Improving Water Distribution in Burunga: Using a Social Census to Project Future Water Demand

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Abstract

Rapid urbanization paired with outdated census information has made upgrading water infrastructure difficult in Burunga, Panama. We conducted a survey of 296 households in three Burunga communities and generated census data on demographics and water facilities which allowed us to forecast water demand in the upcoming years. The analysis will help Panama's water authority improve their water distribution system in Burunga by implementing municipal water infrastructure and a wastewater management system in the next two years.

Executive Summary

Panama has vast water resources. However, it is distributed unevenly, especially in low-income communities. The cause of this is twofold: rapid population growth and ever changing weather conditions in Panama. As a result, the current water infrastructure has undergone major stress. The low income communities surrounding Panama City have the least developed infrastructure. As a result, there is not a consistent supply of water being disbursed to the residents.

Burunga, located just west of Panama City, is one of the regions with the highest population growth rate (17 percent). Because of its mountainous landscape, the region requires a water distribution system that can reach various ground levels. The Institute of Aqueducts and Sewers, IDAAN, is planning to design a new water infrastructure system that can accommodate the needs of the current and future residents in the region.

Figure 1: IDAAN Logo
(IDAAN[Digital Image], 2017)

Our project focused on collecting information in three *barrios* (neighborhoods) of Burunga, La Alameda, Nueva Jerusalén, and 13 de Febrero, to better understand demographics, household water management practices, and the demand for water. The data collected was then analyzed to estimate future water demand by applying the growth factor to the current population. Upon completion we will present all findings to the government stakeholders associated with our project to help them identify the water demand in each community. This information will allow the stakeholders to install a sewerage and water supply system that will deliver the necessary water supply to each community.

For all the three barrios which we did not have prior census work on, we conducted a per barrio census to collect the data IDAAN asked for and with that, estimate the current population. Unfortunately, our team encountered a few obstacles that we needed to overcome before our fieldwork. These obstacles included planning daily transportation, local skepticism, and weather affecting the safety and accessibility within the different barrios. This limited our efficiency on site, however, our team was as effective and efficient as possible.

Figure 2: La Alameda Community

For the barrio of La Alameda, we completed a household census for 220 houses. For the remaining two barrios, we used stratified random sampling to select 30% of the houses to be surveyed. By the end of the data collection process, we surveyed 48 households in Nueva Jerusalén and 28 households in 13 de Febrero.

With the complete collection of data, our final objective was to analyze the demographic and household data gathered, and consequently, developed a population forecast model and a water demand forecast model. The team's main focus when analyzing the data was to predict the future population for years one, two, three, five, and ten based upon of the 17% growth rate. Among the houses surveyed, we calculated that there was an average of 2.78 adult and 2.37 children per home. Because we did not complete a census for 100% of the Burunga population, we extrapolated the missing population using an equation established by the University of Oregon: (amount of household occupants from the survey) + (remaining households * average household occupant). According to this model, the current estimated population of the Burunga region is 5,631. After one year, the projected population will be 6,588. In two years, the population is expected to rise to 7,708. In three years, the population will be approximately 9,018. In the fifth year, the population will be 12,345. Finally, by the tenth year, the population will be at 27,065. With these population predictions, we calculated the water demand in the three barrios, multiplying the estimated population of each respective barrio by 50 gallons of water per day, the amount recommended by the United Nations.

Currently, IDAAN records and analyzes collected census data on paper. This system is unreliable as the physical documentation can be easily lost or damaged. In order to ensure the most efficient data collection process in the future, we suggest that IDAAN digitizes their census. The implementation of this recommendation along with updating a bi-annual census and collecting a feedback survey of the Burunga residents, IDAAN is sure to be successful in providing water services to the area.

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Chapter 1: Introduction

Panama is home to over 4 million people, of whom only 94% receive continuous access to water, leaving 6% dependent on water being delivered by truck and stored in tanks. As citizens increasingly move to urbanizing communities, installation of water tanks is a temporary solution to the lack of water supply infrastructure in these areas. Because these tanks are not provided to every household, the water is disbursed from some of the tanks informally through one-inch PVC pipes that are located above ground. Those pipes are mostly installed by the residents. This raises health concerns, as the location of these pipes makes the water vulnerable to pollutants and chemical leaching. Our project takes place in the Burunga region outside Panama City, where the lack of water supply and wastewater infrastructure has made it difficult to sustain its increasing population. Infrastructural deficiency can be attributed to unforeseen population growth and rapid urbanization (Sánchez-Bender, 2017). When the current administration took office in 2014, the Government of Panama (GoP) developed a plan called Plan de Sanidad Basica 100/0 (Basic Sanitation Plan 100/0) with an aim to provide continuous access to potable water and eliminate the use of dry-pit latrines in order to revamp marginalized cities, including Burunga.

It is imperative that Panama's government and water sector implement an improved water distribution system to ensure all households have consistent access to potable water and proper sewage extraction. Of the organizations that make up Panama's water sector, the Institute of Aqueducts and Sewers (IDAAN) is the most important and is responsible for providing drinking water and wastewater disposal services nationwide. It serves over two million people with its 54 potable water plants. IDAAN was created in 1961 and was made responsible for investments in water supply in urban areas and a significant increase in coverage of potable water and, to a lesser extent, sanitation. IDAAN, with funding provided by the GoP and World Bank, is now able to prioritize the implementation of the water distribution network in peri-urban communities such as Burunga (Inter-American Development Bank, 2017).

Burunga is one of ten subdivisions within Arraiján District (just west of the Panama Canal) and accommodates approximately 17% of Arraiján District's total population. According to The World Bank, the district has registered 17% annual population growth rates in some areas, while 29% of its residents are still living in poverty conditions. The rapid growth of Burunga, however, has not been accompanied by the development of infrastructure and basic services. Only 24% of Panama Oeste's (Western Panama) population is connected to a sewerage system, many of which are in poor condition. Some of these systems date from 1941 and are not connected to a treatment plant. Thirty-eight percent of the population utilizes on-site septic tanks, dry-pit latrines or simply create holes in the ground to dispose of their waste. Septic tank management services are currently provided by unregulated private entities. Due to the inconsistent maintenance, several of the septic tanks in the community are dilapidated (World Bank, 2016). With the current lack of a sewerage system, it is nearly impossible to accommodate all of the incoming Burunga residents.

The goal of this project was to conduct a household survey that would provide IDAAN with information to predict population growth and determine future water demand in the Burunga region. The objective of our team was to conduct the survey in three *barrios* (neighborhoods) in the Burunga region: La Alameda, 13 de Febrero, and Nueva Jerusalén. The analysis of these data will allow IDAAN to predict population growth and water demand, as well as determine water infrastructure needs in the upcoming years. We completed the project in coordination with Footprint Possibilities, and two other WPI project teams. One team was responsible for mapping crucial water infrastructure such as tanks, culverts, and fire hydrants. Another team was tasked with collecting and testing water samples to check for any pollutants present in the bodies of water in Burunga. Together we produced predictions and recommendations for potable water and wastewater infrastructure and management.

Chapter 2: Background

Since its establishment in 2003, Burunga has faced rapid annual population growth. While this growth can have great future economic benefits to the area such as improvement of infrastructure and real estate development, it has also been quite difficult to ensure that all of the incoming residents' needs are accommodated. There are four primary causes that have led to a water supply issue in the Burunga region: the land takeover in the area, Panama City's heavily rising population, an increased local demand for clean drinking water, and a lack of a consistent water treatment system. In the following subsections, we first present the Panama Canal Watershed context and then describe how this series of issues has resulted in Burunga's dire need for a more efficient water supply system.

Figure 3: Burunga Skyline

2.1 Panama Canal Watershed

The Panama Canal Watershed (PCW) is the main source of water in Panama. Water resources from the PCW support the daily operation of the canal locks and provide water for 95% of Panama's urban population. The PCW was artificially created in 1914, during the construction of the Panama Canal. Its waters originate from the Gatún and Alajuela Lakes, which were both artificially created during the construction for the Canal via dams on the Chagres River. Figure 5 breaks down the construction of the Panama Canal.

Figure 4: Panama Canal Authority Logo
(ACP[Digital Image], 2017)

In response to the increasing water needs of a growing population and an increasing demand for the services of the Panama Canal, the Panama Canal Authority (ACP) was created in 1994. The ACP is primarily responsible for the management of the canal and distribution of water to suppliers like IDAAN for human consumption.

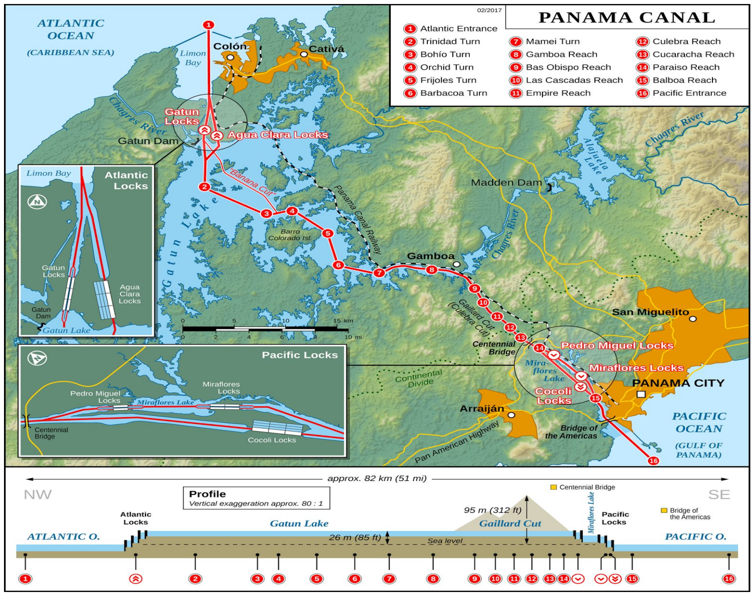

Figure 5: Topographical Map of Panama Canal

2.2 Land Takeover in Burunga

From 1989 to 2010, land takeover was permitted to a certain extent by the Panamanian government. The process consisted of people identifying an unoccupied piece of land in Burunga. They then decided to claim it as their own, cut down trees, build a small house and move in with all of their relatives. The government surveyed the residents and measured the lot. After this, the ownership of the land was registered and presented to Consejo Económico Nacional (CENA). Finally, after all the paperwork was processed, the government transferred ownership to one member of the family.

Figure 6: Burunga Area

There was a series of events that took place while a family waited for their paperwork to be processed. The bank that owns the land, Banco Hipotecario Nacional, assisted with the ownership transfer. Ministerio de Vivienda y Ordenamiento Territorial, MIVI, organized the lots and municipal divisions. Finally, Autoridad Nacional de Administración de Tierras, ANATI, divided the lots into house numbers and barrios.

The land takeover started after the United States released the land ownership to the Panamanian government after the Torrijos-Carter treaties. People saw this as an opportunity to claim unoccupied land, quickly relocate and build their own homes. As a result of this, Autoridad Nacional de Administración de Tierras, ANATI, was created in 2010 to organize the division of land and assign park rangers to designate protected parts of Burunga, which cannot be occupied.

2.3 Panama’s Growing Population

Due to Panama’s shifting demographics and the high percentage of residents of childbearing age, there is potential for further population growth. In 2016, Panama's population was 4.034 million people, a 369% increase in population since 1950. The proportion of the population aged below 15 in 2010 was 29% and 64.5% of the population were aged between 15 and 65, with 6.5% of the population being 65 years or older.

Panama’s mortality rate also decreased heavily from 92.1 (per 1,000 people) in the year 1960 to 17.0 in 2015. Over the course of that time, the rate constantly decreased (Index Mundi, 2016). Fertility has also decreased over time but only at half the speed of mortality. The combination of fast falling mortality and slow falling fertility is a major contributing factor leading to population growth in Panama.

Forty-three percent of the entire Panamanian population lives in Panama City. This means well over one million people have already created or are currently working to create homes in the 13 *corregimientos* (regions larger than barrios but smaller than districts) outside of the city’s metropolitan center. Furthermore, 87.7% of the Panamanian population are non-indigenous while the other 12.3% belong to one of the seven most common aboriginal groups in Panama. Members of some aboriginal groups no longer have native homelands, for example the Guaymí and Ngöbe-Buglé people, whose homelands were originally in the regions west of Panama City. Because their homeland has been taken, indigenous people claim unoccupied land and make homes for themselves and their families. Due to the increasing number of indigenous people taking over land, communities outside of the city are growing rapidly and outpacing the development of critical infrastructures.

2.4 Increased Local Potable Water Demand

One of many problems that arise due to the swift growth of population is the increasing demand for potable water. Panama has relatively high level of access to public sewerage systems as compared to other countries in Latin America. One main problem in Panama is that water supply is intermittent and drinking water is not considered to be safe to drink in rural areas.

UNICEF's Joint Monitoring Program defines potable water and a basic sewerage system in the following way. A community is considered to have "continuous access" to potable water if its source is located at least one kilometer away from the households and there is enough water for each resident to have 50 gallons per day. This program classifies three sources of water supply. The first is the constructed supplies. They are protected against contamination only by the active intervention of humankind. The main substance that may invade this supply is fecal matter. This category includes public aqueducts and sewerage systems both in the community and private. The second source is improved supplies. This includes water tanks and bottled water, among others. The third and final supply is improvised supplies such as: sanitary wells or unprotected brooks, rainwater, surface wells, rivers, ravines or lakes which, by their nature, are exposed to contamination. According to data collected in the 2010 Census, 91.7% of Panama's population had access to potable water through a home connection, such as the public aqueducts via Panama's National Institute of Aqueducts and Sewers (IDAAN), community or private aqueducts. Meanwhile, 6.7% of homes had access without a home connection and 1.6% were subject to other supplies, such as rainwater or tanks (Lima, 2010).

The access to drinking water in Panama City covers as much as 90% of the population. Water supply is also continuous in urban areas while peri-urban and rural areas may experience some breaks in service. IDAAN along with other independent water supply companies cover most of the urban areas.

There are currently over 220,000 people living in the Arraijan district in Panama Oeste. According to La Prensa, the district of Arraijan has a demand for water for over 30 million gallons per day. Currently, the three potable water plants that exist do not meet the current water demand for the district (Montenegro, 2015).

2.5 Water Treatment in Panama

With the current unpredictably growing population in those rural areas, water treatment is rapidly becoming a critical issue. According to IDAAN, about 60% of inhabitants are served by the current governmental sewerage system. This leaves a staggering 40% of the population without a proper wastewater treatment system. Many residents in Burunga collect either surface water or somehow tap into government-issued water supply without the necessary treatment to aptly cleanse it. The water treatment becomes an issue in the Burunga community over recent decades.

In Burunga, septic systems, latrines and open pits are most commonly used for wastewater treatment. However, still tons of water are dumped into the Bay of Panama directly without any treatment. As a result, the government has to spend millions of dollars disinfecting and cleaning the ocean near the city. Panama City has started multiple projects to improve water treatment systems. Water softeners or media water filters are considered the best to use.

Chapter 3: Methodology

Our project goal was to provide IDAAN with information to predict population growth and determine future water demand in the Burunga region. We established an efficient method that could be used to survey three communities in Burunga: La Alameda, Nueva Jerusalén, and 13 de Febrero. Our client, IDAAN, sought to update their existing census and to assemble information that could be turned into a meaningful necessity indicator. With this in mind, we designed our survey based on the information from IDAAN's pre-existing census and incorporated additional questions at the request of Footprint Possibilities. The design of the survey was the first step in the process. Next, we developed a sampling strategy in coordination with IDAAN to determine an adequate sample size and choose which households would be asked to participate in our study. After we determined the best way to go about collecting the information, we put our strategy to action and conducted 296 surveys across all three communities. We then plotted the points of the houses that were surveyed via Google's mapping tool, MyMaps, for visual representation of the data. Once data collection was completed, our team used a population forecast model developed by the University of Oregon to predict the future population and water demand in the region of Burunga. The figure below depicts the order in which these processes were completed.

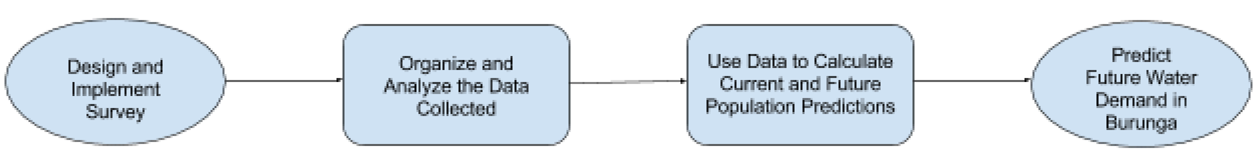

Figure 7: Organization of Methodology

3.1 Designing the Social Census Survey

During the first week of work, our team held an interview with the client, IDAAN, to get a general breakdown of their needs and the information the IDAAN stakeholders wished to obtain as a result of our study. Based on what was discussed, our team determined survey questions that would provide such results. We made a series of modifications to the original survey over the course of this project to accommodate the emergent needs of the client. The survey was created and conducted through Google Forms which allowed us to easily export and analyze the responses.

Along with descriptive factors of location (i.e district, corregimiento, barrio, sector, and house number), IDAAN wanted to know each subject's name, identification number and phone number. They also wanted to know how many children and adults live in each household to make predictions about water consumption. In addition to this census information, we gathered information on how each household primarily obtains the water that they consume and then determined whether the subject household uses a latrine or septic tank to dispose of its sewage. The survey was designed to collect all of this information in the course of a 3-5 minute conversation.

3.2 Designing the Sampling Scheme

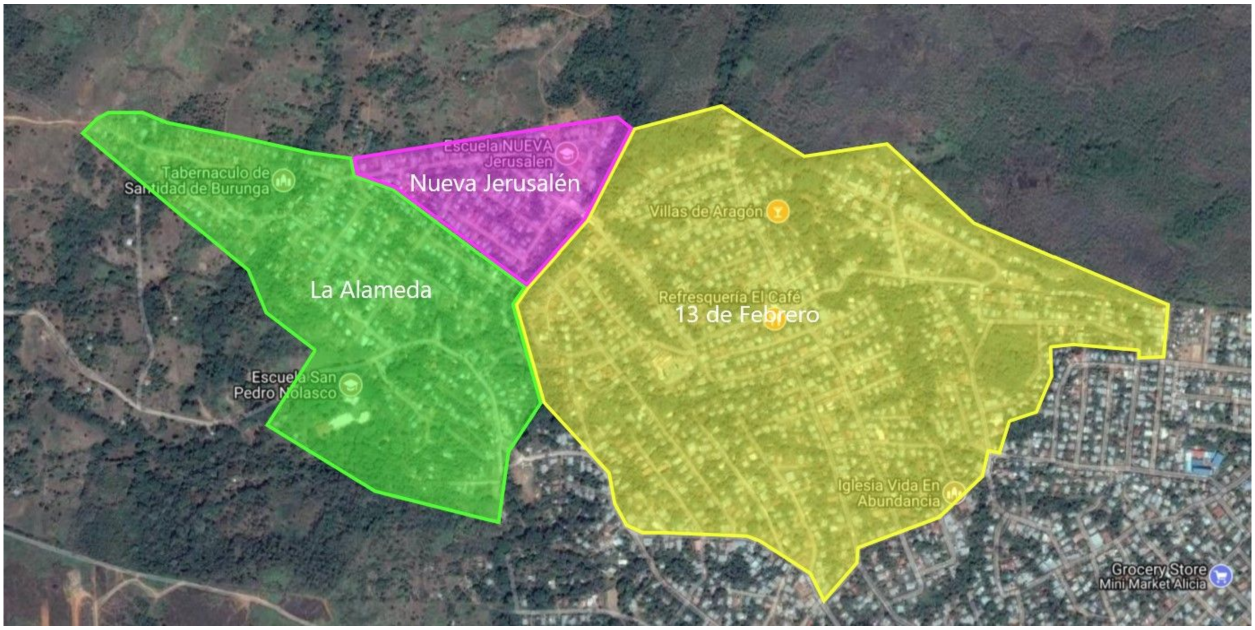

Figure 8: Burunga Community Overview

Among the three barrios pictured above, the only one that required 100% coverage in census data was La Alameda with 300 houses to be surveyed. The IDAAN representatives developed a scheme in which they only required data from 30-40% of the remaining two barrios, 13 de Febrero and Nueva Jerusalén. To ensure our sample was evenly distributed across the communities, we used a Stratified Random Sample. The population was parted into subgroups called strata. Each stratum then became a population within itself from which we randomly selected samples. By using this sampling method, we minimized the likelihood of sample selection bias and ensured certain segments of the population were neither overrepresented nor underrepresented (Investopedia, 2017).

Because demographics have an effect on water collection, dividing the neighborhoods into strata would guarantee an even sample distribution across all sectors of the barrios. After testing La Alameda, we found that if one house in the neighborhood disposes of their sewage through a septic tank, the other houses in the area also use septic tanks. We found a similar pattern with latrines. Therefore, by breaking the regions into various strata, we were able to draw upon survey samples of great variety.

In using this technique, we separated each respective barrio into quadrants. These quadrants acted as our strata. We randomly selected 30% of each stratum via an online random number generator (random.org) to get an overall stratified random sample of 30% of the entire population. There are 160 houses in Nueva Jerusalén. Therefore, we randomly selected 48 houses. IDAAN provided our team with a map of uniquely numbered homes. We entered the numbers through the random number generator in order to get an unbiased, random sample of the strata. We repeated this process in 13 de Febrero. There are 633 houses there in total so we identified a stratified random sample of 190 houses.The red barriers seen in Figure 9 are the bounds for each stratum in the Nueva Jerusalén community. Each blue point on the map marks a selected household that was to be surveyed.

In cases where the randomly chosen subjects were not home at the time we were surveying in their area, we used the house next door as a substitute to ensure we met the target sample number.

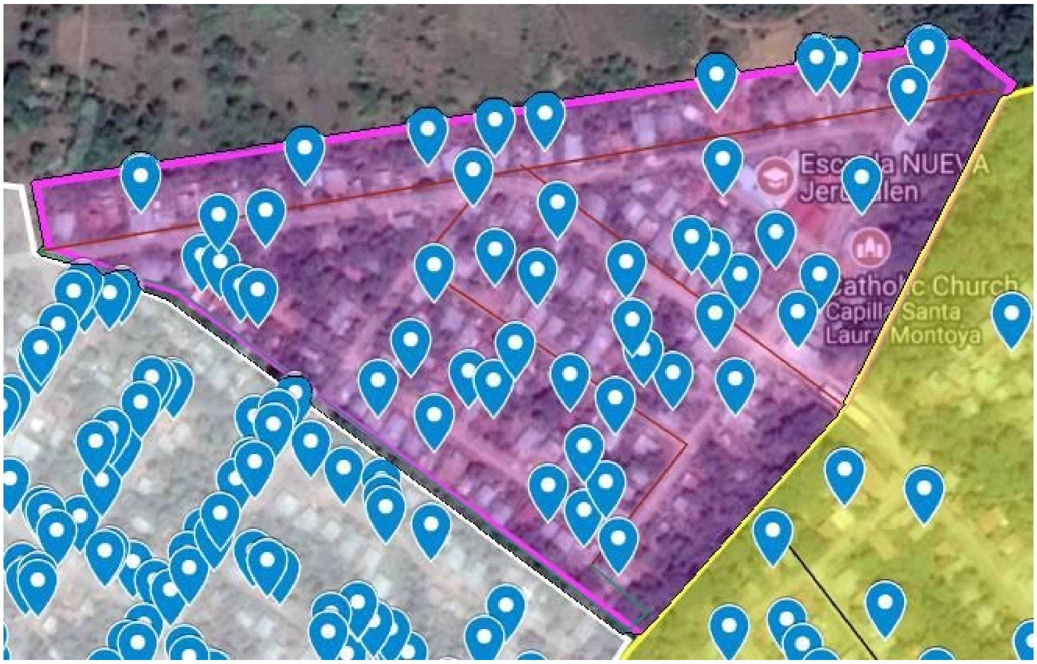

Figure 9: Stratified Random Sampling in the Nueva Jerusalén (shown in pink)

3.3 Conducting the Survey

Our team collected data for a total of 220 houses in La Alameda, 28 houses in 13 de Febrero, and 48 houses in Nueva Jerusalén. It took us a total of four weeks to complete the census for all the areas. Once we determined which houses would be surveyed, we began the data collection process. We immediately encountered challenges (i.e. local skepticism, lack of time in field, and the likelihood of dishonest responses) that were overcome through strategies developed over the course of the project.

Survey Implementation

Spanish was the first language of 100% of the households we surveyed. Among our team, only one student spoke Spanish fluently. As a result, he was delegated the task of conducting the survey at each home. The questions were read off of a document we created in Google Forms. In Google Forms, the user is allowed to submit an unlimited number of survey forms through a smartphone. With this efficient feature, the surveyor, Ruben, entered the responses as the subjects answered the questions. Another team member, Yifei, then identified the households' coordinates through the MapPlus app and attached the data to each survey. Additionally, we were accompanied by a representative from IDAAN who guided us through the barrios. After each survey was conducted, Ruben pressed the submit button located at the bottom of each form and the responses were automatically sent to and organized in the Google Forms database for later analysis.This process was repeated 296 times until every selected household was accounted for. Figure 10 is a picture of Ruben conducting a survey in La Alameda.

Figure 10: Conducting Survey with La Alameda Resident

Local Skepticism

The first day we surveyed the areas, specifically La Alameda, the people were skeptical of who we were and the purpose of the census. The skepticism originated from the fact that we neither looked like nor spoke the same language as the locals. In order to ease their wariness, we explained that our project's purpose was to update IDAAN's database so they can acquire an accurate picture of the Burunga's water needs and make efficient use of the 10 million dollar loan secured from the World Bank to establish a formal sewerage system in the areas of La Alameda, Nueva Jerusalén, and 13 de Febrero.

After team member Ruben developed a concise and effective explanation, survey subjects were more cooperative and open in speaking about the details concerning their needs and current water supply. A sample introduction that was developed throughout the first houses surveyed can be found in Appendix B. In addition to this brief explanation, the team members always wore identifying shirts and badges provided by IDAAN in addition to being accompanied by a representative of IDAAN.

Covering a Large Area in a Small Amount of Time

Because of the size of the area that was to be surveyed in four weeks, using only three out of seven days each week for data collection, our team needed to make efficient use of time spent in the field. The workdays were initially agreed upon based on the needs and schedule preferences of all three teams. In addition, we were unable to work in the rain because our representative used a paper census instrument as an alternative to our digital census that could not get wet. This was a challenge because we were collecting data in the middle of Panama's rainy season. After the first two weeks in the field, we noticed that we were far behind our schedule as we had only covered about 50% of La Alameda at that time. As a result, we had to make adjustments to our daily and weekly agendas. At the beginning of week three, our team, with the support of IDAAN, decided it would be best to add two more workdays to our weeks.

With 4-5 days in the field, it was more likely that we would get a complete sample of all three regions in the midst of potential rainfall.

Because only one of the members of our team spoke Spanish fluently, that student conducted every survey while another student mapped the coordinates of each house and made observations in field as the survey progressed. The two remaining team members stayed behind to organize and analyze the data as they were compiled. This system worked very well and ensured consistent productivity.

Facing the Possibility of Dishonest Responses

Though we collected all of the data that we needed in order to generate a census, we found that 43% of La Alameda residents possibly misrepresented data pertaining to the years during which they have occupied the land. According to our IDAAN counterpart, La Alameda was established 15 years ago. Therefore, anyone who claimed to have lived in La Alameda for more than 15 years faces the high possibility of dishonesty in their response to this specific question. According to the data collected, 43% of the residents reported that they have lived there for 16 years or more. We continued the study under the assumption that each homeowner responded to the survey truthfully because there is not a recent census that can be used to disprove their responses. In addition, homeowners do not possess documentation stating the amount of years they have lived in their present home.

Community Safety Issue

The overall survey experience in Burunga was satisfactory. However, while conducting surveys in 13 de Febrero there was a robbery at a local supermarket. Taking a measure of precaution we, along with our IDAAN counterpart, decided to stop further data collection in this area. As a result, we surveyed only 5% of the 13 de Febrero community instead of the planned 30%.

3.4 Mapping Waypoints via Google MyMaps and MapPlus

In order to plot the location of the houses while in the field we utilized a mobile application called MapPlus. Using MapPlus allowed us to instantly gather information about the homes' latitude, longitude and UTM coordinates to include in our census survey. Upon our return from the field, the waypoints gathered from MapPlus were exported as a .kml file to our computers via email. The .kml file was then imported to MyMaps, a desktop application powered Google, that provides a more advanced work station and features for manipulating maps. For instance, MyMaps provided the ability to digitally plot districts and create layers that distinguished between plotted waypoints for homes, septic tanks and latrines. While IDAAN provided us with maps of the region of Burunga, they were extremely outdated and were very difficult to read. Both MapPlus and MyMaps provided us with both current satellite imagery of the area and the tools to document our findings.

3.5 Predicting Water Demand and Population Growth

The main focus of our analysis was to predict the future population and water demand, for year one, two, three, five, and ten. There are three distinct but interacting ways in which populations grow in a community: expansion, densification, and intensification. Expansion of a community refers to its inward, outward or independent growth around the known boundary of the existing settlement.

Burunga is a rapidly expanding community and it has become a burgeoning issue to provide water, especially in Nueva Jerusalén, 13 de Febrero and La Alameda. Densification refers to the number of residents (or households) per community. Intensification is related to the vertical growth in buildings which is not a factor we encountered in Burunga. Our analysis was focused only on the overall population number and its relationship with the communities' water demand (Abebe, 2011).

In order to estimate the future population of the Burunga region, our team used a basic exponential growth equation established by the University of Oregon. The equation is $Pop(Future) = Pop(Present) * (1 + i)^n$, where *Pop(Future)* represents the future population, *Pop(Present)* represents the current population, i represents the growth rate and n represents the number of years into the future to be calculated (Parker, n.d.). For the i variable, we used the annual growth rate of Arraijan District over the past five years which is 17% annual growth (The World Bank, 2016).

This process was repeated across all three barrios until we calculated water demand for the next year, two years, three years, five years, and ten years. The estimation of Burunga's population in ten years will be the figure with the most uncertainty given it is not likely that the current 17% annual growth rate will remain the same after ten years of rapid growth.

We estimated the water demand by using the forecasted population data and multiplying by 50 gallons per day per person, which is the amount we determined to be sufficient following the United Nations' standards (Zaragoza, 2010).

Estimating Current Population

In order to find the total current population in Burunga the number of homes was multiplied by the average family size of 2.78 adults and 2.37 children which we calculated from the sample. Because we surveyed 73% of La Alameda, 30% of Nueva Jerusalén, and 5% of 13 de Febrero, we extrapolated the missing population data using the following equation:
(Amount of household occupants from the survey) + (Remaining households * Average household occupant).

Chapter 4: Results

Our team successfully conducted the census for 100% of La Alameda, 30% of Nueva Jerusalén, and 5% of the 13 de Febrero community. We collected data for a total of 220 houses in La Alameda, 28 houses in 13 de Febrero, and 48 houses in Nueva Jerusalén. The following subsections will focus on the data collected from the community samples. All of the data gathered was compiled into a table called the Data Register. After compiling the information, we made a few observations on the current water infrastructure including the disbursement of latrines and septic tanks across the communities. Based on the analysis, we estimated population projections and future water demand of the area.

4.1 Data Register

Figure 11 below summarizes the data collected through the 296 surveys. For example, it portrays the primary water source and secondary water source in each barrio. In La Alameda, 96% of households use tap water as primary water source and 4% buy water by the gallon. Furthermore, 96% of households in La Alameda use water reserve tanks as secondary water source and the other 4% buy water by the gallon, use rainwater, or have no secondary water source.

The reason that the possession of reserve tanks is so high in La Alameda is due to the intermittent water service. The residents use them to store water for several days since they usually have a 3-day service and the other four days do not receive water.

	Alameda (220)	Nueva Jerusalen (48)	13 de Febrero (28)	296	--
No. of Adults	616	138	70	824	2.78
No. of Children	544	110	48	702	2.37
No. of houses with Latrines	153	34	2	189	--
No. of houses with Septic Tanks	75	14	27	116	--
% of houses with Latrines (w/out ST)	66	70.8	3.6	--	--
% of houses with Septic Tanks (w/out Latrines)	30.4	29.2	92.8	--	--
% of houses with Latrines and Septic Tanks	3.6	0	3.6	--	--
	Primary Water Source				
Tap Water	191	48	28	267	--
Buy Water by the Gallon	29	0	0	29	--
	Secondary Water Source				
Buy Water by the Gallon	1	0	0	1	--
Collect Rain Water	10	0	4	14	--
Reserve Tank	191	42	17	250	--
None	18	6	7	31	--
	Years of Occupancy				
1-5 years	17	3	1	21	--
6-10 years	82	14	4	100	--
11-15 years	75	9	6	90	--
16-20 years	45	22	13	80	--
21+ years	1	0	4	5	--

Figure 11 : Data Register of all the Communities

4.2 Septic Tanks and Latrines by Community

We also found that people who have lived in the Burunga region for less than 16 years were more likely to have a latrine-based sewage system in their homes: whereas people who lived there for more than 16 years were more likely to have a septic tank system. Based on the pie charts below, as much as two third of houses in Nueva Jerusalén and La Alameda have only latrines. The rest use septic tanks; however, about 5% of houses in La Alameda have both septic tanks and latrines. Because 13 de Febrero was established earliest among those three communities, the majority of the houses there use septic tanks. Only around 5% of them use latrines and 5% have both.

La Alameda

Unlike 13 de Febrero, La Alameda is a newer, less developed community in Burunga. According to the data register in Section 4.1, the majority of the residents in the area have lived there between 5 and 15 years. As a result, the majority of residents (66%) utilize latrines as a means of disposing of their waste. Only 30% have septic tanks in their home and 4% have both latrines and septic tanks. The pie chart below, Figure 12, shows the distribution of wastewater infrastructure in La Alameda.

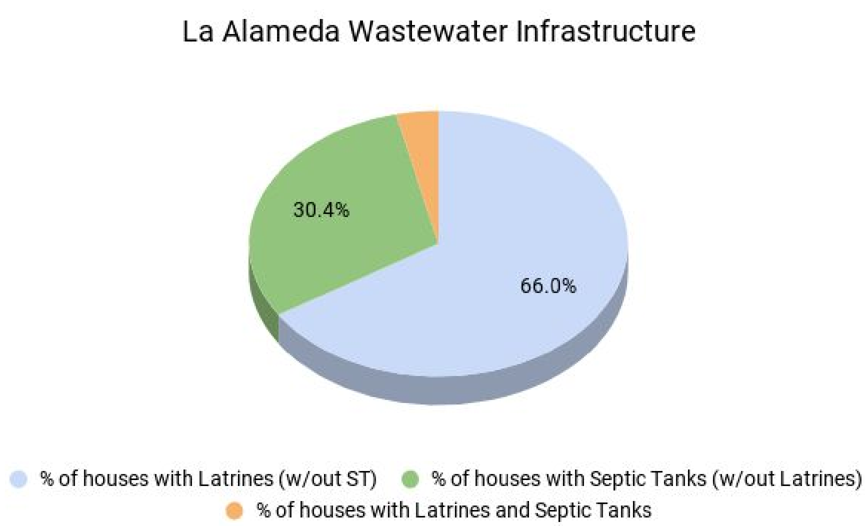

Figure 12: La Alameda Wastewater Infrastructure

Nueva Jerusalén

In the Nueva Jerusalén community, the majority of residents have lived there between 10 and 20 years. The residents that have lived there the longest tended to have septic tanks (29.2%). The majority of the residents (70.8%) still use latrines and no households use both. Figure 13 is a representation of this data.

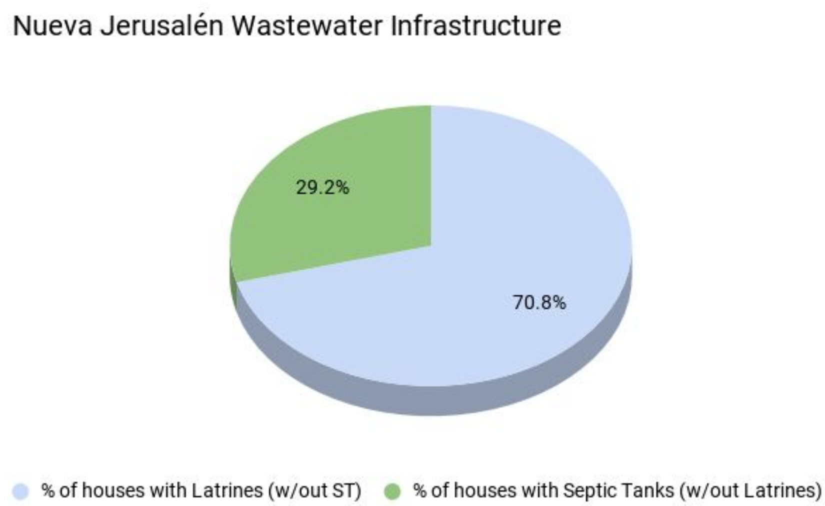

Figure 13: Nueva Jerusalén Wastewater Infrastructure

13 de Febrero

Since 13 de Febrero is the oldest of the three communities, there has been more time for the households to develop a more efficient wastewater disposal system. It is also a more formal community as opposed to La Alameda and Nueva Jerusalén that have only grown through the land takeovers. The majority of residents that have participated in the census survey we conducted have lived there for 15 to 20 years. As a result, most households (92.8%) of the surveyed households use septic tanks. Figure 14 displays the distribution.

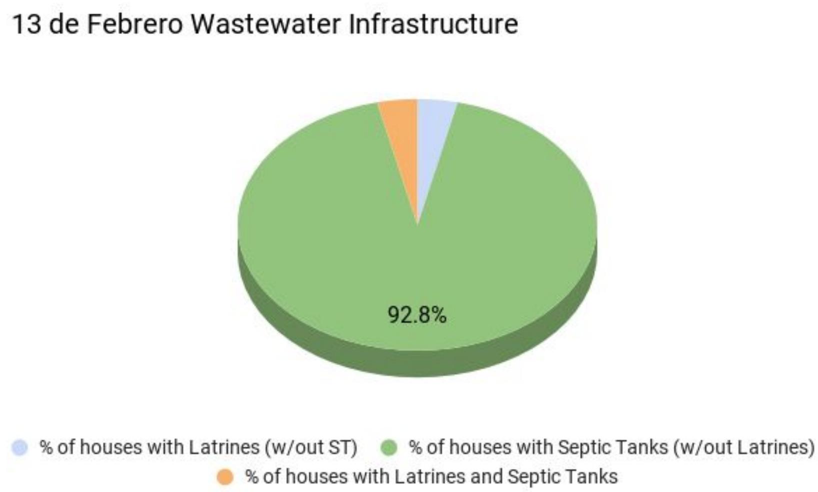

Figure 14: 13 de Febrero Wastewater Infrastructure

4.3 Projected Water Demand by Community

In the barrio of La Alameda, marked in green in Figure 15, we collected data from a total of 220 households out of the current 300 homes. Within the 220 households surveyed, there was a total of 1160 people (616 adults and 544 children).

Figure 15: Topographic Map of La Alameda

To estimate the remainder of the population, we considered the average amount of children and adults per household. According to our survey responses, there is an average of 2.78 adults and 2.37 children living in each home. In total, there was an average of approximately 5.15 people per household. After multiplying the average number of residents per home, we multiplied that figure by the 80 unsurveyed homes in the community. As a result, we estimated that there is a total of 1,572 residents living in La Alameda. The equation is as follows:

$1160 + (80 * 5.15) = 1572$ people

In order to predict the future population, we used an equation established by the University of Oregon: Pop(Future) =Pop(Present) * $(1 + i)^{n}$. The current estimated population of 1572 people is represented by the *Pop(Present)* variable. Our population growth rate of $i =$ 0.17 was added to 1, according to the given equation (The World Bank, 2016). The result was then raised to the respective power given the year we were interested in.

For example, in order to calculate the estimated population projections for Year 1, we set up the equation as $1572 * (1 + 0.17)^{1} = 1839$ people. Similarly, to calculate the projected population for Year 10, the equation was set up as $1572 * (1 + 0.17)^{10} = 7556$ people. Figure 16 shows the results of the calculations for years 1, 2, 3, 5, and 10.

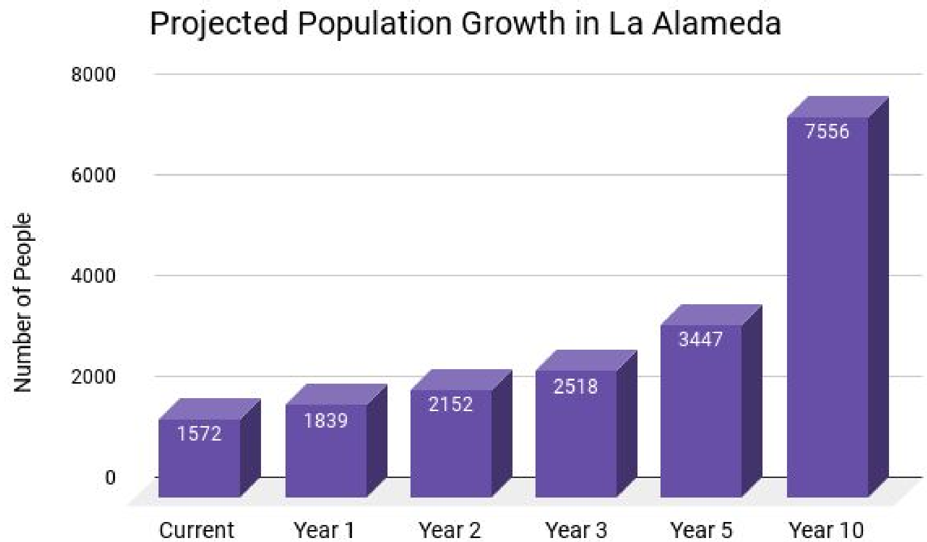

Figure 16: Projected Population in La Alameda

In order to predict water demands for the community of La Alameda, we considered the average water consumption per person per day according to the United Nations which is 50 gallons (Zaragoza, 2010). The projected water demand is the result of 50 gallons multiplied by the total population each year. Estimated water demand in La Alameda can be found in Figure 17. This forecast is based on a continuous growth rate as observed over the past five years.

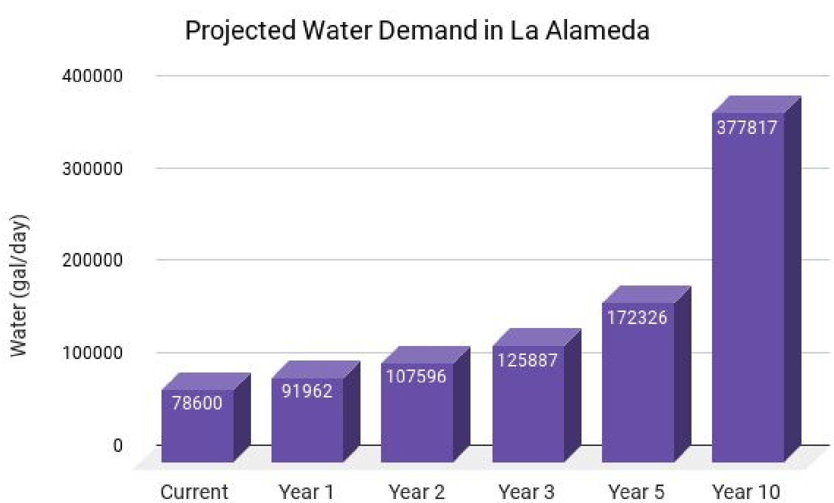

Figure 17: Projected Water Demand in La Alameda

Nueva Jerusalén

Nueva Jerusalén, marked in pink in Figure 18, is the second barrio from which we collected data. In the 48 houses surveyed, there was a total of 248 residents (138 adults and 110 children).

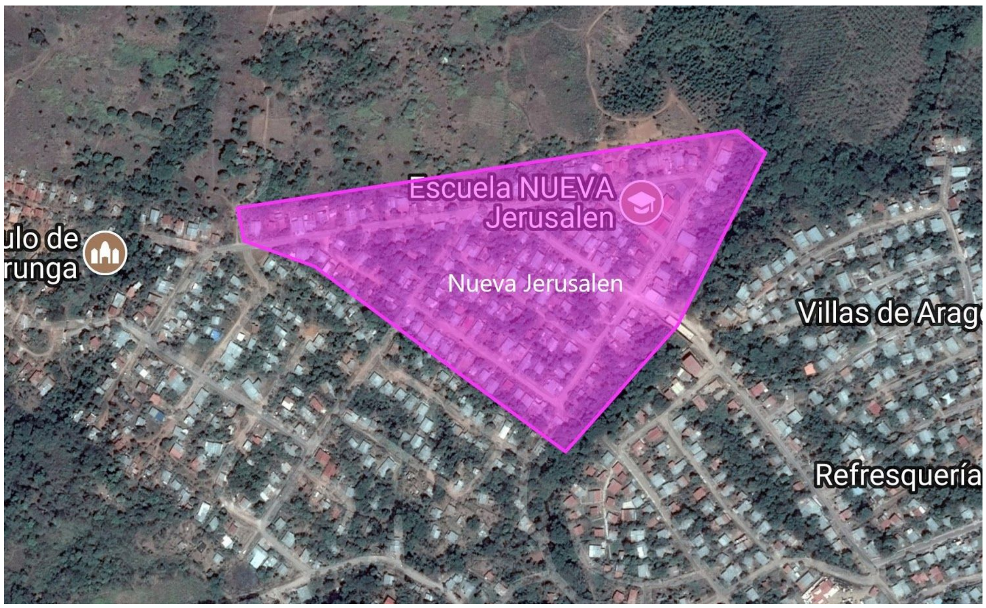

Figure 18: Topographic Map of Nueva Jerusalén

Using the same average of 5.15 family members per household, we estimated that the remaining 112 houses contained 576.8 people. By adding these two figures, we estimated that Nueva Jerusalén is currently home to approximately 825 people. In order to estimate the community's future population, we used the University of Oregon's projected population formula. Similar to the way we calculated La Alameda's projected population, we repeated the calculations for all five year predictions, modifying the value of the *Pop(Present)* variable. We used the 17% growth rate seen in the past five years to ensure calculation stability. This growth rate is subject to change before the ten year mark; however, the calculations below reflect the potential population given the current rate sustains. For example, in order to calculate the estimated population projections in Nueva Jerusalén after 1 year, we set the equation up as $825 * (1 + 0.17)^{1} = 965$ people. To estimate the projections of Year 10's population, the equation was set up as $825 * (1 + 0.17)^{10} = 3965$ people. Figure 19 displays our completed predictions.

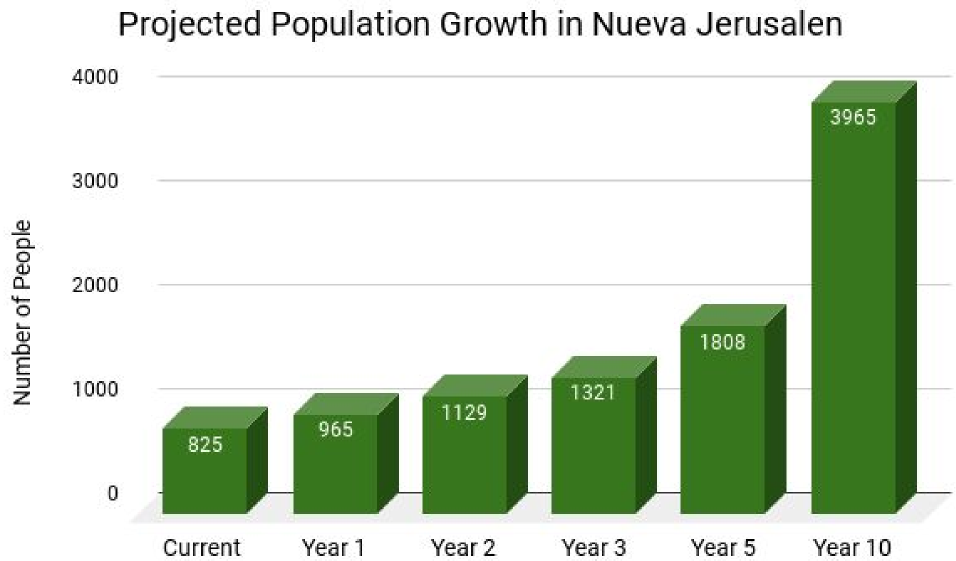

Figure 19: Projected Population in Nueva Jerusalén

Similar to the Water Demand Forecast Model for La Alameda, we calculated the future needs for the area by multiplying the populations by 50 gallons. For example, 56,453 gallons of water per day is the estimated water demand for a population of 1,129 Nueva Jerusalén residents in Year 2. Below is the completed figure.

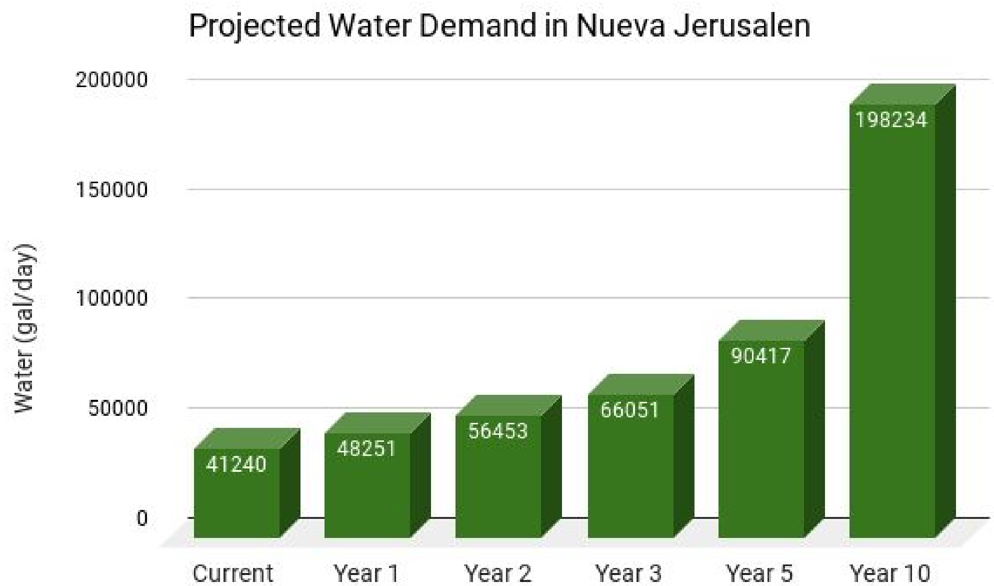

Figure 20: Projected Water Demand in Nueva Jerusalén

13 de Febrero

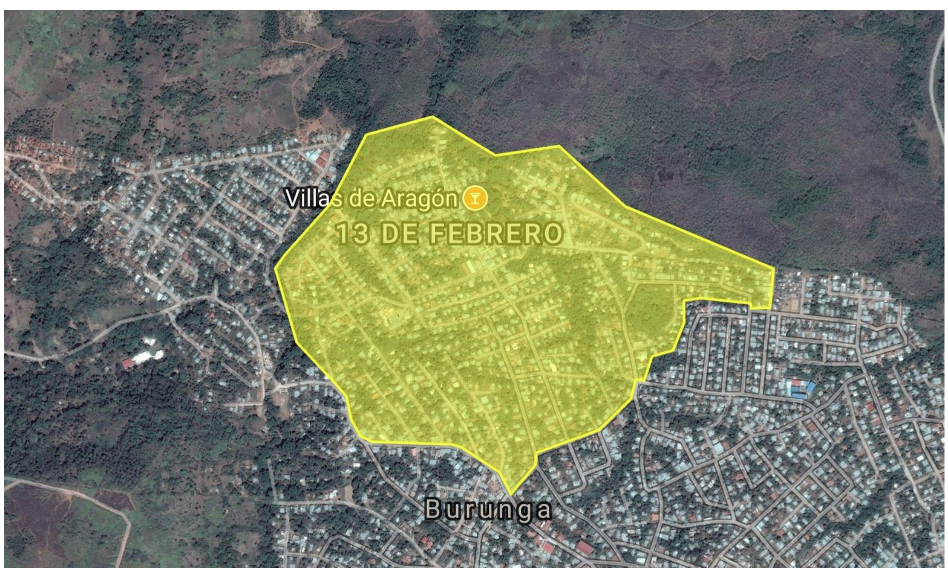

Figure 21: Topographic Map of 13 de Febrero

Due to aforementioned safety issues in this region, we collected data for 28 houses in 13 de Febrero. In the 28 houses were 118 people (70 adults and 48 children). Using the same population predicting equation as before, we estimated that the remainder of the households was 605 and that there is currently a total of 3,234 people living in this community. According to the equation, our calculation for Year 1 is organized as $3234 * (1 + 0.17)^1 = 3783$ people. The projected population in 10 Years is set up as $3234 * (1 + 0.17)^{10} = 15544$ people. Figure 22 shows the projected population in 13 de Febrero and Figure 23 shows the projected water demand (*Pop(Future)* * 50).

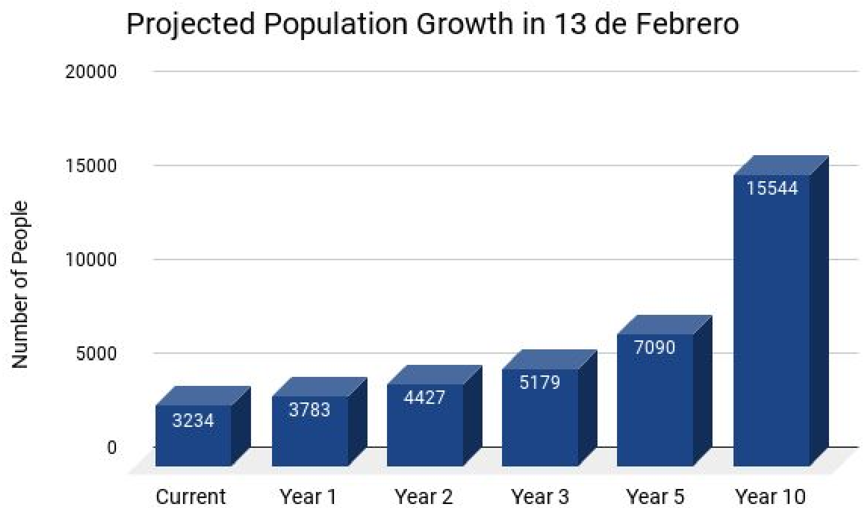

Figure 22: Projected Population in 13 de Febrero

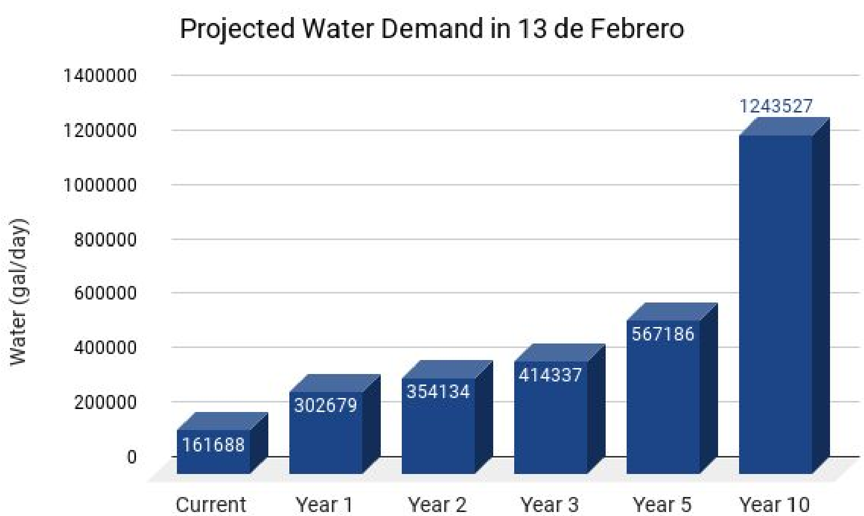

Figure 23: Projected Water Demand in 13 de Febrero

4.4 Overall Analysis of Burunga

In conclusion of our data collection and water demand forecast, Figures 24 and 25 provides a side by side comparison of each community's population and water demand. Figures 26 and 27 provides a compiled representation of the three communities.

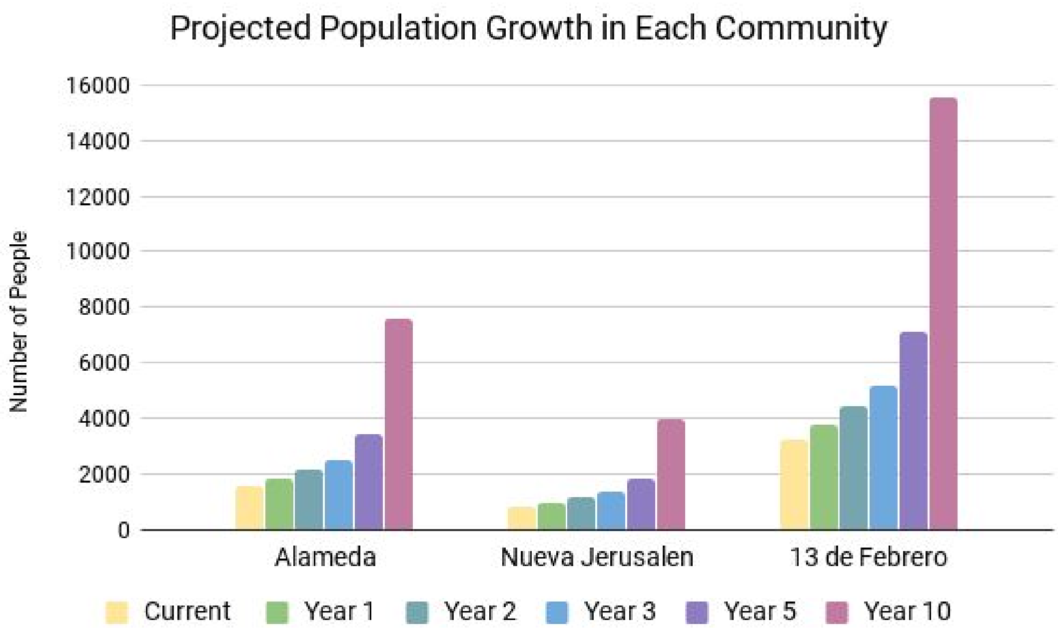

Figure 24: Projected Population in Each Community

In Figure 24, it is evident that 13 de Febrero is the community with the highest water demand as it is the oldest barrio in the region. However, it is also the community that contains the most uncertainty in its estimation because we surveyed only 5% of the barrio. The remainder was extrapolated by using the average of children and adults, which was 2.78 adults and 2.37 children.The The drastic difference in population size can also be seen in Figure 25.

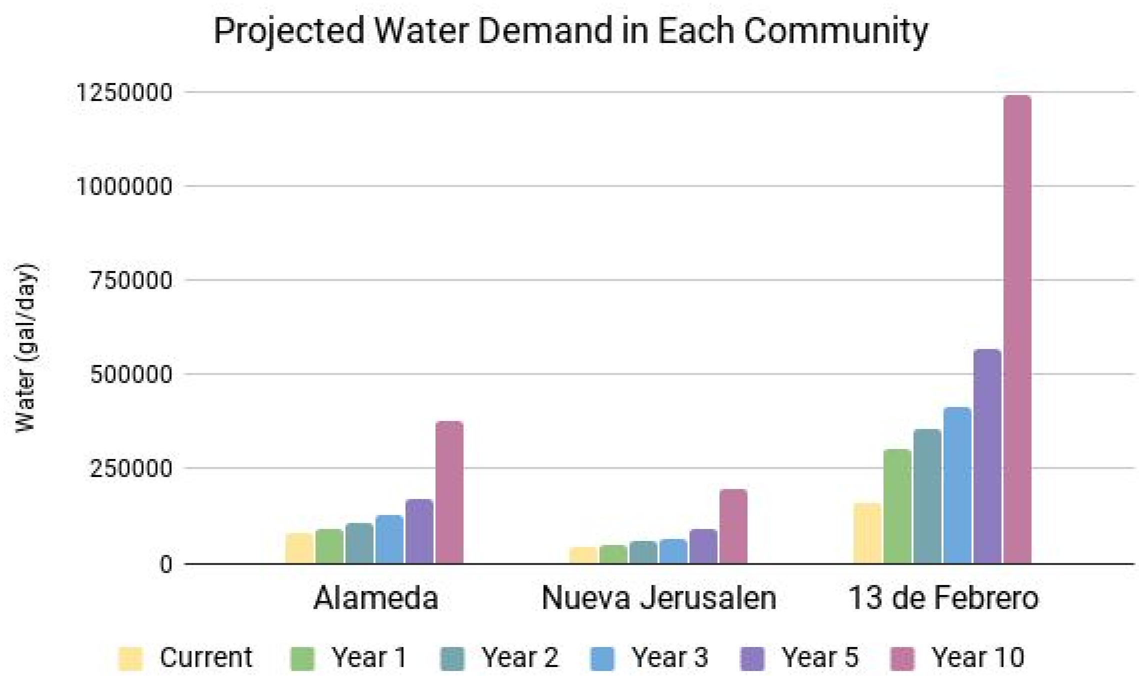

Figure 25: Projected Water Demand in Each Community

Below is the overall population forecast across all three barrios: La Alameda, Nueva Jerusalén, and 13 de Febrero. The population forecast of the region was calculated under the assumption that the 17% growth rate is maintained over the course of the next ten years. The results of Figure 27 was calculated by multiplying 50 by the projected population of each respective year.

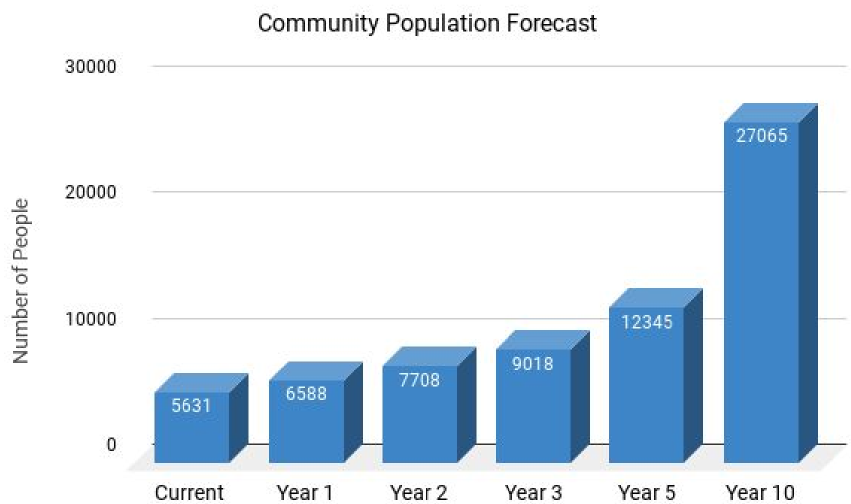

Figure 26: Community Population Forecast

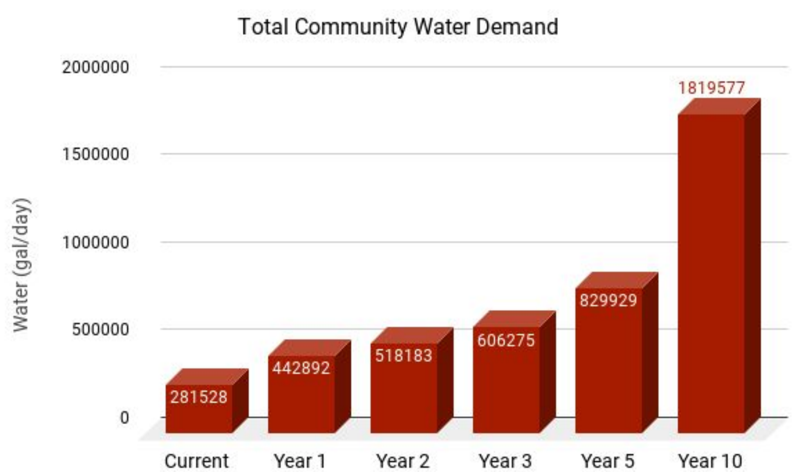

Figure 27: Total Community Water Demand

Chapter 5: Recommendations and Conclusion

Our team and the other two partnering teams worked together to help IDAAN accomplish the following objectives in the Burunga region:

1. Establish an updated map of the boundaries of the barrios La Alameda, Nueva Jerusalén, and 13 de Febrero.
2. Survey a predetermined sample of the three barrios.
3. Compile data and estimate the number of households each community and, through the population forecast, predict potential future IDAAN clients.
4. Calculate the projected water demand by community in gallons/day.

To accomplish this, we surveyed 296 households in three barrios of Burunga. After finishing the surveying phase, the data was sorted, cleaned, and analyzed. Based on the conclusions drawn from the data we collected, IDAAN can establish adequate water infrastructure of the region and provide potable water to the residents on a consistent basis.

5.1 Recommendations

In future surveys and collection of data we suggest that IDAAN does a complete transition into digitalizing their information. We chose to recommend the digitalization of IDAAN's survey data as what we experienced with our IDAAN counterpart is when he updated the 2002 sector's physical census. This activity proved to be inefficient, messy and not very useful as it is handwritten and can be lost or damaged easily. We also found that in order to keep up with the urbanization of the area, we recommend conducting a bi-annual census.

Because plans for a new infrastructural system are already in progress, we recommend conducting a post-infrastructure installation feedback survey to stay up-to-date on the needs of the residents in the Burunga region. The feedback survey should be carefully analyzed and presented to IDAAN's stakeholders. Doing this will provide a clear view on the population's reactions towards the infrastructure system. After applying the above recommendations and implementing the new wastewater system, the residents of the Burunga region are ensured to have an improved quality of life.

5.2 Conclusion

Based on all of the data gathered, it is evident that the Burunga residents are in a dire need for potable water. In order to have access to this, it is vital for the barrios to be connected to the official water infrastructure system. Once IDAAN integrates the system in La Alameda, 13 de Febrero, and Nueva Jerusalén, the residents are ensured to have consistent water access. Furthermore, the water infrastructure system will enable the residents to have a proper waste disposal system. As a result of the connection to the new system, the residents will be able to substitute their latrines and/or septic tanks with a toilet connected to the new sewerage system eliminating all health concerns related to unsanitary waste disposal. In the end, Burunga will be able to adapt to the rapid urbanization of the current peri-urban area.

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Appendices

Appendix A - Sponsor Description- Footprint Possibilities

Footprint possibilities is a private US 501C3 Charity located in Panama. Founded by Ricardo Montanari and his wife, in 2008, the organization's purpose is to enhance general health and provide increased educational and cultural opportunities through technical knowledge, funding and infrastructure improvement. The company’s focus has been mainly in water provision. Over the years they have had great success in the installation of water tanks and other amenities to communities of Kuna Nega, La Paz, and Cerro Patacon. The installation of these water tanks ensures that the communities maintain continuous access when water supply from IDAAN, Panama’s main water supplier is unavailable. Their current projects include working with IDAAN, in the community of Burunga to successfully implement a water network to sustain the growing population.

Appendix B - Ruben’s Introduction to Ease Skepticism

"Good morning! My name is Ruben. We are students at Worcester Polytechnic Institute in the United States. My group and I are doing a professional internship with IDAAN which consists of updating their 2002 census. This will help IDAAN have up-to-date information on the communities of 13 de Febrero, La Alameda and Nueva Jerusalén. With this information, IDAAN plans to implement an official sewage and water systems in the aforementioned areas."

Appendix C - Survey

Social Census Survey

Getting a good idea of the water needs for the area

* Required

Province? *

○ Panama Oeste

District? *

○ Arraijan

Corregimiento? *

○ Burrunga

Barrio?

○ Alameda

○ 13 de Febrero

○ Nueva Jerusalen

○ Other: ____________

Sector?

Your answer

What is the name of the homeowner? *

Your answer

Do you have a designated house number? If so, what is it?

Your answer

What is your houses condition? *

- Under construction
- In ruins
- Complete
- Other: ______

How do you get your drinking water? *

- I purchase water bottles
- I buy water by the gallon
- I drink tap water
- I collect rain water
- Other: ______

Do you have a latrine? *

- Yes
- No
- I don't know

Do you have a septic tank? *

- Yes
- No
- I don't know

When was the last time your septic tank was service

- I don't have a septic tank
- I don't know
- Recently
- Other: ______

Do you have sewage? *

- Yes
- No
- I don't know

Do you have another source of water that we haven't asked about? *

- No
- Other: ______

How long have you lived here? *

Your answer

GPS Point? *

Your answer

Street name? *

Your answer

Name and type of business *

- Not a business
- Other: ______

ID number? *

- I don't have an ID
- Other: ______

Home phone number? *

- I don't have a phone

How many adults live in your home? *

Choose

How many children live in your home? (under 18) *

Choose

Are you an IDAAN client? *

- Yes
- No
- I don't know

How many bedrooms are in your house?

Choose