
XX CONSTRUCTING AND USING A GIS FOR FIELDWORK: THE UNDERWATER MAYA PROJECT

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The Underwater Maya case study argues for use of a GIS from the inception of field research instead of creating a GIS and entering data ex post facto. Before fieldwork, a GIS, Underwater Maya, was created to house the spatial data from the discovery and mapping of wooden architecture at underwater sites in Paynes Creek National Park, southern Belize. Maps, air photos, and satellite imagery in the GIS placed the archaeological finds in the real world. Sites, wooden posts, and artifacts marked by flags at the underwater sites were mapped using a Total Station. The spatial data were downloaded to a laptop and converted to Excel spreadsheets, which were attached to the project GIS using the coordinates of each find. The creation of the “Underwater Maya” GIS, methods for entering spatial data and manipulating the data are described, along with results provide a case study using of the major GIS software. Procedures are given for Geomedia 6.1 by Intergraph, but the general methodology will be similar for other GIS software.

Introduction

The Underwater Maya project on submerged ancient salt works in Paynes Creek National Park, Belize provides a case study of the merits of integrating GIS into research when field research begins. A GIS, Underwater Maya, was created on a laptop to house all of the data from the discovery and mapping of wooden architecture and associated artifacts. Artifacts and posts are mapped using a total station, which provides x, y, z coordinates. The digital data are downloaded to a laptop, converted to UTM coordinates, and linked to the GIS. The GIS automatically updates spatial data added to existing attached excel spreadsheets, which is useful for entering information on the dimensions of building posts, the types of ceramics, and other descriptive data. Using the GIS during field research allows us to visualize patterns, search for missing data, and ask new questions about spatial relationships. Printed site maps from the GIS are useful in examining the patterns of posts and searching for additional posts during fieldwork.

The peat bog below the sea floor provides outstanding preservation of wooden architecture radiocarbon dated to the Early and Late Classic periods (A.D. 300-900). The buildings were structures for the production of salt by evaporating brine in pots over fires. This activity took place indoors because of the significant infrastructure of production—storage space for wood fuel, pots, loose salt and salt cakes, and water jars of brine to evaporate. The short and

unpredictable dry season in southern Belize adds to the need for indoor salt production.

The rise and fall of the Paynes Creek salt industry mirrors the population increase and decline of inland cities where salt—a basic biological necessity—was scarce. Diagnostic “unit-stamped” pottery water jars and figurine whistles tie the salt works to inland consumers in southern Belize and adjacent Guatemala—Lubaantun, Seibal, Altar de Sacrificios, and cities in the Petexbatun (McKillop 1995, 2002, 2005a, 2005b, 2007, 2009, 2010a, 2010b, 2011). The discovery of the wooden architecture, along with the only known ancient Maya wooden canoe paddle—at the K’ak’ Naab’ underwater site—was in 2004 (McKillop 2005a, 2007). Discovery and mapping of some 4000 wooden posts and piece-plotting of temporally distinctive artifacts was carried out between 2005 and 2009 (McKillop 2005a, 2007, 2009, 2010a, 2010b, 2011; Sills 2007; Sills and McKillop 2010; Somers 2007).

Creation of the Underwater Maya GIS

All archaeological material from the Underwater Maya project is recorded as spatial data in a Geographic Information System (GIS) using Geomedia 6.1. Three types of data are part of the GIS, including (1), raster images such as air photos, (2), vector images such as maps we draw using points, lines, and polygons, and (3), information in tables. The UTM (Universal Transverse Mercator) map projection is used for the GIS. A satellite image of Gulf of Honduras region imported to the GIS software and saved

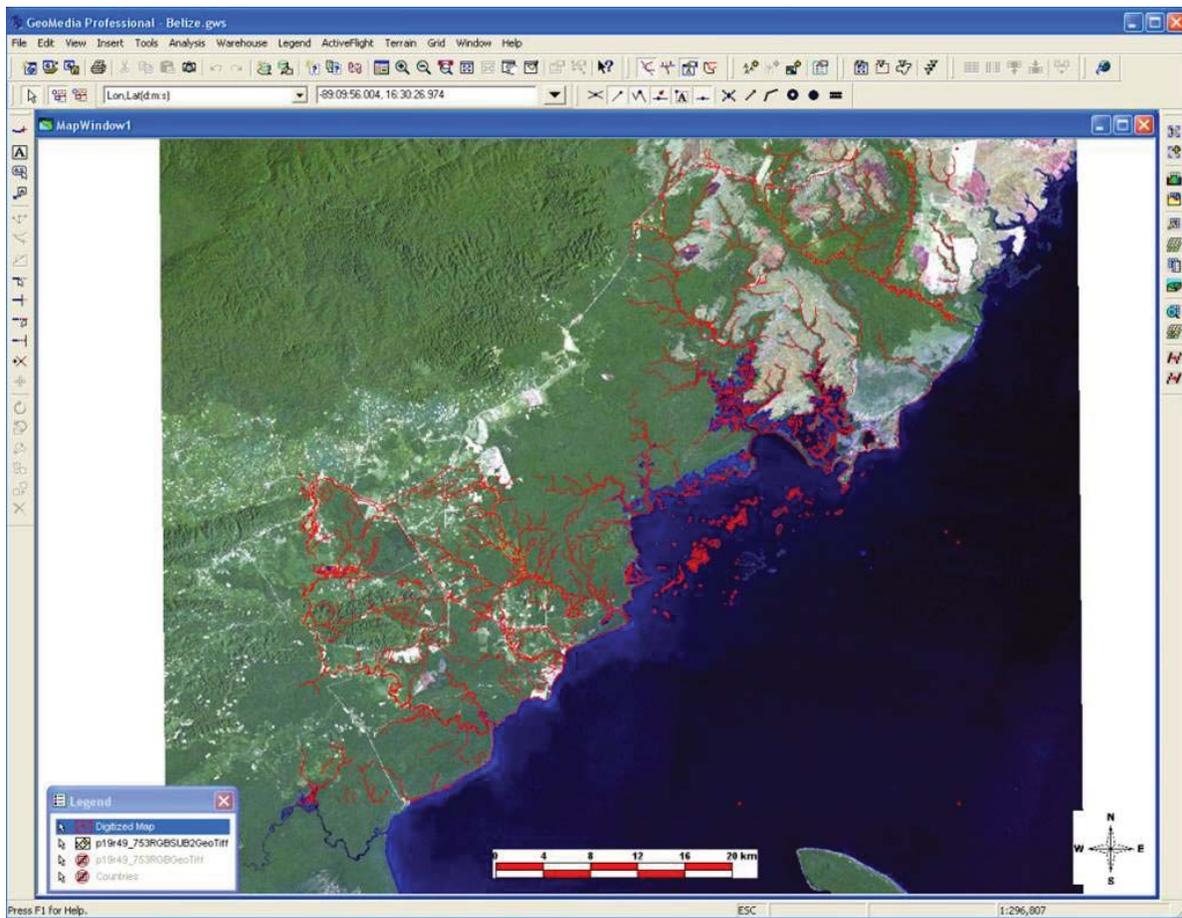


Figure 1. Satellite image of Gulf of Honduras used as a background for the Underwater Maya GIS for housing all spatial data from the archaeological research at the Paynes Creek salt works, Belize (Image courtesy Terrance Winemiller, Carnegie Explorer <http://geomaps.aum.edu/>).

with the UTM projection in the correct geographic zone--16 for southern Belize--forms the background for the mapped archaeological data (Figure 1). Additional images were scanned and attached to the GIS by "geo-referencing," in which common points were located on the scanned image and the satellite image. Several 1:50,000 scale topographic maps of Belize, as well as government air photos, were geo-referenced to the GIS. The images and maps provide a background that is useful at different scales of viewing because of the resolution of the images (number of pixels per square inch). Satellite imagery is useful at a large scale of the region. Air photos are useful at a medium scale of the lagoon system. Images from a low flying remotely operated plane taken

during fieldwork provide the highest resolution for individual sites.

The 1:50,000 Scale topographic maps available for southern Belize that had been scanned and geo-referenced within the Underwater Maya GIS, were "digitized," by tracing the outlines of the shorelines, rivers, and cays with a computer mouse using the GIS software. The vector data are stored as a separate image. The GIS allows stored images to be turned "on" or "off" within the viewing legend, so that the line drawing map was visible on the satellite imagery, for example. When zooming in closer to the lagoon system, the satellite image is turned "off," leaving the vector map. Zooming in closer to individual sites, the vector map is turned off, leaving the site data mapped in the field.

Fieldwork: Discovery and Mapping of the Wooden Architecture

The shallow Punta Ycacos Lagoon system within Paynes Creek National Park is surveyed by a team of archaeologists systematically traversing back and forth across sites, using snorkels and masks on Research Flotation Devices (RFDs). The team travels shoulder to shoulder, marking each post and artifacts of interest by wire flags, or in deeper water, using fish floats tied to fishing line secured to the seafloor by wire. Flags are labeled using a Sharpie marker, with the post or artifact number for later mapping. Some 4000 wooden posts were discovered protruding from the seafloor where the mangrove peat had preserved the wood since the Classic period use of the Paynes Creek salt works. The posts are grouped into separate sites defined by clusters of posts and associated artifacts visible on the seafloor, with areas between sites devoid of visible posts and artifacts.

We create permanent datum makers by pouring cement into a one meter hole with a PVC pipe. To map artifacts, posts, and features underwater, the prism pole person holds the prism pole over the object, levels the pole, and calls on a walkie-talkie to the Total Station person at a datum marker (Figures 2 and 3).

A Topcon 7005 Total Station, with a built-in Windows screen data recorder, is used for mapping. A folder on the Total Station data recorder holds data for each site, with feature records for information on posts, artifacts, artifact boundaries, bathymetry, shoreline, and site markers. Each feature record includes the x, y, and z coordinate data for a named point (post, artifact, shoreline point), as well as any additional information (post diameter, for example) entered into the Total Station during mapping. New feature records are created as needed. The feature record template is copied to folders for new sites instead of recreating the data entry form. The maps are visible on the Windows screen of the total station, which is useful for ensuring mapped data are correctly placed or if there are gaps in coverage of mapped shorelines, for example. Viewing the map as it is created allows the fieldwork to be interactive, by suggesting places to search for additional posts, such as looking for a fourth



Figure 2. Total station mapping at a permanent datum in Paynes Creek National Park (Photo by H. McKillop).



Figure 3. Student holding a prism pole on a wooden post for mapping (Photo by H. McKillop).



Figure 4. Total Station files are downloaded to a laptop at the Village Farm base camp and transferred to Excel files for attaching to the Project GIS, Underwater Maya (photo by H. McKillop).

post to square off a mapped pattern of three posts.

In the evening at the Village Farm project base camp, the spatial data are downloaded to a laptop as an “NEZ” file, using the Topcon 7005 Total Station transfer that also allows us to convert the NEZ file to an Excel file (Figure 4). The UTM coordinates of the datum marker (obtained from a GPS) are entered into the Excel cells for the datum marker, allowing all mapped coordinates to be converted to UTM coordinates (Figure 5).

	A	B	C	D	E	F	G	H
		NORTHING	EASTING	Z	Description	Diameter cm	UTM North	UTM East
1								
2	DATUM6	0	0	0			1800100.1	328699.31
3	NORTH	3.652	0	0			1800103.752	328699.31
4	1	139.964	32.065	-0.38	Hardwood	14	1800240.064	328731.375
5	2	140.049	32.006	-0.377	Hardwood	11	1800240.149	328731.316
6	3	139.899	31.864	-0.432	Palmetto	8	1800239.999	328731.174
7	4	140.568	31.476	-0.415	Hardwood	11	1800240.668	328730.786
8	A	141.504	33.279	-0.412	Artifact		1800241.604	328732.589
9	B	143.389	31.784	-0.417	Artifact		1800243.489	328731.094
10	B1	145.91	20.648	-0.389	Boundary		1800246.01	328719.958
11	B2	145.909	20.648	-0.383	Boundary		1800246.009	328719.958
12	Site_Mark	143.165	27.253	-0.35	Site Marker		1800243.265	328726.563

Figure 5. The downloaded NEZ (northing, easting, zenith) data from the Total Station are converted to UTM coordinates in Excel.

The Excel file is then linked to the Underwater Maya GIS by following several steps. First a new Access file connection is created in “Warehouse” called “all post data original.” In “View,” the “Coordinate System” is selected to choose the same projection system (UTM) as the GIS (Figure 6).

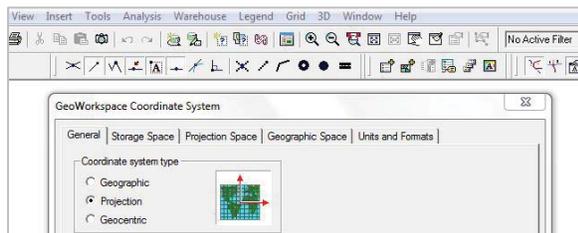


Figure 6. Setting the projection system of the map data as UTM to agree with projection of the GIS.

Under “Projection Space, “Universal Transverse Mercator” is selected under “Projection Algorithm” and under “Projection Parameters, “Northern Hemisphere,” and “Zone 16” are selected. After clicking “OK,” “Units and Formats” are selected on the “Geoworkspace Coordinate System” screen.

When a new screen appears, “distance” is selected under “type,” m under “units,” and 0.1 under “precision.” Clicking “okay” saves the coordinate data (Figure 7).

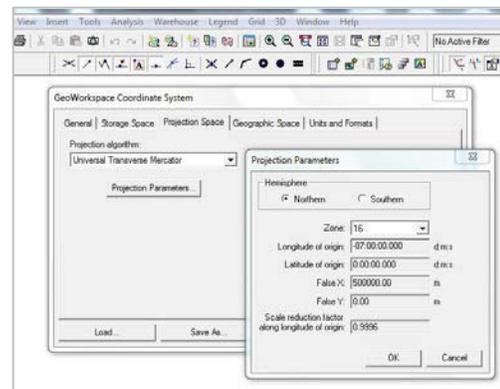


Figure 7. Setting the parameters of the map projection for map data.

The Excel file with mapped data is now linked under “Warehouse.” In “Feature Class Definition,” Excel 97 is selected as the file type (Figure 8). The excel file to be attached is located under “Browse,” in this case “posts all years.” The file name is highlighted in “source table” and moved to the “target table.” Clicking “okay” completes the attachment of the data file to the GIS. The excel spreadsheet is viewable as map data in the “Map Window” or “Data Window” in the “Windows” category. Data can be entered in the data window while Geomedia is in operation. The scale, legend and legend entries (including symbols on the map), and north arrow can be manipulated under “View.”

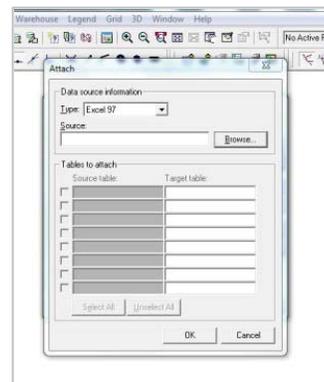


Figure 8. Attaching the Excel map file to the Underwater GiS under Feature Class Definition in the Warehouse category in Geomedia.

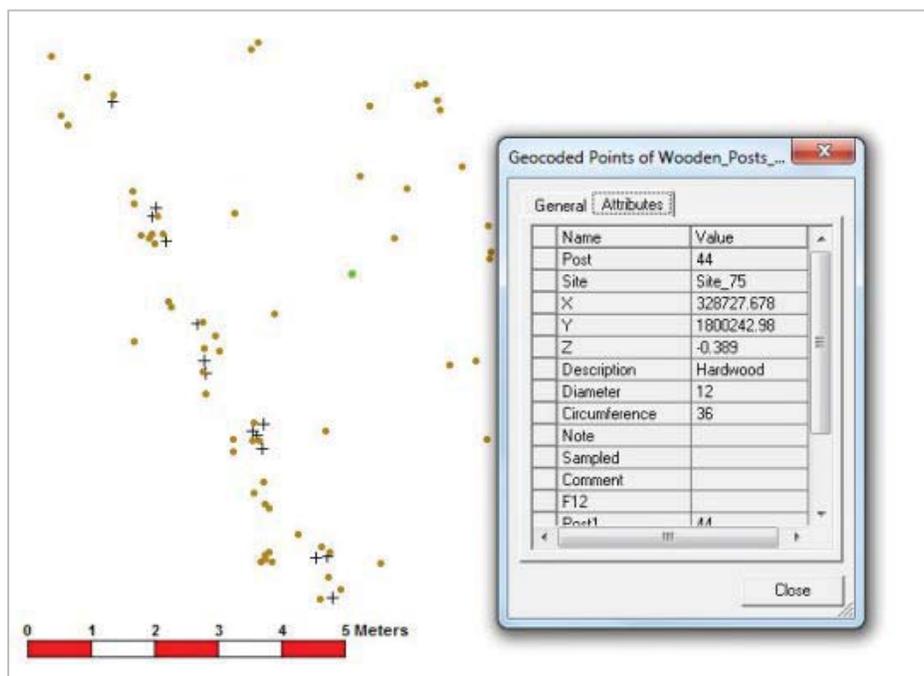


Figure 9. Clicking on a mapped point reveals a data window with the information about the feature from the attached Excel file.

Once the Excel file with data is linked to the GIS, the map is displayed in the Map Window. Clicking on a point, brings opens a window containing all information from the attached Excel spreadsheet about that point (Figure 9).

Each mapped artifact, post, or other feature—as well as any associated information—is referenced to the GIS by its UTM coordinate. As long as the link to the GIS remains the same, the Excel spreadsheet can be updated either in the GIS or separately. Post diameters, measured using a plastic covered cloth sewing tape underwater, are usually recorded in a waterproof notebook, with the data added to the Excel spreadsheet later. It is more time consuming to measure each post and add the diameter information during total station mapping. We usually create and keep the GIS on the C hard drive, so that the GIS and attached files can be easily moved to other computers, with the links to associated files remaining the same. The GIS automatically updates spatial data added to existing attached excel spreadsheets, which is useful for additional information on the dimensions of building posts, the types of

ceramics, and other descriptive data. Additional Excel or Access files can be linked. For example, the original data for a potsherd includes the location and artifact label. A new excel file with attribute analysis data can subsequently be linked to the original file.

Incorporating GIS in fieldwork allows us to study the maps created during the day's fieldwork and search the next day for new posts suggested by the spatial patterning. Since the sites are underwater with only the flags showing above water, printed site maps from the GIS were useful in examining the patterns of posts and searching underwater for additional posts. Patterns of wooden posts formed rectangular footprints of wooden buildings at some sites. Lines of palmetto palm posts define yards outside buildings. Printed maps are put in zip lock bags on clip boards for return trips to underwater sites to search for additional posts. This technique is quite successful. At Orlando's Jewfish Site (Site 58), a triangular arrangement of three posts became a square structure with the discovery of a fourth corner post. At the same site, two bracket shaped arrangements of posts facing one another at some distance became a

single large structure by searching the likely location of wall posts, which were discovered. Despite the efforts of a skilled team of surveyors, the wooden posts are difficult to discover since they barely protrude, if at all, above the seafloor where the mangrove peat preserves the wood.

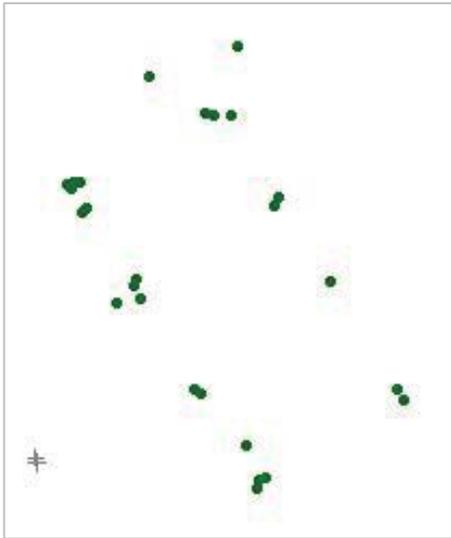


Figure 10. GIS reveals the footprints of a rectangular wooden building as recorded by mapped posts (Map by H. McKillop).

Using the GIS to Explore Architectural Patterns of the Wooden Buildings

The GIS is used to observe patterns, selectively display patterns, and manipulate spatial data. Clicking on a post, artifact, or other feature on the GIS map displays the attached data table. Although data are mapped and stored in one file for each site, all the post data are copied to a single excel file for ease of manipulation of the data. The grouped post data file includes the x, y, and z location as well as post diameter, type of wood (palmetto palm or solid wood), the condition of the wood, and whether a sample was cut for study.

The distribution of posts on the seafloor reveals patterns for individual structures, site patterns, and patterns for the salt works in general. There are rectangular wooden structures at 14 sites and rectilinear patterns of structures at many other sites. Some sites have more than one structure. The distribution of posts at Site 35 in the East Lagoon shows a clear footprint of a rectangular structure with distinct

corners (Figure 10). The building measures 3.4m by 7.6m, with an interior area of 24 sq m. The posts are clustered, with open spaces along the walls, suggesting that either that the wall posts were not dug into the ground (Wauchope 1938) or that the structure was open, with posts at the corners and along the sides to support the roof. The Site 35 building is oriented in a northwest to southeast direction, an alignment that is common at the Paynes Creek sites.

I can group post diameters by size ranges in the Underwater Maya GIS to discover patterns of construction. In the GIS Geomedia, under “Legends,” I can select the “add thematic legend entry” (Figure 11). Under “input feature,” I select “geocoded points of all posts.” Under “type,” I select “range thematic.” In “attribute for classification,” I select “diameter,” and click “classify.” In the new window “classification technique,” I select “equal range,” and leave the default number of categories as “4.” The window displays the minimum and maximum post diameter.

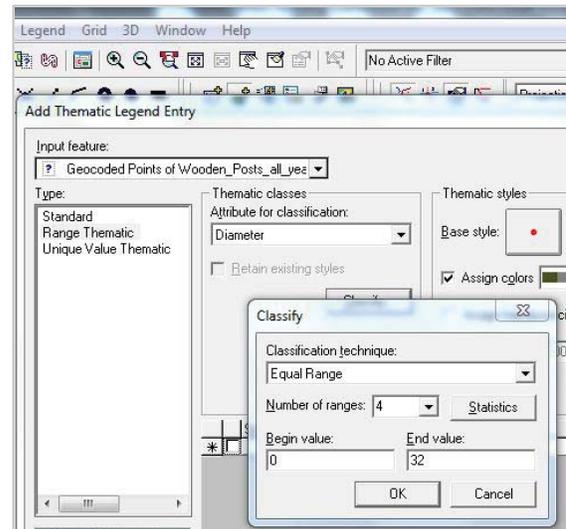


Figure 11. Grouping post dimensions by class intervals using the Thematic option under the Legends category in Geomedia.

When I click “okay,” a new window is displayed with the range data, including “style,” “begin value,” “end value,” and “label,” which can be modified in the table (Figure 12). For example, size, color, and type of symbol can be changed by clicking the displayed symbol under “base style.” In the new window, I select

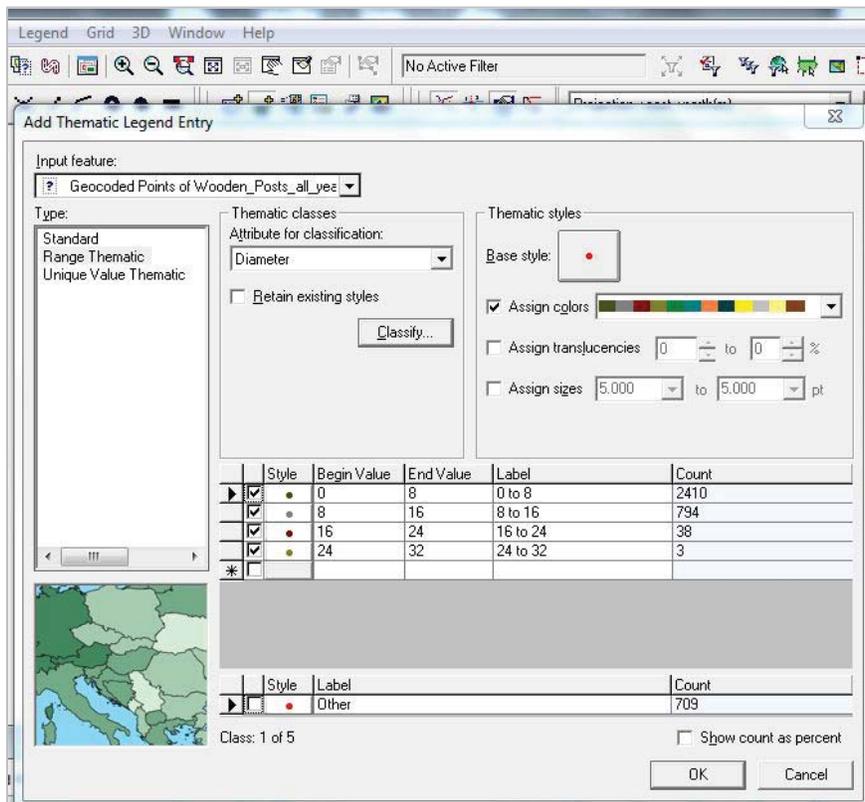


Figure 12. Changing the values of thematic ranges.

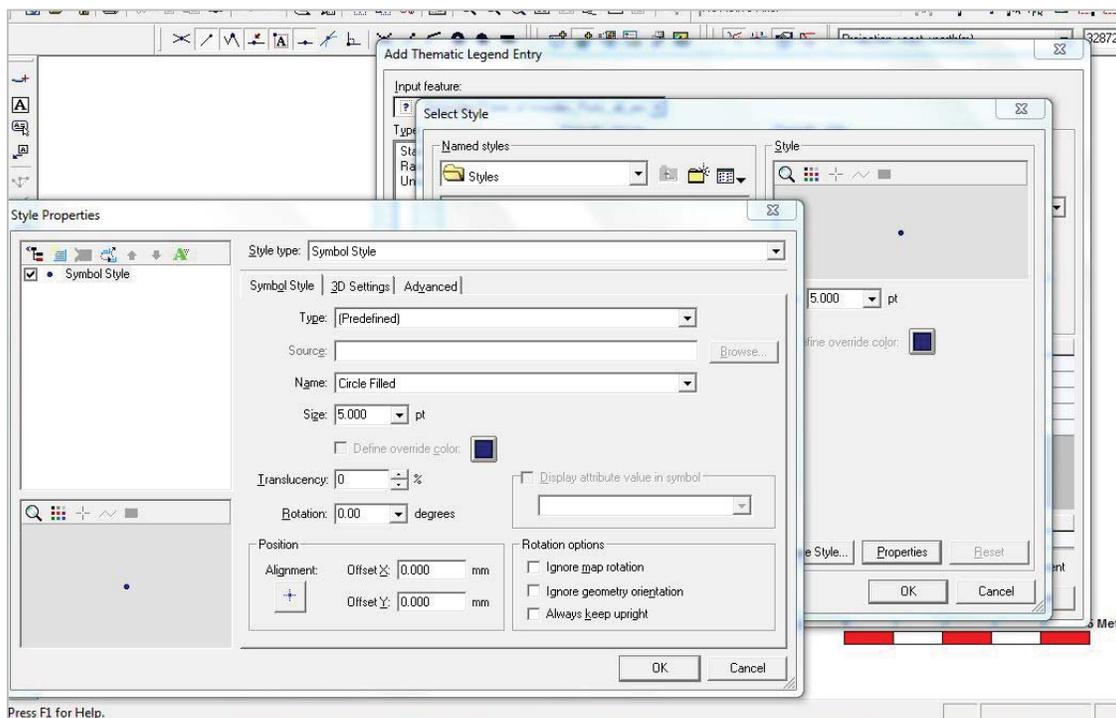


Figure 13. Changing styles and colors of symbols for the map.

“properties” and the “style properties” window appears (Figure 13).

I vary the post diameter ranges from equal numbers to selected ranges, including selecting the size ranges for building posts reported by Robert Wauchope (1938) in *Modern Maya Houses*. Grouping post diameters by the average size ranges reported by Wauchope (1938) reveals similar patterns between modern and ancient construction techniques. Larger, “load-bearing” posts are located in corners and exterior walls; smaller posts are located along exterior walls and inside structures (Figure 14). The same pattern is evident in the modern house image by Robert West (Figure 15). Some smaller diameter posts along the exterior of structures, such as the western side of the Site 75 structure, may be roof poles that supported the overhang of the thatched roof that extended beyond the exterior walls.

Modern Maya use different wood for various parts of buildings, such as corner posts and roof beams (Redfield and Villa Rojas 1962: 35; Wauchope 1938), so the occurrence of different kinds of wood in construction at the Paynes Creek sites is expected. Species identification of wood posts was begun in 2009 by project wood anatomist Mike Wiemann, continued as a PhD dissertation with a case study of Early Classic site 24 and Late Classic site 35 by Mark Robinson, and ongoing by the author, Robinson, and Wiemann.

Grouping all the wooden posts in one excel file facilitates spatial analysis of the entire lagoon system of 105 sites. The visible patterning of posts in the GIS reveals that there is no evidence at the Paynes Creek sites of plazuela groups--buildings arranged around plazas that were the building blocks of ancient Maya settlements, from public stone architecture in the center of cities down to modest household groups (Figure 16). Individual structures have a northwest to southeast orientation. Structures form lines, instead of grouping to form a central plaza. The linear settlement pattern may reflect structures located along shorelines that were flooded, so new structures were built farther away from the water on higher ground.

Structures closest to the water may have been salt works. Structures farther away may have been residences. Elsewhere, salt workers

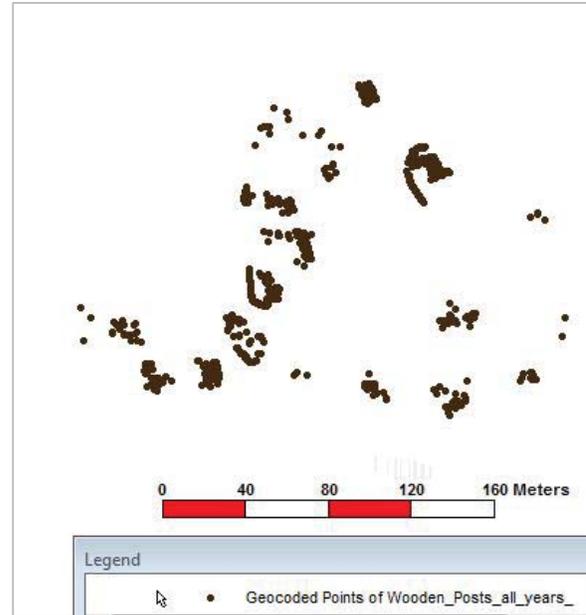


Figure 16. Linear Settlement Pattern of selected underwater sites in Paynes Creek National Park (GIS map by H. McKillop).

do not always reside at the salt works. In central Mexico, Parsons (2001) describes residences at some distance from the salt works. The location of the residences for the salt workers at the Zhongba site in the Three Gorges River area of China was unknown, perhaps flooded after the excavations of the salt works (Flad 2005). Salt workers who extracted salty soil from the salt springs at Sacapulus in the highlands of Guatemala had salt sheds near the salt spring with separate residences farther back (Reina and Monaghan 1981).

Information about the posts collected during underwater survey includes the type of wood, either palmetto palm or “solid wood,” and the diameters of the posts. Palmetto palm (*Acoelorrhaphe wrightii*) posts are easily identifiable from other “solid wood” posts. Evidently, the waterproof nature of the palmetto palm bark was regarded as making the posts useful for land-retention at the water’s edge. I use “range thematic” in “legends” to display palmetto palm posts versus solid wood posts (Figure 17). The lines of palmetto palm posts do not form polygons as would be expected if they were used to define the perimeter of an evaporation pan.

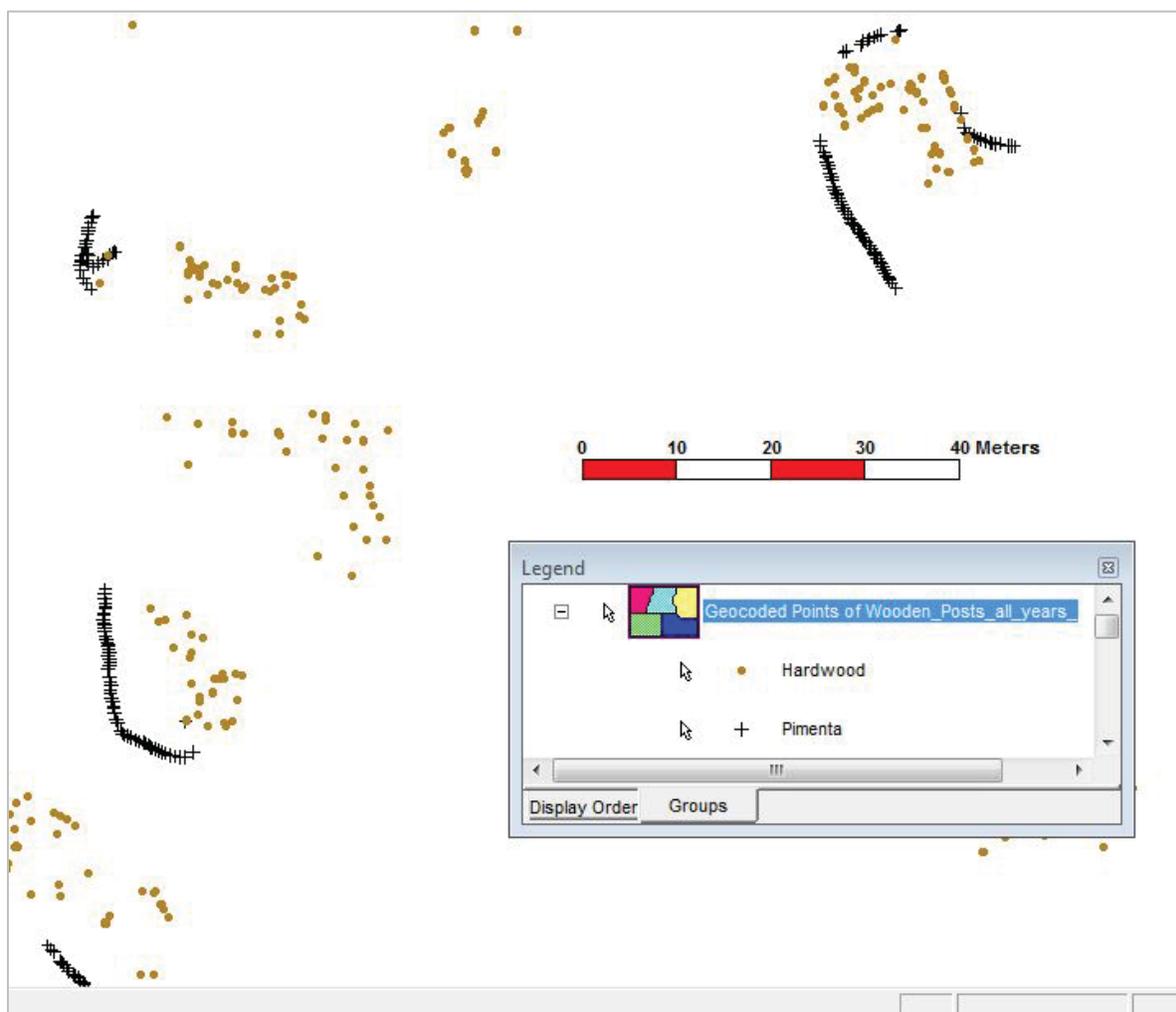


Figure 17. Using the Range Thematic option in Legends in Geomedia to display palmetto palm posts versus solid wood posts (GIS map by H. McKillop).

The spatial patterning of palmetto palm posts suggests they were used in land retention. Individual palmetto palm posts were incorporated into buildings at some sites, but this use was infrequent. Most of the lines of palmetto palm posts form curved lines, although at Site 103 there are four straight lines of posts, each including a corner. Two of the lines have right angle corners.

Ceramic Analysis Within the Underwater Maya GIS

Ceramics that are temporally diagnostic or otherwise informative of the salt industry are flagged and individually mapped using the Total Station. Type-variety and attribute analyses are entered on excel spreadsheets and attached to the

GIS: The excel file with the UTM coordinates of each labeled artifact sometimes is linked by using the identical artifact label on an Excel file with descriptive information. Sometimes it is easier to copy and paste the descriptive data into the Excel spreadsheet already attached to the GIS. The type-variety and modal analyses of Maya ceramics thereby becomes part of a spatial database, in which questions about the distribution and patterning of types, modes, vessel shapes or other descriptive data can be answered (Figure 18).

Ongoing GIS Analysis and Future Directions

A second project began in 2010 focusing on large-scale underwater excavations of selected salt works, sediment coring to collect



Figure 18. Underwater excavations yield large amounts of briquetage—pottery sherds, vessel supports, sockets, spacers, and amorphous clay lumps from the salt evaporation process by heating brine in pots over fires (photos by H. McKillop).

environmental data, and remote sensing in the shallow lagoon. Part of the ongoing research includes transforming the two-dimensional GIS into a three-dimensional world by extruding the posts from the ground. This collaborative research with Terrance Winemiller seeks to allow archaeologists to view the Maya salt works from the ground up instead of having artists' reconstructions. Geomedia Grid and Geomedia 3D are software components added to Geomedia that allow the creation of the three-dimensional world of the Paynes Creek salt works.

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