has been difficult to place an exact boundary for the edge of Chunchucmil as a discrete site.

Therefore, between 2001 and 2005 Hixson utilized LANDSAT multispectral imagery to aide PREP in estimating the limits of Chunchucmil.[2] What he found was that the tightly clustered limestone mounds provide a stark contrast to lower flat soils with fewer mounds. While most remote sensing specialists would suggest that dry season (or "leaf-off") conditions are best for such multispectral remote sensing studies, we have had the best results using early wet season imagery, due to the fact that in this topographically challenged environment, unoccupied flat terrain often floods, while the mounds themselves create well-drained bright surfaces with greener vegetation to improve spectral contrast. Utilizing the LANDSAT 7 imagery, Hixson estimated that the most densely settled portions of Chunchucmil (combining the site center, the residential core, and the residential periphery) covers an area of approximately 25 $km^2$. Subsequent mapping transects conducted by Hutson in 2006 support this estimate.[3]

Once the spectral reflectance values were known for mounded architecture within Chunchucmil, and various other spectral reflectance values were measured in non-site areas, Hixson expanded our survey to the western wetlands between the ancient city and the Gulf coast. Once again, the wet season LANDSAT imagery provided the best contrast between site and non-site areas (fig. C [at end of this paper]). While not all of the secondary sites in Hixson's wetland survey were found using the remotely sensed data (some were located using informants), they do all share similar reflectance values, including common signatures for brightness, dryness and "greenness."[4]

[1]Hutson et al., "Site and Community" (above, p. 218n5).

[2]David R. Hixson and Daniel Mazeau, "Reconocimiento Regional en los Alrededores del Centro Urbano de Chunchucmil," paper presented at the *Segundo Congreso Internacionál de Cultura Maya, Mérida, Yucatán, México*, March 15, 2005.

[3]Hutson et al., "Site and Community" (above, p. 218n5).

[4]To the east of Chunchucmil, PREP member Daniel Mazeau has conducted a separate hinterland survey, but in this semi-arid zone of henequen haciendas the LANDSAT imagery is less useful. This is partially due to the abundant modern and historic disturbances around the many towns of this region, and partially due to the transition away from inundated zones where the spectral contrast is greatest. We therefore feel that this application of multispectral imagery for the direct detection of archaeological sites could certainly be applied to other parts of the Maya area, specifically in flood-prone ecological zones with abundant grasslands such as the near-coastal areas of the Yucatán peninsula.

## 8 Recreating Ancient Chunchucmil: An Experiment in 3D Mapping

While our hand-drawn maps of Chunchucmil accurately convey the various surface manifestations of archaeological features, such as ancient boundary walls, housemounds, temples, and quarries, the viewer is still left with a static image of the site from above. Various archaeological projects have wrestled with the same question of how their site appeared during its apogee, most relying upon professional artists to create their own renditions on canvas. In the last decade, however, archaeological illustrations have caught up with the technology previously available only to those with massive budgets. In trying to draw Chunchucmil's hand-drawn maps into the digital age of 3D environments, Hixson has taken a section of ancient Chunchucmil and created a fully immersive three dimensional real-time walk-through.

The images in figure A (at end of this paper) were created entirely from software that is freely available on the web. The core program is called the Unreal Engine 2 Runtime, a 3D engine originally designed for video games, but now being used by architects, archaeologists and other disciplines to create immersive 3D models of their subjects. The program is compatible with most CAD programs and Autodesk 3ds Max, or any program that can export a static mesh. Since our map of Chunchucmil was originally drawn by hand (and therefore not CAD-friendly), this particular 3D rendering was all drawn within Unreal Runtime, much like the "heads up digitizing" done by Magnoni in GeoMedia Pro.

Many of the textures applied to the surfaces of objects and features within the 3D reconstruction were sampled from digital photographs taken in the field (largely within modern Yucatec Maya households). These include thatched roofs, wattle and daub walls, and painted stucco. Using this mixture of digital photographs with 3D rendering, the surfaces of objects and structures created for Unreal environments can be very detailed, including carved monuments or painted murals (unfortunately, the archaeological site of Chunchucmil has neither). This 3D model, however, is not a static set of wireframe objects. It is a fully immersive 3D environment. The original Unreal 3D map can be walked through at your own pace in real time, and at a higher resolution than most HDTVs (up to 1920 x 1200 pixels).

This is certainly not the first immersive 3D walkthrough of a major Maya archaeological site. A pioneering project working at the Maya site of El Cerén, El Salvador (often called the "Pompeii of the New World") was able to attach their Filemaker-Pro databases to the individual artifacts inside their digital reconstructions of ancient Maya households during the early 1990s (ceren.colorado.edu). And more recently, the Maya site of Palenque has received a stunning recreation by a team working for Atlantic Productions and A&E Television Networks (a History Channel production called "Lost Worlds: Palenque," now available on DVD). Unreal, however, has the capability of online connectivity, meaning that two (or even thirty-two) people, miles apart, could load the map of Chunchucmil at the same time and meet each other there to take a walking tour together. This makes it an ideal platform for interactive learning.

Such virtual reconstructions as "Unreal Chunchucmil" that require the user to take the same paths that once dictated travel through the ancient city may also be quite revealing for scholars interested in social interaction. In such a dense urban setting, social relations between residents and visitors were affected by the spatial materiality of the built environment. Narrow pathways, crowded residential areas, the few open areas for congregation such as the marketplace, were both the outcome and the medium of social production and reproduction.[1] Constructed space was socially produced but in turn social relations between residents of neighboring household groups, foreign and local traders, regional sellers, and all visitors coming through Chunchucmil would have been affected by this spatial materiality.[2] We do not necessarily support a phenomenological approach to the interpretation of the past, but we think that by recreating past built environments we can at least place ourselves in viewpoints from which we can begin to unravel how people navigated this dense settlement.

Three-dimensional reconstructions are also essential for the representation and recreation of past landscapes and lifeways for the general public, who may not relate to the two-dimensional maps as easily as archaeologists do. To this end, we are currently exploring the possibility of installing the Unreal model within a museum display as an educational tool for school children to better understand the ancient Maya of Chunchucmil.

## 5 Conclusion

In conclusion, while we began our settlement pattern studies at Chunchucmil utilizing little else besides paper and pencil, we have been able to integrate our low-tech methods into some of the latest high-tech software, resulting in a robust body of GIS, remote sensing, and multimedia data products. While we have not had time to discuss any one technique in depth, we hope we have provided some inspiring ideas for those faced with similar methodological problems in their settlement pattern studies. Since the archaeological, environmental,

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[1] Scott R. Hutson, *Dwelling and Identity at the Ancient Urban Center of Chunchucmil, Yucatan, Mexico* (Ph.D. diss., University of California, Berkeley, 2004).

[2] Magnoni, "From City to Village" (above, p. 219n5).

and budgetary conditions of each project are different, we acknowledge that our solutions may not necessarily be applicable to other projects, but we hope they can illustrate some of the options available in settlement patterns and landscape studies.

Here we have reviewed our choices of technologies and methods after careful consideration and experimentation with a variety of techniques. Chunchucmil's location in a seasonally inundated region with low scrub forest has allowed us to successfully apply technologies that are often not applicable in the humid tropics, such aerial photography, satellite imagery, and synthetic aperture radar from NASA's AIRSAR platform. The exceptional density of archaeological features together with limited visibility due to thick secondary growth forced us to forego common mapping technologies, such as total station and high-resolution GPS. We instead chose to map this dense and extensive archaeological site taking advantage of portions of an existing historical 20 x 20-meter grid and drawing paper and pencil maps, a technique that facilitated the coverage of large expanses of the site (11.7 $km^2$), although still short of the originally intended 16 $km^2$. This choice of simpler technology, which was an appropriate comprise between speed and accuracy in our environmental conditions (minimal natural topography and dense secondary growth hindering visibility) helped us cover more mapping ground in the field but left us with large amounts of post-field digitizing of archaeological data. Great effort was subsequently put into heads-up digitizing of the site maps into GeoMedia Pro and the drawing of 3D features in Unreal Runtime. Despite having a significant body of raster data that needed to be digitized and entered in a variety of programs (such as GeoMedia Pro and Unreal Runtime), we believe that our paper and pencil maps obtained by pacing off a grid significantly reduced the amount of time spent mapping in the field. Optimizing data collection in the field is essential since permits and funding for field seasons are difficult to obtain, while data entry and digitizing can be easily done without permit and locational constraints at a later date. We do recommend, however, that data entry and funds be allocated in the original budget in order for the data entry process to be accomplished in a timely manner for analysis to proceed.

**ACKNOWLEDGEMENTS**

We thank the Consejo de Arqueología of Mexico's Instituto Nacional de Antropología e Historia (particularly Roberto García Moll and Joaguín García Bárcena) for permitting the archaeology described in this paper. We also thank the Centro Regional Yucatán (particularly Alfredo Barrera Rubio and Luis Millet) and the people of Chunchucmil, Kochol, San Mateo, Coahuila, and Santo Domingo for facilitating fieldwork. Our deepest gratitude to PREP directors Bruce Dahlin, Scott Hutson, and Traci Ardren, as well as our colleague Daniel Mazeau. The research described here was supported in part by an NSF dissertation improvement grant (BCS-0440640) to Aline Magnoni and a NASA Fellowship (GSRP) to David Hixson.

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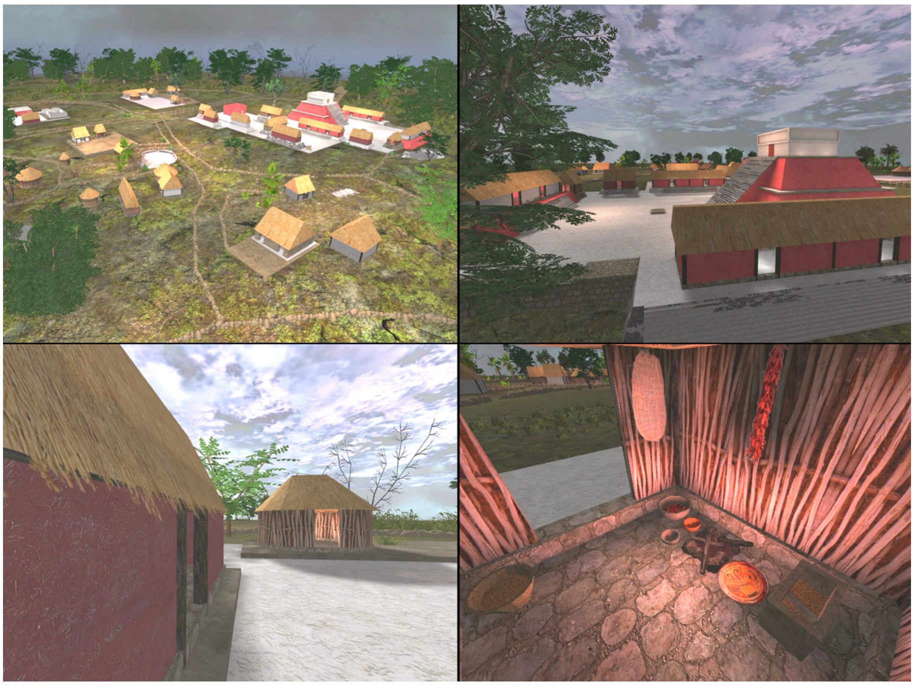

**Figure A**. *Screenshots of the "Unreal" digital reconstruction of a portion of Chunchucmil's site center.*

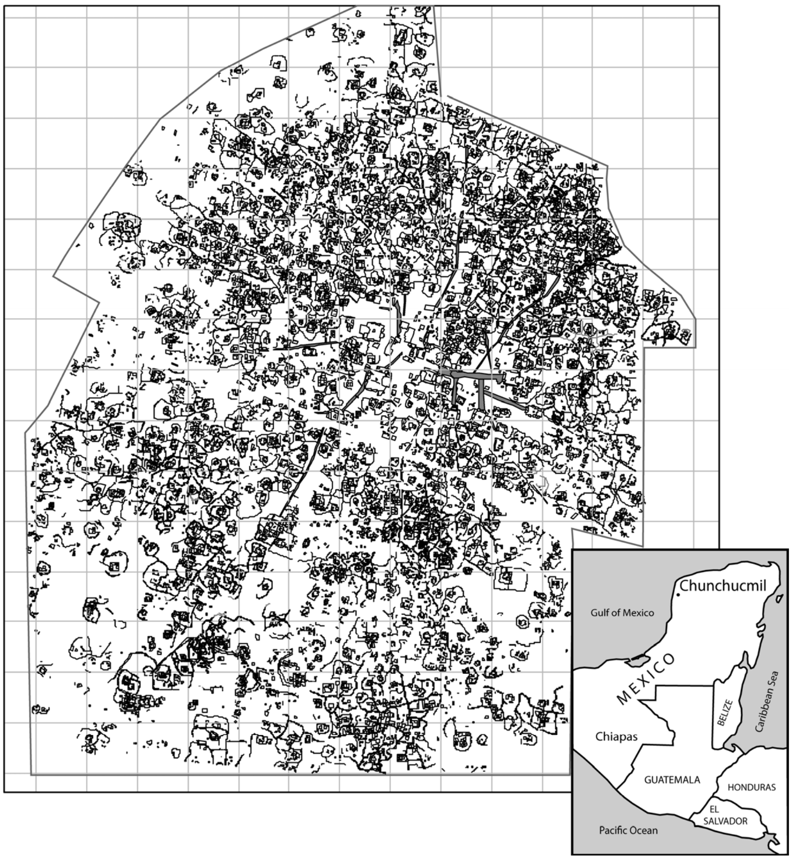


**Figure B**. *Map showing portion of 9.4 km² of the site of Chunchucmil mapped by PREP (not shown are the five transects that bring total map coverage to 11.77 km²). Each grid square is 250 x 250 m. The inset map shows the location of Chunchucmil in the Maya region.*

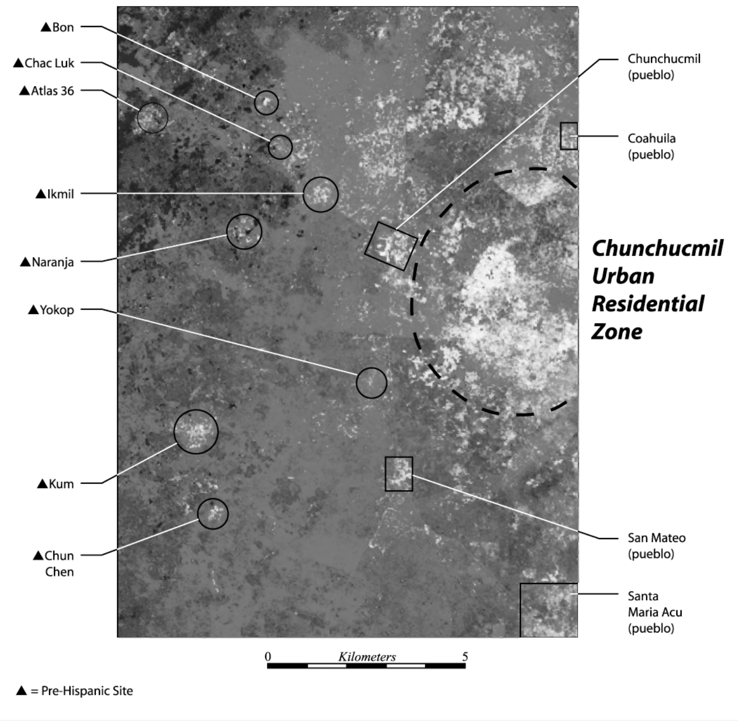


**Figure C**. *Multispectral imagery of Chunchucmil and its western hinterland using NASA's LANDSAT platform, stretched to highlight modern and ancient settlements.*

| **Feature Class** | **Geometry Type** | **Attribute 1** | **Attribute 2** | **Attribute 3** | **Attribute 4** | **Attribute 5** |
|---|---|---|---|---|---|---|
| Albarrada | Compound | Type | | | | |
| Hypothetical Albarrada | Compound | | | | | |
| Chichbeh | Compound | | | | | |
| Pyramid | Compound | Str. Number | Height | Orientation | Architectural Comments | |
| Basal Platform | Area | Str. Number | Height | Orientation | Architectural Comments | Chronology |
| Structure | Compound | Str. Number | Type | Height | Orientation | Architectural Comments |
| Round Structure | Area | Str. Number | Type | Height | | |
| Callejuela | Compound | | | | | |
| Callejón de chichbeh | Compound | | | | | |
| Callejón simple | Compound | | | | | |
| Sacbe | Compound | Number | | | | |
| Chichpile | Area | Height | | | | |
| Column | Point | Comments | | | | |
| Cutstone | Point | Comments | | | | |
| Metate | Point | Comments | | | | |
| Double Metate | Point | Comments | | | | |
| Quern | Point | Comments | | | | |
| Rejollada | Compound | | | | | |
| Quarry | Area | Type | Comments | | | |
| Enclosed *Solar*[1] | Area | *Solar* | Operation | Comments | | |
| Hypothetical Enclosed *Solar* | Area | Comments | | | | |
| Associated *Solares* | Area | Comments | | | | |
| Terrace | Compound | Height | Architectural Comments | Orientation | | |
| Architectural line | Line | | | | | |
| Elevated area | Area | Height | Comments | | | |
| Bedrock | Area | Type | | | | |
| Well | Point | Type | Comments | | | |
| Modern Feature | Compound | Type | | | | |
| Operation | Compound | Operation & Subop.# | Architectural Group Name | Square $km^2$ block | Type of excavation | |

**Table 1.** *Feature Classes and corresponding Geometry Types and Attributes used to digitize features in GeoMedia Professional.*

[1]*Solar* is a Spanish term used to refer to the area surrounding a modern Maya house (also in other parts of Mesoamerica), where domestic activities and crafts are carried out and various plants are grown. *Solares* are generally delimited by a stone wall, or *albarrada*.

| Feature Class | Descriptions |
|---|---|
| Albarrada | Stone boundary wall |
| Hypothetical Albarrada | Possible stone boundary wall, generally in disturbed areas |
| Chichbeh | Narrow raised winding causeway made by two external, parallel retaining courses of stones and filled in with rubble to create a raised surface. Chichbes are half a meter to three meters wide, less than one meter high. |
| Pyramid | Square or nearly square structures higher than 2.5 meters |
| Basal Platform | Platforms supporting structures (or that would have supported non-visible perishable structures) |
| Structure | Structures that are not oval or circular and that may or may not be on top of a platform |
| Round Structure | Oval and circular structures |
| Callejuela | Street made by two parallel running albarradas |
| Callejón de chichbeh | Entrance way to a residential group made by a chichbeh |
| Callejón simple | Entrance way to a residential group made by a callejuela |
| Sacbe | Causeway made by two external retaining courses of stones and filled in with rubble to create a raised surface. Sacbes' width varies from 6 to 25 m and their length varies from to 100 to 800 m. They run straight and do not wind like chichbes. |
| Chichpiles | Accumulation of chich (rubble) that could be a structure or platform without retaining walls or simple natural bedrock eroding |
| Column | Columns and column drums |
| Cutstone | Stone that was cut (e.g. Puuc stones) or engraved |
| Metate | Grinding stones |
| Double Metate | Grinding stones with two grinding depressions |
| Quern | Grinding stones with a circular depression and a spillway |
| Rejollada | Natural depression with soil accumulation at the bottom |
| Quarry | Stone quarries and sascaberas, where sascab, fine lime powder, can be obtained |
| Enclosed Solar | Albarrada groups that are completely enclosed by albarradas |
| Hypothetical Enclosed Solar | Albarrada groups that are not completely enclosed by albarradas |
| Associated Solares | Cluster of enclosed albarrada groups that are isolated from others by empty space or callejuelas |
| Terrace | Raised flat area delimited on two or three sides (but not four) by a course of stones, always offmound |
| Architectural line | Architectural lines visible on structures, platforms, and pyramids, as well as offmound. They do not have any height. |
| Elevated area | Elevated areas on structures, basal platform, and pyramids |
| Bedrock | Bedrock can be high rising bedrock or limestone pavement |
| Well | Prehispanic and modern wells |
| Modern Feature | Modern plantel walls, tranvia lines, roads, cattle ranches, etc. |
| Operation | Excavation operations and suboperations |

**Table 2.** *Descriptions of Feature Classes.*