Mapping Critical Water Infrastructures in the Neighborhoods of Burunga, Arraijan, Panama

Interactive Qualifying Project Report completed in partial fulfillment

of the Bachelor of Science Degree at

Worcester Polytechnic Institute

Submitted: October 11th 2017

By:

Peter Carosa

Brandon Cohen

Alisa daSilva

Luke Fronhofer

Submitted to:

James Chiarelli

Stephen McCauley

ABSTRACT

In the three Panamanian neighborhoods of Nueva Jerusalen, 13 de Febrero, and La Alameda, significant land development and population growth have caused a growing demand for a stable method of water distribution. The area is yet to be fully mapped and documented, causing difficulty for the agencies trying to upgrade community water infrastructures. We created an interactive map plotting roads and existing water features. With this information, we provided recommendations on required pipe infrastructures and water pressure.

ACKNOWLEDGEMENTS

The completion of this project would not have been possible without the help and consideration of those who both advised and contributed to the success of our project. We would like to recognize and thank those who have been a driving force in helping this project along.

We would first like to thank IDAAN and all the employees that provided us with the opportunity to work on and complete their project. We would like to extend a specific thanks to Yamileth Quintero, our IDAAN counterpart, who oversaw the work on our project. With her help we were able to help gain an understanding of our deliverables and scope of work. We would also like to thank Alonso "Franco" Castillo for his work in organizing the project amongst the three IQP teams. He continually provided support and guidance throughout our field work.

Next we would like to extend our gratitude to our sponsor Ricardo "Rick" Montanari and his nonprofit organization Footprint Possibilities. Rick helped define our scope of work and helped us with weekly organization and meetings to ensure the project was on schedule. His dedication to our work was a great help in understanding the needs of our client IDAAN. Whether it was a last second meeting or email updates, his support was always known and appreciated.

Our project would not have been possible without the help from our advisors James Chiarelli and Stephen McCauley for their dedication and assistance in overseeing our projects completion. Prof. Chiarelli in addition to facilitating our ID2050 seminar, has provided his time and guidance in helping our project develop. Prof. McCauley helped provide valuable criticism and guidance in helping our project meet all the requirements of an IQP.

Finally, we would like to recognize and work done by the Footprint Census and Environmental IQP teams. Their work and data collection helped to contribute to our shared goal of providing valuable information to IDAAN. Both teams helped to organize and set up field work as well as continued communication with our sponsor and client. Without the accomplishments and collaborations of these teams, our project would not stand as successful.

EXECUTIVE SUMMARY

Purpose Overview

The Panama Canal runs north-south and divides the country of Panama into Eastern and Western zones. The state-owned lands surrounding the Panama Canal Zone have become home to settlers over the last 20 years due to the availability of the land with the handover of the canal back to the country of Panama. As a result, governmental agencies, such as El Instituto de Acueductos y Alcantarillados Nacionales (National Institute of Aqueducts and Sewers), also known as IDAAN, have been struggling to provide these new communities with basic utilities; most households in these areas do not have potable water.

Arraijan is a district just west of the canal which contains the sub-district of Burunga, where many of the houses have been built within the last 10 years. Currently in the region of Burunga, there exists a water tower holding 50,000 gallons and an additional 1.6 million gallons in an underground reserve tank; this water tower will service three of the over a dozen neighborhoods in Burunga: La Alameda, Nueva Jerusalen and 13 de Febrero. This is part of a World Bank funded project to provide Burunga with a water and sewage system; $10 million of this loan is going to the three communities in which we worked. IDAAN will pump water from the water tower to the highest points in La Alameda and 13 de Febrero where gravity fed water tanks, that are large enough to sustain the community's water needs, will distribute water to the surrounding areas. The underlying issue for IDAAN was a lack of information about the communities and the existing infrastructure in the region. Without this information it has been impossible for IDAAN to distribute the water to the nearby neighborhoods. Therefore existing maps needed to be updated to reflect this population expansion and to establish a baseline profile of existing infrastructures to provide these areas with potable water.

Our project goal was to provide IDAAN with knowledge of the current water infrastructures (such as water tanks and culverts) and create maps of neighborhoods in the Burunga sub-district to establish formal boundary lines and identify paved roads. Our maps of the rural communities in Burunga will help IDAAN and other governmental agencies to assess the living situations of people in these regions and alleviate a major problem that these communities face: the lack of access to a potable and sanitary water supply. We worked in cooperation with Footprint Possibilities, a nonprofit organization that works to improve the

wellbeing of Panamanian communities, in coordination with partners from IDAAN, to reach the goal of helping the rural communities of Panama establish capable water systems and overall community improvement.

Methods

The overall purpose of our project was to plot, organize, and map the communities' critical water features in a single database. This will assist our sponsor, IDAAN, to determine where to allocate the $10 million dollar World Bank loan to much-needed infrastructure in the neighborhoods of La Alameda, Nueva Jerusalen and 13 de Febrero in the sub-district of Burunga.

The features in the area were mainly culverts, personal water tanks, and roads. We mapped these features using the iPhone application Map Plus, which allowed us to mark points with descriptions and pictures of the features and transfer them into a distinct mapping layer for each feature we encountered.

Our first task in the mapping work was to establish polygons representing the boundaries of the neighborhoods, which we determined by referencing IDAAN's latest maps of the region (from 2009) and by walking the perimeter of the communities. Once our areas of work were established we broke up into teams of two and walked each road while making note of the location and description of critical water infrastructures in the Map Plus app.

Our team set out over five days and covered 40.84km (25.38 miles) of roads in the three communities. The communities covered a total of 1.32km^2 (326 acres), but the terrain was very hilly and in some cases difficult to walk. In total our team had an elevation gain of almost 1300 m (4265 ft) and spent almost 14 hours on these mapping excursions.

While plotting and mapping the three neighborhoods, we engaged with community members who showed interest in the work. In many instances we were approached and asked what were we doing and why were we doing it. We used practiced Spanish phrases to establish rapport with community members as well as to explain the nature of our work. This communication was an important component in completing our project.

This year there were three different WPI Project teams coordinating with Footprint Possibilities which required us to work cohesively not only with our sponsor and client, but with two other WPI teams. Our team took on the responsibility of organizing the data collected by the other teams into a comprehensive interactive map to allow all of the data collected to be viewed in one location. One team, the Census Team, surveyed the neighborhoods to later make an estimation on water demand, while the other team, the Environmental Team, tested water quality of the Burunga River which ran along all three neighborhoods. We used Google MyMaps to allow different members of IDAAN to access this information.

To provide recommendations on the pipe requirements to pump water from the water tower to La Alameda and 13 de Febrero we calculated the minimum cross sectional area of the main pipes needed. We also identified the locations of the highest altitudes in La Alameda and 13 de Febrero and mapped a route for the pipes from the existing water tower to the highest points, where IDAAN has plans for gravity fed water tanks to be built. We also used the Bernoulli Equation to estimate the pressure needed to deliver water to these locations.

Results

Table I: Critical Infrastructure in the Three Mapped Communities

	La Alameda	Nueva Jerusalen	13 de Febrero	Total
Water Tanks	23	22	107	152
Culverts	14	10	36	60
Culverts that need Service	1	1	5	7
Bridges	3	2	3	8
Fire Hydrant	0	0	1	1
Roads (km)	3.9	1.8	11.3	17
Area (km^2)	0.39	0.11	0.82	1.32
Highest Elevation (m)	127	85.7	139	
Lowest Elevation (m)	38.9	45.2	24.4	

In La Alameda 23 water tanks were found, in Nueva Jerusalen 22 were found and in 13 de Febrero 100 water tanks were found. A similar trend can be seen with the number of culverts, and fire hydrants found. More established areas were seen to have more infrastructure and less maintenance; the neighborhood of 13 de Febrero is the oldest and largest community which is where a majority of the features we found were located.

The Census Team made predictions for one, five and ten years and using this information we were able to recommend that IDAAN use at least a 12 cm (4.72 in) diameter pipe for the pipes in La Alameda and at least a 22 cm (8.66 in) diameter for the pipes in 13 de Febrero. We also provided Yamileth Quintero, our IDAAN contact and the Arraijan Regional Director at IDAAN, with the estimated water pressure required to pump the water from the water tower, located at 145m (475.7 ft) above sea level, to the highest points in La Alameda and 13 de Febrero.

Figure I: Route to Highest Points

We found that the pressure needed to get to the highest point in La Alameda, which is located 127m (416.67 ft) and 3km (1.78 miles) from the water tower, is 47 pounds per square inch (psi). We then found that the pressure needed to get the 1.5km (0.93miles) to the highest point in 13 de Febrero, located at 139m (456 ft) above sea level, is 30 psi.

Conclusions and Recommendations

At the completion of the project we produced a complete map of each of the three neighborhoods which included the locations, type, and dimensions of multiple water tanks, culverts, and roads in mapping out these regions, we were able to gauge how the community members felt about their current water situation.

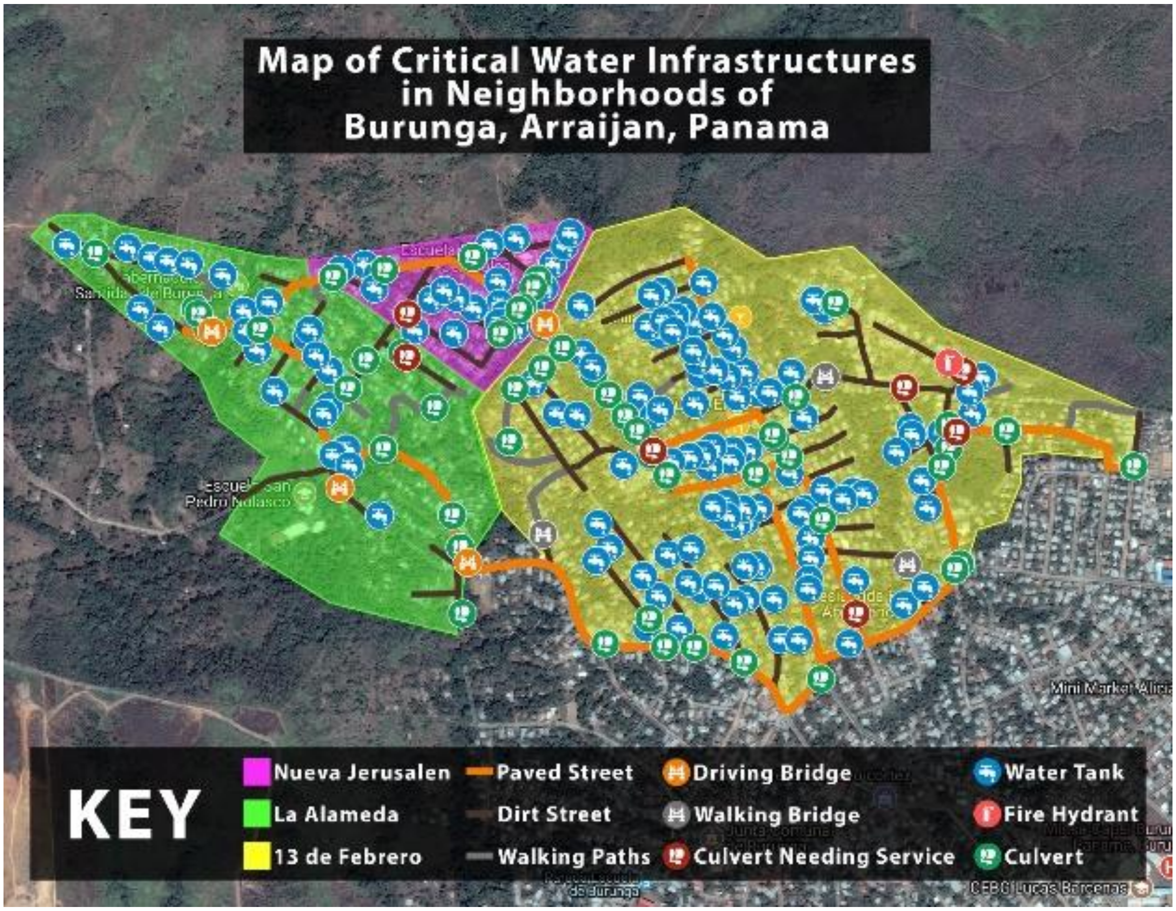


Figure II: Map of Critical Water Infrastructures in Neighborhoods of Burunga, Arraijan

In addition to plotting these points we also came across a single fire hydrant which allowed the Environmental Team make recommendations for their project regarding a proposed use for treated waste water. To assure IDAAN would be able to make use out of our interactive map, access to the online map was provided, along with a printed copy for access away from a computer. This series of PDF files included the maps and a legend indicating what each symbol represented were presented in both English and Spanish. The locations of each feature were also converted and displayed in a table in UTM coordinates so that they would be easily imported and compatible with the software IDAAN uses to map areas across Panama.

AUTHORSHIP

Peter Carosa

Peter shared responsibilities with Luke as the primary data collector during the fieldwork stage of the project. He used his phone to mark points of interest and track the roads of the neighborhoods. Using Photoshop he created offline versions of our interactive maps in English and Spanish. He also wrote some aspects of the Introduction and Findings as well as edited the Methodology and Findings.

Brandon Cohen

Brandon served as the primary author of the paper, having contributed to nearly in all sections. He coauthored the Abstract, Introduction, Background, Methodology, and Findings. He also was the main designer of our poster.

Alisa daSilva

Alisa served as the primary editor by proofreading many drafts and ensuring the paper was of high quality. In addition, she wrote some parts of the Background, Objectives and Findings. She was also made sure the formatting was up to the standards set forth by WPI. She was also responsible for doing the calculations for pressure and cross sectional area for IDAAN.

Luke Fronhofer

Luke, with Peter, was a primary data collector. In addition to marking points of interest and tracking the roads of the neighborhoods. He was the main editor of our online interactive maps. He also wrote aspects of the Background and Findings and edited the Introduction and Background.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1: INTRODUCTION

Of the over seven billion people in the world, one in ten lack access to safe drinking water. Roughly 663 million people, or about twice the population of the United States, are living without adequate access to this vital resource (United Nations, 2010). The social and economic effects of disproportionate water distribution are experienced globally. The lack of adequate water supply and sanitation leads to an annual loss of 260 billion dollars globally (World Health Organization, 2012) due to factors such as health expenses and undocumented tapping of water networks. In Panama the effects of this disproportionate water distribution can be seen in the neighborhoods of Burunga and the surrounding areas.

In many of the areas around Panama City, there exists a series of challenges in providing water services to informal settlements. The lack of access to potable water in Panama lies not only within urban areas, but also in rural areas. In 2009, the standard for clean drinking water in Panama was raised. According to this new standard, 75% of the population of urban areas and only 50% of the population of rural areas around Panama City have access to clean drinking water (UNICEF, 2009). Many of the rural areas outside of Panama City have difficulties acquiring clean drinking water. These areas either informally tap into existing pipe lines or utilize water tanks to store rainwater. The use of these personal water tanks are a popular method of storing water as well as being a backup water source for residents. Water tanks, although helpful in aspects such as having a water supply during a drought, often lead to water hoarding, which builds up a supply of stagnant water which is more prone to becoming contaminated with bacteria. Government organizations in Panama look to help solve the growing issue of water distribution in Panama. Recently, water distribution organizations have begun distributing water tanks which are similar to personal water tanks but are much larger and can be sealed to prevent the growth of bacteria.

Figure 1: Water Tank in Burunga

The Panama Canal runs north-south and divides the country of Panama into Eastern and Western zones. The state-owned lands surrounding the Panama Canal Zone have become home to settlers over the last 20 years due to the availability of the land. As a result, governmental agencies, such as El Instituto de Acueductos y Alcantarillados Nacionales (National Institute of Aqueducts and Sewers) or otherwise known as IDAAN, have been struggling to keep up with the growing population and have provided these new communities with basic utilities; most households in the area do not have potable water.

Arraijan is a district just west of the canal which contains the sub-district of Burunga, where many of the houses have been built within the last 10 years. Currently in the region of Burunga, there exists a water tower holding 50,000 gallons and an additional 1.6 million gallons in an underground reserve tank. IDAAN can then place gravity fed water tanks that are large enough to sustain a level that will allow all of the citizens to have access to water. The underlying issue for IDAAN is a lack of information about the communities and the existing infrastructure in the region. Without this information it is impossible for IDAAN to distribute the water to the nearby neighborhoods. Therefore existing maps need to be updated to take into consideration this population expansion to provide these areas with potable water.

Our project goal was to expand knowledge of information and create maps of regions in the Burunga sub-district to reflect the increase in population that has occurred in recent years. It was important to learn more about existing infrastructure and its current condition in the neighborhoods of Nueva Jerusalen, 13 de Febrero, and La Alameda, so that an appropriate and effective solution can be implemented in these areas. Our maps of the rural communities in Burunga will help IDAAN and other governmental agencies to assess the living situations of people in these regions and alleviate a major problem that these communities face: the lack of access to a potable and sanitary water supply. We worked in cooperation with Footprint Possibilities, a nonprofit organization that works to improve the wellbeing of Panamanian communities, in coordination with partners from IDAAN, to reach the goal of helping the rural communities of Panama establish capable water systems and overall community improvement.

CHAPTER 2: BACKGROUND

This project addresses challenges associated with the issue of water distribution and the growing demand to access potable water in the rural Burunga region outside of Panama City. Panama is a nation with both a growing economy and an expanding population. Part of this growing population is a result of the rise of informal settlements outside of Panama City, such as Burunga, the area in which our project took place. People from surrounding countries migrate to Panama because of the loose existing laws on staking claims to land plots. Residents of informal settlements make claim to either public or private lots of land and find legal protection in inhabiting the land due to squatting laws, which are common in Latin American countries. These settlements arise sporadically, making it difficult for the government to provide vital services such as potable water to these regions (Huchzermeyer, 2002). Burunga is no outlier to this pattern in Latin America. The Burunga settlement was created in 2003 due to the creation of a new law expanding property rights to the citizens of Panama. This law led to a great increase in immigration to this area due to the ability to claim property lots without cost to the settler (Law 42, 2003).

Figure 2: Landscape in Burunga

Water distribution has been addressed successfully in a number of other countries. The national governments of Uganda, Honduras, and Guinea have worked vigorously to correct many of the flaws in their water distribution systems. Although their plans vary in detail, these countries have used similar strategies to address the water crisis. These solutions involve dividing the problem of distribution and assigning responsibility to different levels of government. The federal government in these three countries undertakes the responsibility of creating laws and policies that protect and oversee the distribution of water. Local governments are responsible for the physical transportation and distribution of water and, in some cases, the enforcement of federal laws. In other cases, a communal government is put in place in order to ensure that the laws are followed. Using multiple branches of government helps to ensure the effectiveness of water management, which is essential for efficient water distribution. Although our project will not change the distribution of power in the government, there are smaller scale actions used in other countries that could be applied to increase our impact within the communities (WASH Sustainability Forum, 2013). Our goal in Panama is to leave a similar impact in solving their current water distribution problem by providing IDAAN with the information needed to help address and solve the current issue with water distribution.

2.1 IDAAN

The Instituto de Acueductos y Alcantarillados Nacional ("National Institute of Aqueducts and Sewers" or IDAAN) oversees the water distribution and wastewater management for Panama and is working to improve the welfare of the country through increased access to drinking water, and management of sewage; 97% of the potable water used in Panama is provided and serviced by IDAAN but still only 57% of the population can access this water IDAAN provides (World Bank, 2015). Before IDAAN, the Water and Sewerage Commission of the Sanitary Engineering Division of the Ministry of Labor, Social Welfare, and Public Health controlled water management for around ten years but was replaced when they were not distributing water effectively. Before that, the United States-controlled Panama Canal Authority administered water resources around the Canal Zone. Everywhere else in Panama, the less wealthy communities did not have regulated water sources and more typically had a small well or communal water source. IDAAN was formed in 1961 with the goal of improving water management in Panama. IDAAN has faced many complex financial issues in its history, including a history of debt and mismanagement of spending. In 1982 a water tariff was created with the intention of helping IDAAN balance its operation budget, but it has not been adjusted or changed since, which can be directly connected to the unstable and underfunded water systems throughout Panama. In recent years IDAAN has had support from many banks, including the World Bank through the Panama Metro Water and Sanitation Improvement Project.

The World Bank funded Panama Metro Water and Sanitation Improvement Project is meant to increase the quality, coverage and efficiency of Panama's water supply and sewage system (World Bank, 2010). Even though this initiative is almost 7 years old, there are still many parts of Panama that do not have access to this basic human right. As Panama's population is continuing to expand, it is becoming harder for IDAAN to reach their goal of supplying water to the entire population. With the expanding population, the water tariff needs to be adjusted to accommodate the increase in consumers. IDAAN also does not often collect the money that a community owes because of the current size of their operation across the large area they provide service to. These financial constraints limit IDAAN to supplying a mainline to larger, better-off communities leaving smaller communities and villages without appropriate connections to tap into these lines. This informal tapping causes increased water use to go undocumented and the richer communities are then charged for the smaller village's water usage. Smaller communities that pay for water are given large water tanks but because of the remote locations and the lack of quality roads, these tanks are not as reliable as pipelines. Inconsistent service to its customers is one of the reasons for IDAAN's huge amount of debt. Customers have stopped paying their dues for the services but still are obtaining water (Holtey, 2001).

According to IDAAN's official website, it is their goal to provide clean water and maintain a level of transparency of their actions. The organization continues to battle against the ongoing water crisis and has made significant progress in its efforts to address the water crisis in Panama. Presently, IDAAN is responsible for rural water distribution with a specific focus in the communities surrounding Panama City. Current IDAAN projects include repairing water infrastructure such as pipes and other utilities, delivering water to strategically placed water tanks, and overseeing reservoir operations in Panama. Sustainability is a major component in the long term success of these water systems. This includes the quality of the pipes and other equipment that are brought into the communities. In order to make water efficiently accessible and affordable, infrastructure should not fail within a few months or years, as gravity water systems and pipes have in the past. The quality of water infrastructures has been neglected in the past in many developing countries, but is starting to be an area of major change.

2.2 IDAAN's Current Projects

Developing efforts in Panama and IDAAN are very focused on emphasizing infrastructure quality. A major reason IDAAN is focusing on infrastructure is because they believe sustainability will happen if high quality infrastructure is installed. From 2011 to 2015 the Panamanian government worked with IDAAN to complete the Water and Sanitation Improvement Project in Colón, Panama. The purpose of the project was to increase quality, coverage, and efficiency of potable water and sanitation and to strengthen IDAAN as an institution. Additional projects were also initiated to improve the efficiency of water regulation and water transportation reliability with this project. The benefits of such programs, however, were not directed toward the communities without water, but for those who were already clients of IDAAN. Many of IDAAN's projects are focused on the maintenance of existing infrastructure and on improving reliability (Inter-American Dev. Bank, 2017). In 2015, a 50,000 gallon water tower (as seen in Figure 4) and 1.6 million gallon underground tank were constructed near the center of Burunga, at one of the highest elevations in the community. IDAAN was unable to build the supporting infrastructure needed to distribute water from the tower and underground tank to the local neighborhoods. As a result, the tower and underground tank are not in service and sit full of water that had been pumped from the Panama Canal Zone. Once in operation, IDAAN plans on transporting water from Laguna Alta in the western region of Panama to supply the tower and underground tank. In early 2017, the World Bank approved the $65 million Burunga Wastewater Management Project. The main goal of this project is to provide a sewerage system to the communities in Burunga, including the three communities our group is working in (World Bank, 2017). Ten million dollars of the Burunga Wastewater Management Project are being allocated to build the much needed supporting infrastructure to allow the water tower and underground tank to go fully operational.

Figure 3: Burunga Water Tower

One of the first phases of the Burunga Wastewater Management Project is having residents of the neighborhoods pay $20 per household to have the appropriate connections installed at their homes. This will ensure that all homes will be compatible with the new infrastructure. Before IDAAN carries out this phase, they need baseline information on the community, including maps of current infrastructure, up to date census data, and environmental analysis of the local river. This Burunga project is currently in the process of approval and planning and will take an estimated two years to complete. As of now, the residents of Burunga know little about this current project or the payment for water services.

The efforts of IDAAN have provided a valuable service throughout Panama and will play a critical role in improving water services in the expanding communities around Panama City. Efforts to improve efficiency in delivering water to these areas are ongoing. Despite these attempts, disproportionate water distribution remains a major problem in Panama. It is essential to address the issue in order to maintain a high quality standard of living for the country's citizens. The government of Panama helps to fund IDAAN in an attempt to tackle the ongoing battle against water scarcity.

2.3 Footprint Possibilities

Footprint Possibilities is a non-profit, volunteer based, non-governmental organization (NGO) that is focused on seeking funding for, and organizing local community efforts and improvements. Footprint provides volunteers to serve government organizations such as IDAAN to help tackle problems of water access. The goal of the organization is to enhance basic health conditions and to supply people with accessible clean drinking water. Based in St. Petersburg, Florida, Footprint Possibilities has affected more than ten thousand lives throughout the rural regions of Panama. Although Footprint Possibilities is a non-profit NGO and is strictly operated and staffed by volunteers, closely affiliated companies help with a majority of the expenses. Caterpillar Corporation and Coselecto, two of the major contributors, provide tools and materials for larger projects that need more than just human labor. Other affiliates such as the University of Panama and Engineers Without Borders offer student volunteers opportunities to work with Footprint Possibilities helping to complete projects, large and small.

2.4 Community History

The community of Burunga can best be described as a place of settlers who have come to inhabit the land over the course of the past 30 years. Although Burunga was not officially deemed a sub-district until 2003, many of the community members have held a claim to the land since years before the recognition of the community. It is this sentiment of long lasting communal relationships that characterize Burunga as a tight-knit community. The location and accessibility of the area isolate the neighborhoods of 13 de Febrero, Nueva Jerusalen, and La

Alameda from the other neighborhoods of Burunga. Recent legislation such as law 42 made squatting and staking claim to the land easier and helped to establish a period of growth in the community (Leya 42, 2003). The area remains a close community despite the growing and expanding population. There currently exists no reliable estimation publically available for the population in these areas. Due to increasing financial activity and economic growth in Panama, interest in living in and around Panama City has grown. These factors contribute to both the feelings and behavior of how residents of Burunga react to an outside presence. Residents of Burunga consider themselves closer among each other than they do among government officials and outsiders. This perspective on the community adds a layer of difficulty in collecting information related to the project for community members would typically be less willing to reveal any information that they could perceive as sensitive.

CHAPTER 3: METHODOLOGY

The overall purpose of our project was to map the communities' critical water features in order to establish a baseline for IDAAN to plan their Burunga project. The work of our project was done in coordination with two other WPI project teams also providing valuable information to IDAAN. The Environmental and Census teams both contributed to the overall goal of assisting IDAAN with preparation for the Burunga water distribution project. The Census team focused on collecting information about waste water from residents in the community while the environmental team focused on the quality and disposal of the waste water. The information collected will assist our client, IDAAN, to determine where to allocate the $10 million dollar World Bank loan for much-needed infrastructure in the sub-district of Burunga. Our project was broken down into a set of objectives that included:

1. Understand and interpret the needs of IDAAN and Footprint Possibilities
2. Define the areas of work, map, and measure the current critical water infrastructures as well as the existing roads and walking paths within these neighborhoods.
3. Evaluate community member's perspectives on IDAAN and how current water infrastructure affects their everyday lives.
4. Organize the collected information as well as the data collected from the Census and Environmental teams into a layered interactive map.

5. Calculate recommendations for pipe diameter and water pressure required to provide access to the neighborhoods of La Alameda and 13 de Febrero.

3.1 Meeting the Needs of our Clients and Sponsor

One of the first challenges in tackling our project was to understand what our client (IDAAN) and sponsor (Footprint Possibilities) needed from our work. An initial meeting on August 28th, 2017 at IDAAN's headquarters helped to establish their expectations of our work. Representatives from IDAAN outlined the deliverables in specific terms including the desired features to be mapped and an excel sheet with the UTM formatted coordinates of each feature.

Our sponsor from Footprint Possibilities, Ricardo Montanari, also had requests that he wanted to see in our project: a complete interactive map in which information from all three teams were combined and layered as well as photos weekly of our work in Burunga. Mr. Montanari helped guide our project and helped with communicating with the client.

3.2 Mapping Roads and Critical Water Infrastructure

Our team was tasked with mapping critical infrastructure such as water tanks, culverts, fire hydrants, roads, and bridges. Water tanks can be used to estimate the quantity of water that the region relies on while mapping culverts helps IDAAN understand the condition of the current waste water system in place. Identifying roads and road types helps IDAAN plan what routes are accessible and easy for trucks and vehicles to access. Marking other infrastructure helps IDAAN with their record of what exists within the sub-districts.

Before we could map any roads or infrastructure our team had to research and select a mobile app to be used as our mapping tool. We initially selected an app called MapPath and tested it out while we were still in the United States. Team members tested the app by walking around their neighborhoods and mapping features to get a feel for how the app was going to be used in Panama. After arriving to the Project Center and meeting with our sponsor and client we realized that the requirements for our app changed. We needed an application that was able to relay on the cell phones satellite services and not its data services. As a result, we began looking for a new app that could meet all of these specifications. The mobile app we ended up using was

Map Plus (as seen in Figure 5) and we conducted similar test trials in the large quad on the campus of Ciudad del Saber, our residence during the project term.

Figure 4: Map Plus Icon

The first step in mapping the water infrastructure was creating polygons for each of the neighborhoods. The polygons served to outline the boundary defining the area of work. Our first attempt at drawing the polygons was based upon assumptions of which roads divided the sub-districts and using features such as rivers and bridges to draw district lines. We were later given a series of printed maps and boundary lines, from IDAAN's last mapping of the neighborhoods in 2009. The boundary lines for each district were based on this series of maps we received from IDAAN and were later verbally confirmed by IDAAN representatives at the regional IDAAN office in Arraijan. These polygons served as an important reference to assure that the features we were plotting fell within the assigned neighborhoods.

While plotting in the field, our team often split apart in groups of two to map the region faster. Before each day's mapping we met and established walking routes to efficiently cover each region in a timely manner. Walkie talkies allowed our team to communicate during these moments apart and helped us to further to prevent the overlapping of data. While in the field, we used the iPhone app Map Plus to track and mark the path, and thus we were able to track the path we walked as well as mark and label critical infrastructure points spotted on the way. One member in each of the two member teams used the Map Plus app to track the progress of that team and plot out the locations of the water features passed while hiking. The other member would spot the water features and assist in the measuring of these features. At the end of the day, the data collected from both devices was exported to the Google My Maps (as seen in Figure 6). In order to provide UTM coordinates for the mapped points, which was required by IDAAN, from the app, we used an online batch converter to convert the Longitude and Latitude information from the app to UTM coordinates. The batch converter used is named Earth Point and the owner, Bill Clark, gave our team free access to the program after we explained our work.

He was also available for any follow up questions or additional information, if needed, about the coordinates and conversions.

Figure 5: Google My Maps Logo

Plotting and mapping the desired features and paths was a crucial component of our project; these features included culverts, fire hydrants, water tanks, bridges, and other existing water related structures or features (see Appendix A-G). After the points were collected in the field, the files were exported to the desktop program, Google My Maps, which allowed for easier manipulation of the map data. This allowed for the formation of the data collected into one collective map composed of layers. Each layer on the map was set to represent a certain feature.

In the application Map Plus, the roads are recorded as paths which stretch across a series of coordinates connecting together to form a line. The data collected in the field would be messy and the lines walked not consistent due to walking the same roads twice and issues with phone signal strength, so the maps were polished and refined using Google My Maps program. This was done by redrawing the roads in Google My Maps so the lines were straight and all the same width (see Appendix E).

3.3 Producing the Interactive Map

The final product of this project includes an interactive map containing the data collected from all three teams. Each of the critical infrastructure features was assigned a unique data layer within the Map Plus application to allow for independent viewing of each layer on the final map (see Appendix A-G). It is important that layers could be removed so that the user may view the locations of a specific feature. The Map Plus application would save the information collected on the device, but could not organize the data collectively each day. The data was organized within the Google My Maps program to solve this problem of data collaboration. The organized information was imported into Google My Maps to differentiate between each type of feature, and to also include the measurements taken to the description of each culvert. The map consisted of multiple data layers, each representing a certain feature of the water infrastructure. Culverts were placed in their own layer and labeled accordingly, with their size, length, material, and condition in the description box. Water tanks were identified by their color but were all placed on one layer with the colors detailed in the description box.

Footprint Possibilities also sponsored two additional IQP teams: a team updating the Burunga Census (referred to as the Census Team) and a team investigating the pollutants of the Burunga River (referred to as the Environmental Team). While each of the other teams was responsible for collecting and analyzing its own data, we were responsible for composing the final interactive map displaying all of the teams' information.

The Census team was responsible for gathering information from the houses in the area. This information included information on the number of residents in the household, how the residents get water, housing conditions, and wastewater. Google My Maps restricts the number of layers that could be added to a single map to ten, so each team was allotted a certain number of layers. The information they collected composed their three allotted layers on the final interactive map: a layer for each house survey, a layer for each house that had a latrine, and the last layer illustrated what houses have a septic tank. The Environmental team collected data based on what contaminants are found in the Burunga River, which runs along the border of all three neighborhoods. The data collected from the Environmental team would be arranged as two more layers to the map: one layer marking the estimated sampling points and a layer marking the points that were tested.

While IDAAN is very interested in the interactive map and the visuals of the different layers, they also need to be able to compute our data into their system. They required a CSV file to import into their database for mapping water infrastructure across Panama. A CSV file is a Microsoft Excel sheet that we could be export from Map Plus. Even though the app had the UTM coordinates associated with the individual points, when the file was exported it only carried the more popular latitude and longitude coordinates. After running the excel sheet through the online batch converter, Earth Point, the UTM coordinates were side by side with the latitude and longitude coordinates. When we send the Excel files to IDAAN, they will easily be able to import our data into their database.

3.4 Gaining a Community Perspective

Interacting with the community was an important component of our project. This objective was important because of the difficulties we expected to encounter as a result of being outsiders coming into a secluded community. Our project could not have been completed while silently mapping the area. It was essential to respond to the concerns and needs of the community in order to be welcomed onto private lanes and secluded roads.

Our greatest challenge was the language barrier, which we had to adapt and overcame using strategic planning. Our team considered a list of questions we thought would be the most frequently asked by the community members, such as who we worked for, what we were doing, and the reason for our presence in Burunga. From there we determined the phrases we needed to know in order to respond to the anticipated questions. In an environment where government agencies can be seen as either helpful or hurtful to the community, it was essential that we remind the community that our work aims to benefit them and improve their quality of life. Throughout plotting and mapping the three neighborhoods, we had multiple encounters with curious onlookers and community members. In many instances we were approached and asked in Spanish what were we doing and why were we doing it. We used our practiced Spanish phrases to ease the tensions created by the presence of outsiders as well as to explain the nature of our work. In these instances it was important to explain that we were students working on a mapping project for IDAAN and that the results of the project would serve to benefit the water quality for the community. Although the language barrier was problematic, the Spanish we knew was sufficient enough to both understand and respond to the individuals we encountered. As a result of our preparation, residents were friendly and confident with our presence in their community.

Figure 6: Measuring culverts in La Alameda

3.5 Recommending Pipe Size and Determining Water Pressure

IDAAN had asked us to make recommendations for a pipe size as well as calculation of water pressure in those pipes based upon the information collected from our project as well as the Census team's project. We also were to deliver to IDAAN the location of the highest elevation point in La Alameda and 13 de Febrero, which was recorded by Map Plus app while we were mapping the communities. IDAAN wanted to know the pressure the water would be at these elevations. This information is used to adjust the plant's output velocity (how fast the water is pumped) to benefit the residents of these high elevation points. To solve for the pressure of water at the highest points, given the anticipated pump velocity, we used the Bernoulli Equation (Equation 1). These values are important to IDAAN because they will help provide important estimations for the Burunga wastewater project. Determining water pressure would help IDAAN gain a better idea of the mechanics of their piping network. Another detail to this piping network that is important to IDAAN is a recommendation of choosing the correct diameter pipe (Equation 2) IDAAN should use for their water system as well as the locations of the main lines in each community. This process is straighter forward than the previous calculations. We used the Census team's data on how much water per day each community will need, in 1 year, in 5 years, and in 10 years. With this information and the values given to us by IDAAN we will be able to recommend a diameter for the main pipe lines to be installed in each community.

$$\frac{p_{out}}{\gamma} + \frac{V_{out}^2}{2g} + z_{out} = \frac{p_{in}}{\gamma} + \frac{V_{in}^2}{2g} + z_{in} - h_f \quad \text{(Equation 1)}$$

$$Q = V*A \quad \text{(Equation 2)}$$

Table 1: Variables Used in Calculation of Pipe Diameter and Pressure

Variable	**Represents**	**Value**
P_{out}	Pressure from the water tower	20 psi
V_{out}	How fast water is moving while in the Water Tower	0 m/s
z_{out}	Height above the ground the water tower is located	145 m
P_{in}	Pressure of water at highest elevation house	What we are looking for
V_{in}	How fast water is pumped to the houses	1.5 m/s
z_{in}	Height above the ground where the tallest house is	Varies depending on region
g	Gravity	9.81 m/s^2
γ	Specific weight of water	9.807 kN/m^3
h_f	Head loss (how much energy is lost due to friction within the pipes)	Varies in regards to length of pipe

3.6 Client and Sponsor Interactions

Every Monday morning included a weekly meeting with our sponsor from Footprint Possibilities where we would update him on the past week's progress and give a general outline for the week to come. This proved to be a good time for Mr. Montanari to ask questions from the Footprint Possibilities perspective as well as raise some concerns pertaining to IDAAN. Tuesdays through Thursdays were reserved for the field work of plotting and mapping the planned neighborhoods. During this time we were accompanied by an IDAAN driver who would assist in transportation needs and relaying any urgent information about our project to us. A majority of our information from IDAAN came from Yamileth (our assigned IDAAN supervisor). In order to complete the field work in a timely manner, work dates were assigned to each neighborhood to maximize efficiency (see GANTT Chart in Appendix H). Each neighborhood was assigned a set of dates in which we planned to complete the mapping in that area. It was important to communicate with both parties what we could and could not accomplish in the given time frame. Fortunately, we were able to fit the scope of work specified by from both our client and sponsor into our 7 week time constraint.

CHAPTER 4: FINDINGS

4.1 Community Water Management Practices

After spending two weeks in the three neighborhoods we made some observations while mapping the roads and streets of the sub-districts. In some areas residents had installed 2" PVC water distribution pipes that ran from house to house. The water that flows through these pipes appears to originate from the tanks of other residents. One resident will pay to have their water tank filled by IDAAN or a third-party and then have other residents pay to tap into the same water tank. This explained why we noticed in the areas that had these 2" PVC pipes there seemed to be fewer water tanks. Some houses had both 2" PVC pipes and a water tank. The water tank at these houses was probably used as a backup source of water. The PVC pipes also indicated that the area was more developed and that the residents had been around for a fair amount of time when compared to the areas without PVC pipes where homes seemed less permanent. It was unclear on whether all houses that were visually more affluent used the 2" piping or whether they had professionally installed pipes.

One of the first questions we had before surveying the community was why did these individuals settle in Burunga? One possible explanation was the residents moved to the area for the jobs that had been springing up due to the economic boom of Panama City. However, we quickly found out that the people moved there because the land was available, but one question still remained: where did they work? It was too difficult to determine if the residents worked in the communities in which they inhabited. The proximity between Burunga and Panama City would make working in the city a realistic option. Bus services and the abundance of taxis made commuting to the city a strong possibility. That being said there were still some common occupations that we observed. Taxis were constantly passing by us as we walked the streets and it wasn't uncommon to see a taxi parked in the driveway of the houses in the more affluent neighborhoods. Additionally there were a fair amount of small businesses including convenience stores, cafes, and printing/photocopying centers.

4.2 Community Perspectives

Gaining an insight of the community's perspective was very important in helping understand the impact and effects of future projects in the area. IDAAN's name seemed to have carried a positive connotation among most of the community. After explaining our cooperation with IDAAN, community members understood that the work we were doing was intended to help them.

In one instance, a man approached our group and helped us locate some of the water tanks that were hidden behind houses. In another instance on that same day of field work, an elderly woman engaged us in a fifteen minute conversation about her time in Burunga as well as an account of her experience in the area. We were approached by members of the community every day in the field and had to react and respond to their concerns. On one occasion a lady saw us two days in a row. While on the first day we only exchanged hellos, on the second day the lady was curious about our involvement in the community. She has wondered why the two students were walking around an area in which outsiders were not a common sight. In the same community one group was approached by a lady who seemed concerned about our presence. Once talking to her she was put at ease but she was still curious as to what IDAAN was. She later explained her water situation as heavily dependent on the slope of the land to receive the rainwater from the ditch that leads to her house because her pipes, which we concluded were not IDAAN sanctioned, were not working properly.

We received looks of curiosity as a result of our long sleeve IDAAN blue shirts and yellow high-visibility vests. Many individuals associated us with the nearby construction workers and would ask questions regarding the project progress. This helped them identify us positively rather than as wandering strangers. Communication was an important component in completing our project.

4.3 Mapping of Roads and Critical Water Infrastructure

Our team set out over five days and covered 40.84 km (25.38 miles) of roads in the three communities. Our group of four would split into teams of two to cover more ground. The communities covered a total of 1.32 km^2 (326 acres), but the terrain was very hilly and in some cases difficult to walk. In the biggest community of 13 de Febrero there were many dead ends that would lead approximately 200 m down or up the mountain side on which the locals had no problem driving their vehicles. The highest elevation our teams reached was 139m(456ft) and the lowest elevation was 24.4 m (80ft), both in 13 de Febrero. The communities of Nueva Jerusalen and La Alameda were also very hilly but had half as much area and extent of roads as 13 de Febrero. In total our team had an elevation gain of 1247.6 m (4093.18ft) and a total loss of 1424.39 m (4673.2ft) and spent 824 minutes (13.7 hours) out in the field.

The three communities all had at least one road that seemed to be the main road. In La Alameda and Nueva Jerusalen there was one paved road that went through both communities and connected them to 13 de Febrero via bridge. Both of these bridges connecting the communities were currently under construction in the early phases of the project work and the only way to get to the communities of La Alameda and Nueva Jerusalen was to drive through the river where pavement had been laid down but the river was around six inches deep. After our first few days the bridge connecting La Alameda and 13 de Febrero was complete enough for use, with the bridge connecting Nueva Jerusalen and 13 de Febrero expected to be completed in the following weeks. 13 de Febrero is a little bigger and had more paved roads and many dead end dirt roads.

When it came to the water infrastructure features that were mapped, La Alameda and Nueva Jerusalen were similar in number but there were many more found in 13 de Febrero. In La Alameda 23 water tanks were found, in Nueva Jerusalen 22 were found and in 13 de Febrero 100 water tanks were found.

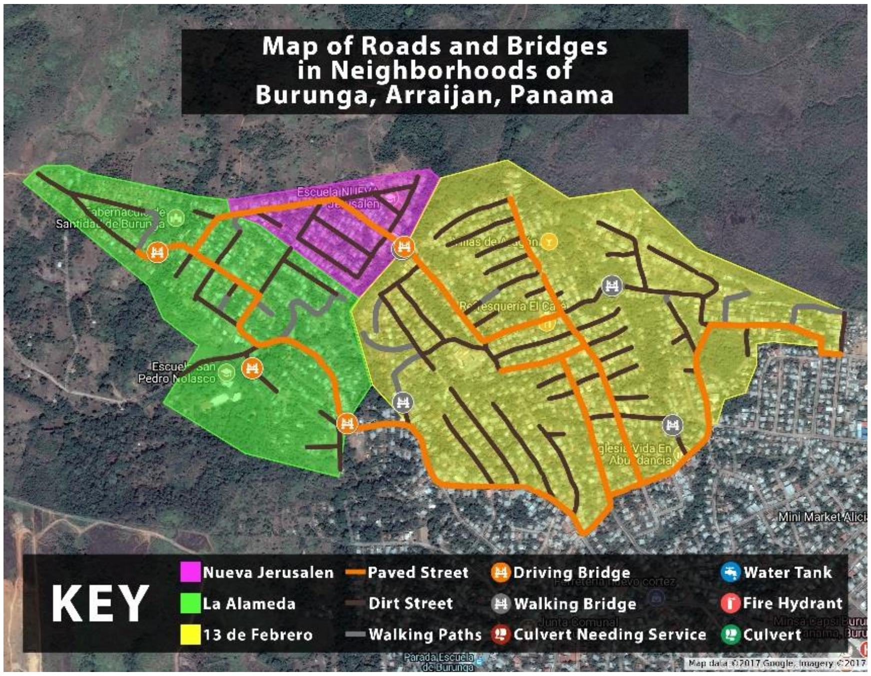


Figure 7: Map of Roads and Bridges in Neighborhoods of Burunga, Arraijan, Panama

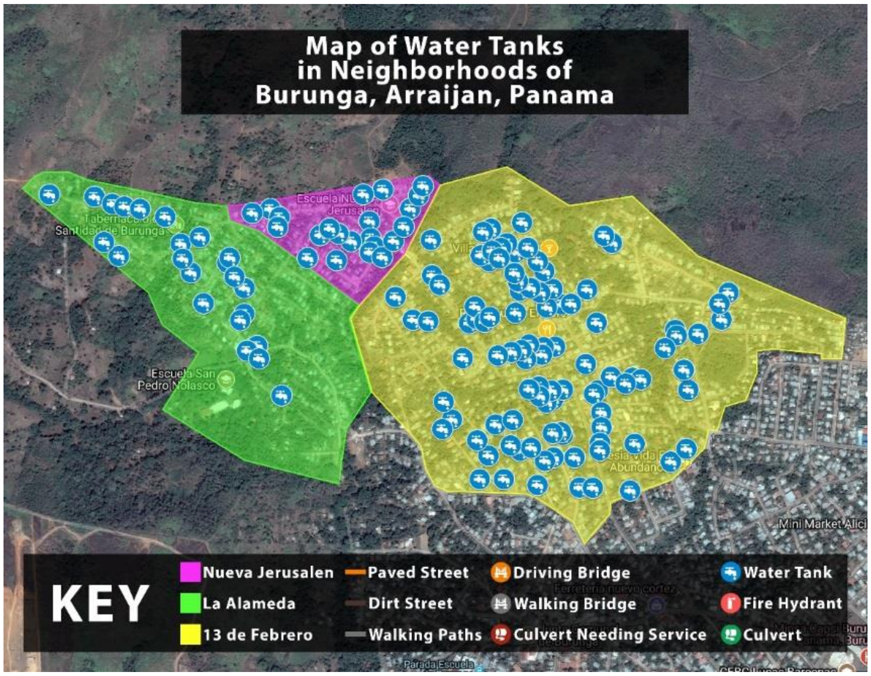


Figure 8: Map of Water Tanks in Neighborhoods of Burunga, Arraijan, Panama

A similar trend can be seen with the number of culverts and fire hydrants found (as seen in Table 1). 13 de Febrero is an older and bigger community so it has more infrastructure. While it is older, we found that a greater percentage needed service or was in disrepair. 13 de Febrero had 36 culverts with five needing service while La Alemada and Nueva Jerusalen had 14 and 10 respectively, with only one in each commnunity that needed service.

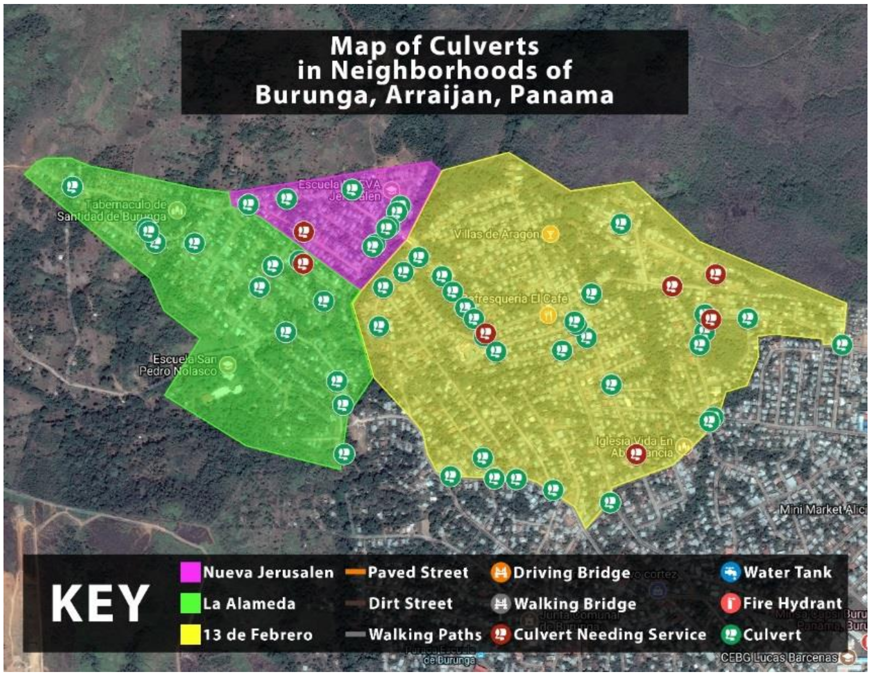


Figure 9: Map of Culverts in Neighborhoods of Burunga, Arraijan, Panama

Table 1: Critical Infrastructure in the Three Mapped Communities

	La Alameda	Nueva Jerusalen	13 de Febrero	Total
Water Tanks	23	22	107	152
Black Tanks	17	16	47	80
Blue Tanks	5	6	43	54
White Tanks	0	0	14	14
Green Tanks	1	0	2	3
Red Tanks	0	0	1	1
Culverts	14	10	36	60
Culverts that need Service	1	1	5	7
Walking Bridge	0	1	3	4
Driving Bridge	3	1	0	4
Fire Hydrant	0	0	1	1
Paved Roads (km)	1.1	0.5	4.2	5.8
Dirt Roads (km)	2.2	1.3	6.1	9.6
Walking Paths (km)	0.6	0	1.0	1.6
Area (km^2)	0.39	0.11	0.82	1.32
Highest Elevation (m)	127	85.7	139	
Lowest Elevation (m)	38.9	45.2	24.4	
Elevation Difference (m)	87.1	40.5	114.6	

4.4 Pipe and Pressure

In order to estimate the shortest route from the water tower in Burunga to the highest points in La Alameda and 13 de Febrero, we first identified the locations of the highest elevations. We drew the routes in My Maps to identify the distances and combined that information with the water demand data collected from the Census Team to determine minimum pipe size and pressure needed to pump water from the water tower to the highest elevations. That team's projections for water demand in La Alameda were 78,600 gallons per day, 91,962 gallons per day, 172,326 gallons per day and 377,817 gallons per day for the current population, 1 year in the future, 5 years in the future and 10 years in the future, respectively. In 13 de Febrero the water demand for the current population, 1 year in the future, 5 years in the future and 10 years in the future were 161,688 gallons per day, 302,679 gallons per day, 567,186 gallons per day and 1,243,527 gallons per day, respectively. We used this data to make a recommendation for the main pipe diameter in La Alameda of 12 cm (4.72 inches) and in 13 de Febrero of 22 cm (8.66 inches). To find the pressure in the individual water tanks IDAAN is planning on building at the highest points in the communities, we used the Bernoulli's equation. Our counterpart Yamileth Quintero gave us the information we needed to solve the equation, including the elevation of the water tower, pressure in the tower and the velocity of the water leaving the tank. We found that the pressure needed to get from the water tower, located at 145m (475.7 ft.) above sea level, to the highest point in La Alameda, which is located 127m (416.67 ft.) and 3km (1.87 miles) from the water tower, is 47 pounds per square inch (psi). We found that the pressure needed to reach the 1.5km (0.93miles) point from the water tower to the highest point in 13 de Febrero, located at 139m (456 ft.) above sea level, is 30 psi.

Figure 10: Route to Highest Points

CHAPTER 5: CONCLUSION & RECOMMENDATIONS

5.1 Overview of Deliverables

We completed this project by mapping each of the three neighborhoods in Burunga as well as making recommendations regarding pipe diameter sizes required to deliver water to the communities. In mapping out these regions, we were able to identify the locations, type, and dimensions of multiple water tanks, culverts, and roads. In addition to plotting these points we also came across a single fire hydrant. We had expected to find more of these features, along with sewer grates and manhole covers, but our mapping efforts revealed that such infrastructure does not exist in the neighborhoods.

To assure IDAAN would be able to make use of our interactive map, we provided our partners at IDAAN access to the online map along with a printed copy for access away from a computer. These series of PDF files included the maps and a legend indicating what each symbol represented and presented in both English and Spanish. The locations of each feature were converted and displayed in a table in UTM coordinates (see Appendix I, J, K) so that they would be compatible with the software IDAAN uses to map areas across Panama. The Google My Maps tool allows users to visualize the data in a compelling interactive format that can support their work with their main data platform. These findings, when plotted on the Google My Map server, helped to reveal trends and differences between the neighborhoods. It was of greater priority to IDAAN that the submitted UTM coordinates worked than the interactive, layered Google My Maps. IDAAN's interest in our data was mainly the spatial coordinates of all the infrastructure in the area and after confirming that the UTM coordinates were correct we made the files neat and easy to understand for IDAAN.

Google My Maps: Critical Water Infrastructure Map:
https://drive.google.com/open?id=1fkIOVhsYLNRqgM_uaxiNwvhN7as&usp=sharing

Google My Maps: 3 Team (Topography, Census, and Environmental) Map:
https://drive.google.com/open?id=1k8h8a4p4hgbcCN5d1GWrFqYRZ0o&usp=sharing

5.2 Observed Patterns and Trends

The information collected on the interactive map database helped us observe a series of patterns and trends that help relate the located features with the type of living in each area. Through background research and the information gathered by the Census team, we know that the water tanks are used as both a primary and secondary source of water for residents who own them. However, we have also learned that some of the water tanks are used to supply water for other members of the community. Some owners of water tanks choose to sub-sell their water, allowing neighbors to purchase and tap into their water supply. In areas of 13 de Febrero where housing was simpler and less affluent, we observed a pattern of increased water tanks as well as increased sighting of the 2" PVC pipe use to tap into the tanks. Areas that appeared to have more affluent and complex houses often had drastically less water tanks in the area as well as less two inch piping. Signs of wealth included the size, material, and conditions of the house, presence of cars and/or garages. We theorize that these areas utilize IDAAN's tap water network either by paying for the service or by accessing the piping through tapping into the water supply undetected.

While we were out looking for infrastructure, we also would mark infrastructure that needed service. The only infrastructure that we found that needed attention were culverts. In total we found seven culverts that needed service and we tagged them in our CSV file to IDAAN, as well as marked them on our interactive map. There did exist only one fire hydrant in the three communities, which we identified as a fire hazard.

Throughout our experiences in the communities we noticed a consistency as to how the communities reacted to our presence as outsiders. While in a high visibility vest and IDAAN shirts, it was obvious to the community that we were not residents of the area. During a number of interactions with the community, there was a trend of positive reactions while mentioning our nature of work with IDAAN. As an organization, IDAAN's name carries a generally positive connotation throughout the communities. The mention of their name put community members at ease and very much helped in their understanding of our purpose. The impact of IDAAN was known throughout all three neighborhoods and some of the community members were aware of the current ongoing projects IDAAN oversees in their area.

5.3 Recommendations for IDAAN

One of our deliverables was to recommend to IDAAN the ample water pipe width and water pressure needed in building the infrastructure to get water from the current water tower to the future water towers at the highest points in the communities. We were able to recommend that IDAAN use at least a 12 cm (4.72 in) diameter pipe for the pipes in La Alameda and at least a 22 cm (8.66 in) diameter for the pipes in 13 de Febrero. We also recommended the necessary water pressure needed to get to the highest point in La Alameda is 47 pounds per square inch (psi) and the pressure needed to get to the highest point in 13 de Febrero is 30 psi. Our IDAAN counterpart, Yamileth Quintero, did not need the information for the community of Nueva Jerusalen because IDAAN is planning something different for the piping in that community.

We would also like to recommend that IDAAN establish and continue a strong line of communication with the community regarding the progress and goals of their projects in Burunga. The community members have a great deal of interest in what occurs in their neighborhoods and are sometimes concerned with the presence of government officials. As we had limited knowledge of the Spanish language we were unable to fully explain the projects of IDAAN so it may benefit them to be more transparent with upcoming and current projects. By clarifying the work and benefits each resident will be entitled as a result of the project, we anticipate the residents may be more willing to cooperate with payments and will overall have more support for the project. The community cares a great deal about the ongoing actions that take place in their area and would benefit greatly from any or all information IDAAN makes public or advertises. As of now the residents have little to no knowledge about the Burunga waste water project.

REFERENCES

Catholic Relief Services. (2013). Water Services that Last in Central America Recommendations: for financial viability, equitable distribution, and water source protection. Retrieved from http://globalwaterinitiative.org/media/AchievingWaterServicesThatLastInCentralAmerica.pdf

Holtey, D. (2001, September 27). Idaan Pays off US$1mn Elektra Debt. Retrieved April 09, 2017, from http://www.bnamericas.com/en/news/waterandwaste/Idaan_Pays_off_US*1mn_Elektra_Debt

Huchzermeyer, M. (2002). Informal Settlements. Latin American Perspectives, 29(1), 83-105. doi:10.1177/0094582x0202900105 http://www.lincolninst.edu/sites/default/files/pubfiles/regularization-informal-settlements-latin-america-full_0.pdf

IDAAN. (n.d.). Retrieved April 09, 2017, from https://idaan.gob.pa/

Inter-American Development Bank. (2017) PN-L1093 : Water and Sanitation Multiphase Investment Program - Phase II. Retreived from: http://www.iadb.org/en/projects/project-description-title,1303.html?id=PN-L1093

Ley 42 De 2003. (2003). Retrieved September 22, 2017, from http://panama.justia.com/federales/leyes/42-de-2003-may-6-2003/gdoc/

Rapport JMP 2008. (2009, February 12). Retrieved September 22, 2017, from https://www.unicef.org/french/media/media_44093.html

Régimen Jurídico. (n.d.). Retrieved August 30, 2017, from https://idaan.gob.pa/regimen-juridico/#1460651290450-f6f67bf6-4a7e

Terrevazzi, O. (n.d.). ORGANIZATION OF WATER SUPPLY AGENCIES IN THE AMERICAS' . Retrieved September 22, 2017. http://iris.paho.org/xmlui/bitstream/handle/123456789/12732/ev1n1p60.pdf?sequence=1

United Nations, General Assembly, The human right to water and sanitation, A/RES/64/292 (3

August 2010), available from
undocs.org/A/RES/64/292

User, S. (2011). Panama. Retrieved September 22, 2017, from http://www.gefcrew.org/index.php/participating-countries/panama

WASH Sustainability Forum. (2013). Sustainability Forum Report. http://www.aguaconsult.co.uk/assets/Uploads/Publications/BMGF-WASHSustainabilityForumReport-2013.pdf

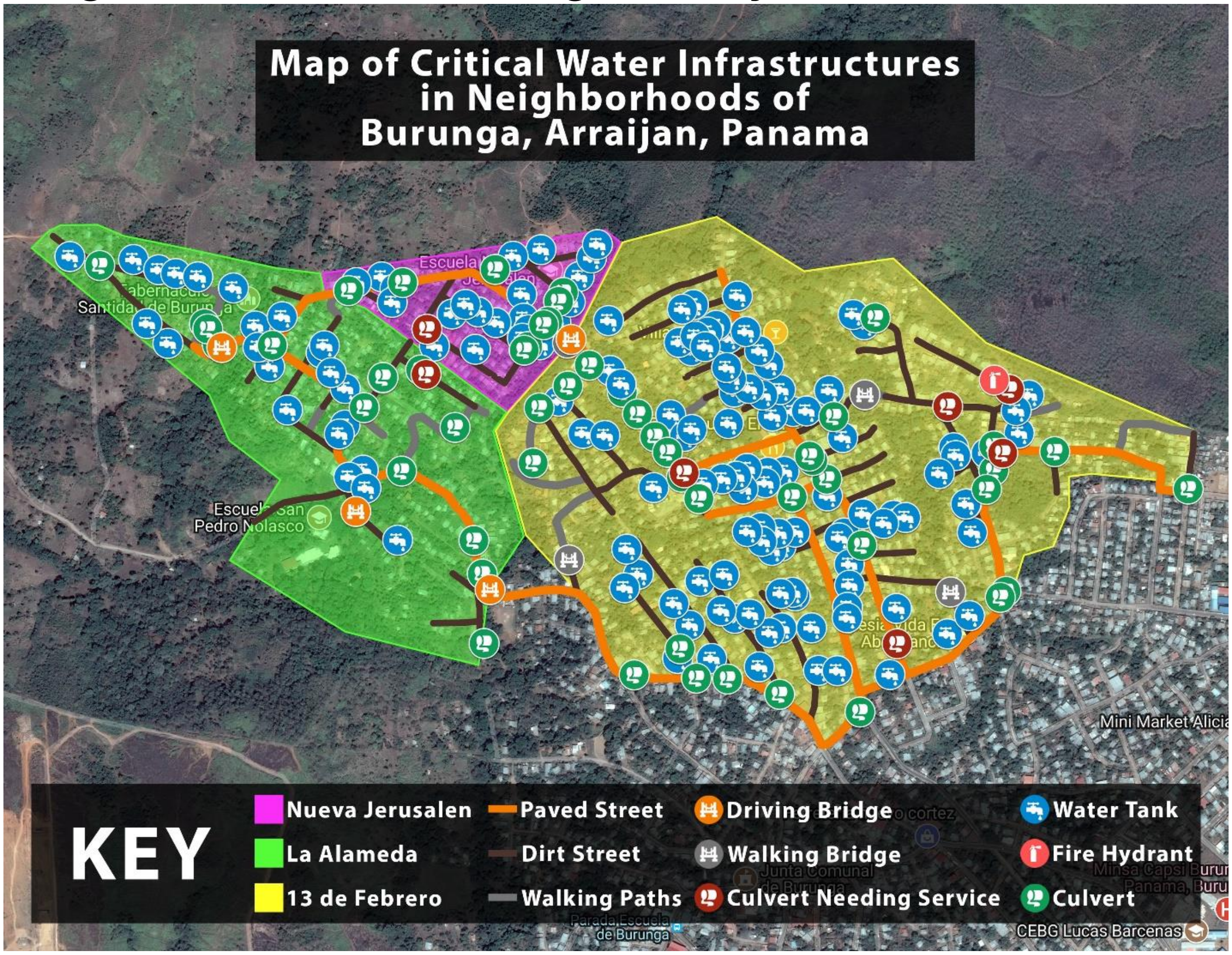
World Bank (2010). Panama - Metro Water and Sanitation Improvement Project. Washington, DC: World Bank. http://documents.worldbank.org/curated/en/676991468057556113/Panama-Metro-Water-and-Sanitation-Improvement-Project

World Bank (2013). World Water Day: Latin America leads in water management but inequalities in access remain. Retrieved from http://www.worldbank.org/en/news/feature/2013/03/22/world-water-day-latin-america-achievements-challenges

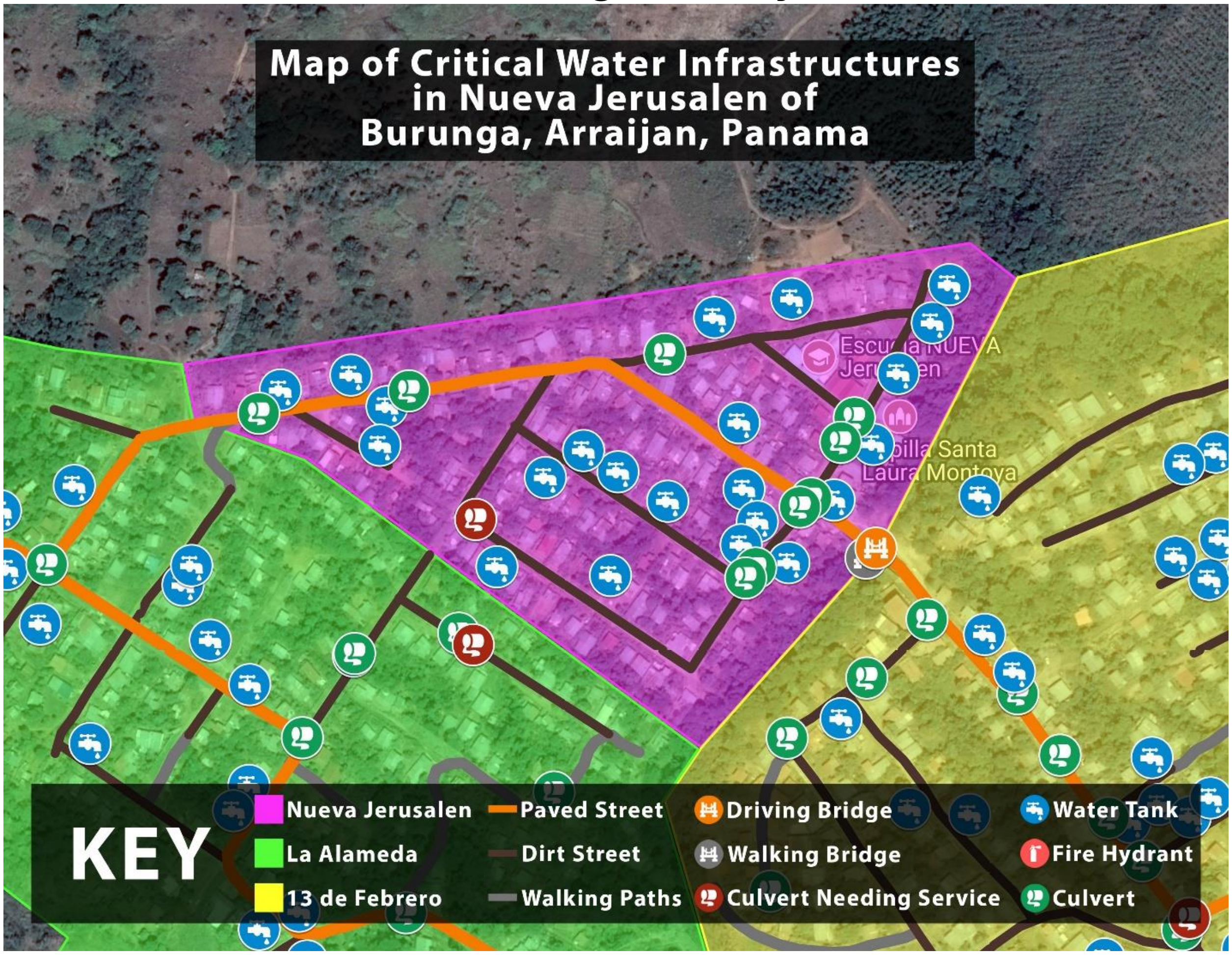
World Bank. (2017). Panama - Burunga Wastewater Management Project. Washington, D.C. : World Bank Group. http://documents.worldbank.org/curated/en/161751491427758866/Panama-Burunga-Wastewater-Management-Project

World Health Organization (2012). Global costs and benefits of drinking-water supply and sanitation interventions to reach the MDG target and universal coverage (WHO/HSE/WSH/12.01). Geneva, Switzerland: WHO Document Production Services http://www.iadb.org/en/projects/project-description-title,1303.html?id=PN-L109

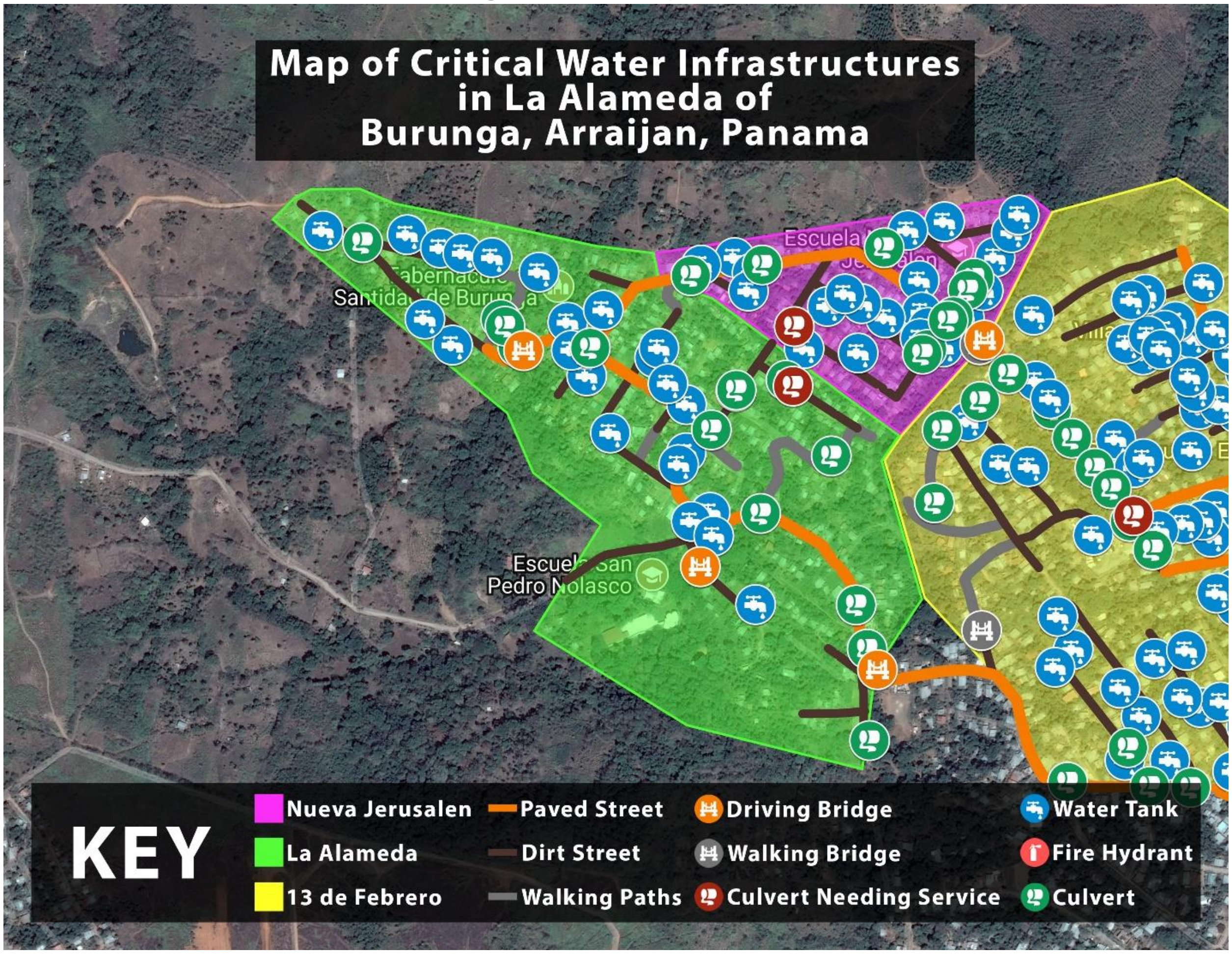
APPENDIX A: Map of Critical Water Infrastructures in Neighborhoods of Burunga, Arraijan



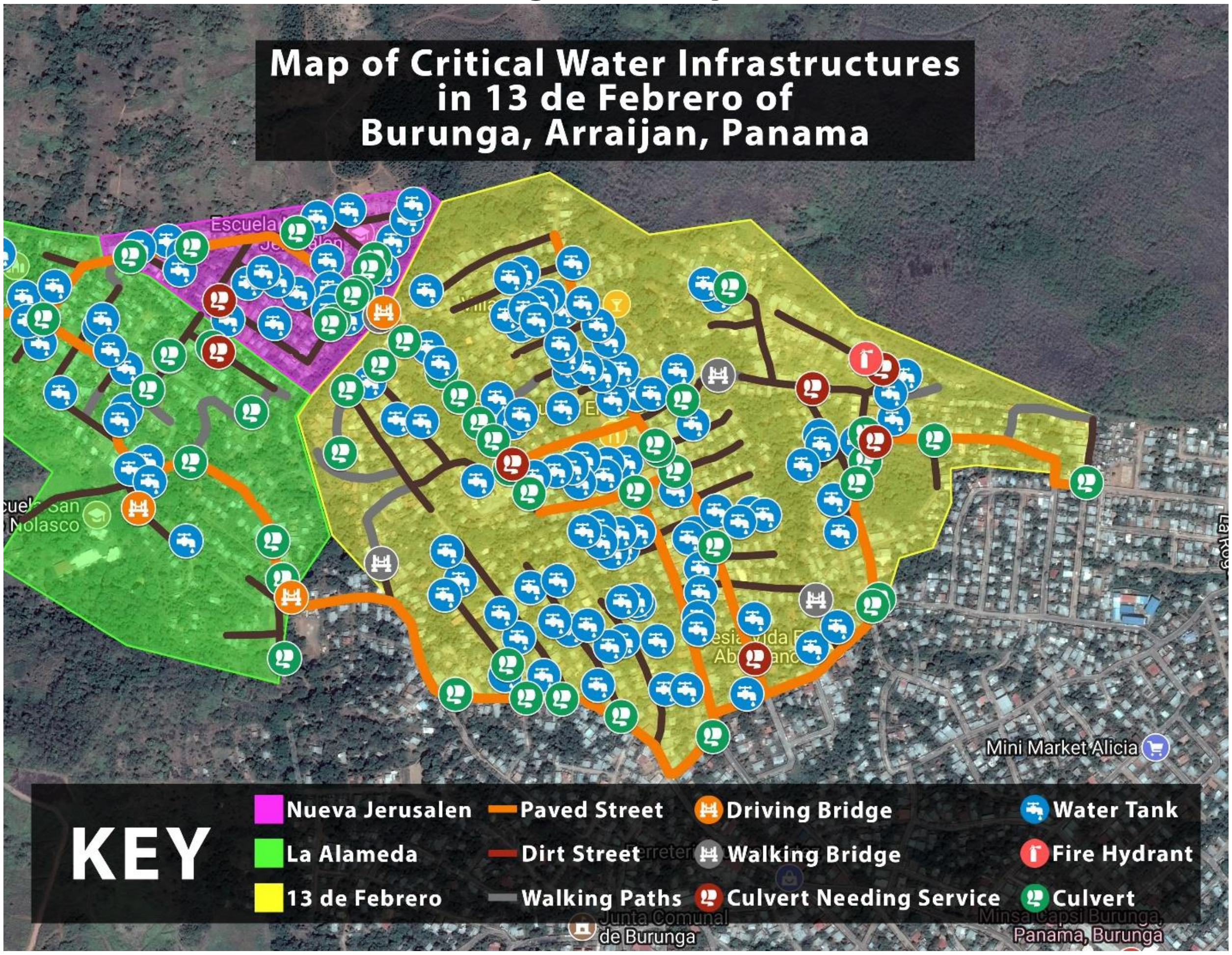
APPENDIX B: Map of Critical Water Infrastructures in Nueva Jerusalen of Burunga, Arraijan, Panama



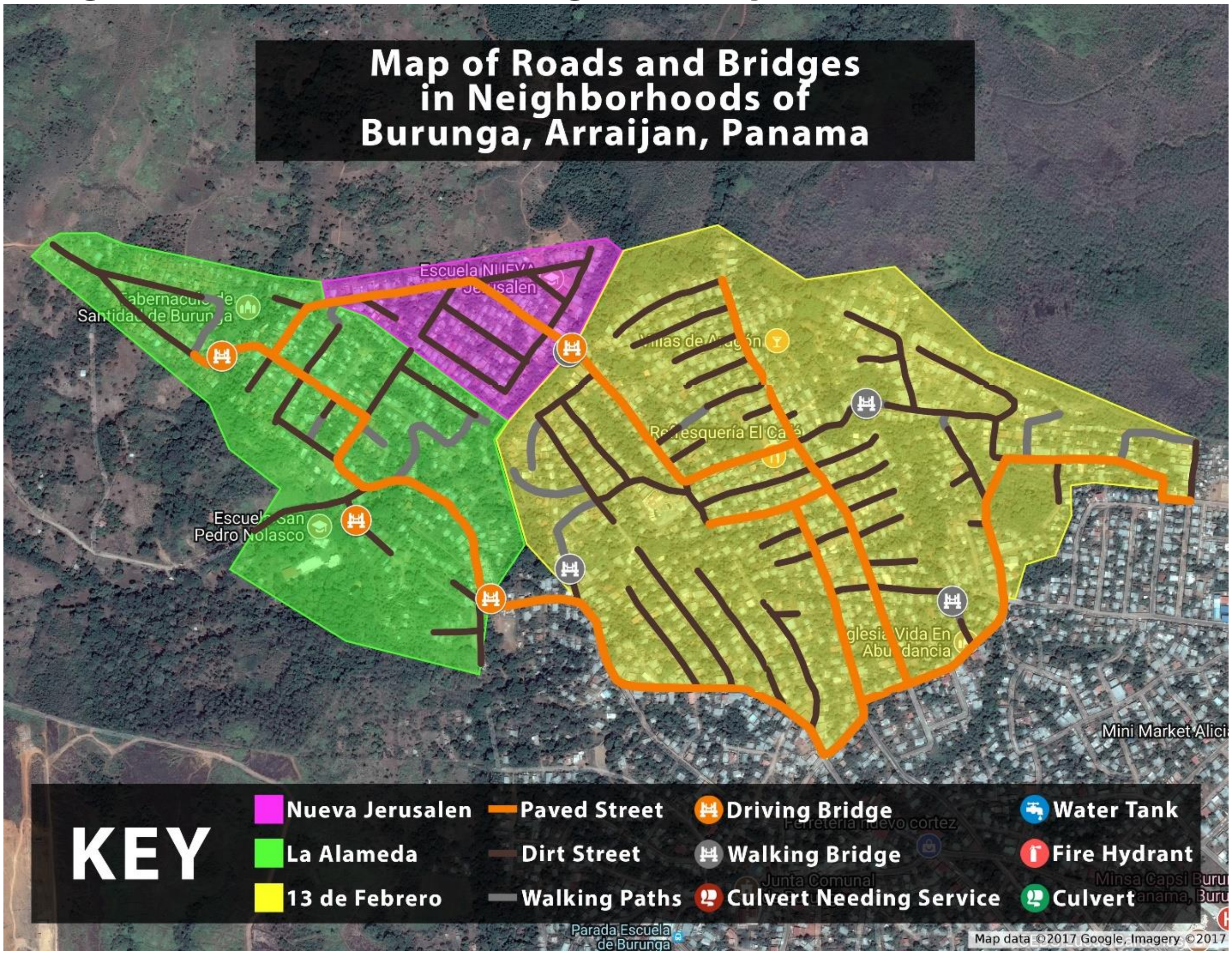
APPENDIX C: Map of Critical Water Infrastructures in La Alameda of Burunga, Arraijan, Panama



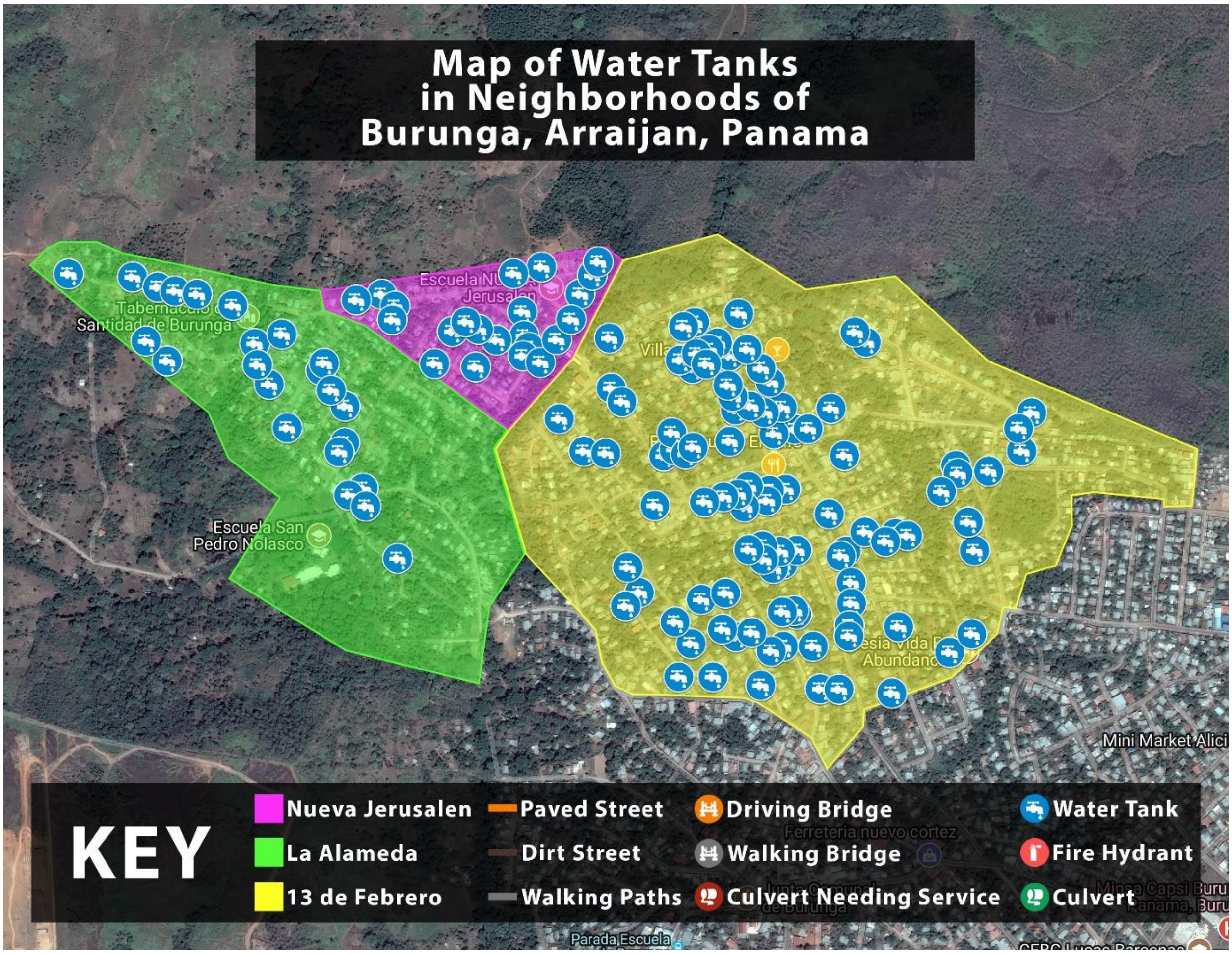
APPENDIX D: Map of Critical Water Infrastructures in 13 de Febrero of Burunga, Arraijan, Panama



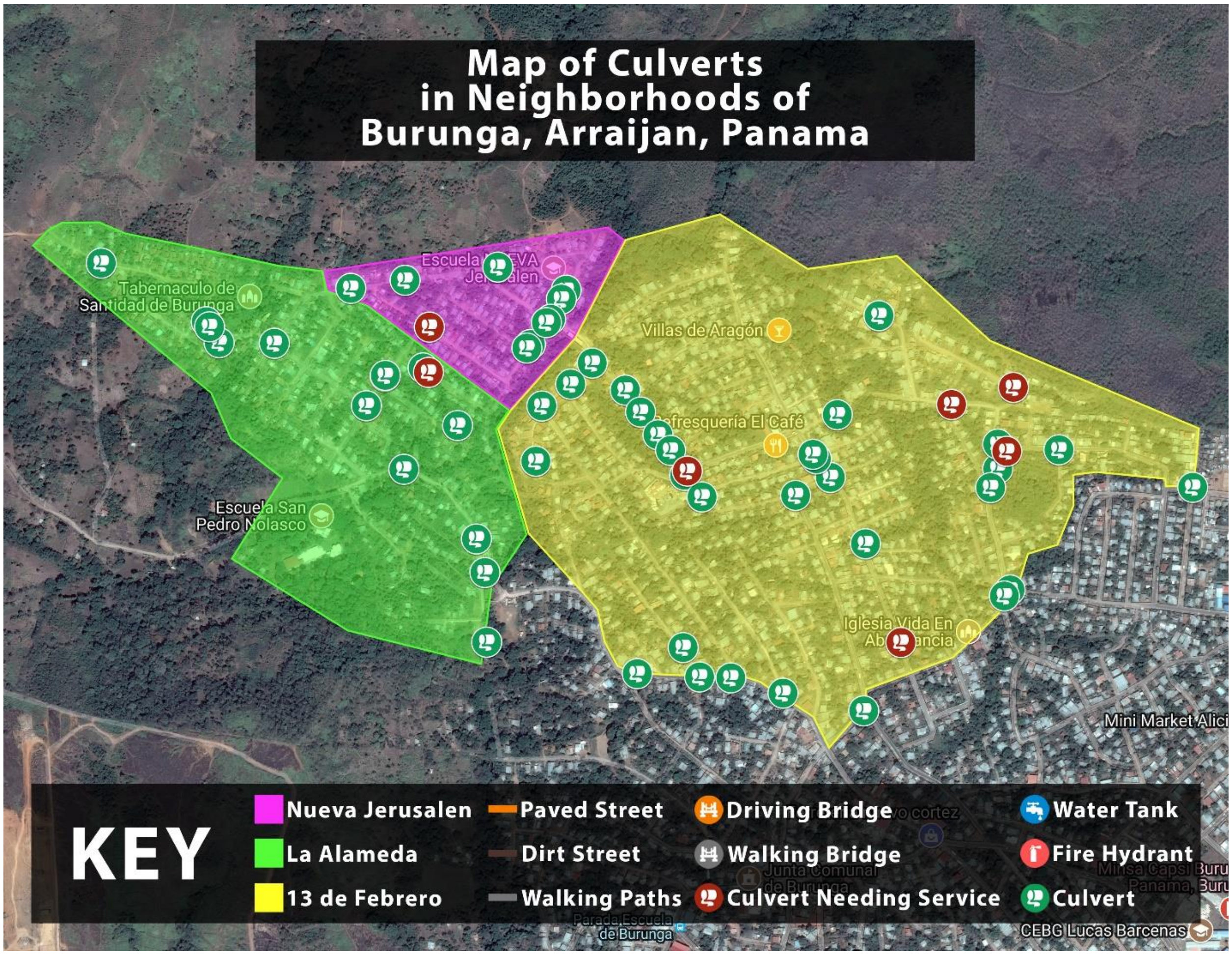
APPENDIX E: Map of Roads of Bridges in Neighborhoods of Burunga, Arraijan, Panama



APPENDIX F: Map of Water Tanks in Neighborhoods of Burunga, Arraijan, Panama



APPENDIX G: Map of Culverts in Neighborhoods of Burunga, Arraijan, Panama

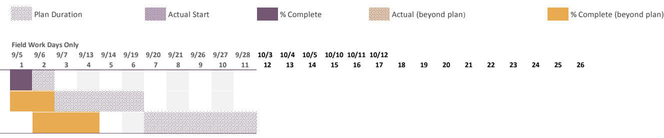


APPENDIX H: Gantt Chart

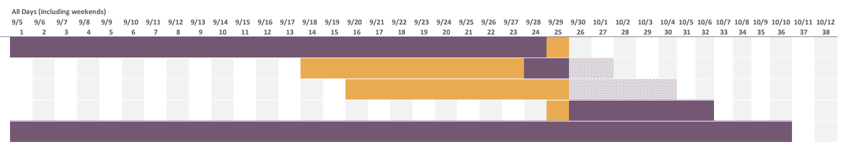
TEAM A - TOPO

The top Gannt Chart consists of days only in the field. The second Gannt Charts includes all days.

ACTIVITY	PLAN START	PLAN DURATION	ACTUAL START	ACTUAL DURATION	PERCENT COMPLETE
Nuevo Jeruslen	1	2	1	1	100%
La Alameda	3	4	1	2	100%
13 de Febrero	7	5	2	3	100%



ACTIVITY	PLAN START	PLAN DURATION	ACTUAL START	ACTUAL DURATION	PERCENT COMPLETE
Mapping (Data Collection and Map Creation)	1	24	1	25	100%
Data Analysis	24	4	14	12	100%
Poster Presentation Prep	26	5	16	10	100%
IDAAN Presentation Prep	26	7	25	8	100%
IQP Paper	1	36	1	36	100%



APPENDIX I: UTM Coordinates of Culverts

Number	Name	Description	Latitude	Longitude	Altitude	UTM	Zone	to East	to North
1	Culvert	2' Wide 14' Long Concrete Circular Pipe	8Â°58'45.17"	-79Â°40'39.71"	66	17P 645360mE 992815mN	17P	645360	992815
2	Culvert	4' Wide 19' Long Concrete Circular Pipe	8Â°58'40.25"	-79Â°40'37.60"	50	17P 645425mE 992665mN	17P	645425	992665
3	Culvert	2' Wide 18' Long Plastic Circular Pipe Overgrown	8Â°58'41.36"	-79Â°40'44.12"	66	17P 645225mE 992698mN	17P	645225	992698
4	Culvert	2' Wide 27' Long Concrete Pipe with Headwalls	8Â°58'40.33"	-79Â°40'54.10"	98	17P 644921mE 992665mN	17P	644921	992665
5	Culvert	2' Wide 40' Long Concrete Pipe with Headwalls	8Â°58'36.35"	-79Â°40'48.16"	79	17P 645103mE 992544mN	17P	645103	992544
6	Culvert	3' Wide 36' Long Concrete Circular Pipe	8Â°58'40.03"	-79Â°40'37.83"	55	17P 645418mE 992658mN	17P	645418	992658
7	Culvert	2' Wide 30' Long Concrete Circular Pipe	8Â°58'40.37"	-79Â°40'57.65"	81	17P 644812mE 992666mN	17P	644812	992666
8	Culvert	4' Wide 20' Long Corrugated Plastic Pipe	8Â°58'45.42"	-79Â°41'5.24"	111	17P 644580mE 992820mN	17P	644580	992820
9	Culvert	3' Wide 27' Long Corrugated Plastic Pipe	8Â°58'41.69"	-79Â°40'58.48"	101	17P 644787mE 992706mN	17P	644787	992706
10	Culvert	3' Wide 27' Long Corrugated Plastic Pipe	8Â°58'41.38"	-79Â°40'58.26"	101	17P 644794mE 992697mN	17P	644794	992697
11	6 Culverts	4' Wide 24' Long Corrugated Plastic Pipe	8Â°58'32.32"	-79Â°40'45.74"	52	17P 645177mE 992420mN	17P	645177	992420
12	Culvert	2' Wide 25' Long Concrete Pipe with Headwalls	8Â°58'27.88"	-79Â°40'41.09"	48	17P 645319mE 992284mN	17P	645319	992284
13	Culvert	4' Wide 30' Long Concrete Pipe with Headwalls	8Â°58'44.33"	-79Â°40'45.67"	85	17P 645178mE 992789mN	17P	645178	992789
14	Culvert	4' Wide Corrugated Plastic Pipe	8Â°58'43.81"	-79Â°40'49.17"	84	17P 645071mE 992773mN	17P	645071	992773
15	Culvert	1.5' Wide 19' Long Concrete Pipe with Headwalls	8Â°58'43.70"	-79Â°40'35.30"	55	17P 645495mE 992771mN	17P	645495	992771
16	Culvert	1.5' Wide 19' Long Concrete Circular Pipe	8Â°58'43.14"	-79Â°40'35.62"	48	17P 645485mE 992754mN	17P	645485	992754
17	Culvert	3' Wide 17' Long Concrete Circular Pipe	8Â°58'38.23"	-79Â°40'46.97"	73	17P 645139mE 992601mN	17P	645139	992601
18	Culvert	3' Wide 17' Long Concrete Circular Pipe	8Â°58'38.76"	-79Â°40'44.51"	68	17P 645214mE 992618mN	17P	645214	992618
19	Culvert	3' Wide 14' Long Concrete Circular Pipe	8Â°58'35.11"	-79Â°40'42.29"	58	17P 645282mE 992506mN	17P	645282	992506
20	Culvert	4' Wide 17' Long Concrete Pipe with Headwalls	8Â°58'38.29"	-79Â°40'46.94"	70	17P 645140mE 992603mN	17P	645140	992603

21	Culvert	Width Unknown 19' Long Concrete Circular Pipe Buried	8Â°58'38.49"	-79Â°40'44.17"	58	17P 645224mE 992610mN	17P	645224	992610
22	Culvert	1.5' Wide 6' Long Corrugated Plastic Pipe	8Â°58'32.82"	-79Â°40'37.26"	45	17P 645436mE 992436mN	17P	645436	992436
23	Culvert	3' Wide 21' Long Plastic Pipe with Headwalls	8Â°58'36.34"	-79Â°40'36.87"	47	17P 645447mE 992545mN	17P	645447	992545
24	Culvert	5' Wide 4.5' Long Plastic Pipe with Headwalls	8Â°58'37.73"	-79Â°40'35.01"	48	17P 645504mE 992587mN	17P	645504	992587
25	Culvert	2' Wide 24' Long Concrete Pipe with Headwalls	8Â°58'39.06"	-79Â°40'33.61"	53	17P 645547mE 992628mN	17P	645547	992628
26	Culvert	2' Wide 20' Long Concrete Circular Pipe	8Â°58'31.94"	-79Â°40'27.67"	72	17P 645729mE 992410mN	17P	645729	992410
27	Culvert	2' Wide 30' Long Concrete Pipe with Headwalls	8Â°58'41.85"	-79Â°40'36.31"	11	17P 645464mE 992714mN	17P	645464	992714
28	Culvert	2' Wide 30' Long Concrete Pipe with Headwalls	8Â°58'41.65"	-79Â°40'36.57"	11	17P 645456mE 992708mN	17P	645456	992708
29	Culvert	2.5' Wide 17' Long Concrete Pipe with Headwalls	8Â°58'37.36"	-79Â°40'31.49"	55	17P 645612mE 992576mN	17P	645612	992576
30	Culvert	2' Wide 18' Long Concrete Pipe with Headwalls	8Â°58'35.95"	-79Â°40'30.51"	61	17P 645642mE 992533mN	17P	645642	992533
31	Culvert	2' Wide 21' Long Concrete Pipe with Headwalls	8Â°58'34.51"	-79Â°40'29.39"	65	17P 645676mE 992489mN	17P	645676	992489
32	Culvert	2' Wide 21' Long Concrete Pipe with Headwalls	8Â°58'33.52"	-79Â°40'28.59"	76	17P 645701mE 992459mN	17P	645701	992459
33	Culvert	2' Wide 35' Long Concrete Pipe with Headwalls Half Buried	8Â°58'32.20"	-79Â°40'27.50"	81	17P 645734mE 992418mN	17P	645734	992418
34	Culvert	2.5' Wide 25' Long Concrete Pipe with Headwalls	8Â°58'27.58"	-79Â°40'16.02"	100	17P 646085mE 992278mN	17P	646085	992278
35	Culvert	2.5' Wide 25' Long Concrete Pipe with Headwalls	8Â°58'16.96"	-79Â°40'16.15"	107	17P 646082mE 991951mN	17P	646082	991951
36	Culvert	3' Wide 30' Long Concrete Pipe with Headwalls	8Â°58'32.35"	-79Â°40'7.51"	71	17P 646345mE 992425mN	17P	646345	992425
37	Culvert	2' Wide 25' Long Concrete Pipe with Headwalls Half Burried	8Â°58'33.46"	-79Â°40'6.93"	73	17P 646362mE 992459mN	17P	646362	992459
38	Culvert	2' Wide 15' Long Concrete Pipe with Headwalls	8Â°58'33.56"	-79Â°40'3.58"	79	17P 646464mE 992463mN	17P	646464	992463
39	Culvert	2.5' Wide 25' Long Concrete Pipe with Headwalls	8Â°58'31.18"	-79Â°39'54.96"	92	17P 646728mE 992391mN	17P	646728	992391
40	Culvert	2.5' Wide 25' Long Concrete Pipe with Headwalls	8Â°58'33.91"	-79Â°40'7.51"	79	17P 646344mE 992473mN	17P	646344	992473
41	Culvert	3' Wide 35' Long Concrete Pipe with Headwalls Half Burried	8Â°58'37.53"	-79Â°40'6.50"	77	17P 646375mE 992584mN	17P	646375	992584

42	Culvert	2.5' Wide 30' Long Concrete Pipe with Headwalls	8Â°58'42.09"	-79Â°40'15.16"	69	17P 646110mE 992724mN	17P	646110	992724
43	Culvert	3' Wide 40' Long Concrete Pipe with Headwalls	8Â°58'25.76"	-79Â°40'40.54"	44	17P 645337mE 992219mN	17P	645337	992219
44	Culvert	2' Wide 8' Long Concrete Circular Pipe	8Â°58'21.33"	-79Â°40'40.41"	46	17P 645341mE 992083mN	17P	645341	992083
45	Culvert	2.5' Wide 24' Long Concrete Pipe with Headwalls	8Â°58'19.32"	-79Â°40'30.73"	76	17P 645637mE 992022mN	17P	645637	992022
46	Culvert	2.5' Wide 20' Long Concrete Pipe with Headwalls	8Â°58'19.12"	-79Â°40'26.70"	96	17P 645760mE 992017mN	17P	645760	992017
47	Culvert	1' Wide 6' Long Pipe	8Â°58'20.99"	-79Â°40'27.77"	98	17P 645727mE 992074mN	17P	645727	992074
48	Culvert	2.5' Wide 20' Long Concrete Pipe with Headwalls	8Â°58'19.06"	-79Â°40'24.70"	119	17P 645821mE 992015mN	17P	645821	992015
49	Culvert	2.5' Wide 20' Long Concrete Circular Pipe	8Â°58'18.08"	-79Â°40'21.33"	123	17P 645924mE 991985mN	17P	645924	991985
50	Culvert	2.5' Wide 55' Long Concrete Pipe with Headwalls	8Â°58'30.65"	-79Â°40'20.52"	104	17P 645947mE 992372mN	17P	645947	992372
51	Culvert	2.5' Wide 30' Long Concrete Pipe with Headwalls	8Â°58'31.80"	-79Â°40'18.29"	94	17P 646015mE 992407mN	17P	646015	992407
52	Culvert	2.5' Wide 35' Long Concrete Pipe with Headwalls	8Â°58'32.98"	-79Â°40'19.19"	93	17P 645988mE 992443mN	17P	645988	992443
53	Culvert	2.5' Wide 35' Long Concrete Pipe with Headwalls	8Â°58'33.26"	-79Â°40'19.41"	93	17P 645981mE 992452mN	17P	645981	992452
54	Culvert	1.5' Wide 8' Long Concrete Circular Pipe	8Â°58'30.57"	-79Â°40'26.55"	87	17P 645763mE 992368mN	17P	645763	992368
55	Culvert	1.25' Wide 2' High 16' Long Concrete Box	8Â°58'35.78"	-79Â°40'17.84"	69.901527	17P 646029mE 992529mN	17P	646029	992529
56	Culvert	3' Wide 1' High 30' Long Concrete Box Burried	8Â°58'36.44"	-79Â°40'10.49"	66.971863	17P 646253mE 992551mN	17P	646253	992551
57	Culvert	2' Wide 18' Long Concrete Pipe with Headwalls	8Â°58'31.16"	-79Â°40'7.98"	79.08754	17P 646330mE 992389mN	17P	646330	992389
58	Culvert	2.5' Wide 25' Long Concrete Circular Pipe with Headwalls Needs Service	8Â°58'21.30"	-79Â°40'13.75"	99.522339	17P 646155mE 992085mN	17P	646155	992085
59	2 Culverts	4' Wide Each 30' Long Each Concrete Pipe with Headwalls	8Â°58'24.26"	-79Â°40'7.09"	77	17P 646358mE 992177mN	17P	646358	992177
60	Culvert	4' Wide 25' Long Concrete Circular Pipe	8Â°58'24.64"	-79Â°40'6.71"	78	17P 646370mE 992188mN	17P	646370	992188

APPENDIX J: UTM Coordinates of Water Tanks

Number	Name	Description	Latitude	Longitude	Altitude	UTM	Zone	to East	to North
1	Water Tank	Negro	8Â°58'43.59"	-79Â°40'37.99"	57	17P 645412mE 992767mN	17P	645412	992767
2	Water Tank	Negro	8Â°58'42.06"	-79Â°40'37.87"	53	17P 645416mE 992720mN	17P	645416	992720
3	Water Tank	Azul	8Â°58'41.32"	-79Â°40'37.56"	49	17P 645426mE 992697mN	17P	645426	992697
4	Water Tank	Negro	8Â°58'41.78"	-79Â°40'39.64"	59	17P 645362mE 992711mN	17P	645362	992711
5	Water Tank	Azul	8Â°58'42.47"	-79Â°40'40.80"	64	17P 645327mE 992732mN	17P	645327	992732
6	Water Tank	Negro	8Â°58'42.33"	-79Â°40'42.49"	70	17P 645275mE 992728mN	17P	645275	992728
7	Water Tank	Azul	8Â°58'42.95"	-79Â°40'41.61"	70	17P 645302mE 992747mN	17P	645302	992747
8	Water Tank	Negro	8Â°58'40.28"	-79Â°40'43.62"	69	17P 645241mE 992665mN	17P	645241	992665
9	Water Tank	Negro	8Â°58'38.97"	-79Â°40'54.26"	103	17P 644916mE 992623mN	17P	644916	992623
10	Water Tank	Verde	8Â°58'39.86"	-79Â°40'50.94"	97	17P 645017mE 992651mN	17P	645017	992651
11	Water Tank	Negro	8Â°58'40.31"	-79Â°40'50.74"	95	17P 645023mE 992665mN	17P	645023	992665
12	Water Tank	Negro	8Â°58'36.22"	-79Â°40'53.10"	98	17P 644952mE 992539mN	17P	644952	992539
13	Water Tank	Negro	8Â°58'37.57"	-79Â°40'49.37"	84	17P 645066mE 992581mN	17P	645066	992581
14	Water Tank	Azul	8Â°58'32.37"	-79Â°40'48.23"	53	17P 645101mE 992421mN	17P	645101	992421
15	Water Tank	Negro	8Â°58'44.73"	-79Â°40'34.27"	55	17P 645526mE 992803mN	17P	645526	992803
16	Water Tank	Negro	8Â°58'45.89"	-79Â°40'33.49"	60	17P 645550mE 992838mN	17P	645550	992838
17	Water Tank	Negro	8Â°58'46.76"	-79Â°40'33.09"	61	17P 645562mE 992865mN	17P	645562	992865
18	Water Tank	Negro	8Â°58'46.44"	-79Â°40'36.76"	62	17P 645450mE 992855mN	17P	645450	992855
19	Water Tank	Azul	8Â°58'46.01"	-79Â°40'38.55"	70	17P 645395mE 992841mN	17P	645395	992841
20	Water Tank	Negro	8Â°58'44.69"	-79Â°40'47.02"	84	17P 645137mE 992800mN	17P	645137	992800
21	Water Tank	Azul	8Â°58'44.34"	-79Â°40'48.67"	84	17P 645086mE 992789mN	17P	645086	992789
22	Water Tank	Negro	8Â°58'43.96"	-79Â°40'46.18"	80	17P 645162mE 992778mN	17P	645162	992778
23	Water Tank	Negro	8Â°58'43.08"	-79Â°40'46.35"	80	17P 645157mE 992751mN	17P	645157	992751
24	Water Tank	Negro	8Â°58'40.08"	-79Â°40'40.98"	65	17P 645321mE 992659mN	17P	645321	992659
25	Water Tank	Azul	8Â°58'40.79"	-79Â°40'37.94"	55	17P 645414mE 992681mN	17P	645414	992681
26	Water Tank	Negro	8Â°58'40.37"	-79Â°40'36.82"	55	17P 645449mE 992668mN	17P	645449	992668
27	Water Tank	Negro	8Â°58'41.82"	-79Â°40'35.78"	55	17P 645480mE 992713mN	17P	645480	992713
28	Water Tank	Negro	8Â°58'43.09"	-79Â°40'34.86"	55	17P 645508mE 992752mN	17P	645508	992752
29	Water Tank	Negro	8Â°58'41.57"	-79Â°40'55.19"	96	17P 644887mE 992703mN	17P	644887	992703
30	Water Tank	Negro	8Â°58'40.45"	-79Â°41'0.84"	110	17P 644715mE 992668mN	17P	644715	992668
31	Water Tank	Negro	8Â°58'41.72"	-79Â°41'2.19"	122	17P 644674mE 992707mN	17P	644674	992707
32	Water Tank	Azul	8Â°58'46.00"	-79Â°41'7.17"	122	17P 644521mE 992838mN	17P	644521	992838
33	Water Tank	Negro	8Â°58'45.80"	-79Â°41'3.04"	112	17P 644647mE 992832mN	17P	644647	992832
34	Water Tank	Negro	8Â°58'45.15"	-79Â°41'1.42"	117	17P 644697mE 992812mN	17P	644697	992812
35	Water Tank	Azul	8Â°58'44.91"	-79Â°41'0.33"	127	17P 644730mE 992805mN	17P	644730	992805
36	Water Tank	Negro	8Â°58'44.70"	-79Â°40'58.90"	125	17P 644774mE 992799mN	17P	644774	992799
37	Water Tank	Negro	8Â°58'43.99"	-79Â°40'56.60"	115	17P 644844mE 992777mN	17P	644844	992777
38	Water Tank	Negro	8Â°58'38.59"	-79Â°40'50.30"	88	17P 645037mE 992612mN	17P	645037	992612
39	Water Tank	Negro	8Â°58'35.25"	-79Â°40'49.40"	72	17P 645065mE 992510mN	17P	645065	992510
40	Water Tank	Negro	8Â°58'34.67"	-79Â°40'49.76"	68	17P 645054mE 992492mN	17P	645054	992492
41	Water Tank	Negro	8Â°58'31.95"	-79Â°40'49.15"	60	17P 645073mE 992408mN	17P	645073	992408
42	Water Tank	Azul	8Â°58'42.15"	-79Â°40'53.46"	104	17P 644940mE 992721mN	17P	644940	992721
43	Water Tank	Azul	8Â°58'40.22"	-79Â°40'55.02"	96	17P 644893mE 992662mN	17P	644893	992662
44	Water Tank	Azul	8Â°58'34.72"	-79Â°40'34.02"	49	17P 645535mE 992495mN	17P	645535	992495
45	Water Tank	Negro	8Â°58'36.79"	-79Â°40'35.61"	45	17P 645486mE 992558mN	17P	645486	992558
46	Water Tank	Negro	8Â°58'38.72"	-79Â°40'32.27"	46	17P 645588mE 992618mN	17P	645588	992618
47	Water Tank	Azul	8Â°58'34.59"	-79Â°40'32.62"	58	17P 645577mE 992491mN	17P	645577	992491
48	Water Tank	Azul	8Â°58'31.26"	-79Â°40'29.48"	77	17P 645674mE 992389mN	17P	645674	992389
49	Water Tank	Negro	8Â°58'34.41"	-79Â°40'28.88"	62	17P 645692mE 992486mN	17P	645692	992486
50	Water Tank	Negro	8Â°58'34.82"	-79Â°40'28.21"	66	17P 645712mE 992499mN	17P	645712	992499

51	Water Tank	Negro	8Â°58'35.90"	-79Â°40'28.37"	70	17P 645707mE 992532mN	17P	645707	992532
52	Water Tank	Negro	8Â°58'34.52"	-79Â°40'27.48"	75	17P 645734mE 992490mN	17P	645734	992490
53	Water Tank	Negro	8Â°58'34.97"	-79Â°40'27.00"	76	17P 645749mE 992504mN	17P	645749	992504
54	Water Tank	Azul	8Â°58'36.11"	-79Â°40'20.45"	95	17P 645949mE 992539mN	17P	645949	992539
55	Water Tank	Negro	8Â°58'35.83"	-79Â°40'21.79"	95	17P 645908mE 992531mN	17P	645908	992531
56	Water Tank	Azul	8Â°58'37.51"	-79Â°40'21.28"	91	17P 645923mE 992582mN	17P	645923	992582
57	Water Tank	Azul	8Â°58'37.16"	-79Â°40'22.43"	91	17P 645888mE 992571mN	17P	645888	992571
58	Water Tank	Azul	8Â°58'37.36"	-79Â°40'24.27"	88	17P 645832mE 992577mN	17P	645832	992577
59	Water Tank	Negro	8Â°58'35.34"	-79Â°40'24.65"	89	17P 645821mE 992515mN	17P	645821	992515
60	Water Tank	Negro	8Â°58'37.59"	-79Â°40'23.31"	90	17P 645861mE 992584mN	17P	645861	992584
61	Water Tank	Azul	8Â°58'38.20"	-79Â°40'24.45"	87	17P 645827mE 992603mN	17P	645827	992603
62	Water Tank	Negro	8Â°58'39.11"	-79Â°40'22.03"	93	17P 645900mE 992631mN	17P	645900	992631
63	Water Tank	Negro	8Â°58'39.99"	-79Â°40'22.63"	83	17P 645882mE 992658mN	17P	645882	992658
64	Water Tank	Negro	8Â°58'40.78"	-79Â°40'24.66"	75	17P 645820mE 992682mN	17P	645820	992682
65	Water Tank	Azul	8Â°58'38.92"	-79Â°40'24.76"	76	17P 645817mE 992625mN	17P	645817	992625
66	Water Tank	Azul	8Â°58'41.20"	-79Â°40'23.52"	83	17P 645855mE 992695mN	17P	645855	992695
67	Water Tank	Azul	8Â°58'41.61"	-79Â°40'25.43"	84	17P 645796mE 992708mN	17P	645796	992708
68	Water Tank	Negro	8Â°58'41.19"	-79Â°40'25.98"	84	17P 645779mE 992695mN	17P	645779	992695
69	Water Tank	Negro	8Â°58'39.99"	-79Â°40'27.04"	77	17P 645747mE 992658mN	17P	645747	992658
70	Water Tank	Negro	8Â°58'40.51"	-79Â°40'27.82"	75	17P 645723mE 992674mN	17P	645723	992674
71	Water Tank	Negro	8Â°58'40.92"	-79Â°40'26.79"	79	17P 645755mE 992686mN	17P	645755	992686
72	Water Tank	Negro	8Â°58'40.25"	-79Â°40'26.14"	82	17P 645775mE 992666mN	17P	645775	992666
73	Water Tank	Azul	8Â°58'43.48"	-79Â°40'24.06"	85	17P 645838mE 992765mN	17P	645838	992765
74	Water Tank	Azul	8Â°58'42.91"	-79Â°40'26.89"	78	17P 645752mE 992747mN	17P	645752	992747
75	Water Tank	Negro	8Â°58'42.64"	-79Â°40'27.62"	77	17P 645729mE 992739mN	17P	645729	992739
76	Water Tank	Azul	8Â°58'41.91"	-79Â°40'32.38"	64	17P 645584mE 992716mN	17P	645584	992716
77	Water Tank	Negro	8Â°58'30.74"	-79Â°40'18.25"	98	17P 646017mE 992375mN	17P	646017	992375
78	Water Tank	Azul	8Â°58'28.37"	-79Â°40'17.17"	103	17P 646050mE 992302mN	17P	646050	992302
79	Water Tank	Negro	8Â°58'28.06"	-79Â°40'17.50"	103	17P 646040mE 992292mN	17P	646040	992292
80	Water Tank	Azul	8Â°58'29.60"	-79Â°40'15.95"	107	17P 646087mE 992340mN	17P	646087	992340
81	Water Tank	Blanco	8Â°58'29.49"	-79Â°40'13.97"	90	17P 646148mE 992337mN	17P	646148	992337
82	Water Tank	Azul	8Â°58'29.36"	-79Â°40'13.22"	89	17P 646171mE 992333mN	17P	646171	992333
83	Water Tank	Negro	8Â°58'28.99"	-79Â°40'14.61"	91	17P 646128mE 992321mN	17P	646128	992321
84	Water Tank	Azul	8Â°58'26.38"	-79Â°40'16.83"	104	17P 646061mE 992241mN	17P	646061	992241
85	Water Tank	Blanco	8Â°58'25.05"	-79Â°40'16.83"	107	17P 646061mE 992200mN	17P	646061	992200
86	Water Tank	Blanco	8Â°58'19.36"	-79Â°40'14.22"	98	17P 646141mE 992025mN	17P	646141	992025
87	Water Tank	Negro	8Â°58'19.61"	-79Â°40'18.83"	124	17P 646000mE 992033mN	17P	646000	992033
88	Water Tank	Blanco	8Â°58'22.32"	-79Â°40'19.27"	130	17P 645987mE 992116mN	17P	645987	992116
89	Water Tank	Negro	8Â°58'22.32"	-79Â°40'21.20"	130	17P 645928mE 992116mN	17P	645928	992116
90	Water Tank	Negro	8Â°58'22.32"	-79Â°40'21.20"	130	17P 645928mE 992116mN	17P	645928	992116
91	Water Tank	Verde	8Â°58'24.36"	-79Â°40'20.34"	134	17P 645954mE 992178mN	17P	645954	992178
92	Water Tank	Verde	8Â°58'24.36"	-79Â°40'20.34"	134	17P 645954mE 992178mN	17P	645954	992178
93	Water Tank	Azul	8Â°58'24.59"	-79Â°40'20.50"	134	17P 645949mE 992185mN	17P	645949	992185
94	Water Tank	Azul	8Â°58'24.59"	-79Â°40'20.50"	134	17P 645949mE 992185mN	17P	645949	992185
95	Water Tank	Negro	8Â°58'24.52"	-79Â°40'21.26"	135	17P 645925mE 992183mN	17P	645925	992183
96	Water Tank	Azul	8Â°58'21.93"	-79Â°40'10.50"	86	17P 646254mE 992105mN	17P	646254	992105
97	Water Tank	Azul	8Â°58'23.11"	-79Â°40'9.07"	86	17P 646298mE 992141mN	17P	646298	992141
98	Water Tank	Azul	8Â°58'28.40"	-79Â°40'8.90"	80	17P 646303mE 992304mN	17P	646303	992304
99	Water Tank	Negro	8Â°58'30.20"	-79Â°40'9.27"	81	17P 646291mE 992359mN	17P	646291	992359
100	Water Tank	Negro	8Â°58'30.20"	-79Â°40'9.27"	81	17P 646291mE 992359mN	17P	646291	992359
101	Water Tank	Azul	8Â°58'30.21"	-79Â°40'9.31"	81	17P 646290mE 992359mN	17P	646290	992359

102	Water Tank	Azul	8Â°58'33.46"	-79Â°40'8.00"	73	17P 646329mE 992459mN	17P	646329	992459
103	Water Tank	Negro	8Â°58'34.75"	-79Â°40'5.86"	81	17P 646395mE 992499mN	17P	646395	992499
104	Water Tank	Negro	8Â°58'37.17"	-79Â°40'5.22"	78	17P 646414mE 992574mN	17P	646414	992574
105	Water Tank	Negro	8Â°58'36.17"	-79Â°40'6.07"	79	17P 646388mE 992543mN	17P	646388	992543
106	Water Tank	Azul	8Â°58'41.64"	-79Â°40'15.87"	69	17P 646088mE 992710mN	17P	646088	992710
107	Water Tank	Blanco	8Â°58'42.29"	-79Â°40'16.60"	69	17P 646066mE 992730mN	17P	646066	992730
108	Water Tank	Blanco	8Â°58'37.46"	-79Â°40'18.12"	73	17P 646020mE 992581mN	17P	646020	992581
109	Water Tank	Negro	8Â°58'31.22"	-79Â°40'48.04"	56	17P 645107mE 992386mN	17P	645107	992386
110	Water Tank	Negro	8Â°58'27.90"	-79Â°40'45.99"	48	17P 645170mE 992284mN	17P	645170	992284
111	Water Tank	Negro	8Â°58'20.37"	-79Â°40'27.92"	95	17P 645723mE 992055mN	17P	645723	992055
112	Water Tank	Blanco	8Â°58'25.73"	-79Â°40'30.45"	91	17P 645645mE 992219mN	17P	645645	992219
113	Water Tank	Azul	8Â°58'24.87"	-79Â°40'31.33"	91	17P 645618mE 992193mN	17P	645618	992193
114	Water Tank	Negro	8Â°58'27.34"	-79Â°40'31.20"	90	17P 645622mE 992269mN	17P	645622	992269
115	Water Tank	Blanco	8Â°58'20.38"	-79Â°40'25.73"	111	17P 645789mE 992055mN	17P	645789	992055
116	Water Tank	Azul	8Â°58'22.49"	-79Â°40'27.13"	107	17P 645746mE 992120mN	17P	645746	992120
117	Water Tank	Negro	8Â°58'23.86"	-79Â°40'28.15"	99	17P 645715mE 992162mN	17P	645715	992162
118	Water Tank	Negro	8Â°58'19.84"	-79Â°40'22.65"	118	17P 645884mE 992039mN	17P	645884	992039
119	Water Tank	Azul	8Â°58'22.02"	-79Â°40'21.98"	123	17P 645904mE 992106mN	17P	645904	992106
120	Water Tank	Azul	8Â°58'22.92"	-79Â°40'24.23"	128	17P 645835mE 992134mN	17P	645835	992134
121	Water Tank	Negro	8Â°58'23.19"	-79Â°40'23.23"	130	17P 645865mE 992142mN	17P	645865	992142
122	Water Tank	Azul	8Â°58'23.40"	-79Â°40'25.10"	130	17P 645808mE 992148mN	17P	645808	992148
123	Water Tank	Negro	8Â°58'25.30"	-79Â°40'26.47"	118	17P 645766mE 992207mN	17P	645766	992207
124	Water Tank	Azul	8Â°58'25.71"	-79Â°40'24.92"	118	17P 645814mE 992219mN	17P	645814	992219
125	Water Tank	Azul	8Â°58'19.59"	-79Â°40'17.62"	110	17P 646037mE 992032mN	17P	646037	992032
126	Water Tank	Negro	8Â°58'23.64"	-79Â°40'16.95"	112	17P 646057mE 992157mN	17P	646057	992157
127	Water Tank	Azul	8Â°58'22.97"	-79Â°40'16.97"	114	17P 646057mE 992136mN	17P	646057	992136
128	Water Tank	Azul	8Â°58'27.53"	-79Â°40'21.25"	123	17P 645925mE 992276mN	17P	645925	992276
129	Water Tank	Azul	8Â°58'27.53"	-79Â°40'21.25"	123	17P 645925mE 992276mN	17P	645925	992276
130	Water Tank	Negro	8Â°58'27.26"	-79Â°40'21.84"	123	17P 645907mE 992267mN	17P	645907	992267
131	Water Tank	Negro	8Â°58'28.43"	-79Â°40'20.34"	111	17P 645953mE 992303mN	17P	645953	992303
132	Water Tank	Azul	8Â°58'28.35"	-79Â°40'21.39"	112	17P 645921mE 992301mN	17P	645921	992301
133	Water Tank	Negro	8Â°58'28.71"	-79Â°40'22.53"	111	17P 645886mE 992312mN	17P	645886	992312
134	Water Tank	Azul	8Â°58'27.82"	-79Â°40'22.47"	109	17P 645888mE 992284mN	17P	645888	992284
135	Water Tank	Negro	8Â°58'28.46"	-79Â°40'23.42"	109	17P 645859mE 992304mN	17P	645859	992304
136	Water Tank	Negro	8Â°58'32.29"	-79Â°40'21.05"	96	17P 645931mE 992422mN	17P	645931	992422
137	Water Tank	Negro	8Â°58'32.24"	-79Â°40'22.09"	96	17P 645899mE 992420mN	17P	645899	992420
138	Water Tank	Blanco	8Â°58'31.58"	-79Â°40'22.25"	97	17P 645894mE 992400mN	17P	645894	992400
139	Water Tank	Blanco	8Â°58'32.49"	-79Â°40'23.45"	95	17P 645858mE 992428mN	17P	645858	992428
140	Water Tank	Negro	8Â°58'31.18"	-79Â°40'23.69"	95	17P 645851mE 992387mN	17P	645851	992387
141	Water Tank	Negro	8Â°58'31.99"	-79Â°40'24.13"	95	17P 645837mE 992412mN	17P	645837	992412
142	Water Tank	Azul	8Â°58'31.82"	-79Â°40'25.03"	93	17P 645810mE 992407mN	17P	645810	992407
143	Water Tank	Azul	8Â°58'31.49"	-79Â°40'26.27"	89	17P 645772mE 992397mN	17P	645772	992397
144	Water Tank	Azul	8Â°58'31.49"	-79Â°40'26.27"	89	17P 645772mE 992397mN	17P	645772	992397
145	Water Tank	Blanco	8Â°58'37.86"	-79Â°40'31.57"	56	17P 645609mE 992592mN	17P	645609	992592
146	Water Tank	Blanco	8Â°58'37.86"	-79Â°40'31.57"	56	17P 645609mE 992592mN	17P	645609	992592
147	Water Tank	Azul	8Â°58'34.45"	-79Â°40'17.27"	81	17P 646046mE 992489mN	17P	646046	992489
148	Water Tank	Azul	8Â°58'36.16"	-79Â°40'19.60"	81	17P 645975mE 992541mN	17P	645975	992541
149	Water Tank	Blanco	8Â°58'33.81"	-79Â°40'10.10"	75	17P 646265mE 992470mN	17P	646265	992470
150	Water Tank	Negro	8Â°58'33.31"	-79Â°40'9.96"	75	17P 646270mE 992454mN	17P	646270	992454
151	Water Tank	Blanco	8Â°58'32.17"	-79Â°40'11.04"	82	17P 646237mE 992419mN	17P	646237	992419
152	Water Tank	Rojo	8Â°58'23.56"	-79Â°40'13.79"	104	17P 646154mE 992154mN	17P	646154	992154

APPENDIX K: UTM Coordinates of Bridges

Number	Name	Description	Latitude	Longitude	Altitude	UTM	Zone	to East	to North
1	Driving Bridge	10' Wide 33' Long 11' High Concrete Bridge	8Â°58'40.20"	-79Â°40'57.36"	83	17P 644821mE 992661mN	17P	644821	992661
2	Driving Bridge	8' Wide 15' Long 2' High Concrete Slab	8Â°58'29.74"	-79Â°40'48.71"	48	17P 645087mE 992340mN	17P	645087	992340
3	Driving Bridge	Concrete Bridge under Construction	8Â°58'40.71"	-79Â°40'34.80"	49	17P 645510mE 992679mN	17P	645510	992679
4	Driving Bridge	Concrete Bridge under Construction	8Â°58'24.76"	-79Â°40'40.04"	16	17P 645352mE 992188mN	17P	645352	992188
1	Walking Bridge		8Â°58'26.65"	-79Â°40'34.93"	58	17P 645508mE 992247mN	17P	645508	992247
2	Walking Bridge		8Â°58'26.84"	-79Â°40'35.00"	57	17P 645506mE 992253mN	17P	645506	992253
3	Walking Bridge	Suspension Bridge	8Â°58'40.48"	-79Â°40'35.03"	49	17P 645503mE 992672mN	17P	645503	992672
4	Walking Bridge		8Â°58'37.18"	-79Â°40'15.83"	17	17P 646090mE 992573mN	17P	646090	992573
5	Walking Bridge		8Â°58'24.61"	-79Â°40'10.29"	19	17P 646261mE 992187mN	17P	646261	992187
1	Fire Hydrant		8Â°58'38.11"	-79Â°40'7.47"	78	17P 646345mE 992602mN	17P	646345	992602