DOWN BY THE RIVERSIDE:
A LIDAR-BASED SETTLEMENT SURVEY IN THE BELIZE RIVER VALLEY

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ABSTRACT

DOWN BY THE RIVERSIDE: A LIDAR-BASED SETTLEMENT SURVEY IN THE BELIZE RIVER VALLEY

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This thesis focuses on the use of LiDAR (Light Detection and Ranging) technology in combination with traditional pedestrian ground survey methods to compare ancient settlement patterns and activity areas in contrasting environmental zones, alluvial floodplains and karstic hills, located in the upper Belize River Valley. The thesis also describes the capabilities and accuracy of LiDAR technology for use in settlement survey in tropical environments. Landscape Archaeology is used as the primary theoretical approach in the study, allowing an examination of human-environment interactions. Lithic and ceramic analysis from assemblages that were surface collected during the survey are also incorporated in our chronologic and activity centric conclusions for the surveyed settlements in study. LiDAR accuracy rates are examined to evaluate the technologies potential for future research in the area. The collected geospatial data obtained throughout this research contributes to a growing body of GIS sourced data in the Belize Valley Region and has the potential to inform future research and heritage management in similar geographic areas.
ACKNOWLEDGEMENTS

There are many people who I would like to thank, for without them the research project would not have been possible. I would first like to thank my committee. I would like to extend great thanks to Dr. Jaime Awe, my Chair. Without Dr. Awe’s guidance, support and enthusiasm my field work and research would not have been possible. Dr. Awe provided an insider's knowledge about the landscape, people, and history of the research area and was an invaluable resource. To Dr. Francis Smiley IV I would like to extend gratitude for his efforts in training and guidance in theoretical and practical applications of GIS. To Dr. Miguel Vasquez whose kind words and questions constantly reminded me of the human component of archaeology.

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Finally, I would like to thank the people of Belize and the people of San Ignacio Town. It is rare that I travel to a place and immediately feel at home and at ease, but the people I have met during my studies have been some of the friendliest and most welcoming people I have met during my travels. I do not know when I will be back, but I feel like I will always have a place in San Ignacio.

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To my friends, family and grandmother, thank you for supporting me during travels and research.
Chapter 1: Introduction and Background

The purpose of this thesis is to examine whether Maya settlement patterns were influenced by environmental conditions in the Belize River Valley. Specifically, the thesis seeks to examine whether there are any discernible differences in settlements within two contrasting environmental zones, alluvial floodplains and karstic hills, in the upper Belize River Valley. Furthermore, this thesis seeks to further test the benefits of using LiDAR survey, a GIS sensing and mapping system, in a rugged environment with heavy vegetation. I use the theoretical approaches of Landscape Archaeology, Political Economy, and Ideal Free Distribution to analyze and interpret differences in settlement patterns in two environmental zones.

Human settlements frequently occur in regions with varied environments, and different environmental attributes, such as temperature, elevation, soil types, mineral resources, access to water, and vegetation can vary within a few kilometers of each other. These differing environments offer human settlers different challenges and benefits and often influence where people choose to locate their permanent settlements.

The research presented in this thesis was conducted during the 2018 Belize Valley Archaeological Reconnaissance (BVAR) field season. The focus of the research was three-fold:

To determine if there are differences in ancient Maya settlement patterns in two differing environmental zones in the Belize River Valley: the alluvial floodplains to the north of the Cahal Pech site core, and the karstic hills found to the south of the ancient city
center. The differences can take the form of site placement, settlement density, and the activities occurring at the settlement.

1. To further test the capabilities of LiDAR technology in its application to settlement research in a rugged and thickly forested landscape by assessing the accuracy of LiDAR in the above mentioned environment.

2. To further fill in the gaps present in the settlement survey data around the site of Cahal Pech.

The theoretical and methodological approaches used for answering these questions are explained in detail in subsequent chapters. Chapter 2 also provides a brief background on the history of archaeological research in the Belize River Valley, particularly as it relates to settlement pattern study.

Background

The Belize River Valley region is in the Cayo district of western Belize. Located roughly 25 kilometers from the western border of Guatemala, the district is composed of a variety of environmental types, from swampy, alluvial soils to elevated, hilly karstic regions (Figure 1.1). Centered in the sub-region is the Belize river and its tributaries, creating rich, alluvial soils along its banks (Awe et al. 2014). The variety of environmental types in a relatively small and localized area creates an ideal location for comparative environmental studies, as locations a mere kilometer apart can be situated in drastically different terrain, as is the case with the landscape surrounding the site of Cahal Pech.
Figure 1.1: Map of the Belize River Valley with archaeological sites labeled. The Map also shows some of the LiDAR boundaries of the 2013 LiDAR survey. Map provided by Dr. Claire Ebert.

The environment surrounding the site of Cahal Pech is a combination of alluvial floodplains and karstic hills. The alluvial floodplains are frequently refreshed by the flooding of the Macal, Mopan, and Belize Rivers. The flooding deposits rich, fertile soils along the banks of the river, creating rich agricultural lands. The richness of the soils is exploited in modern times, as they support vast corn fields and orange orchards. The constant tilling needed to maintain the fields results in the turbation of the soil, which in turn results in the constant exposure of artifacts. The frequent flooding of the alluvial floodplains presents a problem for archaeologists, as in areas without frequent agricultural activity archaeological evidence is swiftly washed away or buried under
meters of deposited soil, leaving little to no evidence. The deposition is frequently mentioned as one of the difficulties present in settlement archaeology along river banks and has hindered archaeological research in alluvial environments (Turnbaugh 1978).

The karstic hills present a drastically different environment from the alluvial soils. Karstic terrain is characterized by extensive underground drainage systems in soluble rocks such as limestone, which result in the sinkholes and caves seen throughout much of the Yucatan Peninsula. In the hills, the limestone that underlies much of Belize lies much closer to the surface, forming rough outcroppings of stone in various places. The terrain and elevation changes create a rough, rolling landscape where farmable land competes with the land needed for structures. In modern times, development has pushed back much of the jungle in the karstic hills, though the hills in San Ignacio retain more jungle than the surrounding alluvial floodplains. The jungle flora, and relatively low levels of soil disturbance, results in a thick layer of humus on the surface where there are no rock outcroppings. The combination of these two features creates a difficult environment for traditional ground survey, as the plants obscure mounds and artifacts lying on the surface. In the bush, one could walk five feet away from a mound off trail and not notice. While recently developed for both residence and agricultural purposes, the rugged area provides an excellent environment for testing the use of LiDAR based survey in the analysis of ancient Maya settlement patterns.

The confluences of the Mopan and the Macal rivers mean that the area around the site of Cahal Pech forms a natural stopping point for travelers coming and going to the coast. The rivers use as a transportation route has noted up until modern times, and is still used for transportation today (Garber 2011).
LiDAR

LiDAR, or Light Detection and Ranging, is a remote sensing technology which, in recent years is slowly being more integrated into archaeological work. LiDAR works by using a fixed-wing aircraft mounted array of lasers and receivers in combination with geospatial sensors to create an extremely detailed digital map of the landscape (Figure 1.2). As the array performs a pass over the survey area, the lasers fire rapidly, recording the landscape below and creating a 3D point map, a 3D map created by data points recorded in the X, Y, and Z dimensions, from the information gathered. The collected points are then matched with geospatial data to create an extremely accurate and precise 3D map, which can then be further manipulated in various software’s, notably ArcGIS, a GIS software suite by ESRI which allows for the viewing and manipulation of spatial data. LiDAR can be particularly useful in environments with thick canopy, such as the rainforest, as the thorough nature of the scans allows the point map to be manipulated and the canopy stripped away, revealing the underlying landscape.
Figure 1.2: A Diagram on how LiDAR functions. The use of laser sensors and GPS data allows for highly accurate recordings of the landscape. Figure provided by Dr. Jaime Awe.

LiDAR offers an alternative method of survey which theoretically allows survey to proceed faster and more accurately than traditional ground survey, which relies on traveling by foot. The mounting of the array on airplane allows the surveyor to cover vast swathes of land in a short amount of time, bypassing the need for a surveyor to clear tracts of land for survey transects. While the precision and accuracy of the readings is sometimes in question, necessitating the in person verification of the sites existence, otherwise known as ground truthing, the use of LiDAR allows archaeologists to significantly increase the amount of land they can survey, offering a cheaper and less time-intensive method when compared to traditional methods.
As previously mentioned, LiDAR technology has only recently been applied to archaeological survey in the Maya area. The first application of LiDAR technology in Belize for archaeological purposes was done by Arlen and Diane Chase in 2009 at the site of Caracol, a site found in Western Belize. The study done by the Chases and their colleagues served to demonstrate the viability and value of the technology in a rugged and tropical environment (Chase et al. 2011). LiDAR technology has also been applied for archaeological purposes in tropical environments in several areas outside of the Maya region, such as Hawaii and Southeast Asia (McCoy et al. 2011; Evans et al. 2013).

More recently, BVAR Project archaeologists have employed LiDAR surveys at the sites of Baking Pot, Cahal Pech and Lower Dover (Awe et al. 2014; Ebert 2015; Walden et al. 2016). The past research in the region has demonstrated the potential of LiDAR in various applications such as settlement survey and quantitative analysis of archaeological features (Ebert 2017)
Cahal Pech

Figure 1.3: A LiDAR Image of the Cahal Pech site core. The surrounding modern-day town of San Ignacio can be seen in the borders of the image. The small bumps present in the image are LiDAR returns of the canopy.

The site core of Cahal Pech is found within the modern-day town of San Ignacio, in the Belize River Valley. The site core is on a summit overlooking the modern-day town of San Ignacio, providing a commanding view of the landscape around the site (Figure 1.3). The location of the site allows for a noticeable presence on the landscape, allowing the site to be seen from kilometers in any direction. Extensive excavations have been done in the last several decades in and around the immediate site core, primarily under the direction of Dr. Jaime Awe and the BVAR project.
Much of the site has been developed and encroached upon in modern times. The site core and monumental structures, however, have been converted into an archaeological reserve which is a major tourist attraction in the town. In contrast to the relatively untouched site core, the Cahal Pech sustaining area, the area which is occupied by a population which supplies both resources and labor to a center, encompasses two developed environmental zones, fertile alluvial bottomlands to the north and north east of the site core which are today mainly orchards and fields, and hilly limestone regions to the south and southwest of the site core, which have been have seen development in modern times for housing. The rolling landscape found in hilly regions, combined with the dense brush, makes traditional ground survey particularly difficult and time intensive, and thus makes Cahal Pech an excellent site for both a comparative study and test of the capabilities of LiDAR.

**Excavation and Survey History**

Extensive excavation and research at the site of Cahal Pech has only occurred relatively recently, despite the site being located in such a prominent place on the landscape. Early investigations at Cahal Pech were conducted by Linton Satterthwaite in the 1950s. Excavations recommenced at Cahal Pech in 1988 and have continued for the last three decades under the direction of Dr. Jaime Awe (Awe 1992). Despite the scale of investigation at the site core, the immediate hinterlands of the polity have been less intensely investigated.

The 1993 field report (Awe and Brisbin 1993) noted the difficulties of preforming survey in the region, as well as the impact that modern development has had and continues to have on the settlement groups in the area. Surveying began in 1989 with
the aim of creating the first comprehensive map of the Cahal Pech site core and to also create an area around the central structures for the creation of what is now the Cahal Pech Archaeological Reserve. In addition to creating the map, another goal was the recording of settlements found in the hinterland regions of Cahal Pech, as the settlements were rapidly being destroyed by modern development. The survey recorded features in an area roughly 1 km x 2.5 km from the Cahal Pech site core, resulting in 75 recorded groups, many of which are part of the “tail” seen in Figure 1.4 to the south of the Cahal Pech site core.

Little survey work was performed in the hinterlands of Cahal Pech after the 1989 survey was completed. Survey again began in the area in 2011 (Dorenbush 2012) with a focus on settlement groups in the southern periphery, as these were least disturbed by modern development, and continued into the 2012 field season. During the 2012 survey, efforts were focused to the northwest of the Cahal Pech site core, in the corn fields and orange orchards located in the alluvial bottomlands. The 2012 survey notes the presence of densely settled areas in these alluvial regions, with mounds being spread out evenly across the landscape. Dorenbush notes that this distribution is in opposition to the settlement distribution found to the south of the Cahal Pech site core, where settlements were less evenly distributed (Dorenbush 2013).
Figure 1.4: Map of the Cahal Pech sustaining area with survey areas included. In addition to this research’s survey zones, shaded in grey, mounds recorded in past surveys are noted in green. The redlines delineate the BVAR Regional Survey boundary.

Settlement Pattern Studies

Settlement pattern studies, studies focusing on the distribution, type, and use of human communities and networks, have a long history in the Western Belize River Valley, with the first known extensive survey undertaken by Gordon Willey between the years of 1955 and 1956. Willey’s work, as well as the work done by archaeologists such as Wendy Ashmore in the 1980’s, created the foundation of archaeological survey in the region, and ancient Maya settlements.
The research performed by Annabel Ford and the BRASS (Belize River Archaeological Settlement Survey) further expanded on the research done by Willey, particularly regarding Willey’s research on settlement placement between the alluvial floodplains and the surrounding hillsides (Ford and Fedick 1992). The BRASS project was developed to examine the connection between settlements and the settlements associated environment. To accomplish the research goals three major transects were plotted by the project, starting from the alluvial plains surveyed by Willey, and ending at the karstic hills further away from the river. In comparison to Willey’s survey, which found that the ancient Maya focused their activities in the fertile alluvial plains, the BRASS survey found evidence of Maya activities across both the karstic and alluvial landscapes. Furthermore, the BRASS survey found that the count of structures present in each structure group in the valley was markedly different then the count of structures found at structure groups associated with Tikal, only 80% of the then recorded structures consisting of one structure (Fedick and Ford 1990). The BRASS project and associated research continued for almost a decade and provided a wealth of information on both ancient Maya settlement in the Belize River Valley, and information for ancient Maya settlement on a wider, regional scale.

Since then, several other researchers (Awe et al. 2014; Awe et al. 2015; Driver and Garber 2004; Helmke and Awe 2012) have continued to build on Willey’s seminal work and have contributed significantly to our understanding of settlement systems in the lowland Maya sub-region. The Belize Valley Archaeological Reconnaissance Project in particular, has been working in the Belize River Valley since 1988, and has expended considerable effort to understand the role of Belize Valley centers in the political
landscape of the central Maya lowlands (see e.g. Helmke and Awe 2012). In 2014, Dr. Claire Ebert preformed a quantitative study of mounds in the Cahal Pech sustaining area. Ebert’s research further demonstrated the potential for LiDAR focused studies in the Belize River Valley and examined the potential for false positives when utilizing LiDAR data for survey.

**Established Typologies**

Past researchers in the lowland Maya region have established detailed typologies, or ways of categorizing and classifying data, to better describe the settlement features recorded in the region, and these typologies are used in this study. Researchers in the Maya area such as Wendy Ashmore and J.J. Ehret have determined minimum residential unit size, the minimum size needed for a structure to be deemed a residence, as well as the various types and spatial arrangements present.

The most prevalent form from the typology in the lowland Maya region is that of a courtyard group. Courtyard groups are groupings of 2-4 buildings spaced around a central courtyard. In a courtyard group, the buildings are often oriented in the cardinal directions, which structures placed to the North, South, West, or East around the central plaza. The minimum residential space required to be an ‘official’ courtyard group is set at 20 square meters, though this can be difficult to determine during survey if taphonomic events, such as bulldozing and plowing, level the structure or spread the structure across the landscape.

Courtyard groups often function as the basic unit of Maya residential housing, and several courtyard groups associated with one another are called clusters, which
have their own variety of forms and density levels. Group clusters can be focused around a specific courtyard or other type of structure, known as the focus. How the focus is determined is not always obvious, though attributes such as size and building purpose offer some clues on the matter. Building purpose, however, is difficult to determine in some cases without excavation, limiting the amount of useful information one can get from a survey.

Structures can also exist as singular entities, not appearing to be associated with any other structure in the immediate (within several meters) vicinity. Ashmore and others suggest that single structures could serve as shrines or other ancillary structures such as food preparation areas.

This typology was further expanded upon in the Belize River Valley by Ashmore and colleagues with the 1994 Xunantunich Excavation report, who utilized Ashmore’s previous work at the site of Xunantunich, a Maya site located to the west of Cahal Pech in the Belize River Valley and utilized a multi-tiered approach. In the multi-tiered approach, groups are categorized by the presence of a formal patio or courtyard, the number of mounds present, and the height of the mounts (Ashmore et al. 1994) The typology presents a total of seven type of groups, with the defining attributes of each type seen in Table 1.1.
Table 1.1 Group Typology as presented by Ashmore et al 1994.

<table>
<thead>
<tr>
<th>Group Type</th>
<th>Attributes</th>
</tr>
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<tbody>
<tr>
<td>Type I</td>
<td>Isolated mounds 1m or less in height.</td>
</tr>
<tr>
<td>Type II</td>
<td>Informally arranged patio groups or clusters of mounds 1m or less in height</td>
</tr>
<tr>
<td>Type III</td>
<td>Formally arranged patio group 1m or less, lacks a focal point.</td>
</tr>
<tr>
<td>Type IV</td>
<td>Structure-focused groups of 1-2m in height.</td>
</tr>
<tr>
<td>Type V</td>
<td>Group-focused clusters of low to moderate height with at least one formal group on a platform.</td>
</tr>
<tr>
<td>Type VI</td>
<td>Formal patio group with platform and mounds 2-5 meters high.</td>
</tr>
<tr>
<td>Type VII</td>
<td>Formal Patio group with platform and focal mounds 5 meters or greater in height.</td>
</tr>
</tbody>
</table>
Chapter 2: Theoretical Approaches to the Survey

The theoretical framework of Landscape Archaeology offers a variety of advantages to a survey-based research project. While definitions for Landscape Archaeology differ from archaeologist to archaeologist it can be broadly defined as the examination of cultural or environmental variables that influence the way humans interact with the surrounding environment, and the impact that the environment has on human actions (Hu 2012).

Landscape Archaeology has its origins in the 1920’s and it became increasingly popular during the 60’s and 70’s with the advent of the New Archaeology movement. Landscape Archaeology straddles the line between the two schools of processual and post-processual thought as both sides differ on the concept of what a “landscape” is. In this research project, Landscape Archaeology provides a theory which allows the pairing of ‘hard’ spatial data with ‘soft’ concepts such as contextual landscape interaction and interpretation, where the landscape is experienced and dynamic (Hu 2012). Landscape archaeological theory integrates smoothly with settlement research as it provides a ready framework for the integration of GIS, Global Information Systems, and LiDAR technology, and allows for easier viewing and manipulation of archaeological recovered data and archaeologically significant landscapes.

Much of modern Landscape Archaeology is heavily reliant upon spatial data and GIS as the technology and data presents the possibility of revealing much more of the landscape to a researcher than could normally be seen with traditional survey methods (Awe et al. 2015; Chase et al. 2011; Connolly and Lake 2006). The reliance on GIS has increase drastically over the years as the technology has developed, reaching a point...
where some authors such as Hu and Wise have suggested that GIS is now having as
much as an impact on anthropological theory as the introduction of carbon dating had
(Hu 2012; Wise 2000). In addition, Landscape Archaeology theory focuses on the
cultural or environmental variables that influence humans. In regions of the world with
varied environmental zones, such as in Belize, Landscape Archaeology offers a
framework to examine the different impact the environmental zones might have had on
human settlement placement and planning, something which has been examined
without GIS systems in the past with work of Willey and Ford (Ford and Fedick 1992;
Willey 1965)

The concept of landscape and its importance to the people living on the
landscape is already well known in the study of the Maya. Ashmore (2004) notes that
the importance of landscape in Maya cosmology, with each of the domains having
associated landscape features. Furthermore, Ashmore discusses the use of natural
landscape features into Maya settlement planning and construction, noting that
structures would be built on natural rises in the terrain to emphasis the height of
structures. Furthermore, the placement of keys structures and settlements on high
points on the landscape grants the inhabitants and structure users a commanding view
of the landscape. Finally, Ashmore also remarks on how the availability of food or water
sources in a landscape can shape and define settlement, constraining the choices that
can be made.

As mentioned in the background chapter, Landscape Archaeology and LiDAR
have been used in past research in Belize. The Chases and their colleagues research
at the Caracol archaeological project have tied together LiDAR and the landscape
perspective, using LiDAR to look at large swathes of forested land surrounding the site of Caracol so that they may better understand how the ancient Maya use and view their landscape (Chase et al. 2009; Chase et al. 2011).

Other archaeological theories such as political-economy theory is useful for exploring alternative hypothesis for settlement placement, such as the hypothesis suggesting the need for arable agricultural land being a deciding factor, or nearness to possible trade routes. Political economy theory combines well with some aspects of Landscape Archaeology, notably the impact of the landscape and how the landscape impacts economic choices and responses. Prior research along these lines has been performed in Belize by Vernon Scarborough and Fred Valdez in the Three River Region (2003). Scarborough and Valdez’s research examined what they termed resource-specialized communities, communities which specialized in the production of local resources and traded for what they needed. The environment of the resource-specialized communities limited the resources available for exploitation.

Communities that also were located near environmental features which could foster trade routes, such as rivers and coasts, might have also acted as important trade nodes which allowed the communities to more easily import resources which could then be traded to other, less advantageously located communities who might otherwise have limited access to the resources. In this way, the communities might not be limited in the exploitable resources.

The above-mentioned approaches pair well with each other, and ultimately play an important role in the Ideal Free Distribution Model, which is described in the following section.
Ideal Free Distribution

The Ideal Free Distribution Model is a concept borrowed from the biological sciences, specifically those that deal with animal populations and migration. The model stipulates that as humans move into a new environment they will settle in ideal “first rank” areas, or habitats. As these areas become more and more densely populated and more competitive, newly arrived individuals will settle in areas that are less populated but that also possess fewer desirable features. Despite the other areas lacking in desirable resources, the lack of competition for these resources allows for roughly the same amount of return for the newly arrived inhabitants as they would if they would have to compete for the resources in the more densely populated areas (Moritz et al 2014).

The desirable features in question vary from environment to environment and from culture to culture, though some basic needs such as access to a food and water source are likely universal commonalities. Culturally specific desirable features such as the features mentioned by Ashmore above as being associated with Maya cosmology, such as hills and subterranean features, likely played a role in ancient Maya settlement patterns, as in areas without these features great effort was made to replicate them, in the form of structures or artificial caves (Stuart 1997) (Brady 1992). Other ideal features, from both an economic and subsistence perspective would be rivers and other navigable waterways as the waterways would allow greater trade access, as well as food and water.
Survey Predictions

The theoretical approaches chosen, paired with knowledge of the ancient Maya worldview, allow for certain predictions to be made of the survey results. The Ideal Free Distribution Model suggests that as people move into a region the people will settle in ideal locations. The ideal locations can be identified by understanding how the ancient Maya viewed and used certain landscape characteristics, such as hills and rivers.

I predict the alluvial floodplains will act as an ideal location for settlement in the region. As previously mentioned, the floodplains are easily accessible by the rivers which act as a major transportation route in the region, and settlement of the region might have begun in the alluvial areas because of the ease of access. Excavations would be needed in order to obtain concrete temporal evidence to support the beginning of settlement in the region, however. The ready access to rivers would in turn allow for greater access to trade and exotic goods. Furthermore, the river would provide a source of freshwater and food in the form of fish, clams and jute (freshwater river snails) for the nearby inhabitants. In addition, the rich, deep soils in the area would allow for intensive agricultural production in the alluvial zone, including the farming of the cacao trees which rely on deep, fertile soils. Finally, the relatively flat land will allow for greater settlement density, as land use will not be as heavily restricted by the terrain as compared to the karstic region. Dorenbush noticed similar distribution trends in her 2012 survey of the region, where the recorded structures were spread out over the landscape (Dorenbush 2013). With the features mentioned above, the alluvial region contains many features which the Maya would have valued and wished to exploit.
In the karstic zones, I predict settlements will likely be concentrated on hill tops, the hilltops being an ideal location in the karstic zone for reasons I will explain next. The hilltops provide several key benefits when compared to the inter-hill valleys present in the karstic zone. First, the elevated position would allow for better viewing of the surrounding landscape, allowing one to survey the surrounding area for dangers or other threats. In addition, the elevated position would allow for better temperature regulation as the inhabitants would be more exposed to cooling breezes, a great boon in the otherwise stifling heat present in the region during the dry season. The concentration on hilltops would also allow the hillsides to be used for terracing, maximizing the otherwise limited agricultural land found in the karstic zone. As previously mentioned, hilltops have also been used by the Maya to emphasize the height of structures, which suggest that any large structures found in the region would be located on the hilltops. Finally, settlement in karstic zone might be less spread out across the landscape, another trend seen by Dorenbush during the 2012 survey and one that can be possible explained by the limited space and difficulty in traversing the hills when compared to the flatter alluvial floodplains.

The predictions laid out above will be returned to in the conclusion section of this thesis, to assess the predictions accuracy.
Chapter 3: Research Methods

The research methodology for this paper is broken into three separate sections, with each section corresponding to a separate phase of my research. The three phases present are my preliminary analysis, which focuses on the work done prior to the research in the field. The second phase is the field research performed during the 2018 BVAR field season where data collection and some lab analysis was performed. Finally, the post-field analysis after the field seasons focuses on further lithic and LiDAR analysis and manipulation.

Field Methods

The preliminary analysis was focused on the LiDAR data collected during the 2013 Western Belize LiDAR Survey which was performed by Dr. Jaime Awe, Dr. Arlen Chase, Dr. Diane Chase, and colleagues. The preliminary stage was focused on locating possible settlement and courtyard groups in the survey areas outlined previously in the thesis. Analysis primarily used the ESRI ArcGIS software suite, primarily the ArcMap visualization and editing program. LiDAR datasets consisting of high quality .TIF image files were uploaded to ArcMap, geospatially adjusted and paired with a map of the Belize River Valley, and visually examined. Emphasis was placed on areas of high elevation and “vista points” which overlooked important sites or valleys. These viewed areas were then marked in ArcMap and their geospatial position logged and transferred to a GPS, or Global Positioning System unit, so that they could be ground-truthed during field research. A LiDAR base map was also added to the GPS unit to allow for “on the fly” course corrections and adjustment if difficulty was
experienced during the survey attempts. In instances were initial ground truth proved unproductive this allowed for more effective use of the crew's time and efforts.

Settlement Group Methods

Field methodology consisted of traditional pedestrian ground survey, though the survey areas were informed by the prior LiDAR data analysis mentioned above. Areas marked in the prior stage of research were traveled to and the existence of sites of archaeological significance was either confirmed or found to be a false positive. Once at the site the dimensions of the courtyard groups or singular structures were measured, and the groups mapped using compass-and-tape methods. A datum was set for each structure and a GPS point taken at the datum then, each corner of the structure was identified, and marked and a bearing and measurement taken of the corner from the datum. This would continue until all corners of all structures in a courtyard group were recorded, using the same datum for same courtyard group structures to maintain the proper orientation of the structures within the group. The number of structures present in the courtyard group, their individual size and orientation to both the cardinal directions and other structures in the group were also recorded. Finally, the elevation of the courtyard group mound was measured and recorded when possible. The recorded information was then used to draft a plan view map of the courtyard groups.

Site disturbances, such as plowing, bioturbation, or construction were recorded by both type and extent of disturbance present. Finally, a short descriptive statement was written for each courtyard group while the crew was still there, focusing on the environment type and location, and an assessment was made to see if the site would be suitable for a test pit to allow for more detailed data collection and analysis for future
research. If a prospective site turned out to be a false positive, being a tree fall or modern-day structure, the site in question was flagged and a short description made for it, describing the initial hypothesis for the site and the result.

**Surface Collection Methods**

Surface collection methodology in the field consisted of the crew walking spaced transects across the courtyard group, collecting or flagging any artifacts discovered as the crew went through the courtyard group. In some instances, the “smear” of cultural materials left after a courtyard group had been plowed or bulldozed allowed for the cultural materials association with a courtyard group, and in the above-mentioned instances similar transect and flagging methods were used. Diagnostic ceramic sherds, ceramic sherds which inform an archaeologist about style and vessel form, were the primary focus of the survey. Survey efforts attempted to collect a minimum of 30 diagnostic ceramic sherds from each surveyed group, with the possibility of more being collected based on sherd abundance and time constraints. The collection of 30 diagnostic ceramic sherds provides the minimum number needed for a statistically significant sample size and allows another avenue of comparing the settlement groups and the two environmental zones.

Lithic tools and debitage were also identified and collected during the survey, while larger ground stone tools such as manos and metates were identified and recorded and were initially left in situ before being collected later in the survey, as BVAR project needs and this paper research needs changed. The collection of obsidian blade shards, the shards of obsidian created when an obsidian blade tool shatters, became a focus during lithic collection due to both project and research needs, as the quantity of
shards found during survey raised additional questions about the activities present in the environmental zones. Other cultural materials associated with ancient Maya settlement, such as daub, a clay material used in the construction of waddle and daub housing where clay and wood are used to create structures, were collected when the pieces present were large enough, being two or more centimeters in size.

All artifact types associated with the site were recorded in a field journal, a lab journal, and in the field and lab forms provided by the BVAR project for the 2018 field season to create a comprehensive list of cultural materials recovered. After surface collection and mapping, the courtyard groups were recorded into a Garmin GPSMAP 64s GPS/GLONASS unit and assigned a surveyed group, or SG, number. Surveyed groups are numbered in order of discovery and time of recording, and were grouped by which survey region they were found in. 31 structures are in the alluvial flood plains adjacent to the Macal River while the subsequent surveyed groups are found in the karstic hills to the south of the Cahal Pech site core. Each surveyed group was also assigned a trinomial prefix, associating the surveyed group with the BVAR project, the year, and the nearby Maya major center of Cahal Pech, to allow for the distinguishing of the collected survey data from others.
Lab Methods

Lab analysis focused on the identification and measurement of collected lithic assemblages and the identification and typing of the collected diagnostic ceramic assemblages utilizing the type-variety-mode system of analysis commonly employed by archaeologists working in the Belize River Valley (Sablof 1975; Gifford 1976). All information collected was recorded into a lab journal and recorded into the relevant BVAR project artifact logs and data base.

Ceramic

Ceramic types and groups were identified using James Gifford’s *Prehistoric Pottery Analysis and the Ceramics of Barton Ramie in the Belize Valley*, and in Sablof’s (1975) study of ceramics at the site of Seibal, Guatemala. Because most of the ceramics in this study were recovered on the surface, the sherds were generally weathered and poorly preserved. For this reason, the study often relied on form attributes for establishing our typology. When a ceramic sherd could not be assigned a specific type due to extreme weathering, a ware type, based on technological attributes, was assigned instead. In the absence of any identifiable information for ceramic ware type, the sherd was marked as unknown. Rim profile analysis was used to identify vessels for diagnostic sherds. All rim sherds were viewed in profile and the sherds lip form and angle were used to discern vessel shape. In cases where the sherd was too fragmentary to discern the vessel form, the sherd was marked as an unknown. Lastly, other diagnostic features, such as glyphs or designs were recorded in the laboratory ceramic log, with notable sherds being placed in a separate bag within the main courtyard group bag to allow for easier finding and examination later.
Table 3.1 Ceramic Types by Time Period

<table>
<thead>
<tr>
<th>Preclassic</th>
<th>Classic</th>
<th>Post Classic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jenny Creek</td>
<td>Floral Park</td>
<td>New Town</td>
</tr>
<tr>
<td>Barton Creek</td>
<td>Hermitage</td>
<td></td>
</tr>
<tr>
<td>Mount Hope</td>
<td>Tiger Run</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Spanish Lookout</td>
<td></td>
</tr>
</tbody>
</table>

Lithics

The lithic typology and identification methods followed the methodology described in the BVAR field manual and supplemental lithic identification sheet. Collected lithics were washed in the lab using water and gentle cleaning with a toothbrush to remove dirt and other debris. Once cleaned, lithics were identified by form attributes to determine tool type and possible function, and this information was logged and recorded in the project’s data base. The dimensions of the lithics in the assemblages were measured and the descriptive qualities of the artifact recorded, focusing on color, texture, wear, and the presence of diagnostic features such as platforms or shelves. Lab photos were taken of each identified lithic item to record for posterity and for further identification in the future, with copies of the photos submitted to BVAR and kept for the author’s records.
Chapter 4: Survey Results and Analysis

The following section discusses the results and subsequent analysis of the field research. The section is divided into subsections focusing on settlement groups and on the cultural remains associated with each settlement.

Settlement Groups

The section of Cahal Pech covered in this survey recorded a total of 62 settlement groups (Figure 4.1). Half (31) of the settlements were found in the low-lying alluvial zone along the Macal river to the north of the site core, while the other 31 groups were in the karstic hilly zone, south of the site core. In both environmental zones, extreme site erosion and destruction was noted, either because of modern agricultural activity such as plowing in the north, or natural bioturbation and bulldozing for modern housing construction in the south. The destruction was particularly notable to the southeast of the site core, as much of this area appears to have been repurposed for either cattle pasture or modern residences that have resulted with the destruction of archaeological features.
Figure 4.1: LiDAR imagery overlaying satellite imagery showing surveyed groups and survey regions. The overlay allows the topography and environment to be easily seen and allows for a better understanding of the positioning of the structure groups than could be offered by a grey-scaled LiDAR image or by flat satellite imagery.
Despite over a millennium of agricultural activity, the settlement groups located in the alluvial zone are still identifiable on the landscape when the fields lie fallow. The groups located in the alluvial flood zone appear to be more densely clustered than groups found in the karstic zone. Almost all the surveyed settlement groups were found within a kilometer of one another (See Figure 4.2), and there is some evidence the settlement groups continue to the west, though during the time of survey the region to
the west appeared to have become a seasonal swamp as a result of the rainy season and was impassable. The intense agricultural activity the zone has experienced has eroded many of the mounds, leading the mounds to look like slight rises in the landscape (Figure 4.3) and (Figure 4.4).

**Figure 4.3:** A LiDAR profile view of SG-7. SG-7 is also located in one of the orange orchards in the alluvial zones. Having experienced the effects of centuries of agricultural activity and flooding, many of the mounds in the alluvial zone are mere rises on the landscape.
Figure 4.4: A LiDAR profile view of SG-48. SG-48 is also located in along the northern edge of the survey zone, along the Mopan River. The mound is somewhat more apparent on the landscape than others in the region, likely because the mound is located outside the nearby fields.

Settlement groups in the alluvial zone appear to have been more affluent and prosperous, with numerous structures present in each group (SG-2, SG-7, SG-8, SG-9, SG-12, SG-13, SG-14, SG-16, SG-17, SG-23). Many of the settlement groups examined appear to have consisted of two or more structures placed around a central courtyard. In addition, one settlement group, SG-17, located an orchard near the confluence of the Macal and Mopan Rivers, presents some evidence of being an elite household group, being of a relatively large size, and having what appears to be a secondary adjacent structure attached to the primary one (Walden 2018). SG-17 is notable both due to the height of the structure (Figure 4.4), being 3.18 meters tall, and its possibly association with the nearby courtyard groups. SG-17 is possibly associated with SG-23 to the west, which consists of two rectangular structures perpendicular to one another forming an ‘L’ shape. SG-17 has several looters pits located on the top of
the structure, though conversations with the local field hands revealed the looters were
captured and arrested quickly, though it is unknown by the author what, if any artifacts
were recovered.

Another courtyard group of note in the alluvial zone is SG-25, located along the
western edge of some cornfields, before they terminate in a steep slope and flooded
swampland. SG-25 appears to be three structures cardinally surrounding a central
courtyard, with the open 'space' being to the west. The open space terminates into the
steep slope that delimits the farmland from the swamp and offers a fairly good view of
landscape to the west.
Figure 4.5: SG-17 looking west from the base. SG-17 is one of the tallest features in the area, though the orange orchard obscures easy comparison. On the southside of SG-17 is SG-23, which might form part of the same cluster.

Figure 4.6: A LiDAR profile view of SG-17. The brown points in the image are trees and other vegetation from the orange orchard, while the pink points represent the ground and mound. As can be seen, the mound is quite notable on the landscape.
Figure 4.7: The karstic survey zone. As can be seen, the karstic zone features spares, hilltop focused groups. The Cahal Pech site core can be seen to the upper right of SG 33, near the center of the image.

Even with the assistance of LiDAR, the karstic zone proved to be a difficult section to survey due to the presence of thick secondary vegetation and the hilly terrain. Despite the difficulties, however, 31 groups were recorded during the survey (See Figure 8). The courtyard groups in the karstic zone appear more spread out when compared to those found in the alluvial zone, as the settlements in the karstic zone...
appear to be concentrated at points of high elevation related to their surroundings. The placement of courtyard groups on the summits of hills would also allow for the agricultural use of the valley, where soils are deeper and more suitable for farming.

In comparison to the settlements in the alluvial zone, the surveyed settlements in the karstic zone seem less affluent, mostly consisting of single mounds in contrast to the of multiple mound groups found in the alluvial region (See Figure 9). Groups with multiple mounds present in the area are mostly found in the southwest region of the karstic zone survey area. Formal courtyard groups were also more prevalent in the alluvial zone.

Further difficulties were caused by the ongoing development of the region, leading to the LiDAR imagery showing several courtyard groups to the southeast of the site core which are no longer present, being destroyed by modern land development.

One interesting courtyard group found during survey in the karstic zone is SG-46, which is located on a small hill in the western portion of the karstic survey zone. SG-46 appears to be a Tier 1 group and is associated with a nearby chultun, a chultun being a small plaster lined storage space constructed into the ground. (Figure 10). SG-46 is possibly part of a larger settlement group, but the tree density on the hill during the survey made a more thorough examination of the area difficult.
Figure 4.8: Comparison of the number of structures seen at each group between zones. The alluvial zone had more multi-structure groups than the karstic zone, which was predominantly Type I Groups.

Table 4.1: Group Type Totals for Survey

<table>
<thead>
<tr>
<th>Survey Zone</th>
<th>Type I</th>
<th>Type II</th>
<th>Type III</th>
<th>Type VI</th>
<th>Total Groups</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alluvial</td>
<td>15</td>
<td>6</td>
<td>9</td>
<td>1</td>
<td>31</td>
</tr>
<tr>
<td>Karstic</td>
<td>25</td>
<td>4</td>
<td>2</td>
<td>0</td>
<td>31</td>
</tr>
<tr>
<td>Total</td>
<td>40</td>
<td>10</td>
<td>12</td>
<td>1</td>
<td>62</td>
</tr>
</tbody>
</table>
Figure 4.9: An exterior shot of the chultun associated with SG-46. The chultun was empty of cultural materials and only had a few scattered leaves and branches that fell in

The settlement cluster consisting of SG56 through SG62 was another notable find during the survey. The settlement group appears to be located on what is now an abandoned tilapia farm, a form of modern aquaculture common in Belize, located along the flanks of a small hill in the western portion of the karstic survey area, according to my work crew and based on the type of debris left behind. The courtyard groups and
structures are clustered close together, and several of the groups (SG-55, SG-57, SG-59) contain evidence of multiple mounds which are uncommon in settlement groups recorded in the karstic survey region.

Cultural Materials

Ceramics

Ceramic materials formed the basis of the chronologic analysis for the survey. Over the course of the field season 731 ceramic sherds were collected primarily from surface deposits and consisted primarily of rims and other diagnostic sherds. Ceramic rim profile and ware analysis points to the Terminal Classic occupation of both settlement zones, with the ceramics from the Spanish Lookout ceramic complex dominating the collection and forming 71% of the sample. Roughly 20% of the sample was unidentifiable due to severe weathering and slip erosion. The remaining percentage of the ceramics appear to be from a mix of New Town, Hermitage, and Jenney Creek group ceramics.
Table 4.2: Ceramic Sherds by Complex

<table>
<thead>
<tr>
<th>Ceramic Complex</th>
<th>Sherds Found (Alluvial)</th>
<th>Sherds Found (Karstic)</th>
<th>Percentage of Sample (Alluvial)</th>
<th>Percentage of Sample (Karstic)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spanish Lookout</td>
<td>353</td>
<td>169</td>
<td>72%</td>
<td>69%</td>
</tr>
<tr>
<td>Tiger Run</td>
<td>15</td>
<td>12</td>
<td>3%</td>
<td>5%</td>
</tr>
<tr>
<td>Barton Creek</td>
<td>9</td>
<td>2</td>
<td>2%</td>
<td>&lt;1%</td>
</tr>
<tr>
<td>Floral Park</td>
<td>5</td>
<td>1</td>
<td>1%</td>
<td>&lt;1%</td>
</tr>
<tr>
<td>Hermitage</td>
<td>10</td>
<td>1</td>
<td>2%</td>
<td>&lt;1%</td>
</tr>
<tr>
<td>Jenney Creek</td>
<td>2</td>
<td>1</td>
<td>&lt;1%</td>
<td>&lt;1%</td>
</tr>
<tr>
<td>Mount Hope</td>
<td>1</td>
<td>0</td>
<td>&lt;1%</td>
<td>0%</td>
</tr>
<tr>
<td>New Town</td>
<td>11</td>
<td>3</td>
<td>2%</td>
<td>1%</td>
</tr>
<tr>
<td>Unknown</td>
<td>89</td>
<td>54</td>
<td>18%</td>
<td>22%</td>
</tr>
<tr>
<td>Totals</td>
<td>487</td>
<td>244</td>
<td>100%</td>
<td>100%</td>
</tr>
</tbody>
</table>

A small number of polychrome sherds were present in the sample, including several specimens with glyphs or pseudo-glyphs. Several modified octagonal ceramic sherds (See Figure 4.9) were collected in the karstic zone of the survey and were marked as special finds for future examination. Most of the polychrome sherds in the collection were collected in the alluvial region, though this is likely due to a combination of the sherds being easier to see in the plowed fields as well as the sherds being less exposed to erosional forces of water and root damage than the sherds in the humus layer found in the karstic zone. It is also possible that the settlement groups in the alluvial zone were more affluent than those found in the karstic zone. Evidence for this possibility can also be seen with the larger and higher mound size present in the
mounds located in the alluvial zone, as well as the higher percentage of Tier III and IV structures (Table 4.1).

**Figure 4.10:** One of the octagonal modified sherds collected in the karstic region, this one being associated with SG-33 and SG-34. The sawgrass seen in the background is one of the many features which made survey and collection and region difficult.
Lithics

During the survey, 56 lithic artifacts were collected, excluding obsidian blade fragments. Several different lithic artifact types are present in the collection, though large (10-18 cm) chert bifaces (See Figure 4.10) make up the single largest artifact type, consisting of 24 of the 56 items collected. A complete breakdown of the lithic artifact types collected during the survey can be seen in Table 4.

The large chert bifaces found in the alluvial area have an unknown use. At least one of the collected bifaces appear to be a broken axe, and exhibits a use wear polished edge (See Figure 4.11), while others might have been used as hoes, possibly like the biface in Figure 4.10. During the research, 19 fragments of Quartz were also collected during the survey of the alluvial region, while only one fragment was found in the karstic region. Notably the largest piece found was 54 mm x 47.55 mm x 26.19 mm and was highly transparent (See Figure 4.12). Manos and metates were also observed and collected during survey when possible. The alluvial zone contained the majority of manos and metates. The implements recovered from the alluvial region were made from granite, which is fairly common for mano and metate construction in the region. The metate recovered from the karstic region appears to be heavily eroded basalt, and is covered in numerous pits and grooves.
Table 4.3: Lithic Artifacts by Type and Zone

<table>
<thead>
<tr>
<th>Lithic Artifact Type</th>
<th>Number Recorded (alluvial)</th>
<th>Number Recorded (Karstic)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biface</td>
<td>22</td>
<td>2</td>
</tr>
<tr>
<td>Mortar</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Pestle</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Obsidian Blade Shards</td>
<td>205</td>
<td>0</td>
</tr>
<tr>
<td>Obsidian Drill</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Obsidian Core</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Exhausted Chert Core</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Limestone Bark Beater</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Manos</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Metates</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Quartz fragments</td>
<td>19</td>
<td>2</td>
</tr>
</tbody>
</table>
Figure 4.11: A large chert biface associated with SG-16 in the alluvial survey zone. The biface measures 22 x 9.5 x 5 cm and was the largest recovered during survey.
Figure 4.12: Another large biface collected in the alluvial region in association with SG-12. The biface appears to be a broken hand axe and the proximal end is worn smooth.

Several lithic projectile points were also collected during the survey. One projectile point of note appears to be an unfinished early chert projectile point (See Figure 4.13). The projectile point was found along a gravel road to the south east of the Cahal Pech site core, an exact location is labeled in the GPS data created during the survey. Preliminary morphological analysis further suggests the early origins of the point, with it possibly being from the preceramic archaic period (8000 – 900) BC year (Prufer 2018; Stemp et al. 2016)
Figure 4.13: The large quartz piece found during survey at SG-22, in the alluvial zone.

Figure 4.14 The possible archaic point found during survey to the southeast of the Cahal Pech site core. The projectile point appears unfinished and was possibly discarded due to a fault in the chert.

Finally, numerous obsidian blade fragments were collected during the survey, primarily in the alluvial floodplain zone to the north of the Cahal Pech site core. Several settlement groups contained large concentrations of obsidian, SG-19 for instance,
contained 49 obsidian blade fragments, and surrounding courtyard groups also contained large numbers of obsidian blade fragments as surface finds. In total, 205 obsidian blade fragments were collected during the survey and were exported for later XRF analysis by the project. The density of the obsidian blade fragments found in the courtyard groups in the alluvial environmental zone suggests the possibility that the area acted as either a trade node or a production center for obsidian blades. At the same time, this may also indicate that settlements in the alluvial zone enjoyed greater affluence and access to goods than those in the karstic hill zone. Further morphological analysis of the obsidian blade, such as the identification of proximal, distal, and medial blade fragments, might shed light onto the distances involved in the blades production and trade. (De Leon et al. 2009)
Chapter 5: Conclusions and Future Research

The purpose of this research was to determine if any noticeable differences in settlement patterns between two different environmental zones in the periphery of Cahal Pech in the Belize River Valley. Furthermore, the research sought to determine whether LiDAR data could be used effectively in the rugged environments such as those found in western Belize and surrounding regions.

The Ideal Free Distribution Model in addition with Landscape Archaeology and some aspects of Political Economy theory suggested certain landscapes would be seen as ideal and would be settled and exploited first and most heavily, while less ideal landscapes would either be ignored or later exploited when the optimal landscapes became overcrowded. The results of the survey appear to match some of the predictions made earlier in the thesis, though in some instances further research is needed.

The survey revealed the settlement groups in the alluvial region seemed to have been more affluent, having more structures around the courtyards than courtyard groups found in the karstic zone, and thus a higher concentration of ‘higher’ type groups. The alluvial zone also had heavy concentrations of obsidian and chert objects and flakes, particularly around SG-17 and SG-19, while surface collection in the karstic zone turned up fewer materials, though the absence of materials collected is likely due to the deposition of the humus layer and the difficulties inherent in preforming surface collection in the thick bush. It is possible the ease of access combined with the favorable conditions present in the alluvial zones lead to the alluvial areas being settled first, as is suggested by the Ideal Free Distribution Model, though excavations resulting in concrete temporal evidence are needed.
The differences in groups seen in the research can be explained by environmental factors, such as water access, as suggested by the theoretical approaches discussed earlier in the thesis. The inhabitants of the alluvial zone would have ready access to trade and water, being located adjacent to the river and thus a major trade route and water source. Higher access to trade would allow better access to materials not found locally, such as obsidian, and might explain the higher concentration of otherwise ‘exotic’ materials in the alluvial zone. In addition, those inhabiting the alluvial zone would be able to grow cash crops such as cocoa, using the rich fertile soils of the flood plain. In the alluvial zone, land above the flood zone would be highly valued, as the elevation would keep the structures and inhabitants safe during the seasonal river floods, the elevation may be why SG-17, the type IV group, is located along an embankment which marks the high water point during floods.

In comparison, groups in the karstic area might be restricted to hilltops to take advantage of available construction materials and maximize available agricultural land in the limited inter-hill valley space. Hilltop focused settlements are seen elsewhere in the Maya world, such as the site of Uxbenka, which occupies the hills in the region, leaving the valleys empty (Awe et al. 2016). Groups in the karstic region are more spread out across the landscape, with gaps present in settlement in the inter-hill valleys, which likely had greater value for agricultural land than for residential use. Despite the predictions involving the Maya use of elevation to emphasize structure height, survey of the karstic zone did not reveal any settlement groups of Type IV or higher on the hilltops in the karstic survey zone.
Further Research

While the survey has helped fill in some gaps, others are still present. Numerous settlement groups are still present in the alluvial zone to the north of town, in the western portion of my alluvial survey zone, and it appears that several surveys in the area have not recorded the extent of settlements here, likely due to modern farming of corn and beans that limits a comprehensive survey of the zone. To address this gap and others, I present two areas where I recommend additional surveying efforts in the future.

The first promising area (Figure 5.1) is located at to the south east of the Cahal Pech site core, directly south east of SG 39 where the river bends and turns south. Examination of the LIDAR data for this specific location reveals what appears to be one large monumental structure and several associated structures. Though the area is mainly cow pasture and sawgrass fields, the area identified by the LiDAR appears to be undeveloped, possibly preserving the structures.
Figure 5.1: The first recommended survey area, with several large mounds highlighted. The survey area is located on the borders of a cattle ranch along the Macal River.

The second promising area (Figure 5.2) is located to the northwest of town, among cornfields south east of SG-29. The mounds located in this area are easily visible on the LiDAR data as well as visually when the surrounding corn fields have not yet been planted. During planting and growing season, however, the site is concealed and generally inaccessible, so prospective researchers should attempt to do survey of the area at the beginning of the field season, before the corn is planted.
Figure 5.2: The second recommend survey area, with the area in question circled in red. The area is easy to get to as long as the corn has not been planted. Several large mounds (2+ m) are present here.

This survey also further tested the use of LiDAR for archaeological research in the region. LiDAR presented a fantastic tool during the preliminary stage of the research, helping identify areas to survey and work in, and the ability to have the LiDAR base map on the GPS unit allowed for quick course corrections if needed. Furthermore, the ability of LiDAR to reveal the landscape was greatly beneficial in understanding settlement placement, for instance, allowing one to easily see drops in elevation, and the flood zones in the alluvial valley. However, it is not a silver bullet and the imagery seen can be misleading, which result to lost time and resources as I discovered after an
ill-fated venture to a supposed ballcourt. Despite appearing almost identical to a ballcourt on the LiDAR imagery, the ballcourt was an old bulldoze trench. Further misadventures can be avoided by understanding where and why monumental architectural features, such as ballcourts, are placed in the Maya world, allowing future researchers to better identify false positives. Finally, relying too heavily on the LiDAR data can also lead to a waste of time and resources, as sites which appear on the LiDAR imagery could no longer be identified and recorded because they have been destroyed by more recent housing or agricultural development which had occurred since the LiDAR imagery was created. A well-rounded understanding of the archaeological history of the research area is still a requirement for the most efficient and cost-effective use of LiDAR
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