8-12-2014

The Implementation and Education of Geographic Information Systems in a Local Government for Municipal Planning: A Case Study of Dangriga, Belize

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THE IMPLEMENTATION AND EDUCATION OF GEOGRAPHIC INFORMATION SYSTEMS IN A LOCAL GOVERNMENT FOR MUNICIPAL PLANNING: A CASE STUDY OF DANGRIGA, BELIZE

by

CRAIG SKELTON

Under the Direction of Dr. Timothy L. Hawthorne

ABSTRACT

Implementing Geographic Information Systems (GIS) in a developing country can improve spatial planning and decision-making. Utilizing a Participatory GIS framework of maximizing community empowerment and limiting marginalization, this thesis research explores the barriers associated with implementing GIS in Dangriga, Belize and how to overcome those barriers. The research included the identification of local needs that could benefit from the use of GIS, the collection of local data through group and individual data collections, and the utilization of locally collected data to conduct GIS training sessions. It was learned that Dangriga faces many barriers found in other developing countries: institutional inertia, resource and technical availabilities, and a lack of trained personnel. Through the collection of local data and training sessions utilizing the data, the barriers of implementing GIS in Dangriga can be minimized.

INDEX WORDS: Geographic information systems, GIS, Participatory GIS, Belize, Participatory research

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A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of

Master of Science

in the College of Arts and Sciences

Georgia State University

2014

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August 2014

DEDICATION

This thesis is dedicated to the residents of Dangriga, Belize.

ACKNOWLEDGEMENTS

I would like to thank several people and groups for their support with this thesis research. First, I would like to thank my thesis advisor, Dr. Timothy Hawthorne, for sharing his knowledge of community geography and love for Belize. The Study Abroad trip organized by he and Dr. Chris Atchison first introduced me to Belize and eventually led to a graduate school experience far beyond my expectations. I would also like to thank my other committee members, Dr. Dajun Dai and Dr. Christy Visaggi, for their helpful comments and insight throughout the research process.

The Town Council and people throughout Dangriga were invaluable in completing this research. Without their warm reception, this research would have not been possible. They showed a willingness to accept a stranger as one of their own in a professional and personal setting. The conversations I had, often testing my knowledge of local dialect and ending with a laugh at my lack of knowledge, will forever remain a fond memory. I will forever be indebted for their support.

I would also like to thank Jim Kostaras of the Institute for International Urban Development for his chance encounter with Dr. Hawthorne while in Belize. The conversations that followed provided insight into Dangriga and the role that I could play. Mr. Kostaras also provided a much needed housing contact of Rosella Zabaneh at the Bonefish Hotel. Her hospitality along with her assistant, Ilana made my stay most comfortable.

Lastly, I would like to thank my friends and family for their support and patience throughout graduate school. The friendships I have made while at GSU have seen me through the frustrating and challenging times of completing this thesis research and will no doubt last for life. Thank you to my mom, whose love and encouragement to continue my education has

already made an important difference in my life. Finally, thank you to Ashlyn, whose love and patience is far greater than anyone I have ever known. My long, sometimes seemingly endless journey of graduate school is ending. The next journey is ours.

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1 INTRODUCTION

In this thesis, a Participatory Geographic Information Systems (PGIS) case study involving the Town Council of Dangriga, Belize is presented. Dangriga is located along the eastern coast of Belize and, similar to a large portion of Belize, suffers from a large technological gap like many other developing countries around the world. Access to and knowledge about geospatial technologies lie at the center of this technological gap in Belize. Many of the geospatial technologies regularly used by city planners of developed countries are unknown to small, local governments in developing countries such as Belize. As a result, the benefits of using geospatial data to address planning concerns are not being achieved. In Belize, resources are often being utilized to support antiquated paper-based methods of data collection and maintenance. However, there is moderate interest at the local level in Dangriga, with encouragement from the national government, to create more systematic geospatial datasets and training opportunities. Dangriga provides an interesting case study to examine the barriers of implementing Geographic Information Systems (GIS) in a developing town and strategies that can be utilized to overcome such barriers.

Dangriga has historically been separated from much of Belize. Comprised of mostly Garifuna residents, who are descendants of Africans and Caribs, Dangriga does not share the same ethnic identity as the rest of the country. As a result of this historic divide, access to and adoption of technologies such as GIS have been notably behind other towns in Belize as resources have been allocated away from Dangriga. Recent efforts by the national government to decentralize power and the World Bank-funded Belize Municipal Development Program have brought an urgent need for geospatial technologies.

The conditions that make this study possible are created by the World Bank sponsored "Municipal Development Plans for Seven Town Councils in Belize," part of the Belize Municipal Development Program, which seeks to devolve municipal financial and managerial authority to local councils. Through this devolution, Local Planning Working Groups are tasked with developing plans that will direct future development and provide the towns with the necessary tools to better manage infrastructure and services. As outlined in Dangriga's "Preparation of Municipal Development Plans," the project includes many tasks that may best be accomplished through the utilization of GIS technologies. Desired tasks include identifying specific land use patterns, drawing the circulation network of the municipality, and identifying vulnerability to natural disasters such as floods and hurricanes. This thesis research is meant to contribute to this plan, and was developed with the assistance of partnerships with James Kostaras, Senior Research Associate at the Institute for International Urban Development (I2UD) in Boston, MA and the urban designer of the project. I2UD had been working to complete the project's goals by collaborating with Dangriga and other towns throughout Belize to assemble interdisciplinary teams of experts to work directly with Local Planning Working Groups. These experts focused on training and technical assistance over a one year period from January 2013 through January 2014. The training modules consisted of five topics: vision, strategy and growth scenario development; socio-economic development and community consultation; land use planning; infrastructure planning and financing; and the key strategies to implementing the municipal plan. There were no evident direct ties to the Belizean national government.

The thesis research also builds from my participation in a 2012 GIS study abroad program led by Dr. Timothy Hawthorne and Dr. Christopher Atchison in Belize (Hawthorne et al. 2014; Hawthorne et al. forthcoming). Utilizing Mr. Kostaras' partnerships with local

Belizeans created through the existing development project, a four week research trip was organized for summer 2013 that would focus on assisting Dangriga's Town Council in collecting and utilizing spatial data to meet project goals. While Mr. Kostaras was instrumental in beginning this research, the research that was accomplished while in Dangriga was conducted without further assistance by evaluating conditions in town and properly reacting. With these points in mind, this thesis research seeks to answer three broad research questions specific to Dangriga:

1. What are the key factors limiting successful GIS and geospatial technology implementation in Dangriga?
2. What role do collaborative partnerships have on Dangriga's ability to implement GIS?
3. How does collecting and utilizing local data contribute to the success of GIS education in Dangriga?

The research connects the implementation of GIS with a PGIS methodology which allows the researcher to engage, learn, and learn with Town Council in ways that are only possible through the creation of a close working relationship. The collaborative relationship that is established provides a means for Dangriga to gain GIS knowledge and support from the researcher while the researcher acquires insight into the barriers that prevent GIS implementation. This mutually beneficial relationship provides maximum gains for both parties. In this study, Dangriga's Town Council gains geospatial empowerment through achieving a basic understanding of GIS, an important first step for the Town Council to begin using the technology. While geographers recognize that empowerment is a complicated term with multiple and complex meanings, this study uses the term only to indicate giving GIS power and authority to Dangriga. The Council also gains geospatial data that they identify as being

important. The researcher gains important insight and knowledge concerning the processes that affect the implementation of GIS in a town in a developing country. Though the analysis draws on broad themes of PGIS and GIS, it is important to note that the barriers affecting GIS implementation are dependent on local context and experience.

In the chapter that follows, the utilization of a PGIS methodology and identified barriers to implementing GIS are placed within existing research literature. Existing case studies are used to connect PGIS literature with barriers in Dangriga and to address how Dangriga might move forward with adoption of GIS based on the knowledge of earlier case studies in other locations in the developing world. Following this chapter, the case study area of Dangriga, Belize is introduced and the methods utilized in the case study are outlined. Chapter four consists of the results and discussion section. Lastly, chapter five summarizes the study and conclusions.

2 LITERATURE REVIEW

2.1 Geographic Information Systems

The need for Geographic Information Systems is real and immediate. Frank, Egenhofer, et al. (1991) lists in order of importance the four major components of GIS: institution, data, software, and hardware. Each of these components has specific responsibilities and their interactions lead to the success or failure of a GIS. There are key defining features that set GIS apart from other technology. Hall (2004: 269) describes "the unique features that distinguish GIS from other types of information systems as (1) data of entities and relationships managed within a spatial framework and (2) ability to perform spatial analyses." With such a wide range of uses, GIS has become a powerful tool around the world for planning and decision-making. "Internationally, GIS is one of the fastest growing industries with more than 170,000 people in the United States currently employed in the geospatial information industry in government, academic, and commercial sectors" Breetzke, Eksteen, et al. (2011: 3).

GIS is part of a broad group of information technologies that experience many strengths and weaknesses in developing countries. Chan and Williamson (1995: 3) note that there are "three views taken by decision makers of IT infrastructure according to the role it is deemed to play within an organization: utility, dependent and enabling." The utility of an IT is driven by the cost savings via economies of scale; the dependent is concerned with benefits for the life of the current strategy; and enabling addresses the current and future flexibility. Chan and Williamson (1995: 2) further state that "IT infrastructure investments are: large and long term; underpin the future competitiveness of the organization; are often made in anticipation of business development; and typically do not necessarily provide direct business performance

benefits." Though the creation of IT infrastructure can be laborious, GIS can have dramatically positive effects in developing countries.

"Over the last decade cities in developing countries have enthusiastically embraced geographic information systems and the supporting spatial data infrastructures" (Bishop, Escobar, et al. 2000: 86). According to Breetzke, Eksteen, et al. (2011), there are three reasons why local governments find GIS technology attractive. First, spatially referenced data represent a large proportion of data processing in local government agencies. Second, information is considered a fundamental resource of government. Third, pressure for improving government performance has prompted governments to look for more efficient ways of doing their work. Frank, Egenhofer, et al. (1991: 3) furthers that "GIS products furnish the required information at the right time, leading to better informed decision makers." This improved decision ability is due, in part, to the fact that GIS allows for integration of information from multiple sources (Hall 2004). Governments are able to use GIS to create connections between departments and increase the flow of information at a local level.

Though GIS has the power to connect various departments within governments, the extent of its influence is affected by the structural composition of governments. In developing countries, governments tend to be more centralized than industrialized countries (Olowu 2003). The centralization of governments negatively impacts a government's ability to easily collect data outside their immediate area of influence. The collection of such data can be used to better collect tax revenue or inform other important government projects. Olowu (2003) notes the lack of local data as an important reason for governments in developing countries to adopt and utilize GIS. The technology gives local governments the capability to challenge the limitations

established under a centralized government. Through the creation of more accurate and detailed datasets, local governments are better able to use local data to make local decisions.

Hall (2004) offers suggestions of often used data. Internal data may include land parcels, road traffic, public buildings, and emergency address locations. External data may include census statistics or legislative districts. The importance of these data types cannot be undervalued as more than 90% of information required for a city's administration has a spatial component (Bishop, Escobar, et al. 2000).

Various case studies have outlined the broad applications of GIS to address development concerns. Facing difficulty in managing solid waste in Singanallur, India, researchers were able to optimize collection routes by conducting routing analysis using GIS. By digitizing and geo-referencing local paper maps and then using the Network Analysis extension of ArcGIS, researchers were able to shorten the collection distance by 46% and, most importantly, save 86.7% on vehicle operation and maintenance expenditures (Velumani 2013).

GIS is also an important asset for analyzing the relationship between roads and flood prone regions in the developing world. As was the case in southern Sinai, Egypt, remotely sensed, geological, geomorphological, and field data were combined using GIS tools to estimate the flood risk along the vital Feiran-Katherine road. Through their GIS analysis, researchers identified important areas of concern and concluded that GIS can be vital in conducting hazard assessments and vulnerabilities. (Youssef, Pradhan, et al. 2011). In Enugu, Nigeria it was believed that building collapses were a result of incorrect land use maps. In response to the problem, researchers at the Federal University of Technology in Nigeria combined soil and geological data to create maps depicting areas with high and low building capacities. The new maps were then compared to existing maps, upon whichit was discovered that existing maps

allowed for the construction of buildings in areas threatened by floods, landslides, and erosion. It was not until multiple datasets were combined in GIS that the cause of the building collapses was discovered.

GIS can also assist in solving clerical issues of a spatial nature in developing countries. For example, groups and individuals have begun calling for increased investment and implementation of GIS in Pakistan and other developing countries. Due to an absence of adequate records that contain information such as land delineation or ownership, land markets are prevented from reaching their full potential (Zahir and Shakir 2012). The existing paper-based system of record keeping has created an administrative bottleneck in the development process as individuals and government officials struggle with record discrepancies and standards. GIS can be used as an information base on which records can be standardized and maintained and assist with planning decisions. The successes of these and other GIS processes are contingent upon the availability of accurate data. Acquiring such data can be a complex problem that creates barriers to successful implementation.

Researchers recognize that accurate spatial data are required for the successful use of Geographic Information Systems. In developing countries, however, the acquisition of data can be prevented through a myriad of factors. Williams et al's (2013) analysis of GIS data in Nairobi, Kenya's reveals that such data are often viewed as commodities. Because of their commoditization, data are often created by those who possess financial resources and data sharing is limited by copyrights or other legal barriers. As shown in Armenia, preventing data commoditization through data standardization can improve data strength throughout an entire GIS infrastructure (Astsatryan et al. 2012). The standardization of data allows data from one source to be easily used in combination with data from another source to create more robust

datasets. An analysis of data sharing in South Africa by Sebake and Coetzee (2013) reveal numerous influencing factors on data sharing. Motivating factors include a reduced cost of data handling, improved data quality, and improved decision making and planning. The authors identified barriers to include data sharing that resulted in a negative impact on revenue, concerns of accuracy and reliability, and lack of common data definitions, formats, and models. Cost as both a motivating factor and a barrier demonstrates the contextual importance of data sharing.

An additional limiting factor of data in the developing world involves concerns over data security. As seen in the United Arab Emirates, many government departments have been reluctant to share data over concerns and uncertainties of restricted and unrestricted data (Yagoub and Engel, 2009). Williams et al. (2013) acknowledge that the power dynamic of data contribute to the creation of inequalities as only certain groups or individuals are able to access data. The inequalities of data sharing are an important factor to consider when implementing GIS. Without appropriate data, GIS is rendered meaningless. In order for data to be collected and made available, participatory GIS is one strategy that can be utilized.

2.2 Participatory Geographic Information Systems

Participatory GIS emerged from participatory approaches to planning and the management of spatial information and communication (Rambaldi and Weiner 2004). Its goal is to empower community members and minimize marginalization through the integration of geospatial technologies based on the need of user-appropriate and user-friendly applications. Empowerment is important for communities as it creates conditions necessary for geospatial autonomy and lessens the reliance on outside resources. Rambaldi et al (2006) continue that good PGIS practices involve long-lasting spatial decision-making processes that are flexible and able to adapt to different socio-cultural and bio-physical environments. In this sense, proper GIS

practices focus on the needs and conditions of users and do not prescribe methods or remedies without first considering the realities of the study area. What has been successful in one study may not have the same results as study conditions change.

Working within PGIS, it is suggested that local knowledge can be incorporated with contemporary GIS data (Harris and Weiner 1998). This combination of top-down expert knowledge, driven by scientific inquiry, and bottom-up local knowledge, driven by the experiences of local individuals, results in a GIS that reflects both the scientific truth of a location and the truth as known to the people of a location. These sets of knowledge can align with one another and they can also be opposed as each represents a unique spatial perspective. The goal of PGIS, however, is not to cleanly combine knowledge. Instead, the goal is for each stakeholder to be represented (Cutts et al 2011). In order for all stakeholders to be represented, local knowledge collections are often done through the use of collection methods such as, but not limited to, interviews, surveys, and mapping exercises. The knowledge that is provided can be useful in community planning initiatives when consideration can be given to the experiences and perspectives of community members.

There are, however, some limits to PGIS as critics cite the discounting of scientific objectivity as a reason for questioning the legitimacy of PGIS (Sieber 2006). Proponents cite the ability of PGIS research to complement conventional data by addressing human influences that are not able to be scientifically represented (Cutts et al 2011). Bernard et al (2011) support this notion by demonstrating the importance of PGIS for determining the human effects on sustainable use reserves (SURs) in approximately 109 million hectares of the Brazilian Amazon. Utilizing interview and community mapping methods, researchers were able to identify hotspots of interaction between inhabitants and SURs. In order to maximize the effectiveness of SURs

and associated resources, the researchers recommend first collecting and mapping socio-economic information. Such knowledge is only available through the production of bottom-up local knowledge.

Following the production of local knowledge, PGIS is also concerned with the unevenness of access to necessary technologies (Craig, W. J., T. M. Harris, et al. (2002). As previously discussed, GIS data can be commoditized in such a manner that groups or individuals are unable to afford access to data. Similarly, groups and individuals can face financial challenges accessing appropriate GIS technologies to utilize data.

Emerging from participatory methods of planning and the management of spatial information and communication, a general discussion of participatory research complements PGIS. The discussion begins with the variance associated with the role of the researcher. Cornwall and Jewkes (1995) discuss shallow versus deep participation. Shallow participation occurs when researchers control the entire research process. The level of involvement by members of a community is drastically reduced and thus their motives for participating may not align with the motives of the researcher. Deep participation, however, involves a researcher releasing control of the research process and allowing members of the community to greatly dictate the direction of a study. Overall, the deep participation method is aligned with PGIS as its goal is to empower communities. It is also important to consider what comprises a community. According to Minkler (2004: 691), "in contrast to popular definitions of community based on shared geography, demographic characteristics, or sense of identity and common interests,…communities are not places that researchers enter but are instead a set of negotiations that inherently entail multiple and often conflicting interests." The idea of a negotiated space places the researcher and researched in a position of power in the research process. Each

member or group possesses certain expertise and it is the negotiation of that expertise that dictates the amount of involvement by each. It is the responsibility of a researcher to navigate a negotiated space in a manner that maximizes the potential for empowerment.

Participatory research exhibits a high degree of collaboration, reciprocity, and relationship building (Guta 2012). The relationship between those directly implicated in a research study, the insiders, and those who are conducting or assisting the research, the outsider, is an important dynamic to consider when conducting participatory research. By establishing a partnership, barriers are able to be broken down and each individual or group is seen as an equal contributor to the process (Minkler 2004). The previously discussed dynamic of power is influential in this manner by allowing a researcher to retain expert knowledge while also embracing the desire of the people who are being studied. It is this negotiation of what shall be studied that is the central point for a researcher to retain a favorable view from those whose community is being studied.

An added benefit of the need for building a relationship in order to conduct research is the dissolving of conventional boundaries (Guta 2012). No longer must there be a tension between what the researcher desires and what the community wants. Instead, each party works together in order to study a cause and create a solution to the problem. It is important to note that the quality of such a research process is affected from the initial contact of the researcher and community through the end of the research (Minkler 2004). The continuation of a positive relationship maintains the groundwork for the success of participatory research. Maintaining positive relationships places both actors in the best position for addressing and overcoming the barriers of implementing GIS. As described above, utilizing PGIS methods can provide many

important benefits in the research process. In the section that follows, general barriers to implementing GIS will be outlined. Overcoming such barriers will be explored in section four.

2.3 Barriers to GIS Implementation

For developing countries, there must be great consideration given to utilizing GIS as the process can be laborious and complicated by barriers. GIS barriers include institutional inertia, resource constraints, technical constraints, and a lack of trained personnel, referred to here as education (Ramasubramanian 1999, Bishop et al. 2000). In order to avoid these barriers of implementing GIS, it is first necessary for an organization to become aware of GIS. Developing countries are beginning to recognize the potential of information and communication technologies (Câmara and Fonseca 2007). Awareness, unfortunately, does not equate to success. Heeks (2002: 101) outlines three distinct possibilities: a "total failure of an initiative never implemented or in which a new system was implemented but immediately abandoned", a "partial failure of an initiative, in which major goals are unattained or in which there are significant undesirable outcomes," or a "success of an initiative in which most stakeholder groups attain their major goals and do not experience significant undesirable outcomes."

Creating a successful initiative can be a challenging task. In developing countries, evidence points towards a high rate of IT failure (Heeks 2002). Ehikhamenor (2003) quantifies that there is a 54.6% rate of success in implementing new technologies. Implementation of a technology does not occur in a vacuum and there are important factors that affect its potential. "The potential for using any technology to support governmental decision making is driven by the match between the capabilities of the technology and the needs of its potential users" (Mennecke and West Jr 2002: 46).

An immediate barrier of concern is that "the successful implementation and use of spatial information infrastructures in developing countries is dependent on political and institutional support" Bishop, Escobar, et al. (2000: 96). Given the lack of major industries in developing countries that would use GIS, the users of GIS are often governments hoping to utilize spatial data. If the leaders of the government decide that the program is too expensive, whether that be financial or otherwise, the risk of implementation failure increases. This risk can be lessened through the creation of institutional inertia and support by determining the appropriate role of GIS in an organization (Somers 1998). The appropriate role may be determined by applying the capabilities of GIS to a specific problem.

Such a situation occurred in Cape Town, South Africa when it was hypothesized that a GIS could achieve a model-based approach to upgrading informal settings in a manner that was both structured and replicable (Abbott 2003). Utilizing GIS on a small-scale project, researchers determined that the success of the pilot study could allow for the larger investment and use of GIS technologies on large-scale projects of similar themes.

The composition of an organization, however, can increase the problems of introducing a new technology. Organizations must be flexible because "introducing a new technology into an organization requires that the organization adopt new methods for decision-making. Organizations are very difficult to change and they react very slowly and reluctantly to pressure for change" (Frank, Egenhofer, et al. 1991: 1433). If an organization shows willingness and capability to adjust to using GIS, the inclusion of spatial data can be vital for economic development (Mansourian and Zoej 2008). Before economic developments can be achieved, it is first necessary to acquire the capital needed for implementation.

GIS is a broad technology that includes a wide array of capabilities. It is important that these capabilities are aligned with need. It is unreasonable for an organization to invest in a technology that does not yet have an identified role. According to Frank, Egenhofer, et al. (1991: 1435), "new technology should not be introduced unless it can be shown to be cost effective. To use modern technology for its own sake is quite unreasonable; however, showing cost effectiveness of an information system, and especially a GIS, is difficult." A cost benefit analysis is suggested as a reasonable method of determining need, as was conducted in Ghana (Karikari and Stillwell 2005). By measuring quantifiable benefits and identifying those that were not, the researchers were able establish a framework to assist managers and policy-makers in determining the utility of GIS. The authors acknowledge that a cost benefit analysis is not without problems but note that the methodology provided beneficial results. Worrall and Bond (1997: 366) provide further insight to considerations that should be made when conducting a cost benefit analysis. First, an organization must "examine the relationships between GIS and spatial analysis, policy analysis, spatial decision support systems and spatial modeling," second, one must "examine current and emerging role, function and positioning of GIS within organizations," and third, an organization must "examine GIS and its role as an 'information integration tool' in the context of information management within organization and the need to ensure that internal operation systems can be used in conjunction with externally derived information from the census and various other 'strategic' information resources."

An additional concern for GIS implementation in the developing world is the cost of such implementation. Steiniger and Hunter (2013) find that no matter the intended use of GIS, whether for businesses to accomplish routine tasks in an efficient manner, for researchers to develop new concepts and algorithms, or for teachers to demonstrate and explain processes, there

are associated costs. Through the completion of a strength, weakness, opportunity, and threat (SWOT) analysis, Taleai et al (2009) find that issues of funding in developing countries are experienced most among academic experts. Government experts differ by finding funding to be only a concern and not a leading weakness of GIS. In order to navigate the financial considerations of GIS, governments have relied upon outside investors and government funded development projects to fund the development of a GIS infrastructure. In the municipality of Addis Ababa in Ethiopia, government officials invested in GIS after determining that the benefits of the technology in managing development projects outweighed the cost of its implementation (Berisso and de Vries 2010).

A simple calculation of benefits and costs are not always easily achievable. According to Mendes (1995: 99), "cost evaluation relies on assumption that it is possible to predict costs from a small amount of gathered observational data." As organizations work to increase the role of GIS, barriers may be reached that can only be solved by further investing in the GIS system. It is barriers such as these that can lead organizations to doubt the necessity for further investment. In developing countries, where financial limitations are inherent, the concern of long term resource availability continues well past the initial stages of implementation. The monetary limitations directly affect the ability to acquire the necessary tools to properly utilize GIS.

2.3.1 Technical Constraints

Moving past the immediate difficulties of integrating a GIS system, there are long term technical difficulties associated with the design-actuality gap: "the match or mismatch between IS [information systems] designs and local user actuality" (Heeks 2002: 101). Heeks continues by outlining four distinct forms of these gaps. The following is a discussion of each form.

First, "the GIS design assumed reliance on formal types of information borne via technical channels as compared to the informal channels of information that were used in practice" (Heeks 2002: 107). This is applicable to developing countries as much of their history and local knowledge is maintained through oral traditions. Studies have shown that this invaluable information can be included in a GIS. In Vietnam, researchers were able to collect local flood knowledge in a GIS using interviews and other participatory rural appraisal techniques (Tran, Shaw, et al. 2009). The knowledge that residents provided gave helpful insight and understanding about historical flood conditions of the area that could not have otherwise been mapped. The researchers note the importance of including local knowledge in a GIS as it allows for participation and disaster risk reduction. The vast amounts of resources that are dedicated to collecting environmental data often do not occur in lesser developed countries and local knowledge is able to supplement the lack of data.

Second, "the GIS design assumed a form of working culture wherein decisions are made on criteria of rationality and principles of cartographic science. This mismatched an actuality of politicized decision making" (Heeks 2002: 107). Countries that are accustomed to making decisions based on personal observations or beliefs may have difficulty transitioning into Western based pragmatic decision making. Benefits of pragmatic decision making have been seen in Kwara State, Nigeria where the waste of approximately 800,000 people is collected. Without formal reasoning for waste bin locations, researchers added demographic, solid waste, and collection data into a GIS to determine optimal placement. Researchers conclude that by improving the number of waste bins and their location, residents walked shorter distances to bins and economic and environmental benefits increased (Aremu 2012). It was only through the use of GIS that the assumed knowledge of Nigeria could be corrected.

Third, "the GIS design representations of the [land] conflicted with the actuality of [land] officers' representations, which did not see land as something that is out there and that can be objectively measured and standardized in GIS models" (Heeks 2002: 107). Representing land with GIS has been shown to help combat various problems by presenting a new perspective in developing countries. In the case of India, GIS was used to effectively study HIV/AIDS related issues (Kandwal, Garg, et al. 2009). Researchers gathered HIV/AIDS data throughout the country to visualize the prevalence and awareness of the disease in hopes of preventing a possible epidemic. The results showed concentrations of HIV/AIDS throughout India that had not previously been realized. The results were also able to challenge conventionally held beliefs by government officials and promote effective policies in addressing the disease. In countries that are not familiarized with having their land represented visually and that have always relied on personal views and perceptions, the inclusion of GIS may challenge conventionally held beliefs.

Heeks (2002: 108) outlines in the last gap that, "the GIS design required values of trust in the technology, in new forms of rationality and in persons unknown and absent. This mismatched the real values of trust in persons known and present. The result was a significant design–actuality gap". Duncan (2007) provides further details through an analysis of the Coastal Landscape Analysis and Modeling Study in western Oregon by outlining four broad factors related to trust: comfort with the data and models, personal experience and personal relationships, level of controversy associated with a project, and the pressure for information versus pressure for a decision. The importance of human-technology relations cannot be ignored. Developing countries often lag behind the technology standard of developed countries. Such a difference is caused by an unfamiliarity of technology and results in inability to

effectively use the technology as it has been designed. In developing countries, groups may experience hesitance to fully utilize the capabilities of GIS. This hesitance can lead to eventual implementation failure if not addressed. One of the best ways in which this problem can be addressed is through proper education that addresses concerns and prepares users to fully utilize the capabilities of GIS.

However, in developing countries such as Belize, GIS education is often limited. "There is an acute shortage of trained professional GIS personnel capable of introducing spatial information technologies in developing countries" Bishop, Escobar, et al. (2000: 98). With such a shortage, it is difficult to disseminate GIS knowledge throughout an organization. Aside from having the necessary number of individuals to conduct training, "training usually takes a long time and is expensive" (Frank, Egenhofer, et al. 1991: 1434). This problem leads to a further exacerbation of issues associated with the necessary investment of capital. Further issues spawn from a lack of individuals. "GIS is a new field with a limited clientele in many developing countries. Often there is little vendor support for GIS software. Often, monopolistic conditions exist for a vendor who provides software and after sales support. This monopolistic phenomenon often results in higher costs, poor services and limited expertise" Bishop, Escobar, et al. (2000: 99).

GIS education can vary depending on the needs of an organization. "Education is the process of learning and acquiring information. It can be classified into two: formal learning through an institution such as a school, and self-taught learning or what is often termed as life experience" (Behr et al. 2012: 273). Sui (1995) directly relates GIS to overall education by noting that there are two aspects of GIS education – teaching *with* GIS and teaching *about* GIS. Behr and Sui are aligned when considering that teaching about GIS is conducted in a classroom

setting and teaching with GIS is part of a larger, experience-driven education initiative. To educate individuals on how to best use and utilize GIS in their daily work, it is important to focus on both types of education to facilitate the best learning experience. By focusing exclusively on teaching with GIS, a student may not grasp technical concepts that address how and why GIS works. Not teaching about GIS can educate a student about technical concepts while failing to educate how to apply the concepts. A failure for an individual to holistically learn GIS is a failure to prepare a person to best utilize the tools of the technology.

A case study of ranger-based monitoring in the Virunga-Bwindi region of East-Central Africa provides an example of how effectively teaching GIS can result in great benefits (Gray, and Kalpers 2005). Utilizing GPS units and patrol ranger observations, researchers were able to identify and locate various events occurring throughout the area. These events included the growth of specific plant life, human activities, and gorilla activity. Through detailed training, 157 park rangers developed the skills necessary to continue to program well after its initial implementation. Dr. Robert Downs, at the Educational Systems Research Institute User Conference, noted the importance of GIS education throughout all education systems by noting that GIS needs "to become as ubiquitous in the educational system as a yellow pencil" (O'Dea 2002: 1).

As with any information technology, data quality is of the utmost importance. In the developing world in particular, the inclusion of local knowledge in GIS data form is important. The inclusion of such data has been seen in various developmental case studies to benefit those who are providing the local knowledge. In Cameroon, researchers use local knowledge in GIS to enhance local carbon forestry planning (Minang and McCall 2006). Through the inclusion of local knowledge, it was learned that current land and forest use systems could hamper local

participation in the creation and management of carbon forests. Young residents noted that the process enabled them to better learn about the community from the old. GIS addressed the problem by facilitating the transfer of knowledge and by providing a voice to members of the community who had been left out of the decision making process.

In the process of educating individuals on how to best use GIS, local data are equally as important. Some studies suggest that local data are the critical components to successful GIS implementation (Meyer and Butterick 1999). As previously discussed, utilizing prior knowledge can elicit the best response to GIS education. "One of the reasons that working with local data is attractive is that it is familiar to the students. It is not removed from their experience" (Keiper 1999: 58). "Participants appreciate the concepts more if they use datasets closer to home or related to their own fields" (Behr et al. 2012: 91). When students encounter data outside of their periphery of knowledge, there is an extra burden placed on student to learn the location of the data. This was seen by The Community Geography Project in Portland, Oregon (Merrick 2003). While using "canned" tutorials and online training options, it was learned that these tools were unsatisfactory to the learning process. Instead of focusing on the software, users were more concerned with addressing their own needs. Using local data removes the extra burden and allows students to focus on GIS. This in turn creates an opportunity for additional teaching possibilities. "Many teachers also prefer using local data sets because they open the door for more teaching possibilities, particularly in combining interactive mapping and spatial analysis with community field trips" (O'Dea 2002: 2). This reinforcement through field trips allows students and teachers to visually analyze the data that they have been using. Students are then able to confirm or reject the concepts and data manipulation that have been introduced through the teaching sessions.

Doering, A. and G. Veletsianos (2007) demonstrate this importance by conducting focus group interviews of 65 individuals who had completed geospatial lessons. Through the interviews it was learned that using local data that had been collected by the participants assisted learners in developing a sense of place and allowed for the co-construction of knowledge by working with others. Participants were able to further their own knowledge by combining their existing knowledge with the newly collected data.

Unfortunately in developing countries, local data in digital form is not readily available (Yeh 1999). Instead, data are available in paper form and in the oral traditions and stories of the people. These datasets are not able to be included in GIS and thus pose a serious difficulty in educating local GIS users about the technology. Teachers in these regions are forced to rely on outside data that often times have been collected by individuals unrelated to the teaching endeavor. This locks teachers into a cycle of relying on others for data that are not local and also may not easily be manipulated to reflect local problems.

McClurg and Buss (2007) further address this problem. In analyzing the experience of students' abilities to grasp GIS concepts, the authors view local datasets as providing an opportunity for students to conduct spatial analysis on local and substantive issues. Eui-kyung (2006: 116) notes that "when using GIS, teachers should use projects that have built-in flexibility so that students would have opportunities to operate and manipulate GIS data easily, instead of providing fixed formula for the students to follow." Conducting education sessions in such a manner assists in ensuring that local issues and knowledge are at the forefront of students' minds, thus achieving Keiper's (1999) teaching strategies.

GIS education in developing countries has been conducted in various ways. Takada et al. (2008), in an analysis of five case studies of world heritage sites and urban cities in developing

countries, summarizes common education needs and results. The authors note that a dedicated full time GIS team must be organized with training to teach about rapidly changing technologies. Such training must address the capabilities of the GIS team in order to teach what is possible for the team to achieve. If proper training is able to accomplish this, it is possible for these programs to motivate GIS users to sustainably implement and use the technology.

2.4 Overcoming Barriers

After outlining barriers to GIS implementation, there are several strategies that can be utilized. The Chorley Committee from the United Kingdom identified six factors which make an organizational environment conducive to the successful introduction of GIS: First, geographical information is essential to operational efficiency. Second, the agency can afford some experimental work and trials. Third, there exists a corporate approach to geographical information and a tradition of sharing and exchanging information. Fourth, there is a tradition of multidisciplinary approach. Fifth, an organization has strong leadership and enthusiasm from management with a group of enthusiasts at the working level. Sixth, there is some experience of, and commitment to, information technology and the use of existing databases in digital form (Clarke, A. 1991). While these six factors are ideal, it is believed that developing countries will not satisfy all factors. In these instances, strategies must be formulated that maneuver developing countries to a position in which they can best address the Chorley Committee's factors. Through an analysis of the implementation of spatial data infrastructures in Africa, Tumba and Ahmad (2014) challenge the macro level approach that has typically been used. Citing multiple failures and noting no examples of success, the authors advocate for local implementation as local governments are better situated to inventory their resources and plan accordingly. Obermeyer (1999: 609) adds, "GIS must be assessed in comparison with existing

practices." If a developing country finds no utility in GIS, a notion not supported by academic literature, then there is no reason with moving forward with a plan to transition to using GIS.

Initial transition stages of GIS implementation are important as they set the pace and tone of success. "It is often necessary to continue with an established plan, even if it does not involve the absolutely newest technology. This means, in practice, that one starts the acquisition process with a functional description and an indication of some existing product, adding 'or the best available at the moment of purchase' so that the decision on the specific product is delayed until the moment of that actual order" Frank, Egenhofer, et al. (1991: 1434). By establishing expectations, it decreases the threat of the design-actuality gap playing a role in the GIS' failure. Additionally, expectations should be controlled by ensuring that "GIS developments [are] not…pushed by what technology makes possible, but by understanding what society needs and how it can benefit from GIS" Frank, Egenhofer, et al. (1991¨1435). GIS integrators who advertise the power of GIS through applications that do not relate to developing countries make it difficult for organizations to find value in the technology. Instead, the technology should be adopted to complement the existing tasks of developing countries. As each country has its own development priorities due to unique circumstances, GIS integration may focus on a wide range of topics. These focuses may include boosting agriculture through a collection of land use data and subsequent best use analysis, or increasing government efficiency through a collection of land use by plot number and subsequent tax collections.

The largest issue of integrating GIS is to acquire the capital necessary to purchase the technology. Academic literature offers many suggestions to overcome this problem. First, Bishop, Escobar, et al. (2000: 96) note that "cheaper and faster computer technology is coming within the reach of most organizations in developing countries." Any access to cheaper solutions

will benefit GIS integration and increase the chances of success. Second, integration needs "a large and long term investment, intending to provide a platform for the flexible, speedy and economical development of other applications" Chan and Williamson (1995: 4). As discussed earlier, GIS integration may require an influx of capital beyond the amount initially estimated. Without access to additional capital, GIS integration may stall before accomplishing the goals of the initial project. By having continued financial support, developing countries are able to be assured that any financial stress will be assisted and supported by other organizations. This certainly eases the responsibility of needing to be the sole financial support of GIS integration.

The creation of partnerships has been one strategy used to overcome barriers experienced by resource poor and marginalized GIS users (Elwood 2006) Partnerships enable developing locations to utilize basic GIS necessities, such as technology, that are available in developed countries while allowing local users to focus on collecting accurate and useful data. By removing the technological burden on developing countries, many of the pitfalls that can lead to a failure of GIS implementation can be avoided. Similar case studies have demonstrated the willingness and success of groups in developed countries to reach out to other organizations. In combating the distance between developed and developing countries, a strategy of developed countries forming partnerships with local experts in developing countries can result in success (Keiper 1999). Though potentially not as easily and readily achieved as partnerships among organizations in developed countries, local experts are able to better situate GIS in the local context. Local knowledge is important to successful implementation of GIS and local partnerships enable a much deeper connection between GIS student/user and the local expert.

This connection was evident in Nairobi, Kenya where researchers worked with local partners (Williams et al. 2013). As the research occurred, it was realized by the researchers that

sharing locally collected data with local partners strengthened their partnership by building trust through the demonstration of commitment to the project. Through such partnerships, developing countries will not have to confront the vast differences between themselves and developed countries. Instead, developed and developing countries can work in accord to bridge these differences.

Though partnerships can offer many benefits to developing countries, limitations and risks still exist. The challenge is to develop greater understanding between partners while acknowledging the structural limitations of knowledge creation (Puri and Sahay 2003). Inherently a GIS partnership between a developed and developing country has a power dynamic which places the developed country in an authoritative role as they possess GIS capabilities. Developing countries, however, are reactionary to the developed country and may become dependent on provided resources. Breakdowns in partnerships have been shown to lead to IT project failures. In Tamil Nadu, India, a partnership sought to provide technology to the region (Best and Kumar 2008). After an initial investment, the resource rich partner withdrew their support of the project. Without the necessary resource assistance to sustain the project, the resource poor partner was unable to continue the project and the project failed. As developing countries turn toward developed countries for assistance, consideration must be given for the long term vitality of partnerships.

2.5 Conclusion

A review of academic literature situates this research within a larger context of Participatory Geographic Information Systems and utilizes existing knowledge to understand the barriers that affect GIS implementation, particularly in developing countries. It is concluded that by utilizing the practices of PGIS and incorporating existing knowledge from similar studies, the local and

unique GIS needs of Dangriga's Town Council can be addressed. In the chapter that follows, the case study and methods are outlined to address these needs in Belize.

3 CASE STUDY AND METHODS

3.1 Case Study

Belize, located south of the Yucatan region of Mexico and east of the Guatemalan border, lies along the western edge of the Caribbean Sea. The country has a rich cultural history that spans from Mayan developments circa 1500 B.C. and British colonization during the nineteenth century, to full independence in 1981. Since independence, the country has strived to increase its economic development by relying on its geography for agricultural production and tourism.

Located in a tropical climate with rainy and dry seasons, the economy of Belize relies heavily on its natural resources to sustain the country. Tourism is the primary foreign exchange earner in Belize followed by exports such as marine products, citrus, and bananas (CIA Factbook 2014). Though the country is able to generate money through its exports, there still exists a large income disparity among the 300,000 Belizeans. With an annual per capita GDP of $8,900, more than 4 out of 10 people live in poverty and approximately 11% are unemployed (CIA Factbook 2014). Coupled with a large foreign debt burden, Belize faces many economic concerns as it strives for prosperity.

Belize is divided into six administrative districts: Belize, Cayo, Corozal, Orange Walk, Stann Creek, and Toledo. Each district is jointly run by various government functionaries such as Finance Officers, the commanding Officer of the District Police, and the Heads of government departments. District towns are controlled by a locally elected seven member Town Council (Embassy of Belize in Washington D.C. 2014).

Dangriga (see Figure 1), located in the Stann Creek district along the Caribbean Sea, is the district capital and cultural center of the Garifuna people (Stann Creek). As of the 2010 census conducted by the Statistical Institute of Belize, the town is home to approximately 9,000

individuals. The citrus, banana, and shrimp farming industries dominate the town's economy although much of the labor is imported from other Central American countries. This importation prevents much of the earnings from going to Dangrigan families.

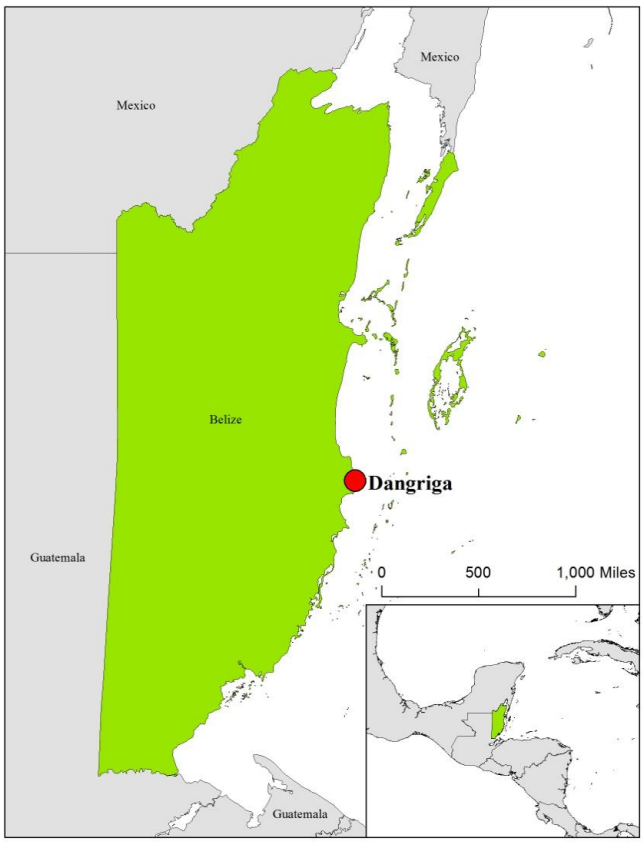

Figure 1 Dangriga

The atmosphere of Dangriga is subdued in comparison to the tourist towns that dot the landscape of Belize. Paved roads connect important destinations such as the central business district and airport, but dirt roads take people home, most often by bicycle or on foot. Situated along Dangriga's busiest road, the central business district contains restaurants, food carts, markets, and retails shops whose contents spill onto the edges of the sidewalks. The buildings in town, typically constructed of either concrete or wood panels, are generally small but functional and exhibit few signs of economic excess.

The Town Council is located just north of the town market in a three story building which houses the various departments that are responsible for maintaining the town and the Stann Creek district. Each department possesses multiple computers, although some of those computers are personal laptops. The computers owned by Town Council have basic word processing software and access to the internet. A secured Wi-Fi connection is also available. The Council does not, however, have wide access to GIS software as only one computer contains ArcGIS. Most spatial data is contained in a series of aerial maps with plot numbers overlaid. These plot numbers correspond to a series of file cabinets with various handwritten forms containing associated information.

The challenges that Dangriga faces are rooted in a complete unawareness of geospatial technologies. This state of knowledge is a matter of education and not capabilities. The practices and tools that are regularly used at the Council demonstrate an era of reliance on paper records with little thought given to a digital transition. Following the creation of documents and forms using word processing software, there is little digital engagement by Council employees. Forms are completed and then stored in filing cabinets. The antiquated practices at the Council are reflected through the employees' lack of knowledge of basic geospatial concepts. The unfamiliarity of GIS and other geospatial technologies creates difficulties in demonstrating the benefits of utilizing such technologies. Without an understanding of geospatial tools, it is difficult for the employees to find benefits and to buy in to the idea of utilizing such tools on a daily basis.

The initial goal of this research project was to assist Dangriga in collecting the necessary spatial data for completing the checklist items found in the "Preparation of Municipal Development Plans," such as land use patterns, circulation networks, and vulnerabilities to

natural disasters. This assistance would come primarily in the form of data collection as identified by the Council Detailed plans had not been created before the trip as coordination with Town Council proved difficult without direct communication. All plans were created from the knowledge of Dangriga and its current conditions that were provided during conversations with Mr. Kostaras at the International Institute for Urban Development (I2UD).

Upon arrival and introduction, it was clear that there existed limited geospatial capacity in Dangriga and most of the plans that had been discussed were of little use. Collecting data for the town to use would be a dead end task as Town Council would find no functional use for the data. It was necessary to educate Town Council about geospatial data and best practices in order to maximize capacity. From this point forward in the research, the partnership established by Mr. Kostaras at I2UD offered little assistance as it became my responsibility to forge my own partnership with the Council.

Personal reactions were mixed after the first interaction with Town Council. While limited resources were expected, an almost absolute absence of infrastructure to support GIS and associated geospatial data came as a surprise. The role of researcher in Dangriga had been described by various individuals as a task to assist and further the existing infrastructure. In reality, Town Council had been given a limited introduction to GIS and how the technology could positively affect Dangriga. The Council, however, had no working knowledge that could assist in its decision making. A change of direction in research had to occur in order to improve the capabilities of Town Council and maximize the likelihood of them becoming self-sufficient users of GIS. This change occurred by refocusing the research from collecting data that Town Council could use to teaching GIS through the utilization of locally collected data with the

assistance of Council employees. The necessity to adapt to local needs, as outlined in the PGIS literature, would influence the entirety of the research project.

3.2 Methods

This study was conducted over a four week period in Dangriga, Belize. Working alongside Town Council employees, various spatial datasets were collected based on the needs identified by the Council. The data that were collected was then used as instructional material during two hour GIS training sessions conducted during the final two weeks of the study. The tools utilized during the study that were supplied through the support of Georgia State University included a Trimble GPS handheld unit containing ArcPad software, a Garmin GPS unit, a Panasonic Toughbook laptop, and 60-day trials of ArcGIS as available through the ESRI website. Other tools that were utilized but supplied through Town Council include a projector for displaying collected data during training sessions, desktop and laptop computers, and a motorcycle for collecting road data.

Utilizing PGIS influences and practices, an assessment of GIS was conducted to answer the three research questions of the study:

1. What are the key factors limiting successful GIS and geospatial technology implementation in Dangriga?
2. What role do collaborative partnerships have on Dangriga's ability to implement GIS?
3. How does collecting and utilizing local data contribute to the success of GIS education in Dangriga?

This assessment was completed by working closely with the Town Council in order establish a first-hand account of conditions in Dangriga. By applying previous research literature to observations made during the study, a better understanding of GIS in Dangriga is reached.

The start of the research was slow to produce tangible accomplishments as approximately the first week was dedicated to meeting with various individuals at Town Council. These meetings helped to establish goals of the research and, most importantly, the goals of Town Council. While the process felt slow, it was important to ensure that Town Council could establish their role in the research, a fundamental principle of PGIS. Though this time did not meet immediate and impatient expectations, taking time to build relationships with the Council would prove essential for completing the tangible portions of this research. Upon building foundations for continued partnership, a series of databases and educational exercises were created to facilitate GIS implementation in Dangriga.

3.2.1 Roads

Creating an appropriate geodatabase for storing shapefiles was the first task. This was completed by utilizing ArcGIS to create a file geodatabase. Next a line shapefile of the roads in Dangriga was created. Given the limited amount of spatial data available, the roads were chosen first as the data could be used to provide a situational basis of subsequent data through its use as a base layer. In order to cover each road in a time efficient manner, Town Council provided a helmet, a small motorcycle typically used by the Valuation Department, and an official letter stating the purpose of using the motorcycle. Using the Trimble GPS unit and antenna attachment, the unit was set to automatically record its location in two second intervals while on the motorcycle. The two second interval was arbitrarily chosen as it was believed to provide a sufficient number of points while traveling through Dangriga, much of which contains an approximately 30 mile per hour speed limit. After becoming comfortable with the motorcycle, the Trimble GPS unit was placed in a backpack in order to ensure its safety and the magnetized GPS antenna was affixed to the helmet.

Knowing the difficulty of driving a motorcycle and referring to a map to determine the areas where data had already been collected, major roads and landmarks were used to mentally divide Dangriga into manageable sections. For example, the main road through Dangriga lies along a north and south heading dividing the town into eastern and western sections. Additionally, the North Stann Creek River runs west to east and thus divides the town in north and south sections. These divisions leave four large sections which could then be subdivided into more manageable areas. The roads in each section were then collected according to their orientation. All roads in an east and west orientation were collected first followed by roads with a north and south direction, or vice versa depending on which direction would be most efficient. It was important to collect the location of the roads in a systematic manner in order to prevent any roads from being omitted. As a general reference and method of identifying missing sections, an aerial photograph of Dangriga was applied as a basemap on the Trimble GPS unit. By using the basemap layer below the collected points, it was easy to identify sections of town that had yet to be collected. Without designated town boundaries, the decision of where to stop collecting data was determined by the amount of built environment on certain roads. Due to the length and number of roads in Dangriga and the ever changing weather conditions during the rainy season, the collection of road data required three days.

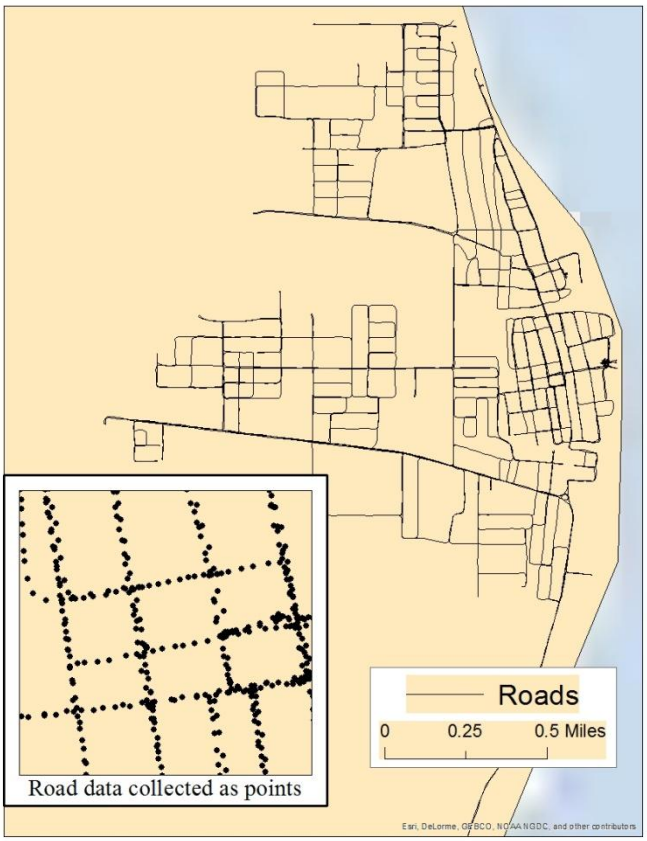

Figure 2 Roads

3.2.2 Drainage Culverts

Collecting the locations of drainage culverts (figure 3) was the first opportunity to have employees of Town Council in the field learning how to collect data. While travelling to the chosen site, a ten to fifteen minute walk, the employee was given a general overview of the upcoming process. This included an introduction to the Trimble GPS, how it worked using GPS satellites, and an explanation of the basic functions of collecting data using ESRI's ArcPad software. The introduction was brief and focused on having the employee comfortable with holding the Trimble and interacting with its touch screen features.

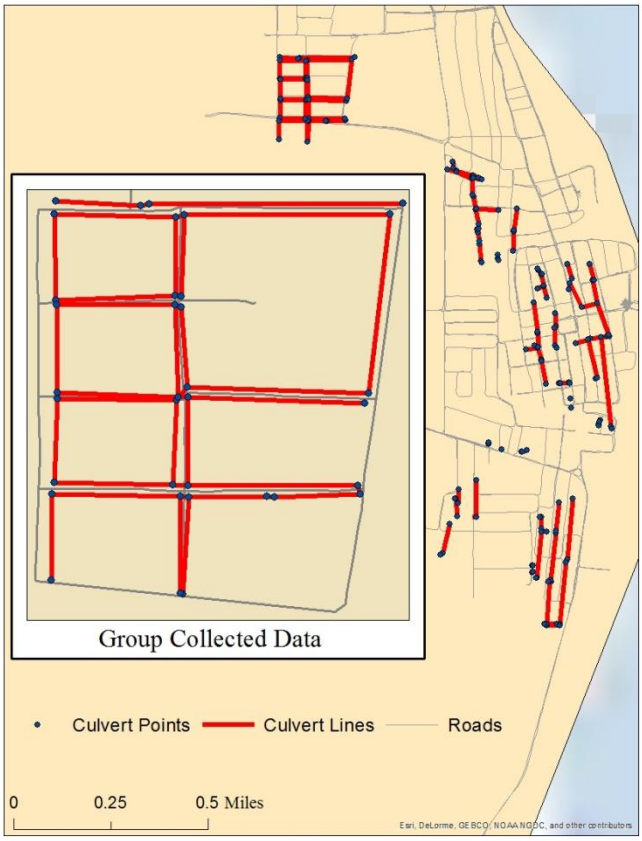

Figure 3 Culverts

Working in flood prone areas as identified by employees, the ArcPad software installed on the Trimble GPS was utilized to map the culverts. The Town Council employee was first tasked with creating two shapefiles: a point shapefile denoting the endpoint or connecting sections of a culvert, and a line shapefile to connect the points. The line shapefile contained fields denoting the condition of the culvert.

The process of collecting data involved walking from end to end of each culvert and placing corresponding points and lines. At the beginning of each culvert, a point was placed using the GPS coordinates to denote the culvert's beginning. The employee then proceeded to walk alongside the culvert to its ending point where another GPS point was recorded to denote its end. While walking from beginning to end of each culvert, additional points would be placed to signify the beginning or ending of changes in direction or changes in condition. As points of a

culvert were collected, the line shapefile was then used to connect the dots and denote the condition of the culvert as well as the direction of its flow. The line was manually drawn using ArcPad and the line snapping feature. In locations that featured multiple points within close proximity, the snapping distance required adjusting. This process was taught to the Council employee. Throughout the data collection process, Council employees were taught best practices of data collection which included saving the data while in the field and backing up all data once it had been collected. It was observed almost immediately that the time of collecting data was influential on the process. During the warmest parts of the day, approximately 11:00 am to 4:00 pm, Council employees showed the most reluctance of leaving the comfort of their office fans.

In some instances it was necessary to collect data without the assistance of a Town Council employee. During these occasions, the emphasis was placed on maximizing the total area covered. Broad sections of Dangriga had been introduced as having had past flood problems, typically located in the southern portion of town. These sections became the focal point of individual data collection efforts. Using the same methods employed while working alongside the Council, data was collected during the morning and late afternoon hours in order to work during the coolest part of the days. A typical morning or evening of collecting data lasted approximately two hours.

3.2.3 Land Use

The collection of land use data (figure 4) involved many of the same methods used to collect drainage culvert data. An important difference was that the database structure had already been created before going into the field. Using an aerial photograph overlaid with parcel numbers as a reference, a point shapefile was created using ArcPad on the Trimble GPS unit that featured two fields: parcel number and land use type. The parcel numbers were determined

using the aerial photograph and each land use type reflected the existing classifications used by Town Council. The data collection occurred in the northern most parts of Dangriga as determined by the Valuation Department, a department within Town Council.

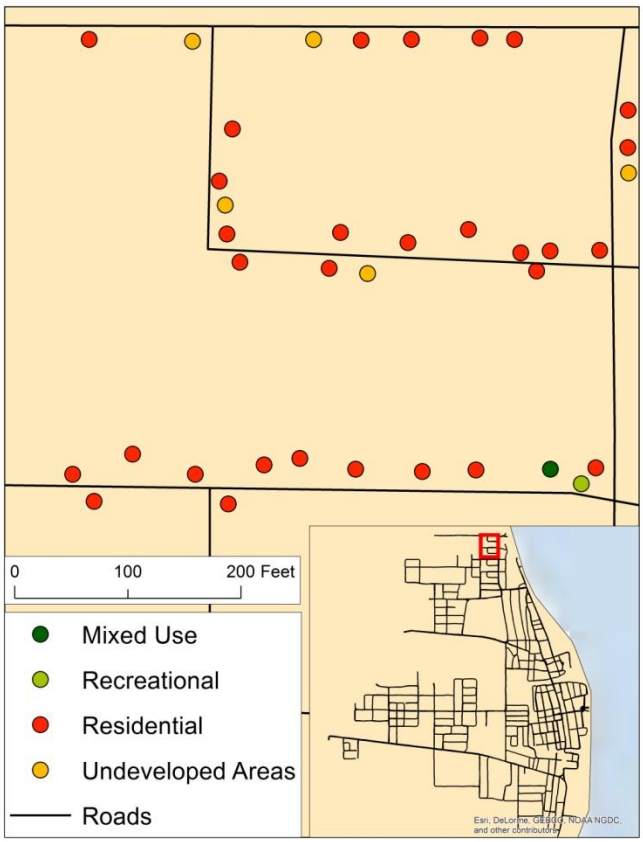

Figure 4 Land Use

The data collection occurred while shadowing a Valuation Department effort to notify businesses and households of new fees associated with garbage collections. While parcel owners were being notified by a Council employee about the upcoming changes, a GPS coordinate point was recorded using ESRI's ArcPad on the Trimble GPS unit. Each recorded point included the parcel number as shown on the Valuation Department's aerial photograph and the land use types were determined using a visual inspection method.

The data collection experienced numerous problems and was not continued after the first attempt. It was quickly realized that the Council employee was concerned with his own work instead of learning about the data collection process. Days later the employee resigned from his position at Town Council in order to pursue other career interests. Additionally, the usefulness of the data was questionable as an existing shapefile was presented with land use data for most of Dangriga. While the shapefile contained gaps in the data, the time required to fill those gaps appeared to be best spent collecting data types not yet collected.

3.2.4 Garbage Routes

The mayor of Dangriga, Gilbert Swaso, made a personal request to map the routes of the town's garbage truck (figure 5). This passive data collection project required setting a Garmin GPS unit to collect points at a set interval and placing it in the cab of the garbage truck each morning before the day's route began, usually at 5:00 am. As the garbage collection workers made their way through Dangriga, the GPS would record their movements. At the end of each day, the GPS unit would be retrieved from the truck and downloaded to a computer for processing. This process was repeated on several mornings during the last week of the study.

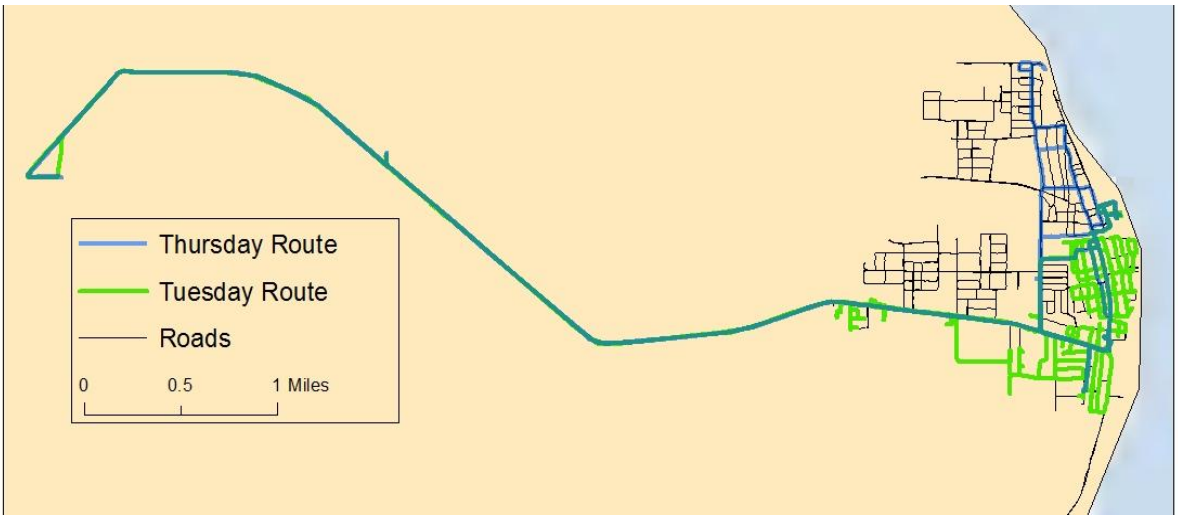

Figure 5 Garbage Routes

3.2.5 Training Sessions

The two hour, two week long training sessions utilized the datasets collected throughout the study. These training sessions began during the third week. Much of the first two weeks were focused on defining the needs of the Council and how to best address those needs. In order to effectively demonstrate and allow Town Council employees to use GIS technology, 60-day free trials of ArcGIS were downloaded from ESRI's website and installed on designated desktops and laptops owned by the Council or its employees. For each afternoon of training, computers with the installed software were brought to the designated training location, typically the Council's conference room. At the conclusion of each training session, Council employees were able to continue using their computers as normal.

The training session consisted of two components: instruction and guided practice. The instruction portion of the sessions involved explaining and demonstrating GIS capabilities of ArcGIS on a Panasonic Toughbook laptop that had been provided by Georgia State University. Utilizing the Council's projector, the laptop was projected onto a screen so that Council employees could follow along as GIS capabilities were demonstrated. Guided practice allowed each training participant to manipulate data and explore the application of instructional concepts to personal projects using ArcGIS. Throughout the guided practice time, assistance was provided to answer questions or assist in technical concerns associated with the software. In a normal session, each component lasted approximately one hour. It should be noted that training sessions were not made mandatory by Town Council and that some employees exhibited sporadic attendance due to the demands of their jobs. A typical training session consisted of approximately 6 individuals, 3 of whom were consistent in spending time outside of the training sessions to work on individual projects and seek my assistance. On some days, particularly

Fridays in which Council employees were permitted to leave at 4:30pm instead of their normal 5:00pm, a lack of attendance would cancel the day's session.

Initially training sessions mimicked GIS classes at Georgia State University of presenting a lecture and lab on a predetermined set of topics. It was quickly realized that a formalized approach did not offer the flexibility needed to address individual concerns about the software and how it related to each person's job. Additionally, it was noticed that gaps in general geographic knowledge existed among a few Council employees that prevented easy comprehension of some GIS concepts. In order to best facilitate learning, the initial approach was abandoned after the first day and was replaced by an outlined approach that focused on achieving certain goals and levels of understanding of the technology as informed by the employees' personal goals at Town Council and existing knowledge that could be applied. Given the limited opportunity to engage with employees, it appeared best to engage geographic knowledge differences through the completion of tasks using ArcGIS. This flexible approach led to the creation of generic daily outlines of topics to cover while the details of each topic were influenced by the feedback of Council employees throughout each session.

Using the data that had been collected in Dangriga and ArcGIS, the training sessions topics consisted of the following:

Day 1 – General introduction to GIS: functions and importance

The first day of training focused on introducing GIS: what it is, how it is useful, and how to use its functions. The initial explanation began by briefly discussing the history of GIS in order to show that the technology is evolving but not new. Next, the discussion transitioned into how GIS can and has been applied to community planning throughout the United States. This portion of the introduction focused on how utilizing the technology has the potential to make

specific jobs easier for each employee. Lastly, employees were shown the different functions of ArcGIS, such as importing data, zooming in and out on features, and looking at the attribute table of shapefiles. In terms of a formalized, self-selected classroom approach to GIS education, this first day accomplished little. In Dangriga, however, where Council employees were unfamiliar with GIS and required additional background information, the first day began the process of familiarizing each person with the technology and laying the groundwork on which additional knowledge could be built.

Day 2 – ArcGIS interface and database creation

Following the previous day's introduction to GIS, employees began using ESRI created datasets to explore the interface of ArcGIS. Employees used functions such as identify and multiple methods of selection to find data within maps and in the attribute table. At this time, an introduction to databases was presented which discussed the structure of databases and how they were created. Additionally, particular emphasis was placed on the table of contents within ArcGIS in order to explain layers and how they function with each other to create maps. The session concluded by exploring the different views within ArcGIS and how each serves a role as either data manipulator or data presenter.

Day 3 – Symbolizing data and creating a basic map

The third day began the focus of using local data in the training sessions. Utilizing the road data collected during the study and the Dangriga land use shapefile acquired through Marion Cayetano, a well-respected GIS leader in Belize, a flash drive was passed from employee to employee so that each person would have the same datasets. The datasets were explored by analyzing the attribute tables and discussing the data that each contained. A brief discussion ensued as to what would be beneficial to display and symbolize to create a map of the data.

Symbolizing the data focused on using different attributes as the categorizing input and how each attribute could best be symbolized through the different colors and lines as provided through ArcGIS. Each employee was encouraged to explore their inner artist and work towards creating an aesthetically pleasing but functional map. The session ended with employees sharing their creation and receiving feedback from their colleagues.

Day 4 – Join data, creating and editing shapefiles, and changing projections

It was evident through conversations with employees that many had spreadsheets that could be used in ArcGIS. As a result, day four focused on how to utilize existing data by joining it with a shapefile. In order to complete this task, employees were shown how to format spreadsheets for easy conversion into an attribute table and how to carry out that conversion. Next, the session focused on creating shapefiles, a task that included a discussion about the various shapefile types. Having already learned about attribute tables, this portion of the session focused on the steps necessary to achieving the end product of an attribute table. After creating a shapefile, Council employee learned how to edit the shapefile by adding fields and making various changes to the shapefile properties. Lastly, because of different projections among the provided data, the session addressed how to change different projections through the ArcToolbox functions. This was the first introduction of the ArcToolbox and employees were provided a brief overview of its functions.

Day 5 – Friday

Council employees were able to leave thirty minutes early on Friday. Due to the scheduling of training sessions late in the afternoon and the impending weekend, Council employees were focused on finishing their final tasks for the week and were not interested in training.

Day 6 – Map layout and map design

By day five of the training sessions, employees began discussing how the technology could be applied to their own work. This was taken as a sign to present map layout and design in the training session. This session involved discussing general mapping strategies, such as minimizing white space and maximizing map features, and exploring the different options using ArcGIS. These options included adding legends, scale bars, and titles to the maps. At the end of the session, employees shared what they had created with their colleagues.

Day 7 – Introduction to analysis tools, printing. Individual projects

Day six of training sessions focused on expanding the possibilities of GIS and how it could be used at Town Council. Given the limited amount of data and no specific project in mind, employees were presented with a wide array of functions from ArcToolbox. In some ways, this day served as an opportunity to push employees to see the functionality of using GIS to expand and improve the efficiency of their jobs, as well as address any issues within Dangriga. The printing portion of the session focused on adjusting margins and printing a large map on multiple pages. The printers at Town Council were limited to printing no wider than a standard 8.5 x 11 inch sheet of paper. By printing on multiple pages and assembling the pages by hand, employees would be able to present their work through a relatively large map. Additionally, the training session was used to discuss individual projects and how to best assist employees with their project.

Day 8 – Unable to conduct training session

Due to a lack of attendance by Council employees, the time during this training session was used to collect culvert data.

Day 9 – Individual projects

The final day of the training sessions was used to finalize any projects that remained incomplete and to provide a wrap up to what had been covered. Though no formal classroom time was designated for this, each employee was met with who regularly attended the training sessions. This meeting consisted of answering any questions that remained and to better understand the perceptions each employee had of GIS. Though these meetings were informal, each employee discussed GIS and how their vision for the technology had changed during the two week training sessions.

Day 10 – Last day of training

As was experienced the previous Friday during fifth day of training, Council employees focused on finalizing their remaining tasks knowing that they were allowed to leave thirty minutes early. This was also the last day of the research and much of the afternoon was spent discussing the experience with participants.

4 RESULTS AND DISCUSSION

Life moves at a slower pace in Belize. This fact was initially hard to accept as I found myself antsy and ready to solve all of Dangriga's many GIS needs during a four week period. The first two weeks of the project were largely spent getting to know those working at the Council and to learn what it meant to live in Dangriga. This meant learning that outside work was conducted in the morning and late afternoons and that following lunch, the largest meal of the day, it was acceptable to find a comfortable and shaded location to work and pass the hours of peak sunshine. As a small town of only a few thousand, relationships were important and the way to navigate through the various barriers to implementation and usage of GIS.

The study underwent an evolutionary phase shortly after my arrival and introduction to the problems facing Dangriga. Initially the study was proposed as a way to assist Dangriga by collecting spatial data and supplementing their existing infrastructure. Upon learning that the town possessed virtually no GIS infrastructure or knowledge and that the only existing spatial data had been collected at a national level, it was clear that the goals of the study would be modified. The emphasis would be placed on GIS education at the Council while the collection and use of spatial data would fulfill an accompanying role. Below, I revisit the three research questions at the core of this thesis research, and discuss how the fieldwork relates to these questions.

Research question 1: What are the key factors limiting successful implementation of GIS in Dangriga?

4.1 Limiting Factors

There were two conspicuous factors preventing the implementation of GIS in Dangriga: a lack of capital investment in GIS technologies and a lack of functional GIS knowledge. Though simply listing these factors grossly generalizes the challenges of implementation, each factor contained many smaller components that increased and complicated the challenges. These interconnected contributing factors worked to create a network of problems that required addressing multiple issues in order to accomplish the research goals. In Dangriga, there was no singular solution. In discussions with Town Council, it was evident that if they were to overcome the complexities of GIS there would need to be a thorough plan in place. Each action taken to implement GIS would need to solve a small portion of a larger challenge.

4.1.1 Capital Investment

Poverty is of great concern in Dangriga. While interacting with various individuals in town, there were stories of impoverished and malnourished children who regularly searched for food. Often, as I was told, these children would rely on various religious organizations and expatriates for nourishment. For those who could afford to feed their families, health concerns resulting from food quality were increasing. Words such as diabetes and cancer were clearly beginning to cause strain in Dangriga. Aside from food availability, the homes in which Dangrigans reside reflect the impoverished nature of the town. Typical homes are constructed using a wide range of materials that may include plywood and metal siding for those most impoverished to concrete brick structures for the most affluent. Often the differences in structure quality are constructed next to one another. With such a high prevalence of poverty in town, it is difficult to collect tax revenue that could afford the Council with modern technologies. When confronted with an increase in monthly charges, as is later discussed during the collection of the

land use dataset, even the seemingly smallest increases in fees can cause additional stress to families in Dangriga.

Before investing in a new and potentially expensive technology, academic literature confirms the need to conduct a cost benefit analysis of GIS. It is unreasonable to expect a government organization to invest in a system that will not bring benefit to its residents. By comparing the costs of GIS to its benefits, Town Council can evaluate if a true need for GIS exists in Dangriga. If a need is confirmed during a broad evaluation of GIS, it is important to further evaluate the specific technologies that comprise a larger GIS. It would not be prudent to invest in extensions of GIS that have no use to Dangrigans. By accurately evaluating GIS, Town Council can lessen the financial risks associated with investing in new technology.

The inability to collect large sums of tax revenue is evident at Town Council. Located in a modest three story building, the halls of the Council echo practices of the past. There was a clear reliance on paper as stacks of forms and reports could be found on almost every desk and numerous filing cabinets were located throughout the building. Upon inquiry, employees at the Council noted how modern technologies such as computers were available but were not always integrated into one system. This left them with a combination of computer and paper-based records on which the town's data was stored. Due to the inherent digital nature of GIS, paper-based records are unable to be utilized without first converting the data to a digital form. This additional strain on resources would require further investment by Town Council.

The computers located throughout the Council appeared to be dated, even though many contained Windows operating systems and programs that had been released within approximately the last five years. When loaded with a trial version of ArcGIS, the computers demonstrated their limited computing capacity when completing GIS tasks. These tasks were

often slow to be completed and resulted in momentary work stoppages as the computers struggled to complete the processes. In order for successful implementation of GIS in Dangriga, consideration must be given to the condition of the computer hardware. Any needed upgrades will certainly require an additional capital investment by the Council or other partners.

The most troubling condition at the Council that could be alleviated through additional spending was the limited number of ArcGIS program licenses that were available to the Council. A license is defined by ESRI (2010: 1) as "the ability or right to use a specific product for a specified period of time." Program licenses are purchased from ESRI and allow the purchaser to utilize ArcGIS for a given amount of time depending on the length of the purchased license. There were two types of licenses: single use and concurrent. Single use licenses authorize the use of ArcGIS on one computer. Concurrent licenses are authorized to a particular server and may run on multiple machines. The number of computers on which the program can run, also known as the number of seats, is dependent on the number purchased with the license. At the Council, there was one single use license that had been installed on the computer of the person in charge of technology and one concurrent license with one seat. This meant that no more than two people could utilize GIS at a given time, well short of the possibilities of full implementation. While licenses can be expensive, it is important for all employees at the Council to have ready access to the software. Without proper licensing to allow for access, it is impossible to expect Council employees to utilize GIS in their daily work.

Aside from the hardware and software needs of the Council, great consideration must be given to the monetary needs of the personnel who will utilize GIS. As evident through the reliance on paper forms and the limited software on Council computers, advanced computer processing does not regularly occur. It is necessary to invest in GIS education in order to align

the performance of Council employees with new technologies and increase their skills. A detailed discussion of GIS education follows this section. The academic literature confirms that educating GIS users can be an expensive but necessary task. Depending on the level of previous use, training new GIS users may be time consuming and require great amounts of resources.

Currently, Dangriga does not have enough trained employees for GIS to be successful. One possible solution is to train a GIS champion at Town Council. A GIS champion is an individual that the Council can utilize and rely on to support initial implementation and who will maintain functional operations. This person would be responsible for, but not limited to, assisting the employees at the Council with troubleshooting problems, answering questions about GIS, and training new employees. While the person in charge of technologies at the Council demonstrated characteristics of an individual who was capable of becoming a GIS champion, he did not exhibit the knowledge to currently fulfill the role. It is necessary that he, or other designated GIS champions, are given the opportunity to thoroughly learn about GIS and how to best utilize the technology. This requires that additional investments be made available to support classes or other types of instruction in order to designate leaders and provide a foundation for the growth of GIS. The lack of available training was not limited to the GIS champion. Its reverberations were felt throughout the Council and influence the next factor preventing the successful implementation of GIS, education.

4.1.2 Education

Within the realm of practical application, GIS knowledge did not exist in Dangriga. The barrier of GIS education had a deeper meaning than being taught software manipulation. It meant a complete introduction to the technology: its existence, its applications, and its potential role in Dangriga.

While discussing how I would work with Town Council to address their GIS needs, it became clear that for many at the Council GIS held no meaning or was a largely undeveloped concept. Further discussions lead to my understanding that some at the Council had been told that GIS was needed but were provided no explanation or reason for this apparent need. This lack of context contributed to their inability to envision how GIS could exist at the Council, let alone flourish into something constructive for Dangriga. Absent of a thorough explanation, any attempt to implement GIS would end in almost certain failure. The employees at the Council would first need to contextualize the technology to their town.

Academic literature makes clear the need to situate GIS in a local context. Absent of this context, GIS is viewed as an outsiders' technology without local application. Once this perspective is reached, it can be terminal to the goal of implementing GIS. Additionally, it is important to consider that the local context will contain unique circumstances that can contribute or hinder GIS. Only by properly addressing these circumstances and working closely with Town Council can one expect to affect a positive change. In Dangriga, the local context required teaching basic concepts in order to cultivate GIS knowledge.

During training sessions, later discussed in greater detail, I was confronted with a simple question of "What is GPS?" Wrongly assumed that GPS technologies were as well known as in the United States, I realized that the basic spatial knowledge on which many GIS concepts are founded did not exist in Dangriga. The individuals that I interacted with at the Council were well educated, many of whom possessed college degrees. Their lack of geographic knowledge speaks to a possibly larger issue of geographic education throughout Belize. In order to overcome the gap in education and properly explain and apply GIS to local problems, geographic

concepts had to be an essential component of training sessions. Any assumption of knowledge threatened to undermine the project.

Beyond requiring overall awareness of GIS and basic geographic knowledge, education was needed to bridge the gap between the possibilities of GIS and the reality of Dangriga. Sui's (1995) discussion of teaching *about* and teaching *with* GIS is influential in determining appropriate forms of education. In this sense, the Council first needed to know about general concepts and ideas concerning GIS. Next, the Council needed the opportunity to analyze local problems with the application of GIS. This narrowing of focus was important as it gave an opportunity for individuals at the Council to learn about the potential of GIS and then see its ability to address local issues. Academic literature further supports Sui's discussion by noting that GIS education should focus on needs instead of GIS possibilities. While GIS may hold the possibility of solving complex geospatial issues, it is important to remember that introducing GIS for the first time means that the foundation of knowledge on which complex issues can be built does not yet exist. Through specific application, GIS can capture the imagination of those employed at the Council and be cultivated into something complex and transformative. Absent of basic connections being made, it is difficult to imagine that the Council would take ownership of GIS and utilize the technology to its full capabilities.

Aside from the challenges of developing a functional knowledge of GIS, introducing GIS may challenge traditionally held beliefs. Heeks (2002) discusses the fixed nature of governments and their reluctance to incorporate new practices of GIS. Governments are accustomed to making decisions using traditional methods that include personal observations and beliefs. GIS can challenge the traditional decision making process by introducing methods of scientific analyses which may have outcomes that differ. As decision makers are forced to reevaluate

ideas and beliefs they held self-evident, tensions can arise. While there was no initial evidence of this in Dangriga, it is important to remember that this study lasted only four weeks and was an introduction of GIS for the Council. If tensions are to arise, it will likely occur as implementation reaches later stages.

Further consideration must be given to the problems that can form through new land representations. Just as GIS can challenge tradition decisions, it can also challenge users to reconsider their view of the land and space around them. Heeks continues that new practitioners may find the ability to measure and standardize land using GIS difficult to initially grasp. While Council employees showed some signs of difficulty grasping new two-dimensional representations of their town, most of the problems appeared associated with the newness of GIS and its interfaces. As previously mentioned, the Council had access to aerial photographs overlaid with parcel numbers. The addition of GIS did little to challenge the ways in which they viewed their town. Instead, GIS proved to be a technical challenge.

Heeks concludes his discussion of information systems by discussing the trust that must be given to a new system. GIS in Dangriga was not met with contempt. It was met with a hesitant but optimistic openness to the idea of using new technologies to improve the decision making process. The trust that seemed inherent in Dangriga is important if GIS is to take hold at the Council and have a positive influence. If GIS is met with doubt and unwillingness for it to succeed, it almost certainly will fail.

As Town Council moves forward with GIS education and takes a conventional approach to education, one that replaces a graduate student researcher with paid consultants, the resource strain placed on the Council is certain to increase. The direct financial burdens of education have already been discussed, but it is important to recognize the time required to properly train

Council employees. Case studies on GIS training acknowledge the time consuming and laborious nature of educating users. As in Dangriga, it is often necessary to address mitigating factors that contribute to educational barriers, such as addressing larger issues of geographic knowledge. These additional factors can increase the amount of time required for education and in turn can become an unforeseen expense.

The implementation of GIS in Dangriga hinged upon the success of educating the Council. Education provided an opportunity for the Council to learn, discuss, and reflect on GIS and how it could best be utilized. Though the need for GIS education can be succinctly summarized, the process of educating the Council provided great opportunity to examine my role as a researcher and teacher.

Research question 2: What role do collaborative partnerships have on Dangriga's ability to implement GIS?

4.2 Participatory GIS

Participatory GIS studies have typically focused on the empowerment of community members through bottom-up, locally-driven approaches that challenge the conventional top-down, expert-driven approach of larger organizations. Such studies often characterize governments as top-down and guilty of marginalizing individuals and smaller groups. In this case study, Dangriga is considered marginalized as it faces similar concerns of inclusion. The problem originates from the political landscape in Belize which gives GIS authority and control to the Ministry of Natural Resources and Agriculture's Land Information Center (LIC). This monopolization of GIS resources creates a reliance on the LIC to complete geospatial tasks. More importantly, Dangriga is forced to seek and rely on the LIC's resources instead of using

local knowledge and local resources to complete local projects. PGIS is best situated to challenge the status quo and empower Dangriga.

The factors that constrain the implementation of GIS and Dangriga's inability to autonomously address those factors reveal a need for outside assistance and partnerships. The process of implementing GIS is simply too large of a project for an organization that lacks funding and knowledge. Collaborative partnerships hold the promise of addressing limiting factors by forming a long term, mutually beneficial relationship and providing much needed organizational, monetary, and knowledge support. These partnerships allow all parties involved to focus on their own strengths and maximize the effectiveness of a project.

In Dangriga, collaborative partnerships hold particular promise in their ability to provide monetary support of GIS. The initial capital required to fully integrate a GIS far exceeds what can be afforded in Dangriga. As discussed in the literature, costs can quickly rise and exceed anticipated amounts when first beginning the process of integration. These unexpected costs can lead to an eventual failure of GIS. Dangriga does not have the capital to invest in a project that is destined to fail. Outside partnerships are able to lessen the financial liability by providing financial assistance or by guiding the implementation process. Regardless of the particular form of assistance, the knowledge that can be shared is invaluable.

The benefits of collaborative partnerships extend beyond the reaches of monetary support. Collaborative partnerships also support the sharing of knowledge. By utilizing the experiential knowledge of outside partners gained during other GIS projects, Dangriga can increase its likelihood of successful implementation. This guidance can be invaluable at preventing needless costs associated with unknowingly attempting to utilize GIS. The mutually

beneficial nature of collaborative partnerships provides an opportunity for outside partners to gain valuable opportunities to further their own knowledge that can be applied to future projects.

Dangriga should be wary about blindly or carelessly partnering with any person or organization that offers to work with the Council. As discussed in the literature review section, the power dynamics of partnerships can place the Council in a role of relying on a partner for resources. A retreat by a partner could have negative, and potentially project failing, consequences. Instead, Town Council must situate itself so that any partnership that it participates in focuses on maximizing the sustainability of GIS in Dangriga. An exploitive partnership would threaten the vitality of GIS.

Beyond the immediate benefits of monetary and knowledge support, collaborative partnerships are capable of extending and expanding the tasks that are being completed through the addition of third party partners. This study benefited greatly from the connections and friendships that were extended through the network of Jim Kostaras. As an outsider seeking to conduct research, I had few direct connections to Dangriga. While organizing the research trip, I was forced to approach the planning as a traveler who had decided to stay in Dangriga to complete work. The relationships that Jim and his associates had developed in Dangriga and throughout all of Belize provided great assistance as the planning for the trip developed. Through discussions with Jim, it was made clear that the housing options I had decided on were not the best option as there was a local Dangrigan hotel owner and community activist who would be willing to provide sharply discounted lodging during my stay. Since housing was a considerable percentage of my costs, this connection eased my financial strain. Applied to other researchers and GIS activists, local assistance from previously built relationships has the possibilities of enabling more partners to join as their costs can be lessened.

The organizational benefits of collaborative partnerships, as felt by third party partners such as me, do not end with monetary assistance. The benefits extend into a sense of legitimacy felt by the new partner. As previously discussed, I had no connections to Dangriga while developing this research. The relationships that Jim Kostaras and his partners had developed provided me a sense of legitimacy upon my arrival to Dangriga. Though barriers still existed, as will be further discussed, my tasks were viewed as having purpose and I was given an opportunity to work. Absent of connections, I surmise that I would have been viewed as little more than a college student passing through Dangriga. Instead, the doors of Dangriga were opened.

Working as a collaborative partner to Town Council, the literature of participatory GIS guided my research. It was important from my first day in Dangriga that those working at Town Council understood that I sought to be a collaborative partner who would bring a positive change to their town *and* to address personal research questions. Both had to be done in unison and in a non-exploitative manner. As Pain and Francis (2003) outline, there are three important factors of PGIS: developing relationships, sharing knowledge, and engaging in action. Each of these factors had to be addressed in order for the research to be successful.

As a researcher, developing a relationship with Town Council was the first checkpoint to working in Dangriga. During my first introductions at the Council, I spoke about the possibilities of my time in their town and the role that I wished to assume. While friendly and attentive, I felt that my conversations with various individuals had as much to do with them learning about myself and my motives as it did about me learning the needs and direction of Dangriga. I was often invited into air conditioned offices, something I soon realized was reserved for the most important persons working at the Council, to discuss small particulars

about my work and about my life as a graduate student. When I would redirect the conversations into a more constructive manner for my research, the conversations would eventually revert back to the topics I had initially been asked to discuss. After several days of this and noticing a change in demeanor among those working at Town Council, I realized that those conversations had served as my interview and eventual welcoming to work in Dangriga.

An additional consideration of these first conversations is the institutional inertia required to begin implementation. As Bishop, I. D., F. J. Escobar, et al. (2000: 96) note, "the successful implementation and use of spatial information infrastructures in developing countries is dependent on political and institutional support." While the Council showed no signs of being against the use of GIS, they lacked the awareness, education, and feasibility to accomplish implementation. For the Council, implementing GIS may have been a good idea, but there was no reason to give support to a notion that may or may not occur. Throughout my research, it was important that I gave reason for considering GIS and to provide the necessary spark for institutional inertia. After the initial conversations at Town Council and the relationship between the Council and I strengthened, the conversations turned to aligning the needs of Dangriga with the skills that I could provide. As the PGIS literature addresses, the role of an expert within a community is important to answer research questions and affect change. The expert is capable of empowering individuals to take action. For the Council, they possessed extensive knowledge about Dangriga. For myself, I possessed GIS knowledge that could be the catalyst of the Council utilizing GIS tools. It was only through the successful marriage of these two sets of knowledge that Dangriga could be empowered to act.

The marriage of ideas occurred by analyzing existing practices at the Council and determining how GIS could be used to best improve those tasks. As I discussed my ideas for

action with the Council, it was important that I proposed realistic and achievable goals. Frank, A. U., M. J. Egenhofer, et al. (1991) warn against presenting GIS in a manner that promotes goals that are not likely to be achieved. This would cause a negative perception of the partner responsible for implementation and of GIS. Instead, partners must work together to establish expectations that will satisfy all involved. As successes occur, GIS projects can expand to include more complex tools and analysis.

Participatory GIS focuses extensively on developing methods of action to help individuals instead of methods to improve knowledge, as is common within academic research. The development of such methods occurred during the negotiation process. Through various conversations, I narrowed an assembled list of datasets that the Council wished to collect. The initial list had been compiled during my first introductions when the Mayor and others at the Council listed numerous concerns that they felt should be mapped. While the Mayor and Council had many focuses, it was evident that mapping items of immediate concern, such as the location of culverts to address issues of flooding, outweighed the need to map burial plots. As the expert in the relationship, the process of negotiating focal points was easy as the Council had many areas of concern but did not dictate the specifics of what they wanted done. This left me with the autonomy to adapt my work to their needs while doing so in the most effective and impactful manner that I could.

Once a relationship had been established, the process of sharing knowledge and engaging in action could begin. Though building a relationship with Town Council had a specific time sensitive role to the research process, sharing knowledge and engaging in action was a continuous negotiation between Dangriga's needs and the knowledge that I could provide. This negotiation continued throughout the entirety of the research.

It was important that I focused on tasks that could lead to long term sustainability for Town Council. As a student researcher, my role in the relationship was limited to what I could provide while I was in Dangriga. The research project had taken almost a year to organize and any future knowledge that I could share or local action that I could participate in was unknown. It was paramount that while in Dangriga, I worked diligently to position the Council to further their GIS knowledge once I left. Through various data collections and leading daily training sessions, I was able to best engage the Council by building a mutually beneficial relationship as outlined by the PGIS literature.

Research question 3: How does collecting and utilizing local data contribute to the success of GIS education in Dangriga?

4.3 Local Data as a Tool for Instruction

The original intention for collecting data was to increase Dangriga's inventory of spatial data that could assist in the decision making process. The task assumed a dualistic role as the collected data became an important addition to the daily training sessions. A discussion of each data collection and the training sessions follows.

4.3.1 Data Collection

4.3.1.1 Roads

The roads dataset was the first collected. There were two influential factors for conducting this field work first. The first reason resulted from the lack of known accuracy with the provided roads dataset. During my initial introduction at the Council I had been given various datasets that had been collected, including roads, by Marion Cayetano. Unfortunately,

little metadata was known about how or when the data had been collected. Though the data visually appeared to be accurate, it was decided that collecting new data would best serve the purpose of this study. The second reason for collecting a new dataset was to have an accurate dataset that could be used to situate subsequent data. Roads would serve as location identifiers when collecting the locations of culverts, land use, and garbage collection routes.

Collecting the roads dataset was an enjoyable process of driving a Council-owned motorcycle throughout Dangriga while tracking the movement via the Trimble GPS unit. I had been given a letter written by a Council member that was to serve as my temporary license while in Town. The contents of the letter essentially ensured the reader that I was a skilled motorcycle driver and had the full support of the Council to use the motorcycle while conducting my work. The entire process was broken up over several days as my mornings were often spent in conversation with those working at the Council, and my afternoons were often spent avoiding the brief, but heavy showers and thunderstorms. Once this dataset had been collected, it was incorporated into the training sessions that occurred during the afternoons later in the study.

This initial dataset proved influential in guiding the training sessions. As discussed in a previous section, local and accurate data is essential for conducting proper GIS education, a theme that will be explored in a later section. Although the motorcycle was owned by Town Council, they did not possess a GPS unit or similar device for collecting road data. Instead, the Council was forced to rely on outside datasets that had been created by unknown individuals and that had not been shared until my arrival. It is important to note that I was responsible for sharing the data that had previously been collected. While I am hesitant to hold any group responsible for not having already shared the data, I do question if and when the data would have been shared without my presence. Regardless of who or why the data had not been shared, it was

evident that Dangriga held no authority or power in their relationship with the LIC. Dangriga's reliance on the LIC was already working against their geospatial empowerment and promoted an almost certain continuation by the LIC. By utilizing the goals of PGIS and working alongside Council employees, empowerment and a sense of ownership began taking place. For the first time, Town Council needed not to rely on the LIC for its geospatial data.

This relationship serves as an example of the academic literature's analysis of data acquisition and subsequent commoditization and control. Existing literature notes that centralized governments harm the data collection process of peripheral groups. In Dangriga there had been no known attempt by the LIC to include the local council in collecting local data. The data that was collected was kept under the control of the LIC, whose office is approximately a ninety minute drive west of Dangriga. There had been no effort to share the data with those who are represented in the data. Upon it being shared, there was no consideration given to the standardization of data. It was shared as it was with little metadata. If Dangriga and the LIC are to work well together, it is imperative that each share control in the designs and outcomes of future GIS-related projects.

4.3.1.2 Land Use

The land use dataset was collected next. Using an aerial photograph overlaid with parcel numbers, I worked alongside a Council employee from the Valuation Department. He had been tasked with notifying the public of a garbage collection fee that would soon be required. While he spoke with citizens of Dangriga, I walked parcel to parcel collecting land use types. My original goal had been to collect data and demonstrate the capabilities of GIS and how he could incorporate it in his daily work. While the man was friendly and listened to what I had to say, he was reluctant to participate in collecting data and instead focused on his own task. By midday I

had little water left to drink and was becoming frustrated by his lack of engagement. Reluctantly I decided that my time could be better spent collecting other forms of data or preparing for the upcoming training sessions. We parted ways and I returned to the comfort of an oscillating fan and began preparing for my other tasks. A few days later I was informed that the man I had been working with had left for the police academy in a different region of the country.

The frustrations that I experienced that morning can be explained through academic literature. The literature discusses how it is important that individuals buy into GIS and that they believe in the tools that are offered. For this man, unlike others that I worked with, GIS held little importance as his future job would likely not have the same spatial needs. His only concern was to complete the job that he had been tasked with as he was soon transitioning into a new role. Another potential factor in this experience is what the literature describes as "lack of skilled personnel to establish and manage the infrastructure" (Bishop, I. D., F. J. Escobar, et al. 2000: 87). The man I worked with had few technological tools available at the Council. When a computer was needed, he had to ask to use one belonging to someone else. The files from which he used to reference parcel information were contained not in digital format, rather the files were located in three, four drawer filing cabinets located in the Valuation Department. At no time did I see him ever use technology in a manner that would make me believe he has the technical knowledge to quickly learn GIS. For this man, his apparent lack of technical knowledge left me with the impression that teaching him GIS would need to involve first teaching him many basic computer operations. If such attention is extrapolated to a large scale, as done throughout academic literature, the result would be certain failure of implementing GIS. Without belief from the individuals or groups who will regularly use the technology, GIS is doomed for failure.

4.3.1.3 Culverts

The collection of culvert locations was one of the most important data collections identified by Town Council. Given the town's recent flooding events, it was clear that an accurate and detailed inventory was needed to further the community's ability to prepare for inundation. Initially it was agreed by the Council that I would map current culvert locations and where future culverts should be placed. After conducting the first part of the data collection, as later discussed in this section, it was apparent that I was not qualified to identify locations of need. This would need to be conducted by an individual with proper training. Instead, my focus should be on mapping current culverts so that the Council could make appropriate planning decisions.

The historical flooding in Dangriga and the lack of related data demonstrates the strained relationship between Town Council and the Land Information Center. The LIC had asserted itself as the official collector and keeper of GIS data. As recently as a few months before the research started, a tropical storm caused flooding throughout Dangriga. Yet, the LIC had made no discernible effort to utilize GIS in planning and responding to known flood dangers. This apparent lack of attention given to Town Council underlines their need to autonomously utilize GIS in the best interest of Dangriga. The goal of empowerment is found throughout the PGIS literature. Dangriga's need to act quickly and smartly in response to natural disasters is an essential reason for providing the necessary tools for the Council to appropriately utilize GIS in their decision-making processes. As a researcher, my goal was to begin their empowerment by collecting culvert data.

The collection of culvert locations was broken into two parts. The first part involved collecting data with people from the Town Council while the second part consisted of

independent data collections. Group data collections proved the most challenging as a detailed explanation of the data collection process was necessary. This involved asking employees who were accustomed to working in cool offices to now work outside in the heat. The change of setting was met with some hesitance, most notably because of walking in uncomfortable shoes. Once in the field and accepting of the working conditions, there was a considerable difference in the demeanor of those who planned on using GIS in their everyday jobs. These individuals were receptive to explanations concerning the collection of GIS data and best practices while in the field. The greatest difficulty for those in the field was learning the various functions of ArcPad on the Trimble. With a limited knowledge of computers, using a handheld device caused frustrations. The frustrations stemmed from the small screen and a lack of knowing the various functions of ArcPad. My explanations focused on topics that were currently being applied in the field so that there was an opportunity to learn from repetition. The data collection lasted approximately two hours until one section of Dangriga's culverts had been mapped.

The second component of collecting culvert locations involved independent data collections during the morning and afternoons. I had already learned that midday was often too hot to spend hours walking throughout Dangriga and that collecting culvert data could be used to demonstrate an immediate use of GIS. I adapted to the conditions by scheduling data collections early in the morning, typically before 10am, and late afternoon, typically from 5pm until sunset. The data collection itself was merely nothing more than a search throughout the southern portion of town. Dangriga had no maps of culvert locations so the data I was collecting was the first of its kind. Once the locations were identified, it was then necessary to follow the water flow to complete the culvert network. Most culvert networks were comprised of two or three under

maintained sections. At times the lack of maintenance made it difficult to discern a culvert from a depression alongside of the roads.

Without needing to demonstrate GIS technology to others, collecting culvert locations was a quick but labor intensive project. Unlike when collecting the roads dataset, this dataset required walking to identify each location. Considering the experiences of collecting culvert data with Council employees, I imagine that tasking an individual with collecting data throughout Dangriga may be met with some resistance.

The importance of the culverts dataset comes from the empowerment literature of PGIS. Given the adverse affects and frequency of flooding in Dangriga, it was important that data were collected that could better inform local officials of existing conditions. As discussed, it was apparent that the national government did not view such information as a priority as there had been no known collection of data. If Dangriga were to learn more about the flooding conditions of town, it would be their responsibility. Approaching data collections from a decentralized approach allowed the Council to have input throughout the entire process. The Council was empowered by addressing self identified needs through a partnership and the utilization of GIS tools and knowledge that I was able to provide.

Using GIS to begin studying the flood problems was also useful in establishing a value of the technology in Dangriga. Prior to collecting culvert locations there were no spatial data concerning culverts, and what may have existed was incomplete and not useful for making decisions. By collecting these data, the Council was able to see how GIS technologies can be useful in creating accurate and up to date datasets that can positively impact Dangriga. While this one dataset is unlikely to lead to widespread support throughout the Council, it certainly demonstrates the capabilities of GIS.

4.3.1.4 Garbage Collection Routes

The mapping of garbage routes was my least engaged data collection project. With an early start and late finish for the garbage men, it was impractical to shadow the men while they worked. Additionally, it was not needed. All of the necessary data was collected by placing a GPS unit in the cab of the truck each morning. Each afternoon I would retrieve the unit and backup the data. This project began during my last week in Dangriga at the request of Dangriga's mayor. The data was not used during the training sessions.

4.3.2 Training Sessions

Conducting training sessions and educating the Town Council about GIS was the most important task. The various data collections that were conducted held no independent meaning. Each was contingent on the Council's ability to utilize the data in a manner that allowed for further development and improvement of Dangriga. In order to train the Council on how to use GIS, I began by utilizing strategies that I had seen during introductory GIS classes at Georgia State University. It was soon apparent that these strategies were insufficient to address the needs of Town Council and that I would need to adapt throughout the process.

In the lead up to beginning of the first training session, two weeks into my time in Dangriga, the Council and I had grown to know each other in such a positive manner that I had gained the trust to train employees. In reflection, I believe that without first establishing a relationship the training sessions would not have been successful. As previously discussed, the initial interactions saw the Council reserved in their discussions as they came to know me. By the time the training sessions began, I was being reintroduced to people I briefly met during my first day of work. Their demeanor showed openness to what I was to teach them.

The first training session reversed the roles of teacher and student. My original plans had been to use ESRI created data to demonstrate the capabilities of GIS and how to manipulate basic data. This quickly ran into problems as the data held no meaning and thus left those participating in the training sessions searching for meaning to what they were doing. Questions that should have been focused on specific functions of ArcGIS were instead focused on gaining an understanding of the data. It became apparent that if future training sessions were to be successful, it would be necessary to incorporate the local data that had been collected, a concept echoed by academic literature. The end of the first training sessions left me with the impression that I had learned more about how to not conduct future training sessions than any knowledge that had been transferred to the Council employees. If the training session were going to be successful, I would need to rethink my approach.

The second training session began by sharing the roads dataset that I had collected the previous week. At the first sight of the data projected on the screen, the Council employees immediately reacted in a manner that demonstrated their connection to the data. Subsequent training sessions experienced the same positive result from utilizing local data in the lessons. Council employees were eager to learn more about the data that was being represented and, most importantly, showed interest in applying what they were seeing to their daily tasks at the Council. The literature discusses the problems in two ways. First, there was an additional burden placed on those attending the first training session. From discussions I had with various individuals at the Council it was apparent that there was a lack of basic spatial knowledge. Without a basic understanding, individuals focused on understanding the data and were unable to make connections between the data and GIS software. Their preoccupation with understanding the content of the data was a distraction preventing their full engagement with GIS concepts.

This needed to be addressed before moving forward with training. Second, the uses of local data throughout the training sessions lead to their eventual success. Had the problems experienced during the first training session continued, it is safe to assume that the frustrations and confusion would have lead to the eventual failure of the training sessions. The strategy I employed during the first training session asked too much of the attendees. By utilizing local data, there was no need to learn about the flowers that exist in a far away land, or any other dataset far removed from Dangriga. Instead, local data allowed for the application of local knowledge and context that gave meaning to the data was being manipulated and analyzed. Those attending the training sessions were able use their existing knowledge to confirm or reject the results of using GIS.

Influenced by PGIS literature and the mistake of using data collected from outside of Dangriga, I decided that the topics that I covered during training sessions would be dictated by the availability of local data and the knowledge that the Council wished to obtain. While there were numerous topics that I had identified before the first training session, such as how to use a digital elevation model to map flooding, the lessons learned from the first training session and the lack of available data in Dangriga limited the topics that I could cover. The availability of data certainly limited the extent of influence I had on the training sessions, but the attendees' desire for knowledge offset any limitation. It was important that those attending the sessions had the ability to influence the topics that were covered. I did not want to be seen as a dictator of knowledge as PGIS literature warns. Instead I wanted to be viewed as a resource for their learning. By having an open-ended list of topics to cover each day and inquiring about how the topics connected to the work being done at Town Council, I was able to demonstrate specific real world applications in Dangriga. This often resulted in those in attendance expanding and applying new concepts.

The time constraints and training session prioritization influenced the effectiveness of the training sessions. While I had the blessing of the Council to conduct the training sessions, those attending also had to maintain their regular responsibilities. Existing literature concerning barriers to implementing GIS acknowledge this problem through discussions of monetary and time expenses. This often caused attendance problems. The attendance of the sessions ranged from as few as three individuals to as many as ten, with the average attendance of approximately six. At times, individuals would arrive an hour into that day's session. With such a fluctuation in attendance, it was often required to cover past topics at the beginning of each session. While I worked to independently teach already covered topics during the second half of sessions when the attendees were encouraged to explore what had been taught by applying it to their own work, it was sometimes necessary to teach the previous topic once again so that it could be applied to the current day's lesson. Repeating a previous lesson often gave confirmation that previous concepts had been retained as attendees would often speak up to help or playfully joke about what the person was doing wrong. During these occasions, I preferred to observe and interject when necessary instead of leading the discussion. The group atmosphere that was constructed reinforced my observations of Town Council beginning to take ownership of GIS and take the first steps towards empowerment.

As the training sessions progressed during the last two weeks of my being in Dangriga, there was a clear difference between those readily using ArcGIS and those who were only using the software during the sessions. The first sign of difference came from the questions that were being asked. Those who were regularly using the software, no matter the extent, began asking questions about how to further what they had already learned. These questions were typically asked when an individual worked on a project outside of the training sessions and sought to push

the project outside of the boundaries of the topics that had been covered. Such questions were answered during the training sessions for the betterment of all in attendance, but specific answers were given during one-on-one time outside of the sessions. Those who did not work outside of the training sessions either asked no questions at all while they followed along with the lesson or asked questions remaining within the topics being covered.

The training sessions demonstrated that full GIS implementation at Dangriga's Town Council was possible. Though there were certain to be a multitude of challenges that would require attention before declaring project success, Council employees demonstrated a willingness and ability to adopt basic GIS processes in their daily tasks. As outlined in the barriers of GIS implementation literature, creating value in GIS is a basic problem that must be overcome. Council employees were quick to the find value and move beyond this initial step. By the end of the sessions, employees were seeking to learn much more than what I was capable of demonstrating during the two weeks. The desire to continue learning and better utilize GIS proves a needed commitment by partners to work with Town Council to implement GIS in Dangriga.

5 FUTURE DIRECTIONS

Though my work in Dangriga, as detailed and analyzed in this thesis, has ended, Town Council's efforts to fully utilize GIS should not. The following section outlines three focuses for the Council as it continues the process of implementing and learning GIS.

First, it is important that the Council continues existing partnerships and works towards developing new relationships with organizations. As a student researcher, I faced many limitations including time and resource constraints. It is important that Town Council develop partnerships with individuals and organizations that are committed to the long term sustainability of GIS in Dangriga. The partner or partners chosen should be invited by the Council and not thrust upon them by outside governments or organizations. Such partners should exhibit the PGIS tenet of focusing on local needs and ensure that benefiting Dangriga is at the core of the partnership. Of those identified as potential partners, Dangriga should focus on those who are able to provide the largest amount of resource and knowledge and who have a history of success. Dangriga's geospatial infrastructure is far too frail and in its infancy to withstand a toxic partnership that will not reap benefits.

Second, Dangriga must acquire the necessary tools to conduct data collections. Potentially benefited from a successful partnership, the acquisition of Trimble, Garmin, or similar GPS units are vital for Dangriga to ensure that they are able to utilize GIS under their own guidance. As discussed throughout this thesis, collecting data is an essential component to empowering GIS users. The, at times, tumultuous relationship with government organizations throughout Belize underlines the need for Dangriga to assume control of data collection. It is not enough to rely on other, outside groups to collect data. Dangriga must be able to act on its own.

Lastly, Town Council must continue the process of educating its employees about and with GIS. The amount of knowledge that I was able to share during my four weeks in Dangriga is only a small percentage of GIS. If Dangriga is to find benefits in GIS, it is important that the Council has a wealth of knowledge to properly utilize its tools. As extensively discussed throughout this thesis, self reliance is essential for GIS to be successful. Self reliance is only possible if Council employees are able control the entire GIS process from data collection through map creation and decision making. A break down anywhere in this process threatens the overall focus on the needs of Dangriga. While educating its workforce may not be cheap, it is an important step that cannot be overlooked. Dangriga may find many educational benefits through partnerships as discussed in the first recommendation.

While the conditions of Dangriga may warrant specific changes or additions to the three recommendations outlined in this section, it is most important that Dangriga remain on track to fully utilizing GIS at Town Council. Participatory GIS literature makes it clear that the focus of continued efforts must be kept on the needs of Dangriga. Above all, it is most important that the Council adopts this PGIS sentiment and remains focused on itself and doing what is necessary to benefit the residents of Dangriga.

6 CONCLUSIONS

This research used a Participatory GIS methodology to address concerns of implementing GIS in Dangriga, Belize. As discussed in the PGIS literature of chapter two, issues of empowerment and access are essential concerns. By using a PGIS methodology that included data collection and training sessions, Dangriga's Town Council was able to challenge the existing power structure of GIS in Belize by learning common practices and implementing those practices in their daily tasks.

The existing power structure is not the only challenge facing Dangriga. The barriers of implementing GIS, outlined in chapter two, are not easily assuaged. Instead, the Council must constantly face these barriers as they work towards fully utilizing GIS. Struggles of institutional inertia, resource constraints, technical constraints, and education can be assisted through successful partnerships. These partnerships provide important resources and knowledge that are not available in Dangriga. By turning to partnerships for help, as described in multiple case studies in chapter two, Dangriga's Town Council has an opportunity to be successful in its use of GIS.

Dangriga must consider the types of partnerships that they will require to continue what has been started at the Council. As a graduate student researcher I was greatly limited in what I could achieve. These limits were realized during the first meeting with Town Council when I realized that I was to play many roles while in Dangriga. I first had to show the usefulness of GIS and that it was something that the Council could regularly utilize. This role required many days initially and consequently the momentum achieved through the research peaked as my work was coming to an end. In future efforts, it is important that the Council has clear expectations and goals that they wish to achieve in order to maximize efficiency. These goals should be

conveyed to those assisting the Council. While my research came during a time when the Council was cautiously exploring the possibilities of GIS, further GIS inquiries should seek to condense tasks similar to those completed during my four weeks in Dangriga. The pace at which this research occurred is understandable given the newness of GIS at the Council but future efforts should be capable of achieving more.

The role of partnerships must consider what each partner is capable of providing. As the literature of chapter two outlines, partnerships can be exploitive. Town Council cannot afford a destructive partnership. Given the fragile condition of GIS in Dangriga, partnerships should be vetted so that those only with proven successes are to be included in implementation. These partnerships should focus on the greatest needs of Dangriga, maintaining the PGIS goals of this study. As evaluated during this study, the Council suffers from a lack of resources and training. The initial challenge of raising awareness and establishing a need has been completed. It is the role of future partners to assist the Council with achieving and maintaining GIS autonomy.

As a PGIS researcher and temporary partner to Town Council, it was important to focus on local issues to complete the research. The initial goal was to assist Town Council by collecting local data. Upon introduction to the Council, it was clear that there was no infrastructure to collect or, more importantly, utilize data. In order for this research to have any useful meaning it was necessary to shift focus and work towards educating the Council. This was accomplished through a series of data collections and training sessions.

The data collections resulted in the first known GIS datasets that had been collected with Town Council. Existing datasets were controlled by the Ministry of Natural Resources and Agriculture's Land Information Center and had not readily been made available to the Council. The new datasets provided empowerment to the Council by having them decide the data that was

needed. Concerns associated with roads, land use, garbage, and flooding were identified. Through the partnership that had been formed, I was able to use my resources as a graduate student researcher to address their concerns, thus achieving many of the goals of PGIS. While working to collect data, Council employees showed some advances in their knowledge of GIS. This knowledge, however, could not initially be confirmed. It required training sessions that gave opportunity to manipulate and analyze the data that had been collected in the field.

It was discovered in the first training session that outside data had little meaning to those working at the Council. If GIS was to be learned, local data was needed. This need was met through group and independent data collections focused on current problems that Dangriga was facing. Employees at the Council showed great willingness to learn and implement the new technology as they learned more about its possibilities. Academic literature extensively discusses the need for individuals to find value in GIS before it can be successfully used. This occurred in Dangriga as the willingness of Council employees to learn originated in their ability to manipulate GIS tools. With each success, momentum and support for GIS was gained. The training session confirmed the small hints of success during data collections. The final outcome saw a basic, but functional use of GIS by those who participated at the Council.

This research has demonstrated the difficulties of implementing GIS in Dangriga and the results of one researcher's efforts to educate and train Town Council. As the Council moves forward to fully implement GIS, it is important that they maintain the momentum from this research. Employees began showing considerable buy-in to using GIS by the end of the study. It was clear they held a true desire to continue learning and using GIS on a regular basis. This desire must be protected and employees must be encouraged to continue striving to a higher level

of understanding of GIS. The future of GIS in Dangriga appears promising, but it will require continued effort and assistance in order to consider GIS fully implemented.

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