Water Distribution Project

Final Design Report

La Peñita, Panamá

December 13, 2019

KSG WaterWays

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CEE 4916 Fall 2019
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LETTER OF TRANSMITTAL

December 13, 2019

KSG WaterWays
1400 Townsend Dr., Houghton, MI 49931

To: Mr. Ricardo Montanari
Footprint Possibilities Inc. USA

Copy: Mr. Julio Granados
Global Brigades-Panama

Re: La Peñita Water Distribution System Final Design Report

Dear Mr. Ricardo Montanari & Mr. Julio Granados:

KSG WaterWays has designed a sustainable and economically feasible water distribution system to provide the members of the La Peñita, Panama community with potable water year-round. Water will be pumped from the Chucunaque River to elevated storage tanks. The water will be filtered and chlorinated before it enters the storage tanks. The water will then be distributed to each residence, among other locations throughout the community, via a gravity fed PVC piping network. Existing infrastructure was incorporated into the proposed water distribution system design.

The KSG WaterWays design portfolio includes a hydraulic model, drawing set, cost analysis, construction schedule, and operations and maintenance plan for the system. It is estimated that the system will cost $22,200 U.S. dollars and require 17 weeks for construction completion.

The team would like to thank Dr. David Watkins, Mr. Mike Drewyor, Mr. Kiko de Melo e Silva, Mr. Julio Granados, Mr. Rick Montanari, and the La Peñita community members for their contributions to this project and their assistance in collecting necessary data.

Sincerely,

KSG WaterWays

Samantha Cepeda   Grace Kluchka   Kendall Welling

DISCLAIMER:

This report, titled “Water Distribution Project: La Peñita, Panamá”, represents the efforts of undergraduate students in the Civil and Environmental Engineering Department of Michigan Technological University. While the students worked under the supervision and guidance of associated faculty members, the contents of this report **should not** be considered professional engineering.

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Executive Summary

As part of an international senior design program, the KSG WaterWays team was created to coordinate with Footprint Possibilities and Global Brigades Panama to design a water distribution system to provide clean water to the residents of the La Peñita, Panama community. The team visited the La Peñita community and collected data required for the design. The team evaluated the existing infrastructure and existing conditions and incorporated the information into the proposed water distribution system design. The KSG WaterWays design portfolio includes a hydraulic model, drawing set, cost analysis, construction schedule, and operations and maintenance plan for the system.

La Peñita is a rural community in the province of Darien located in the Eastern Panama. Currently, there are approximately 177 residents, and they do not have access to potable water. Existing infrastructure was designed to be used to pump water from the Chucunaque River source to two elevated storage tanks. A water treatment plan also exists. However, there is no distribution network to transport the water from the elevated water storage tank location to the homes and public locations.

KSG WaterWays has designed a sustainable and economically feasible water distribution system to provide the members of the La Peñita, Panama community with potable water year-round. Water will be pumped from the Chucunaque River to an elevated storage tank location. The water will be filtered and chlorinated before it enters the storage tanks. The water will then be distributed to each residence, among other locations throughout the community, via a gravity fed PVC piping network. Existing infrastructure was incorporated into the proposed water distribution system design. It is estimated that the system will cost $22,200 U.S. dollars and require 17 weeks for construction completion.

1.0 Introduction

1.1 Program Description

As a part of the International Senior Design program at Michigan Technological University, the KSG WaterWays team traveled to La Peñita, Panama. The team worked with Footprint Possibilities (FPP) and Global Brigades-Panama (GBP) to connect with the La Peñita community and identify design requirements for a water distribution system for the community. The team spent two weeks in Panama during which time they assessed the water situation in La Peñita, including the existing infrastructure and the project constraints. The team also engaged in discussions with the community to better understand the community's vision for the water distribution system (Figure 1).

Figure 1. KSG WaterWays with community members [1]

1.2 Community Background

The La Peñita community is located in the Darién Province in eastern Panama (Figure 2). There are approximately 110 adults and 70 children residing in about 55 home. Additional public buildings include a school, community bank, clinic, police station, stores, and churches. The homes and public locations lack access to potable water. Community members rely on rainwater for their drinking water needs as the weather allows. When rainwater is insufficient, community members purchase bottled water for drinking purposes. The rainwater collection systems used throughout the community are depicted in Figures 3 and 4.

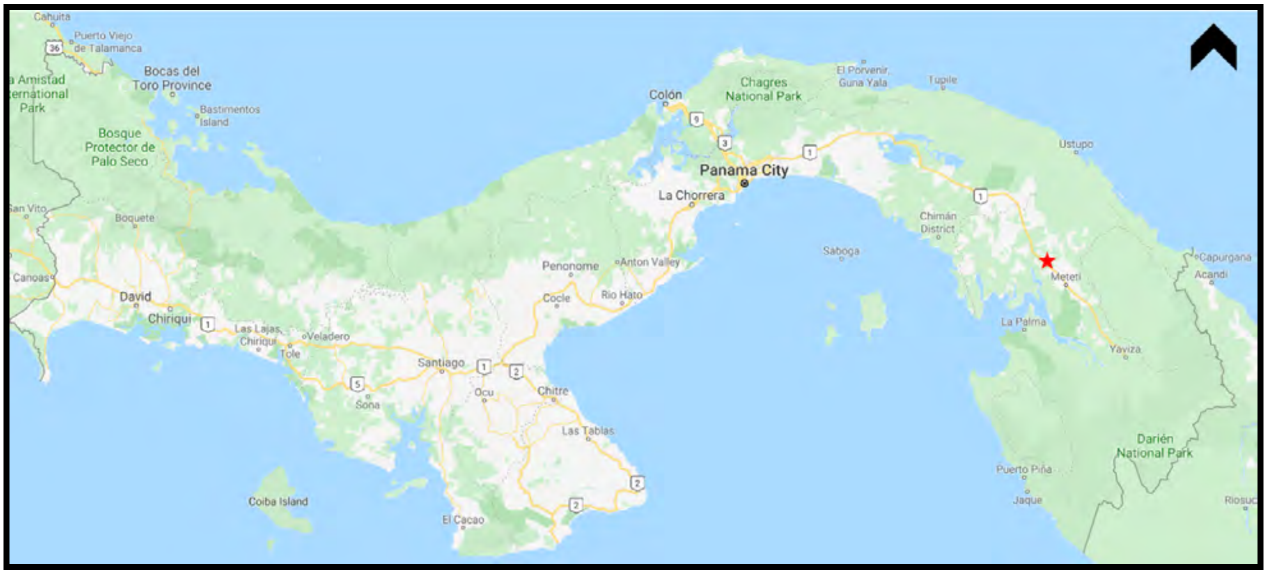

Figure 2. La Peñita in Eastern Panama [2]


Figure 3. Rainwater collection at home [1]

Figure 4. Rainwater collection at school [1]

The Chucunaque River flows along the east side of the community. It is used for bathing purposes, laundry, and recreational activities. Two residences have independent water systems that pump water from the river to water storage tanks at the residence (Figure 5). The river also brings refugees to La Peñita, but the government provides the refugees with water, so the La Peñita community water distribution system does not need to provide water to the refugees.

Figure 5. Independent water system pumps from Chucunaque River to residence [1]

La Peñita elevation, water quality, and demographic data, among other existing conditions, were documented. The information was collected and analyzed by KSG WaterWays. The team designed a water distribution system for implementation in La Peñita considering the existing conditions and system requirements identified by the stakeholders. The final design includes pump specifications, a water treatment plan, water storage tank specifications, and piping network details.

2.0 Data Collection and Analysis

2.1 Surveying and Elevation Profiles

The community was surveyed to evaluate the hydraulic constraints for the water distribution system design. A GPS was used to record northings and eastings, and a laser rangefinder and tape measure were used to measure relative elevations and distances.

The GPS points are presented in Figure 6. The river, homes, and proposed trunk lines, as well as the existing intake structure, supply line, and storage tank location, are identified.

Figure 6. La Peñita GPS points

The tank location is the highest point in the community, while the river location is among the lowest points in the community. The difference in elevation is 40 feet.

2.2 Water Quality

Water quality tests were performed using 3M petrifilm plates. Water samples were collected upstream of the intake structure in the Chucunaque River, at the intake structure, and at the school's rainwater-supplied kitchen sink faucet. Petrifilm plates provide detection and enumeration of *E.coli* and total coliform colonies present in water samples. Using a pipette, 1 mL of the water sample was added to the plating surface. It was then evenly distributed throughout the plate using a spreader. The plates were incubated on a flat surface for 48 hours. After incubation, all colonies inside the ring were counted. The presence of blue and red colonies represent *E. coli* and coliform contamination, respectively. Three trials were performed for each water sample, and the results were averaged for greater accuracy.

E. coli and coliforms were found in the two Chucunaque River water samples collected at the intake structure (Figure 7). Only coliforms were present in the rainwater sample from the school kitchen, as shown in Figure 7 on the rightmost Petrifilm. Based on the water quality analysis report conducted by Ambitek and provided by FPP (Appendix A), the maximum contaminant limit (MCL) is 3 CFU/100 mL and 1 CFU/100mL for total coliforms and *E. coli*, respectively. Results are based on the technical regulation DGNTI-COPANIT 23-395-99.

Figure 7. Water quality test results illustrate the presence of *E. coli* and coliforms in the three water samples [1]

2.3 Existing Infrastructure

The Municipio de Chepigana, a Panamanian municipality group, is working with the La Peñita community to establish a part of a water system for the community. The plans for this system, which is under construction, were drawn by engineering technician Elpidio Chiari Morales and are provided in Appendix B. The existing infrastructure includes an intake structure located in the river and an electrical control booth approximately 50 feet from the bank of the river. Two water storage tanks have been purchased, and an elevated water storage tank platform is being constructed. In addition, there is a supply line that runs from the intake structure in the river up to the tank location. The existing infrastructure is mapped in Figure 8. The intake structure in the river has been constructed (Figure 9), and the electrical control booth is empty but also constructed (Figure 10).

Figure 8. Existing infrastructure on community map


Figure 9. Existing intake structure in the Chucunaque River [1]


Figure 10. Electrical control booth [1]

The contractor has also installed the supply line. This is a 2-inch diameter PVC pipe that is buried in a 2-foot deep trench and extends from the intake structure to the tank location. At the tank location, there are six column footings (Figure 11). A tank platform will be constructed atop the existing footings according to the plans provided in Appendix B.

Figure 11. Tank platform foundation [1]

2.4 Demographic Data

KSG WaterWays conducted a demographic survey that expanded on the FPP survey data, resulting in an estimated community population of 177. A 20-year design life was considered for the La Peñita water distribution system. A population growth rate of 2% per year was factored in so that the system may continue to fulfill the community water demand throughout the design life of the system. As demonstrated in Figure 12, the La Peñita population 20 years in the future, given a 2% annual growth rate, is predicted to be 263. While the system is not designed for refugee usage because the refugees obtain water from an independent system managed by the government, the presence of the refugee population in La Peñita may lead to the community population growing at a rate greater than average. Therefore, the 2% annual growth rate was used instead of the standard 1.7% [3] annual Panamanian population growth rate.

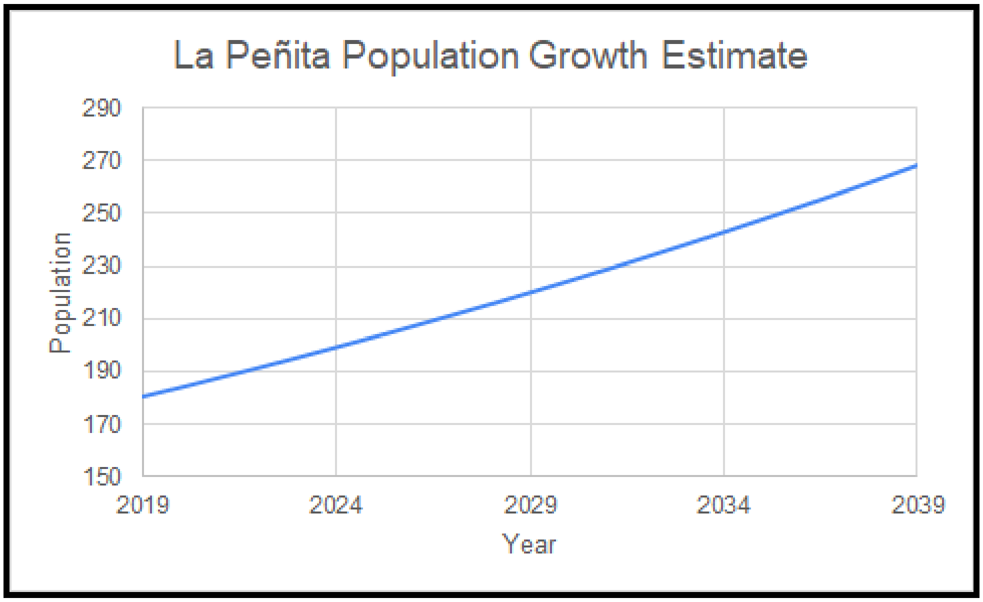

Figure 12. La Peñita population growth estimate

Based on the World Health Organization (WHO) recommendation and previous projects implemented in Panama, the system is designed for a water demand of 21 gallons per capita per day [4], which results in a total daily demand of 5,500 gallons. More detailed demographic data and corresponding demand data and calculations are provided in Appendix C.

3.0 Proposed Design

KSG WaterWays has designed a water distribution system to distribute water to La Peñita community members (Figure 13). Water will be pumped from the Chucunaque River up to an elevated water storage tank location via a 2-inch PVC supply line. At the water storage tanks, the water is treated. The filtered and chlorinated water is then distributed to the homes and other community buildings via 2-inch PVC trunk line and ½-inch PVC branch lines.

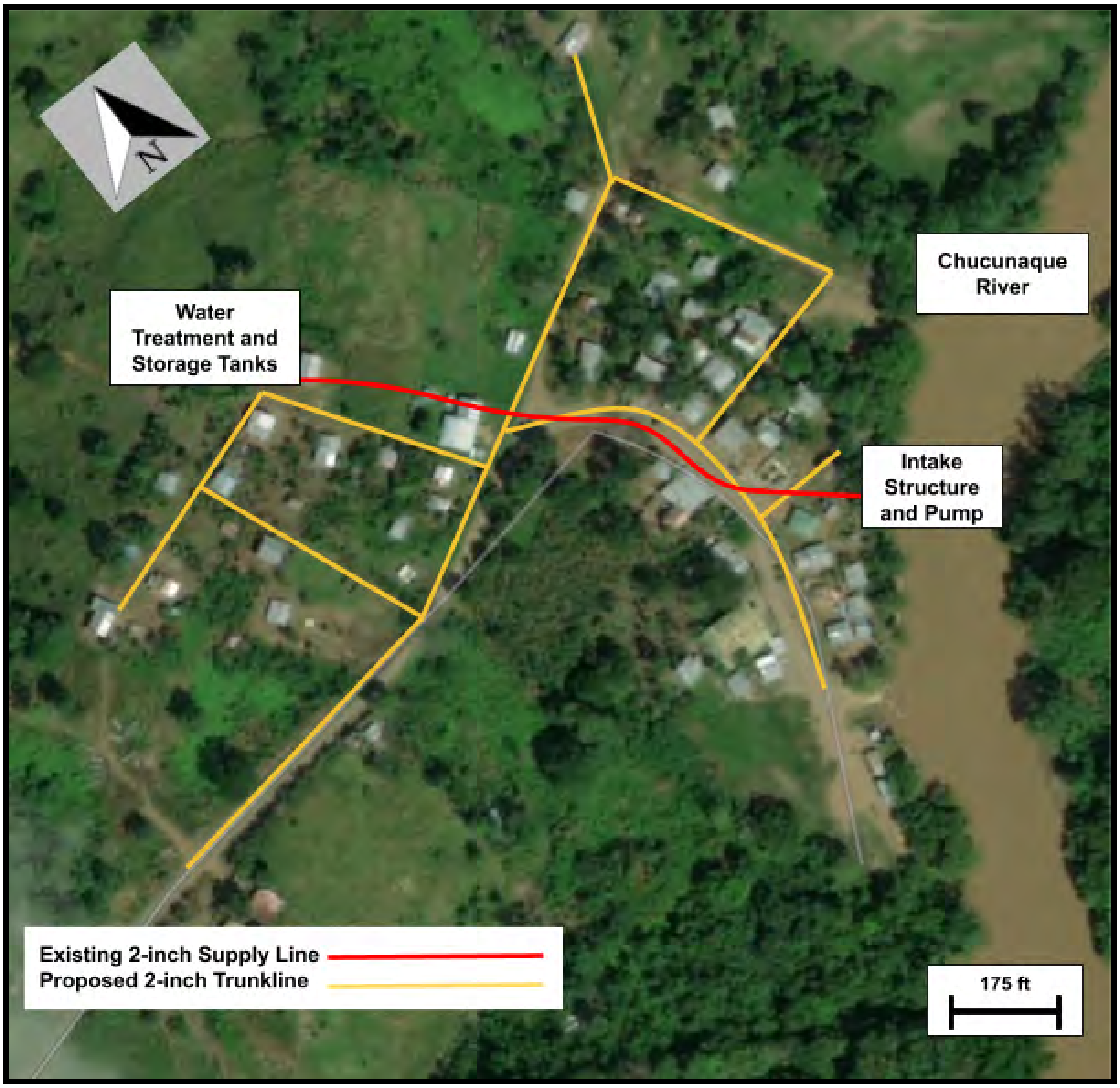

Figure 13. Map of proposed water distribution system path, including component locations [5]

EPANet was used to model the system and ensure hydraulic feasibility. Appendix D summarizes the model inputs and outputs. The river was modeled as a reservoir. The pump modeled in the system is defined by a pump curve for a pump similar to the one to be implemented in the system. A single 2,000-gallon tank is used in EPANet to model the two 1,000-gallon tanks in system. Nodes were defined for each building in the system and at all trunk line junctions and connected with pipes of specified diameters, lengths, and roughness values. The schematic of the resulting model is presented in Figure 14.

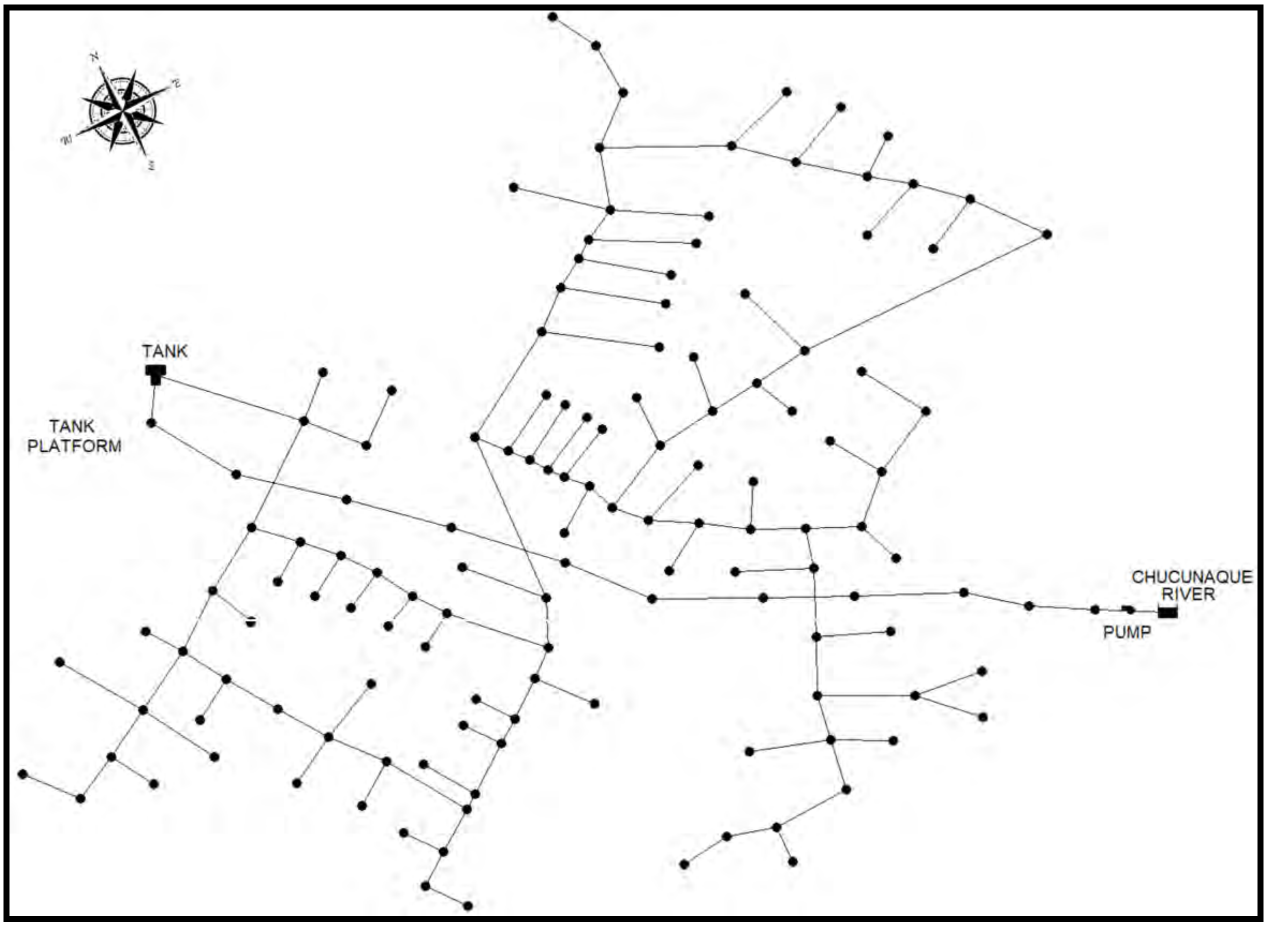

Figure 14. EPANet Schematic

The proposed design incorporates existing infrastructure which reduces the amount of resources required for the implementation of the water distribution system. Additional considerations, including recommendations for meter replacement and accounting for population growth, will help to ensure the system is capable of fulfilling its 20-year design life. Automatic pump shut-offs and metering are specified to encourage reasonable water usage.

3.0.1 Design Assumptions

Design assumptions were made.

1. No refugees will use water from this system. The system was designed for use by La Peñita community members only. The government provides the refugees with water, so, as per discussions with the stakeholders (FPP and GBP), the system is not designed for refugees usage. While the system is not designed for refugee usage, the presence of the refugee population in La Peñita may lead to the community population growing at a rate greater than average. Therefore, the 2% annual growth rate was used instead of the standard 1.7% [3] annual Panamanian population growth rate.
2. The intake structure, electrical control booth, supply line, storage tank, and storage tank platform design are not included in the KSG WaterWays scope. Evaluations of these components was completed as necessary to incorporate the existing infrastructure into the distribution network design.
    a. The intake structure was not accessible for inspection while the team was on-site. Also, the supply line was buried, and only the tank platform foundation had been constructed when the KSG WaterWays team was on site. Therefore, the proposed design was prepared to incorporate the existing infrastructure as it appears in the plans presented in Appendix B. The team recommends the existing infrastructure be compared with the plans and the proposed design be reevaluated if as-built conditions vary from the Appendix B plans.
    b. The electrical control booth will house the necessary equipment to supply power to the pump. Commercial electricity will be used.
    c. The supply line is buried 2 feet.
    d. The storage tank platform will support the weight of (2) 1,000 gallon water storage tanks and withstand the environmental conditions.
3. The recommended chlorine dose should be reevaluated based field testing once system construction is complete.

3.1 Tank Specifications

Two 1,000-gallon tanks are called for in the existing plans for the La Peñita water distribution system. KSG WaterWays evaluated the two 1,000 gallon tank system design and confirms that the 2,000-gallon tank capacity is capable of fulfilling the system demand for the entirety of the 20-year design life.

Water is pumped from the river, then passes through a water filtration system and fills the storage tanks from above. The storage tanks are elevated to 40 feet above the intake structure. This elevation is adequate for gravity-fed distribution of the treated water from the tanks to the buildings included in the system. Figure 15 shows the inlet pipe passing through the filter and chlorinator. The treated, potable water then exits each tank and flows out to the community.

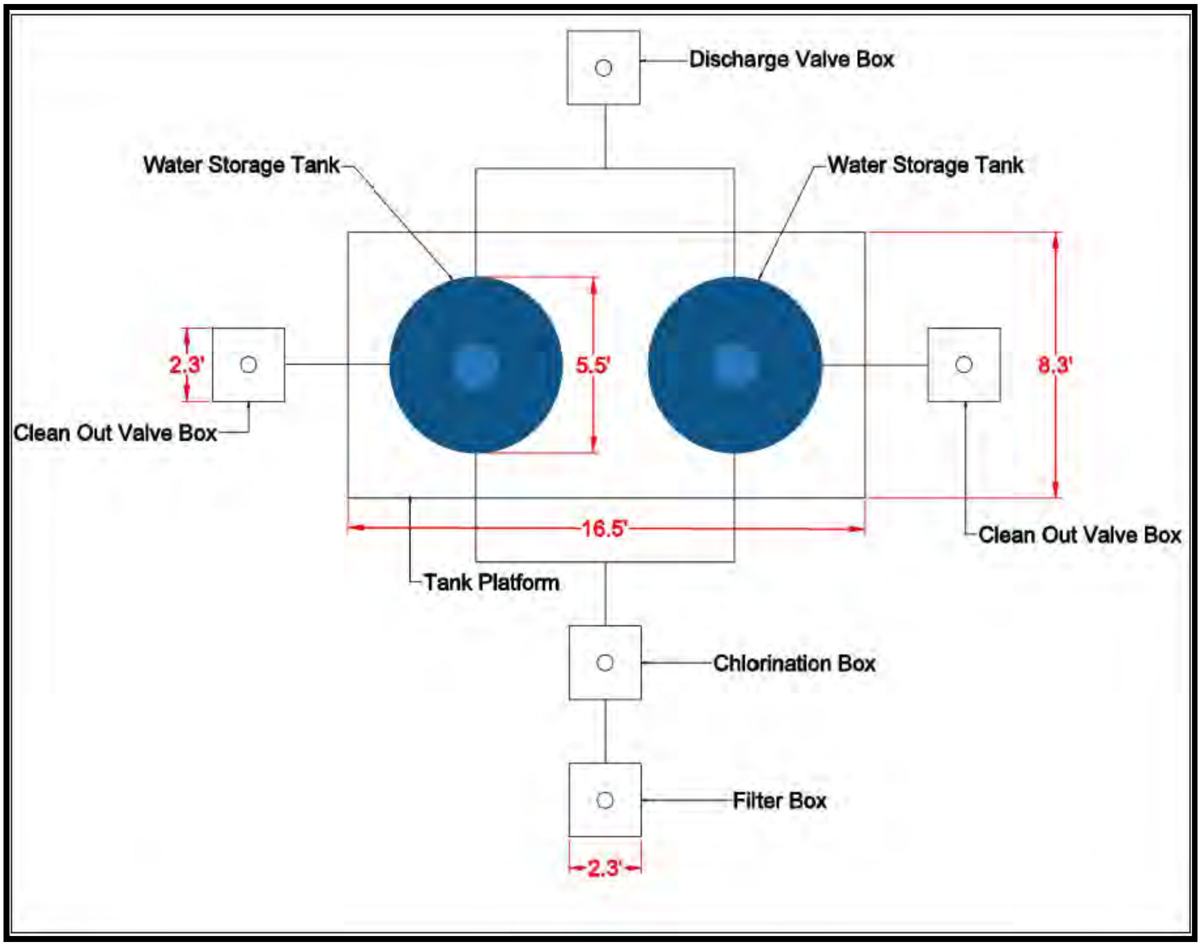

Figure 15. Plan view of water storage tanks, filtration box, chlorination box, clean out valve boxes, tank platform, and effluent valve

Each tank includes a float switch. One float valve per tank is called for so that in the case that one tank is offline for cleaning or maintenance, the other will not overflow due to not having a shutoff mechanism. The switches are located near to the tops of the tanks and, when triggered, communicate with the pump, shutting it off. The tanks are also braced by a railing as shown in Figure 16.

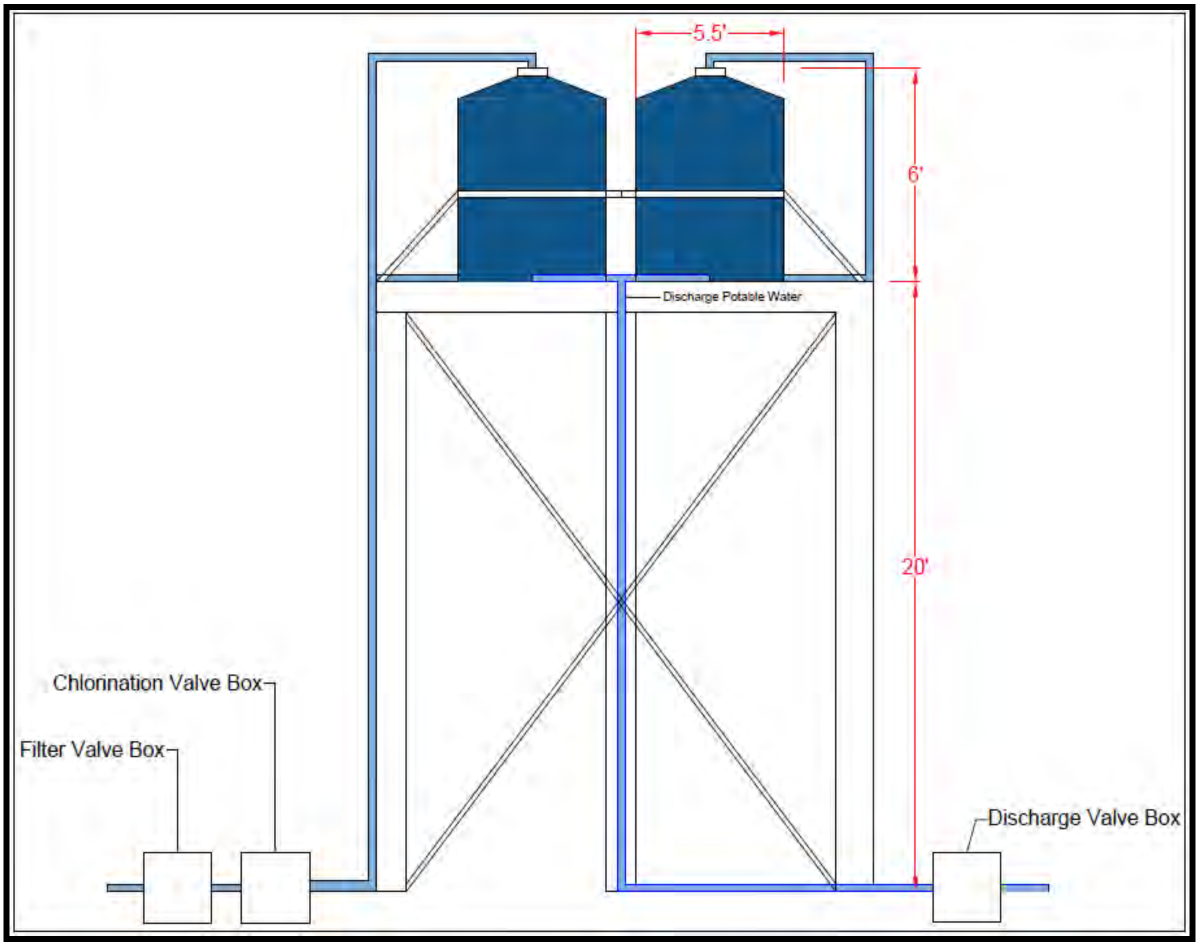

Figure 16. Side view of water storage tanks

The storage tank in Figure 17 is assumed to be similar to the tanks that have been purchased for the community. It is a 3-layered plastic tank. The inner layer serves to repel bacterial growth, the middle layer provides structural support, and the outer layer provides protection from ultraviolet radiation and prevents photosynthesis within the tank.

Figure 17. Example of a triple walled water tank [6]

The proposed storage tank design specifies that the elevation of the storage tank platform is 20 feet from the ground level beneath it, so the storage tanks are then elevated to 44 feet, which is 40 feet from the lowest elevation in the community at the river. This elevation difference provides adequate pressure for gravity-fed water distribution to all of the homes and other community locations included in the distribution network.

3.1.1 Roof Structure

A mono-pitched zinc sheet roof supported by metal framing has been designed to shade the water storage tanks. The purpose of this roof is to shade the storage tanks to reduce the temperature of the water. Six metal posts will be connected to the concrete tank platform with post brackets and concrete screws. Metal studs will be used for framing. Three 20-foot metal studs will run lengthwise, and eleven 12-foot metal studs will run widthwise for support (Figure 18). The metal framing will be anchored to the metal posts with self-tapping screws and gusset plates. The zinc roof will be secured to the framing using zinc roofing screws. The roof will have a 2-foot overhang on each side.

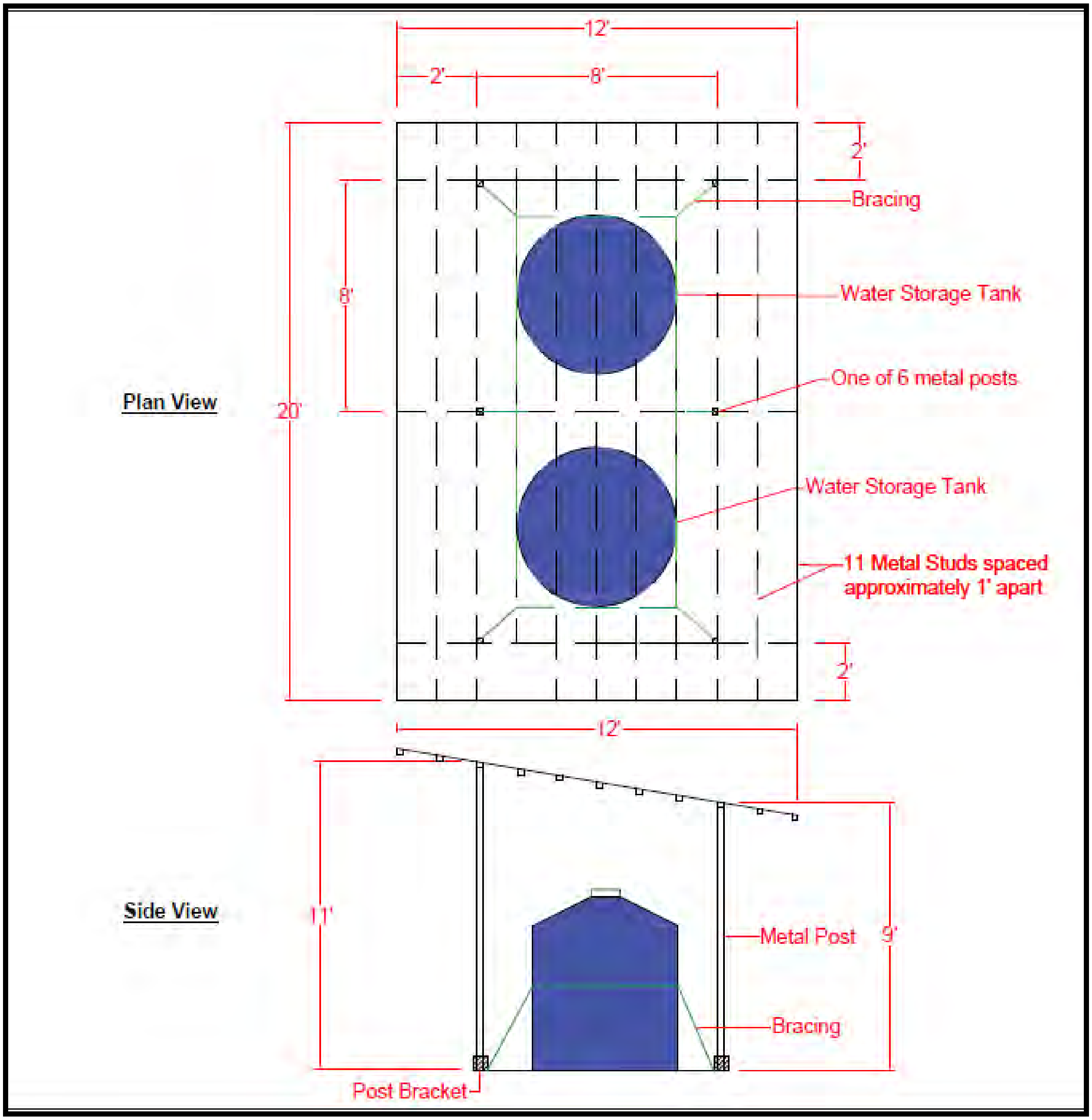

Figure 18. Water storage tank roof design

Serviceability was taken into account. The front of the roof will be 11 feet tall, and the back of the roof will be 9 feet tall. The storage tanks are 6 feet tall which leaves a minimum of 3 feet above the tanks which is adequate clearance for access to the top of the tanks for cleaning and maintenance. To prevent erosion at the base of the storage tank platform, gravel will be placed in the runoff area, as shown in Figure 19.

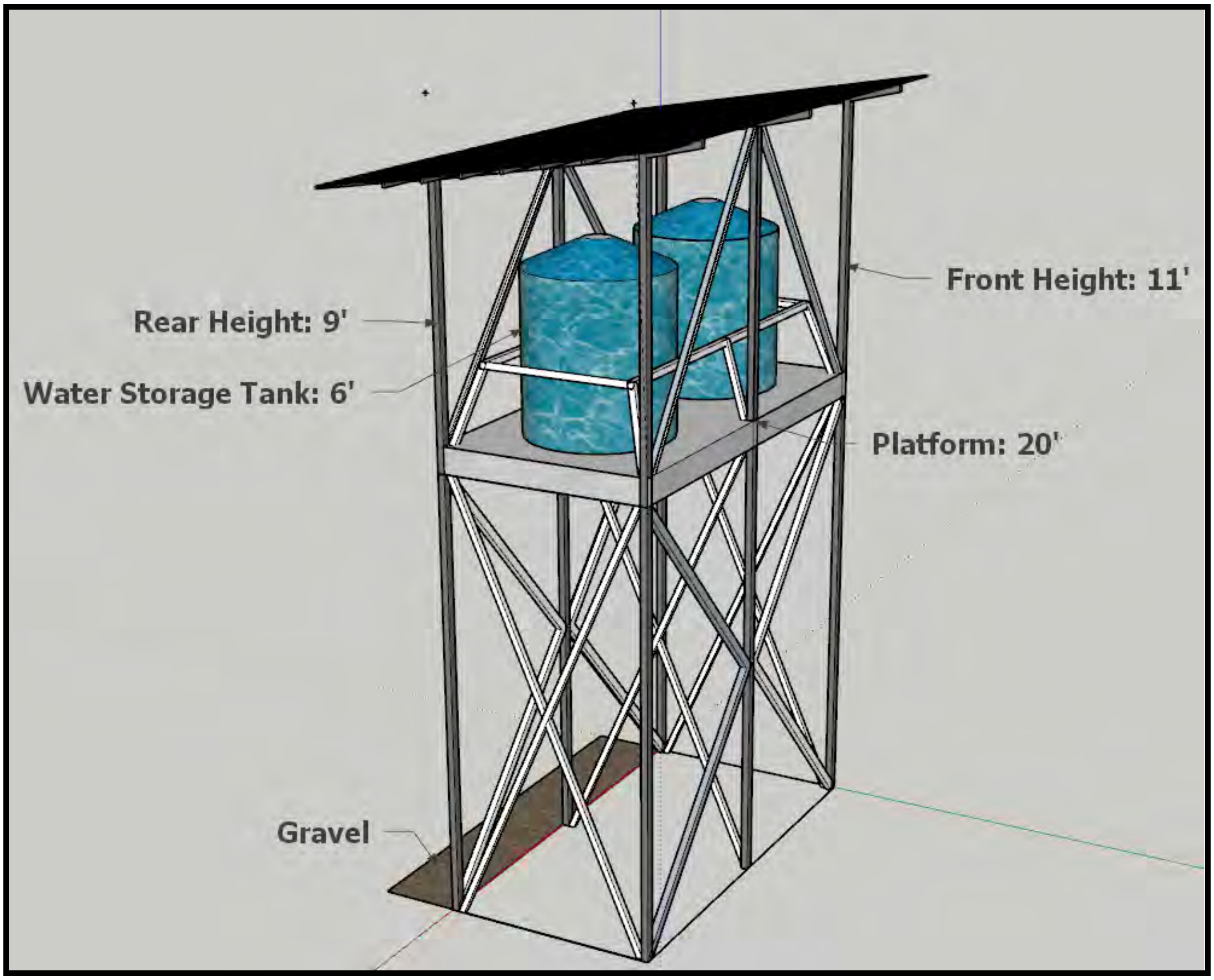

Figure 19. Water storage tank roof

3.2 Pump Specifications

The water must be pumped from the river source, which is at an elevation of approximately 4 feet, up to the tank location, which is at an elevation of 44 feet, through the existing 2-inch supply line. The pump location is among the system component locations presented in Figure 13. A submersible pump is recommended to make use of the existing infrastructure. The pump will be submerged in the existing well-like intake structure.

As detailed in Appendix B, the current plans call for a 1.5 HP, 2” submersible pump with a capacity of 30 gpm. The pump curve for a pump with similar specifications was used to define a pump curve for the pump in the EPANet model of the system. The pump that is modeled is a High Capacity Submersible Pump. The pump curve is the -40 curve depicted in Figure 20. Data points from the manufacturer's pump curve [7] were used to generate the pump curve for the pump in the EPANet model presented in Figure 21.

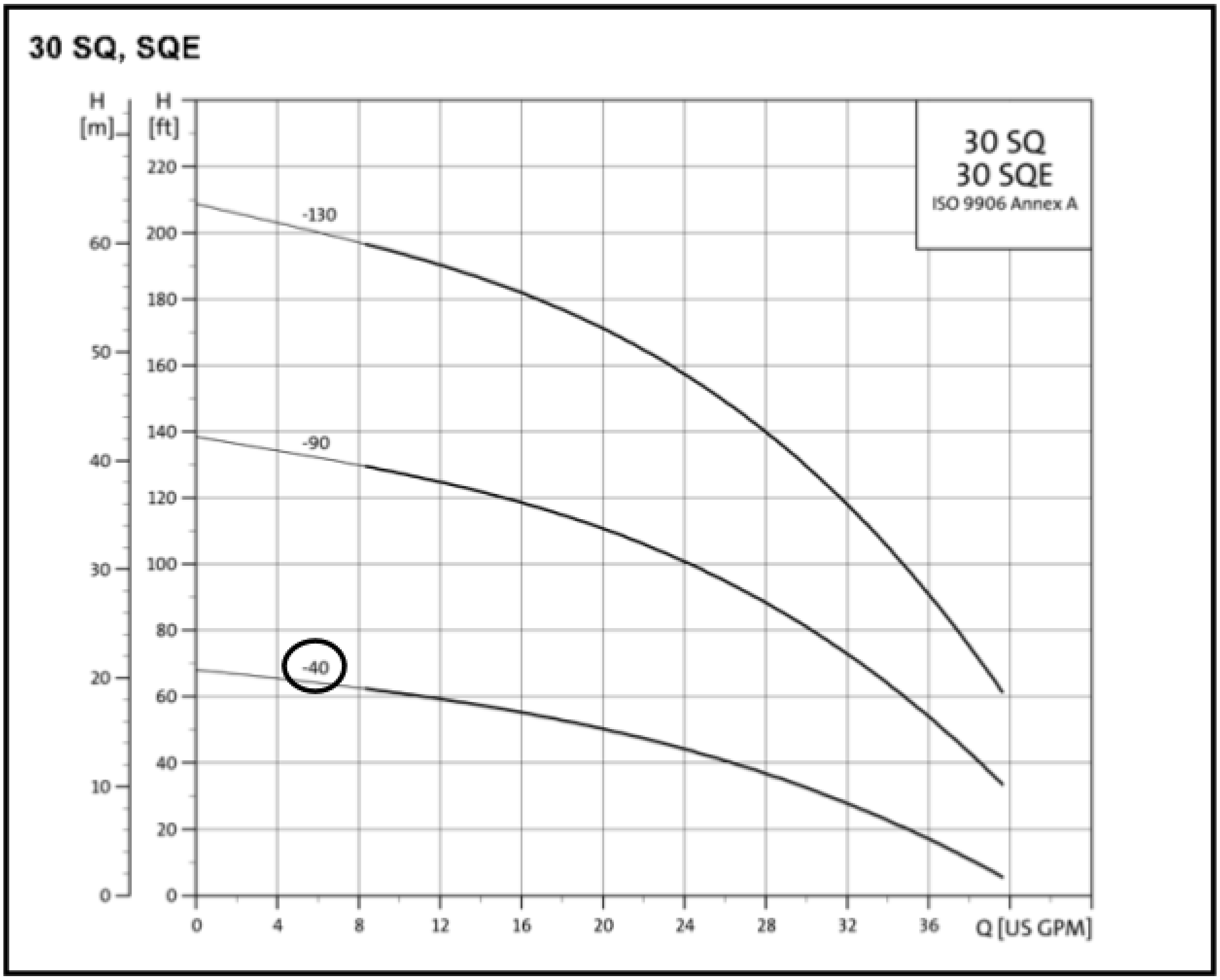

Figure 20. Pump curve for submersible pump used in EPANet model (-40 curve represents recommended pump) [7]

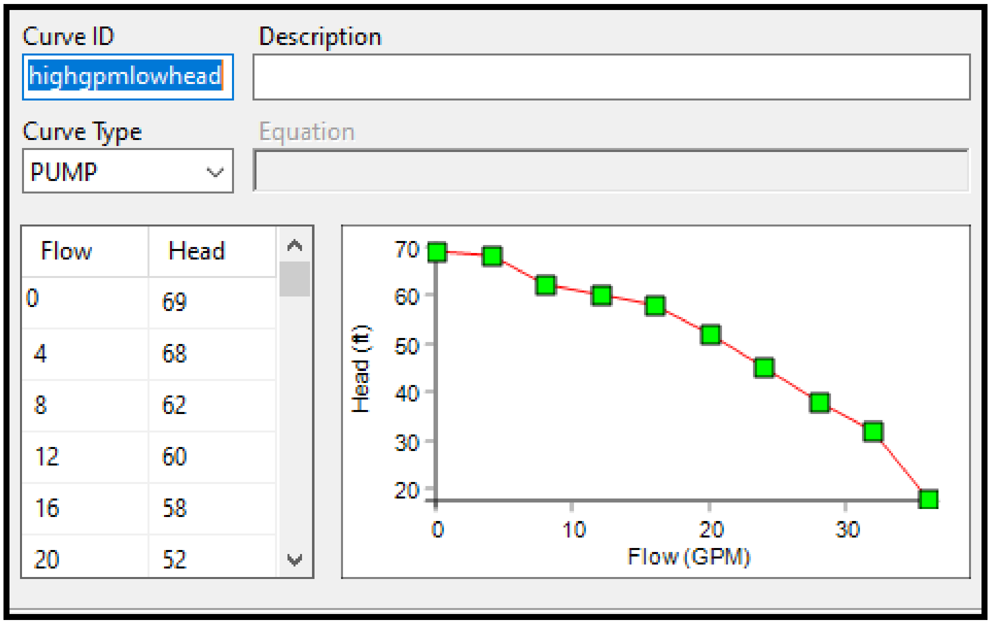

Figure 21. EPANet pump curve model

The pump will run intermittently throughout the day due to the limited tank capacity of 2,000 gallons as compared to the daily demand of 5,500 gallons. This concept was simulated in the EPANet model using the rule-based pump controls feature (Figure 22). A maximum water level of 5.25 feet is specified because it corresponds to a volume near the 2,000-gallon maximum tank capacity. A minimum tank level of 2 feet is specified, meaning the pump will begin to run when the water level of the tank gets down to 2 feet. An automatic shutoff switch will be implemented to stop pumping at a water level of 5.25 feet so that the tank will not overflow.

```
RULE 1
IF   TANK   tank LEVEL ABOVE 5.25
THEN PUMP pump STATUS IS CLOSED
RULE 2
IF   TANK   tank LEVEL BELOW 2
THEN PUMP pump STATUS IS OPEN
```

Figure 22. Pump controls coding

A second shut-off switch controlled by the wet well water level will prevent the pump from running when there is no water in the wet well to be pumped, which would result in pump damage. The wet-well pump control will have priority over the tank water level pump control. That is, if the wet well water level is insufficient, the pump will not run, regardless of the amount of water in the storage tanks.

A time series plot for the flow through the pump was generated using EPANet (Figure 23). The plot demonstrates that the pump will need to be run 3-4 times throughout the day. The total daily run time for the pump will be about 4.3 hours based on the system demand of approximately 5,500 gallons per day and the pump rate of 20 GPM. Under demands lower than the 21 gallon per capita per day design demand, the pump discharge would run less often.

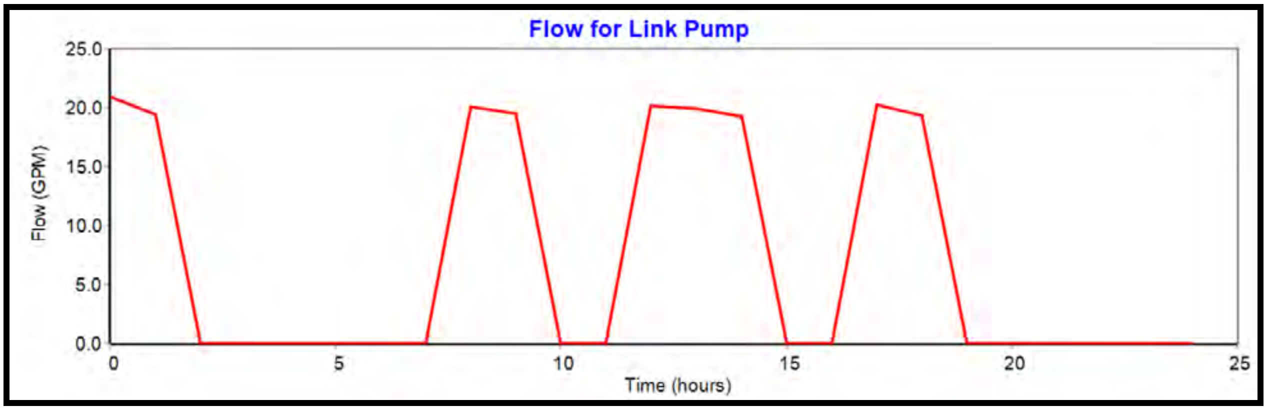

Figure 23. Pump time series plot for 24-hour period

The head in the system varies based on the water level in the storage tanks. Therefore, multiple system curves were generated; one for no water in the tank, which corresponds with the lowest system head, and the other for the highest water level of 5.25 feet, which corresponds with the highest system head. The pump and system curves are plotted together in Figure 24 so that the operating range of the pump may be visualized.

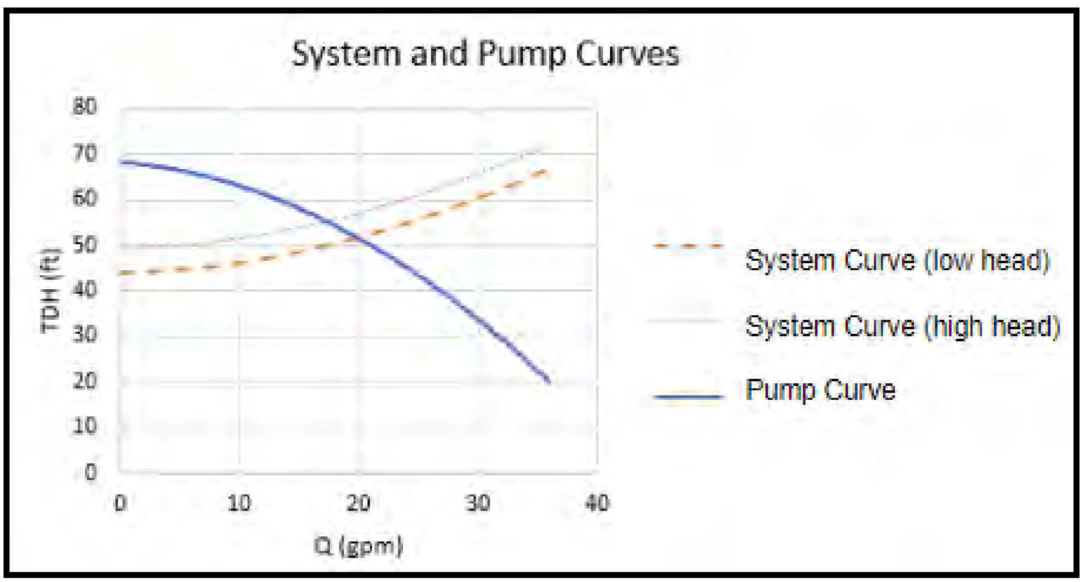

Figure 24. System and pump curves plot

The annual pumping costs for the system were evaluated considering the 0.17 U.S. Dollar per kWh cost of electricity in Panama [8] and assuming a pumping efficiency of 50%. The projected annual cost of the system's pump operations is approximately $640. Refer to Appendix E for pumping cost calculations.

It is assumed that the pump will be stationary. As the water level changes, the pump will remain at the same elevation. Therefore, while the exact river water level throughout the year is unknown, the pumping required will be consistent. During the dry season, however, the water level may reach low levels such that the pump is no longer fully submerged. The pump must be submerged to operate, or it will be damaged. Hence the recommendation for the aforementioned pump shut-off switch based on the wet well water level. Therefore, the pump will not run as often as modeled if the river source supply is limited. Additionally, it is assumed that filter pack surrounding the well reduces the turbidity of the water such that the water may be pumped without damaging the pump.

According to community members, the river level drops significantly during the dry season. Therefore, river trenching is recommended (Figure 25). As the water level decreases, the river continues to flow along the bank opposite of the community (B). Therefore, a trench (line AB) has been dug somewhat perpendicular to the flow of the river to route the water from the bank opposite of La Peñita towards the intake structure (A) on the west (La Peñita) side of the river.

Figure 25. Chucunaque River trenching diagram [5]

3.3 Water Treatment System

The water is treated before it enters the storage tanks, as indicated in Figure 13. Prior to this main water treatment location near the storage tanks, the river water turbidity is reduced in the wet well before pumping. Filter pack aggregates act as a filter media by reducing turbidity and collecting precipitates containing impurities. In addition, the pump includes an inlet screen between the motor and the pump casing to remove particles from the river water. After pumping, the water will travel through a backwash filter and in-line chlorination system, each of which are located inside a protective concrete service box (Appendix I).

The existing design calls for a 300-micron plastic filter; however, KSG WaterWays has found a more appropriate T-line backwash filter (Figure 26), the specifications for which are presented in Table 1. Periodically backwashing is recommended every time the pressure decreases and/or the water is changing its turbidity. Backwashing show be performed once every 4 to 6 weeks A pipe reducer prior to the chlorinator will be used to integrate the 1.5-inch chlorinator system, as the filter system has a 2-inch diameter.

Figure 26. Recommended T- line filter [9]

Table 1. Specifications for Imperial filter [9]

Specification	Description
Screen	120 Mesh stainless steel
Maximum pressure	145 psi
Range of Flow rate	80 - 120 GPM
Cartridge Length	9.9 in
Cartridge Diameter	4.7 in
Pipe size/plumbing	2 in

Results from the water quality tests showed the presence of *E.coli* and coliform bacteria. For this reason, the water will be subjected to chlorine treatment. Each chlorine tablet weighs 200g and contains 60-70% of available chlorine. The amount of chlorine to properly disinfect the water is better to be calculated by performing field test. However, a recommended concentration of chlorine for water drinking is 1mg/L [9]. An estimated of three tablets of chlorine every 1 to 2 weeks can be used, based on a flow rate of 20 gallons per minute. The CT value for the system is 59.2 mg*min/L which provides a proper disinfection of the water. In the case that there is not enough pressure to backwash the filter while it is installed in the concrete service box, a possible option is for community members to remove the filter mesh and clean it carefully using only clean water.

The team recommends an inline chlorinator based on the existing design dimensions and the chlorine demand. The specifications presented in Table 2 are for an inline Hayward Chlorinator (Figure 27), which automatically feeds chlorine to the system. The chlorinator can hold up to 20 tablets of chlorine. It has a dial control that allows for feed rate adjustments. The storage tank detention time was calculated to be one hour and 32 minutes based on the flow rate of 20.16 gallons per minute calculated by the EPANet model. Using the detention time and assuming a 0.3 baffling factor for a circular tank with inlet on top and outlet at the bottom [9], the chlorine contact time was calculated to be 29.6 minutes (Appendix F). Under lower demands or supplies, the chlorine contact time would be longer [10, 11, and 12].

Figure 27. Recommended in-line chlorinator [10]

Table 2. Specifications for Hayward Chlorinator [10]

Specification	Description
Model	CL2002S
Pipe size	2 in
Height	14-¾ in
Width	9 in
Flow rate	50-90 gpm

3.4 Piping Network

The two 1,000-gallon tanks in the design were modeled in EPANet as a single 2,000-gallon tank with the same height but a diameter adjusted to account for the volume difference. The diameter and not the height of the composite tank is changed to avoid introducing error associated with unrealistic water levels and heads. A 1,000-gallon water storage tank is 5.5 feet in diameter and 6 feet tall.

$$d := 5.5ft$$

$$h := 6ft$$

$$V := \pi\left(\frac{d}{2}\right)^2 h = 1.066 \times 10^3\ gal$$

A 2,000-gallon water tank with the same height of 6 feet would have a diameter of around 7.5 feet, and these tank parameters are used in the EPANet model.

$$d := 7.5\text{ft}$$

$$h := 6\text{ft}$$

$$V := \pi \left(\frac{d}{2}\right)^2 h = 1.983 \times 10^3 \text{ gal}$$

The Hazen-Williams approximation was used to model the head loss in the system.

$$H_L = L\left(\frac{4}{D}\right)^{1.17}\left(\frac{V}{C_w C_H}\right)^{1.85} \text{ [13]}$$

H_L = head loss

L = length

D = diameter

V = velocity

C_w = 1.318 for English units

C_H = 150 (PVC material property) [13]

Potable water is distributed to homes by 2-inch PVC trunk lines and ½-inch PVC branch lines. The trunk lines and branch lines for the water system total approximately 3,200 feet and 3,200 feet long, respectively. Major survey points throughout the community were used to develop an EPANet model according to the topographical relief of the community.

Hourly demand patterns were generated for each demand type. The water demand pattern for the homes is presented in Figure 28. It was created based on discussions with community members about water usage throughout the day. Peak water demands occur early in the morning, around lunchtime and after working hours are over. Other locations throughout the community including the school, church, clinic, police station and community bank have unique water demands as described in Appendix D.

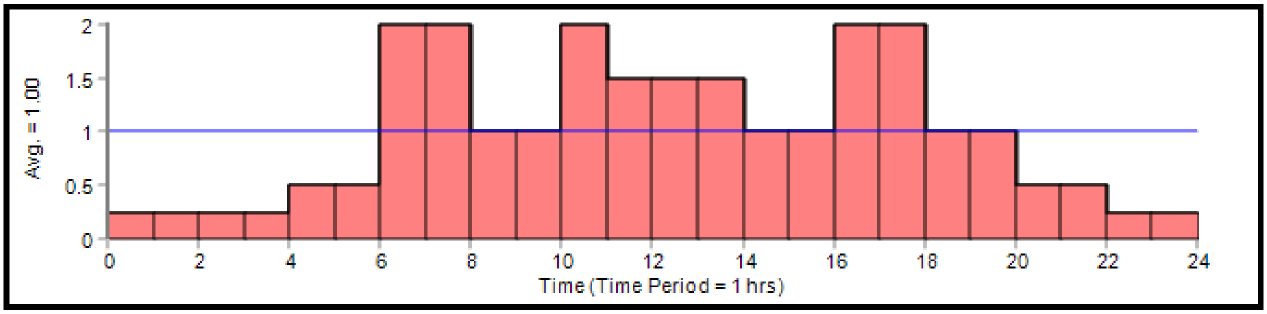

Figure 28. Hourly demand pattern for homes

EPANet outputs showed a maximum pressure of 15.16 psi and minimum pressure of 3.46 psi among the homes. The schematic of the system illustrates the pressures throughout the network (Figure 29). Positive pressures ensure water is reaching every home. More detailed EPANet model outputs at each node are described in Appendix D. The pipe entering the storage tank has a loss coefficient (k) of 16.35 due to water flowing across the filter media. More detailed calculations and a head loss diagram of the filter are included in Appendix D.

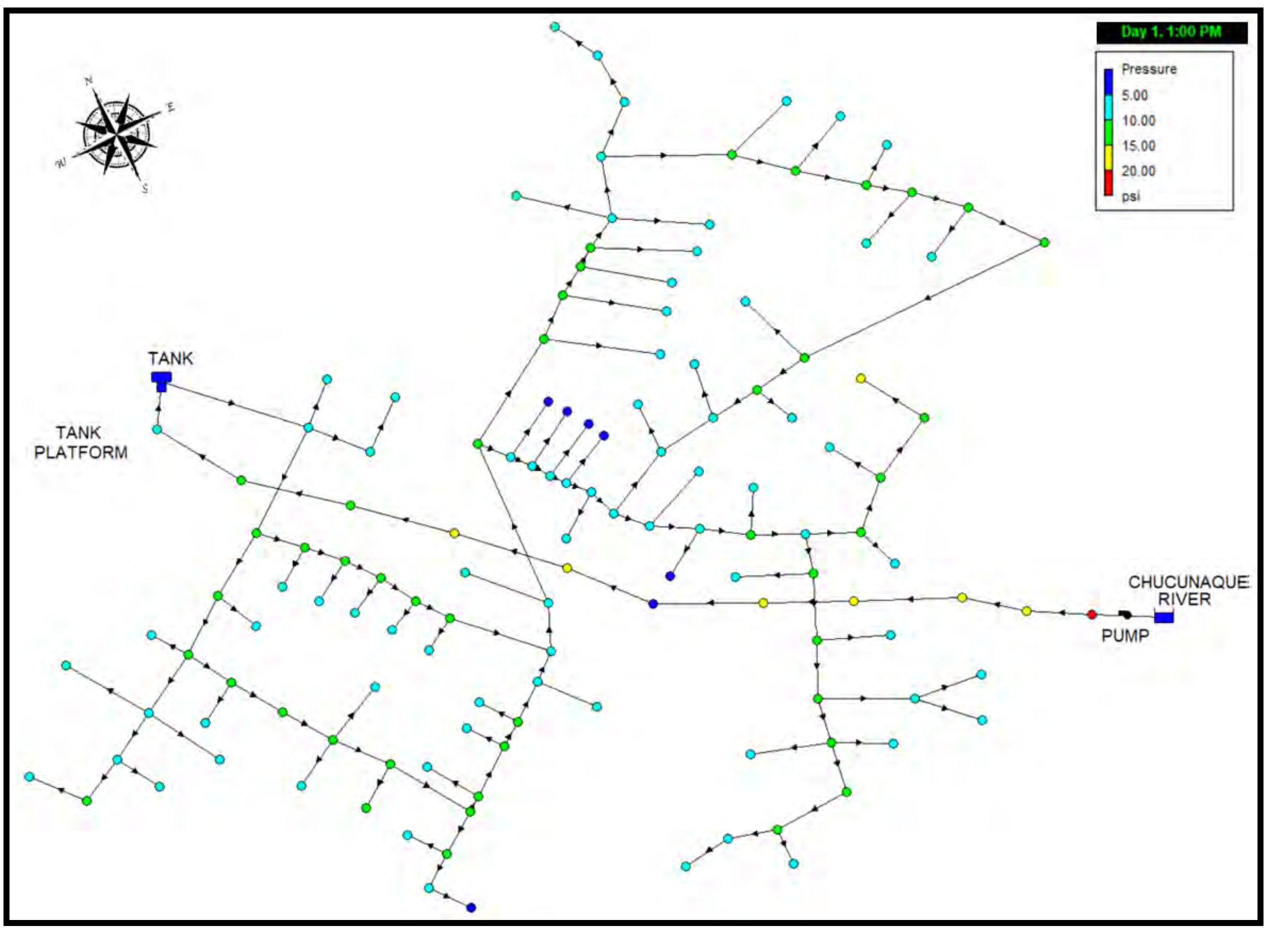

Figure 29. EPANet schematic including pressures at each node during a peak hour

A tank pressure profile generated by EPANet indicates an increase in pressure while the tank is being filled with water and a pressure drop during water usage peak hours. Pressure ranges from 0.43 psi to 2.21 psi during a 24-hour period (Figure 30). A system flow balance profile was generated by EPANet to illustrate the relation between the water consumed by the community and the water produced by the pump during a day as seen in Figure 31. The system meets the community water demand at all times.

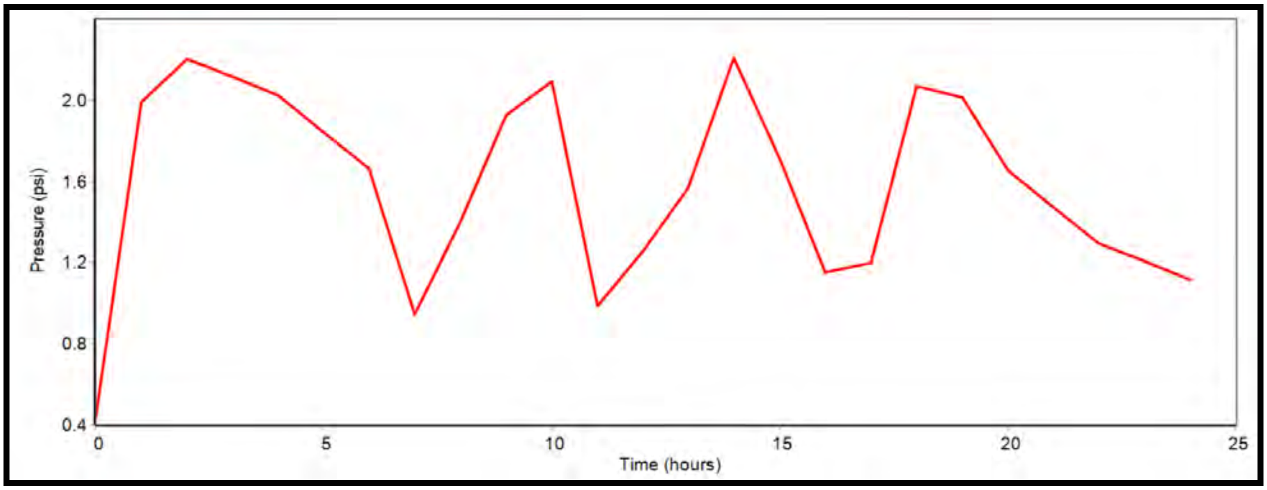

Figure 30. Tank Pressure Profile (24-hr Duration)

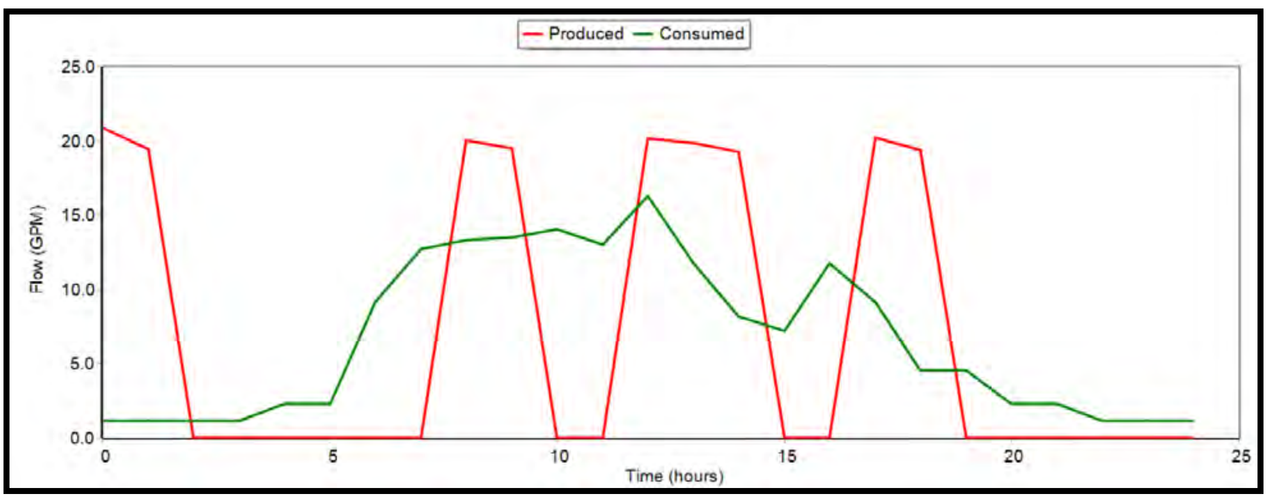

Figure 31. System Flow Balance (24-hr Duration)

Loops have been added to the distribution network design for redundancy. The loops are circled in Figure 32. Figure 32 also specifies recommended valve locations within the loops. In the instance of pipe damage, valves may be closed as necessary to cut off the section of the system that is under maintenance, and the rest of the system may continue to operate as normal. Valves will be protected by in-ground storage boxes (Figure 33). Valves may be accessed via the storage box access holes when necessary. Ball valves were selected for the system since they can immediately shut off the flow of water in case of an emergency situation.

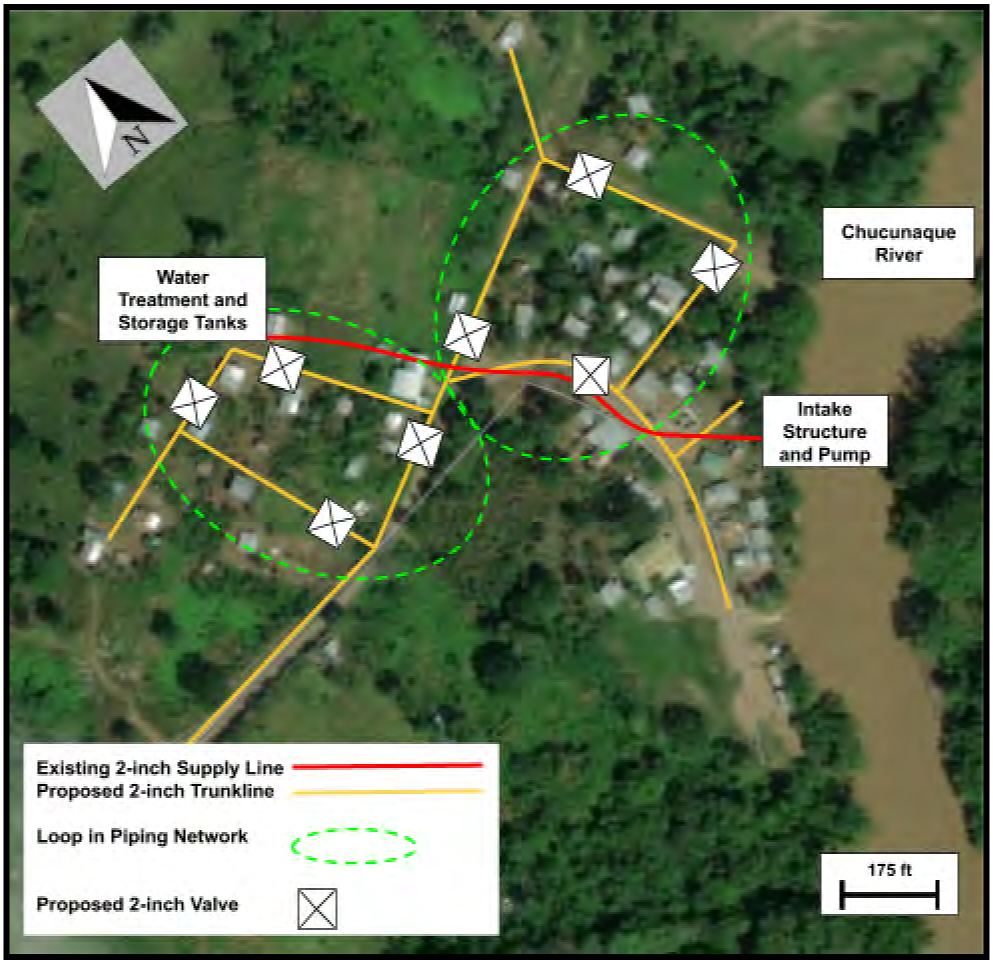

Figure 32. Aerial image of community with valve locations specified [5]

Figure 33. Recommended protective in-ground storage box [14]

3.4.1 Metering

Water will be piped to each community member's home. The water intake at each residence will be metered. The metering system piping in Figure 34 is recommended to allow water to be supplied to the home while the water meter is being serviced. For regular usage, the valve on the left would be closed and the two valves on the right open. When the meter is being serviced, the two valves on the right will be shut off and the valve on the left opened, allowing water usage at the home by bypassing the meter under maintenance. It is recommended that the meters be replaced every five years so that metering remains accurate. Economy Plastic Water Meter - WM-PC Series [15] meters (Figure 35) are recommended. The meters will be tied into the 0.5-inch PVC branch lines as per Figure 36 [15]. The meters will be placed in protective boxes like the ones used to protect the valves in the distribution network (Figure 33) in the ground to prevent meter damage [14]. The boxes may be locked for security purposes.

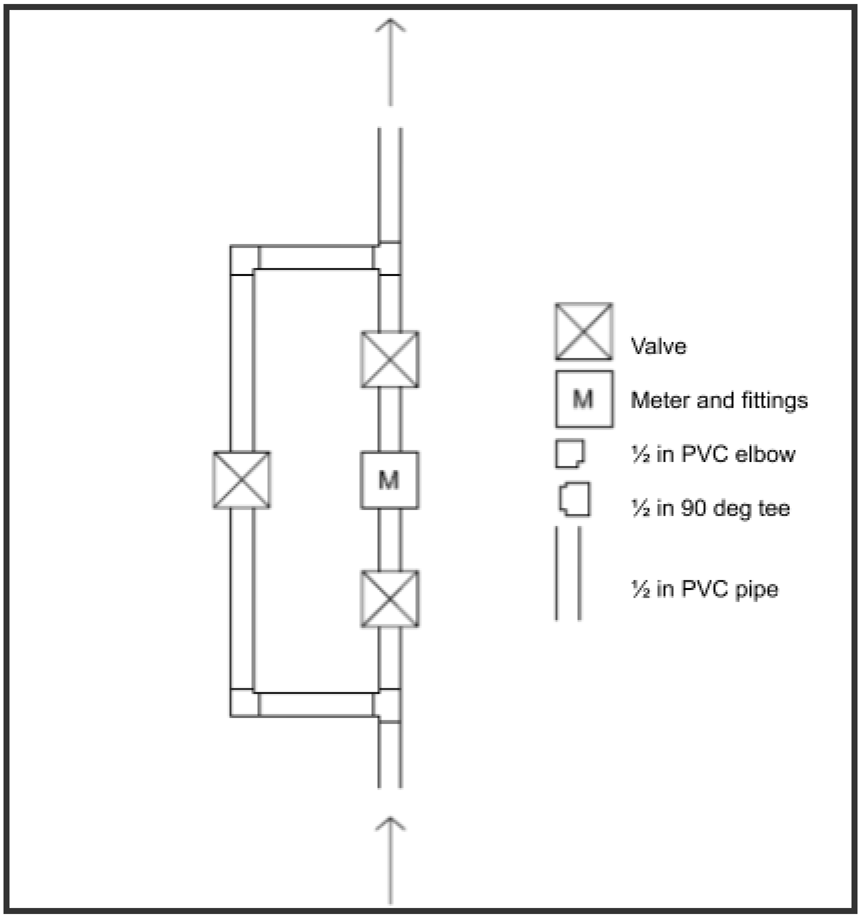

Figure 34. Water meter piping

Figure 35. Recommended Economy Plastic Water Meter [15]

Figure 36. Recommended water meter connection [15]

3.4.2 Vertical Pipe Support

The ½-inch PVC pipe branch lines that are buried at a depth of two feet will be brought back up to the surface at each home and building for water access. The pipe will be supported by the structure to which it will be supplying water. The pipe will be attached to wooden structures using metal pipe straps and nails (Figure 37). Pipes will be attached to concrete structures using zip ties (Figure 38).

Figure 37. branch line attachment to wooden structures using metal pipe strap and nails [16]

Figure 38. branch line attachment to concrete structures using zip ties [1]

4.0 Construction Schedule

Construction of the water distribution system in La Peñita will begin with the transportation of materials from Panama City and other surrounding areas. As the material is being transported over a two day period, people working on the system will be given a safety presentation and construction instructions.

Construction of the system will consist primarily of digging trenched and laying and connecting PVC pipe. 2-inch PVC pipe will be used for the trunk lines and ½-inch PVC pipe will be used for the branch lines. The tunklines will mainly run along road sides, and they will be placed in a trench that is dug two feet deep. The trenches will be dug in 20-foot sections. Once a section is dug the pipe will be placed in the trench and connected to the previous pipe using primer and glue.

When a T connection is needed for a branch line connection, workers will dig a 2-foot deep trench off of the trunk line in the direction of the home the branch line is connecting to. Next, they will add the T connection to the trunk line and add a 2-inch to ½-inch reducer. They will then install the ½-inch pipe and meter box. The meter connection piping configuration is presented in Figure 32.

Once the branch line reaches the house an elbow will be installed to bring the branch line to run vertically upwards for access at the house. The rest of the branch line will be secured as per Figure 35 and 36 depending on the structure type. The trench will be backfilled and workers will continue working on the trunk line until the next home requiring a branch line is reached. These aforementioned process will be repeated for each branch line. When a 20-foot trunk line section is completed and a branch line is not needed, another 20-foot section of trunkine will be tied in.

Once all the PVC pipe is laid, connected, and the trenches backfilled, the water distribution system will be shock-chlorinated, and all of the lines will be flushed. Next, the water distribution system should be tested. This is to ensure each home is receiving water, that there are no leaks in the lines, and that each meter is working properly. There is one day planned for additional adjustments to be made as necessary.

Overall, it is expected to take about 18 weeks to complete the construction and testing of the water distribution system. This is assuming six people work on the project for five days each week and perform eight hours of labor each day with a 10-minute break per hour. For the construction schedule, it is estimated that it will take this group of six laborers one day to trench, lay and backfill 120 feet of pipe. It is also estimated that three meter boxes and the associated piping will require one day for installation. The time estimated to construct the storage tank roof is 10 days, but the roof may be constructed concurrently with the distribution network. There are 8 contingency days incorporated in the total construction time.

Table 3 reports a consolidated view of the construction schedule. The complete schedule is presented in Appendix J.

Table 3. Construction Schedule

Task	Duration
Material Transportation	2 Days
Safety and Training	1 Day (concurrent with transportation)
trunk lines (3213 feet)	27 Days
branch lines (3211 feet)	27 Days
Meter Installation	21 Days
Tank Roof	10 Days (construction concurrent with piping network construction)
Testing and Flushing of System	2 Days
Contingency Days	8 Days
Total Duration:	87 Days (17.4 weeks)

5.0 Cost Estimate

The mobilization, material, and labor costs associated with the proposed design are detailed in Appendix G. Figure 39 presents the estimated costs associated with each portion of the project, and Table 4 shows the details of material and labor costs for each of the major components.

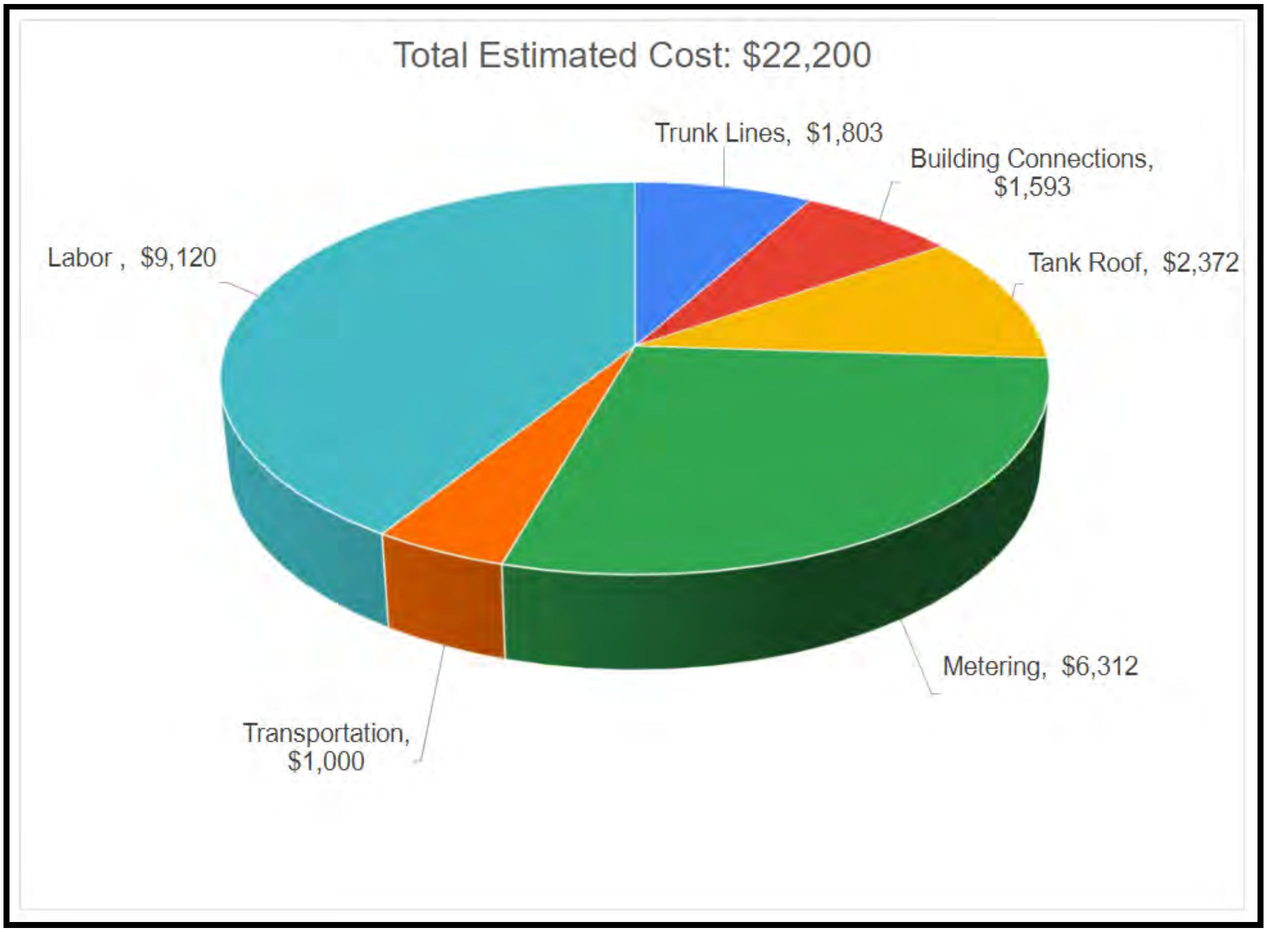

Figure 39. Estimated project cost breakdown

Table 4. Cost breakdowns for major components

Task	Materials	Labor
Transportation	N/A	$1,000
trunk lines	$1,803	$2,592
Building Connections	$1,593	$2,592
Metering	$6,312	$2,016
Tank Roof	$2,372	$960
Flush and Test	N/A	$192
Contingency Days (8)	N/A	$768
Total	$12,080	$10,120
Total	$22,200	

Note: Labor costs were estimated by paying six workers $2/hour [17]

6.0 Project Sustainability

6.1. Operations

Annual pump costs are anticipated to be about $640. Annual water treatment costs are estimated to be $110. For water filtration, three chlorine tablets will be added every 1 to 2 weeks for proper disinfection. The water filter will need to be backwashed once every 3 to 5 weeks and replacement of the media should be done once per year approximately. The community should be prepared for additional intermittent maintenance costs as the system will require repair on occasion. KSG WaterWays recommends the La Peñita water committee collect fees according to water usage, as recorded by the water meters, to cover the operating and maintenance costs.

6.2 Maintenance

If one or more homes is not receiving water there may be a break in the PVC line. The pipe leading up to the first home without water will need to be dug up to identify the location of the break in the line. The water to that line may then be turned off by closing the nearest upstream trunk line valve. Once the water supply is shut off to the affected area, the section of broken line will be cut out and replaced using the appropriate adapters, primer, and glue. Before backfilling, the valves should be opened, allowing the water to flow, to make sure the system is operating properly. Upon confirmation that the leak has been successfully repaired, the trench may be backfilled. Finally, the system should be flushed to evacuate any contaminants that entered while the system was under maintenance. All valves that have not been used in a month should be turned at least once per month to prevent any future additional maintenance and plumbing issues.

Water quality will need to be monitored at all times at each house. Any presence of solids, high turbidity, change in color and even strong chlorine odors are signs of poor water quality. Immediately, the water has to be tested and analyzed before continuing to drink. If a pressure drop is detected across the system, the operation of the backwash filter needs to be verified. A pressure drop can imply a saturation of the filter media and therefore, the filter needs to be properly backwashed to have a regular operation. If bacteria is found in the water reaching the houses, shocking the system with household bleach is recommended to kill bacteria and eliminate any buildup material inside the piping network.

7.0 Conclusion

KSG WaterWays has designed a sustainable and economically feasible water distribution system to provide the La Peñita community members with potable water year-round. The system will pump and distribute water from the Chucunaque river to each home and other community locations. Water will be treated by filtration and chlorination before it enters the two elevated water storage tanks. The water will reach homes via a gravity-fed distribution system. It is recommended that water usage be metered and community members be held accountable to using reasonable amounts of water.

As of December of 2019, it is assumed that the La Peñita community has infrastructure in place to pump water from the river source up to an existing elevated water storage tank location. KSG WaterWays incorporated the existing infrastructure into the comprehensive water distribution system design to reduce total cost and construction time. The system will cost $22,200 U.S dollars and require about 18 weeks for construction completion.

8.0 References

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Appendices

Appendix A. Water Quality Test Results

Table A1. FPP Water Quality Test Results (Chucunaque River- La Peñita).

#	Test	Method	Results	Uncertainty	Units	MDL	MCL
1	Total Coliforms	SM 9222 B	$5.4x10^5$	± $0.5x10^5$	CFU/100 mL	1	3
2	Fecal Coliforms (thermotolerant)	SM 9222 D	$3.0x0^3$	± $0.3x10^3$	CFU/100 mL	1	1
3	Turbidity	SM 2130 B	20	± 1.8	NTU	0.08	1
4	pH	SM 4500-H+ B	7.9 (22.2 C)	± 0.1	-	NR	6.5-8.5
5	Hardness	SM 2340 C	87.8	± 5.8	mg/L	NR	100
6	Total Alkalinity	SM 2320 B	69.3	± 5.9	mg/L	NR	120
7	Total Dissolved Solids	SM 2540 C	152	± 22	mg/L	25	500

*Water test analysis were done by Ambitek services on 07-19-2019. ID sample-MU01. MDL (Method Detection Limit), MCL (Maximum Contaminant Level). MCL is based on the Panama Technical Regulation code DGNTI-COPANIT 23-395-99.

Table A2. FPP Water Quality Test Results from Upstream of Intake Structure.

	Sample #1	Sample #2	Sample #3	Average
E. Coli	4	1	0	2
Coliforms	179	253	236	223

*Count of bacteria is based on CFU (colony forming unit) per 1ml water sample

Table A3. FPP Water Quality Test Results at Intake Structure

	Sample #1	Sample #2	Sample #3	Average
E. Coli	5	5	1	4
Coliforms	153	153	200	169

*Count of bacteria is based on CFU (colony forming unit) per 1ml water sample

Table A4. FPP Water Quality Test Results from Rainwater collection at La Peñita School

	Sample #1	Sample #2	Sample #3	Average
E. Coli	0	0	0	0
Coliforms	80	97	133	103

*Count of bacteria is based on CFU (colony forming unit) per 1ml water sample

Table A5. FPP Final Water Quality Test Results

	Average (CFU/1mL)		
	River Upstream on Intake Structure	At the intake structure	Rainwater at La Peñita School
E. Coli	2	4	0
Coliforms	223	169	103

Appendix B. Existing Infrastructure

The following are photographs of the plans for the existing infrastructure and system that was under construction during the KSG August 2019 site visit. The drawings were prepared by engineering technician Elpidio Chiari Morales and provided to KSG WaterWays by Julio Granados (GBP).

Table B1. Drawing Register

Figure Number	Drawing Name	Drawing No.	Version No	Issue Date	MTU Receiving Date
B1	Water pipe sizes	1	V1.0	October 2016	08/21/2019
B2	Valve casings	2	V1.0	October 2016	08/21/2019
B3	Submersible pump installation	3	V1.0	October 2016	08/21/2019
B4	Storage tanks plan view	4	V1.0	October 2016	08/21/2019
B5	Single phase submersible pump	5	V1.0	October 2016	08/21/2019
B6	Water storage tanks platform	6	V1.0	October 2016	08/21/2019
B7	Control booth elevations	7	V1.0	October 2016	08/21/2019
B8	Chlorination system within storage structure	8	V1.0	October 2016	08/21/2019
B9	Architectonic plan	9	V1.0	October 2016	08/21/2019

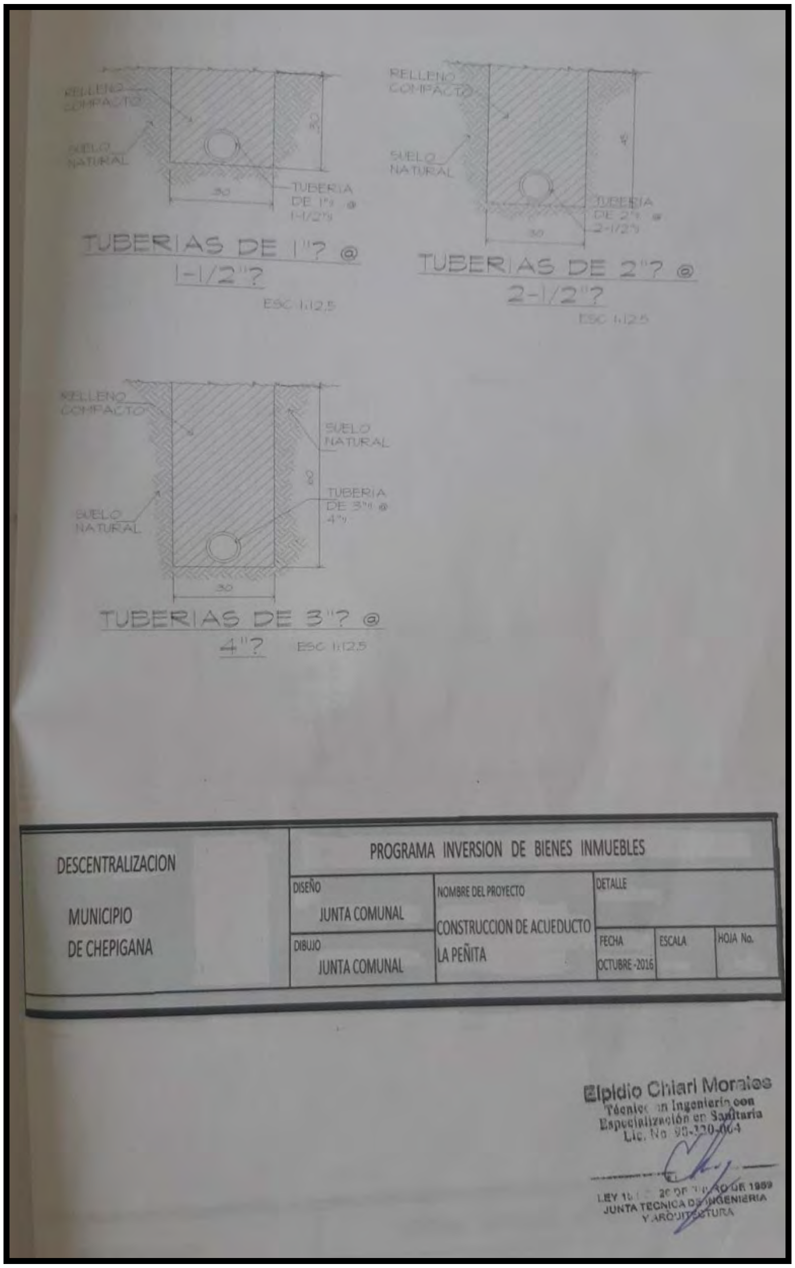

Figure B1. Water Pipe Sizes

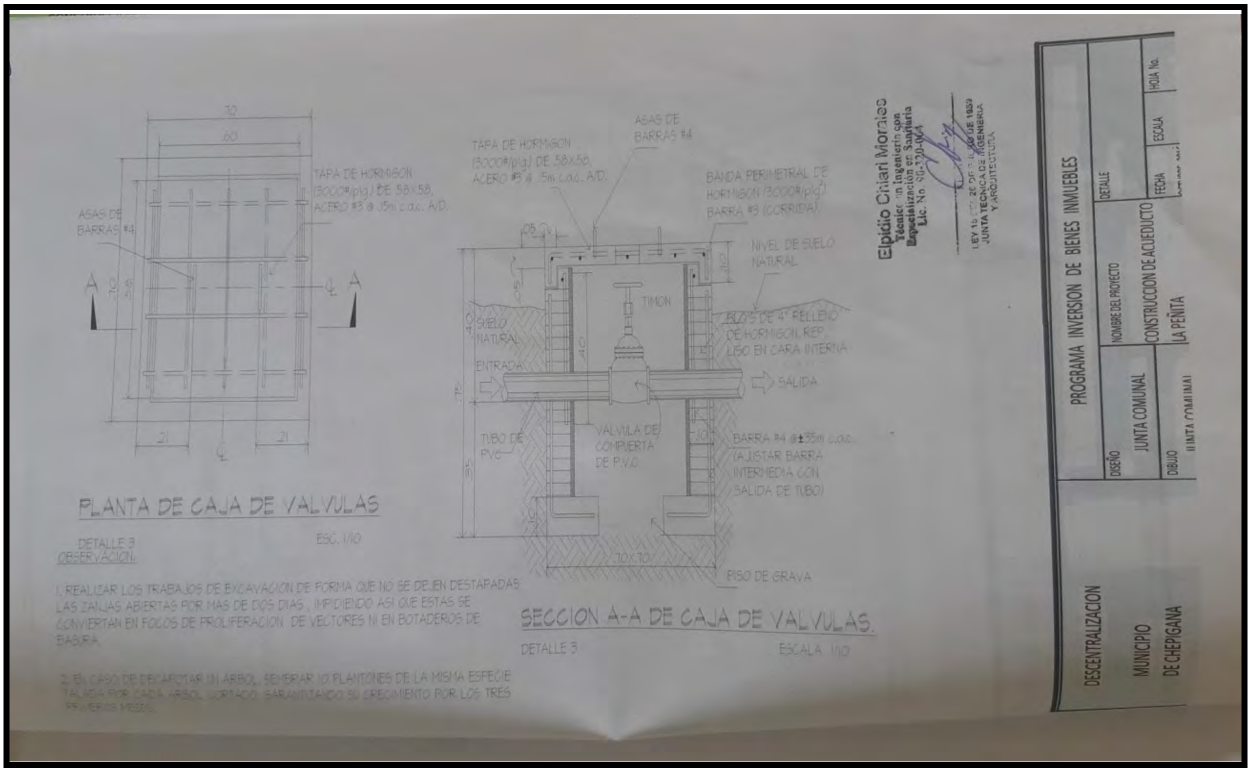

Figure B2. Valve Casings

Figure B3. Submersible Pump Installation

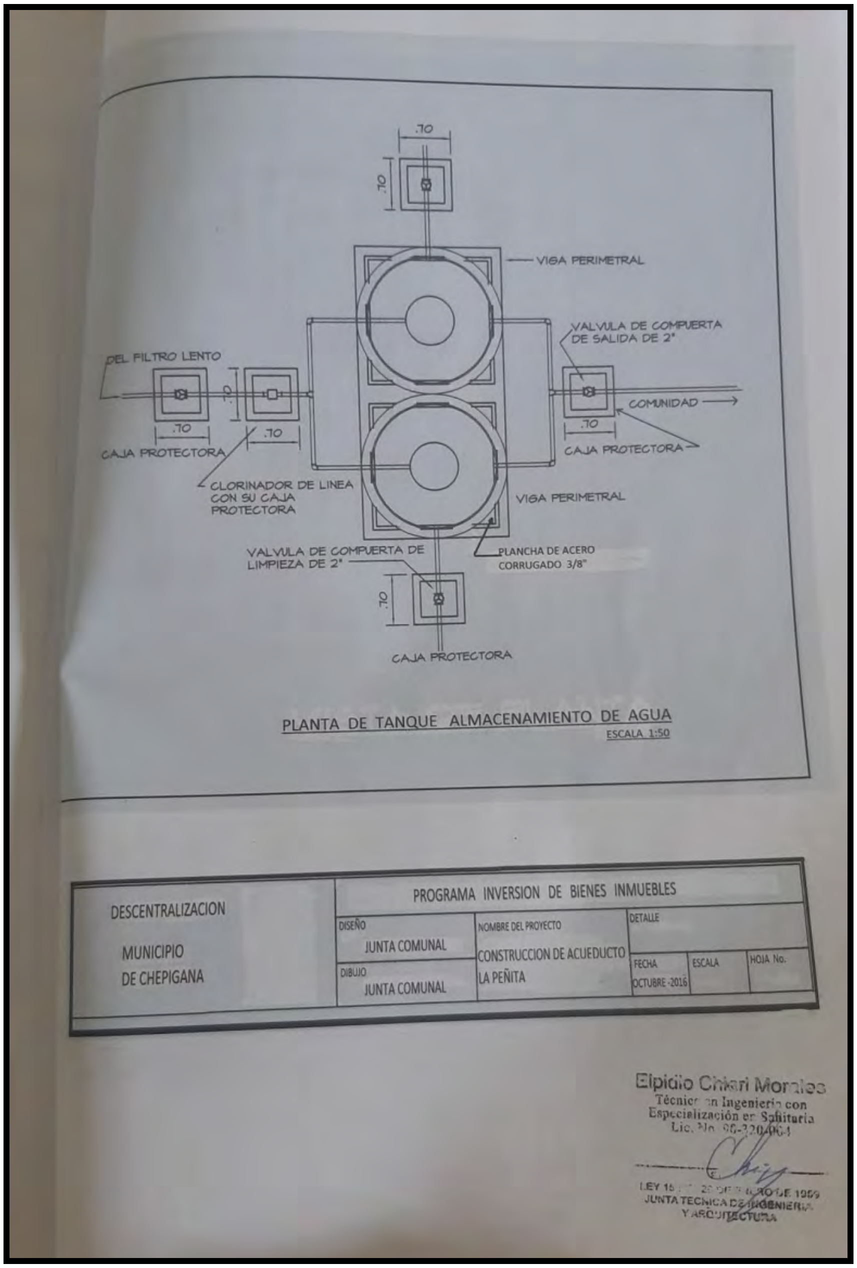

Figure B4. Storage Tanks Plan View

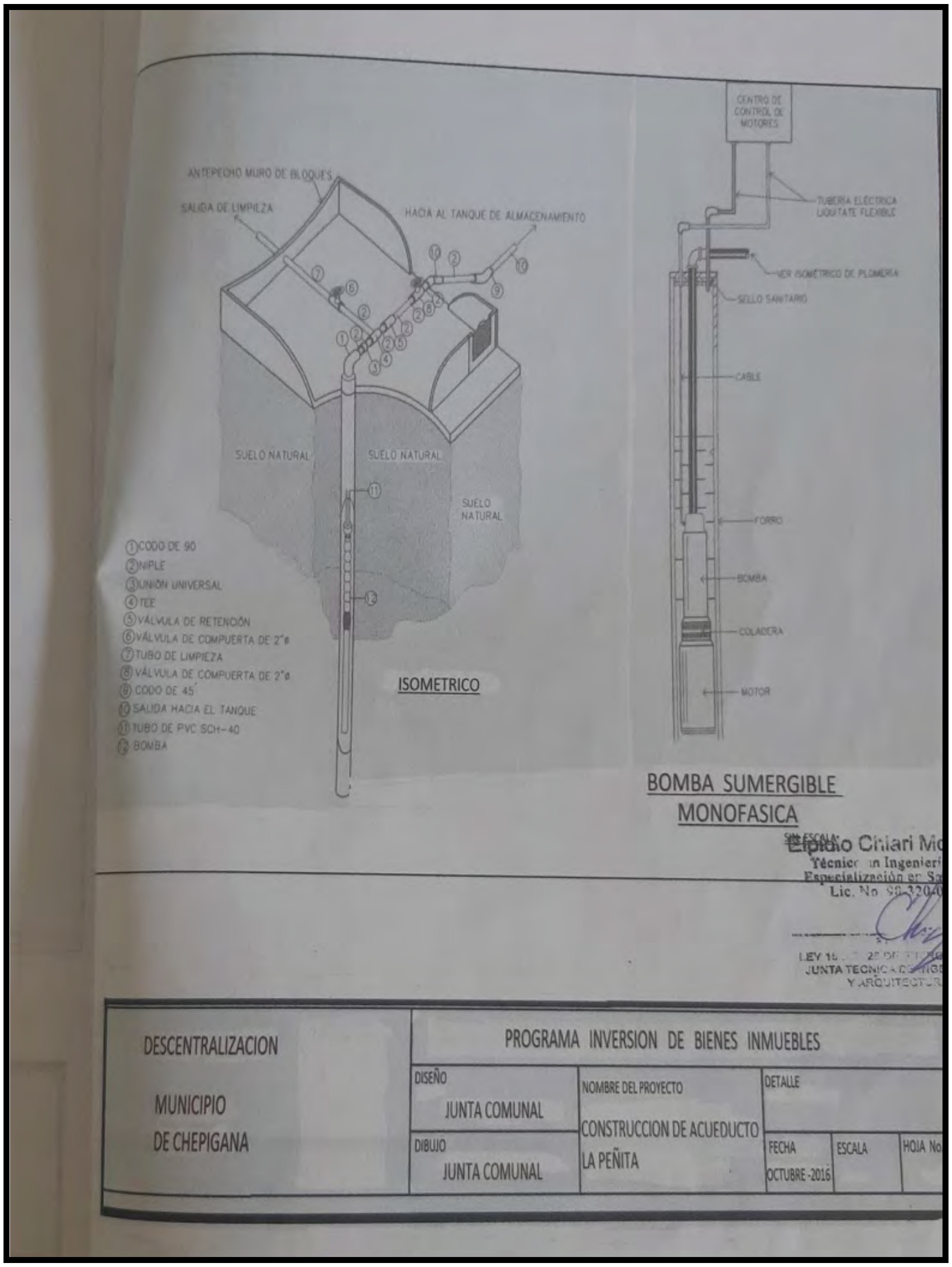

Figure B5. Single Phase Submersible Pump

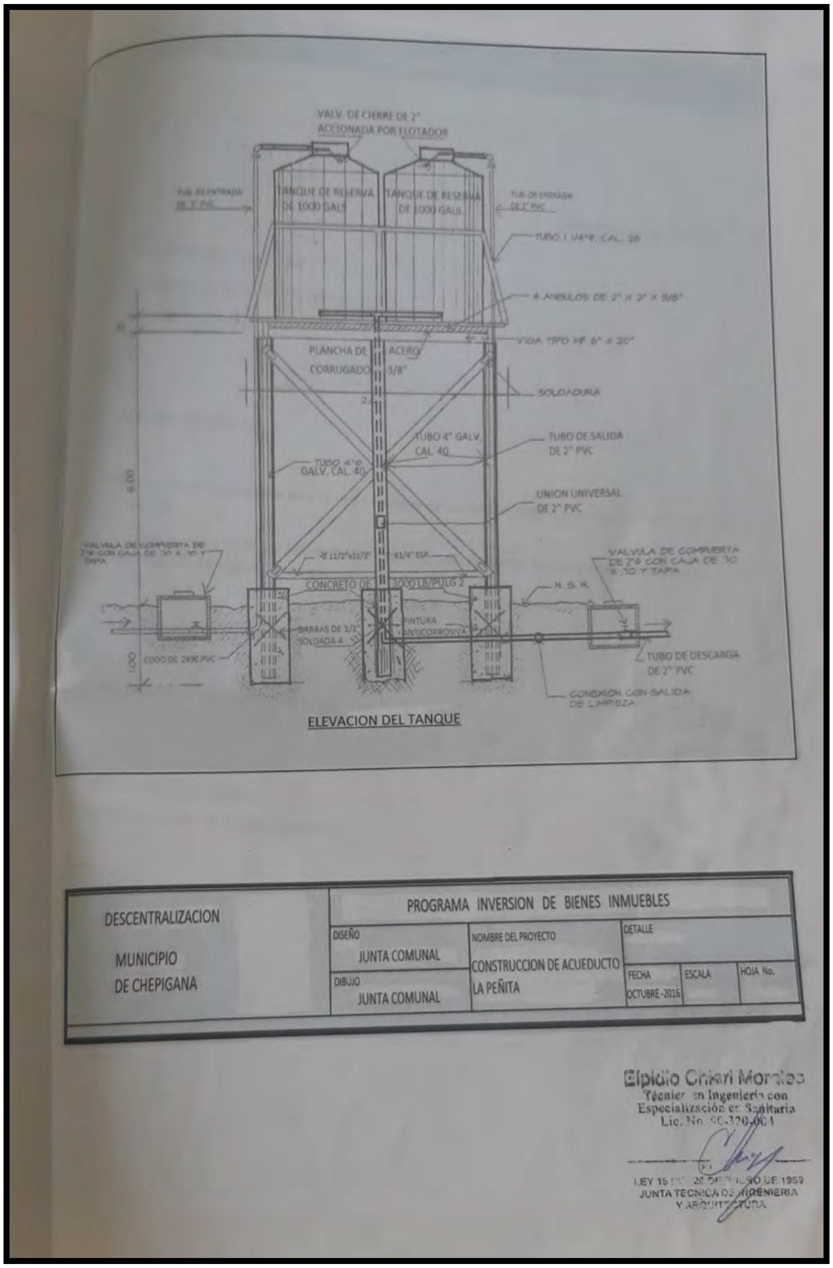

Figure B6. Water Storage Tanks Platform

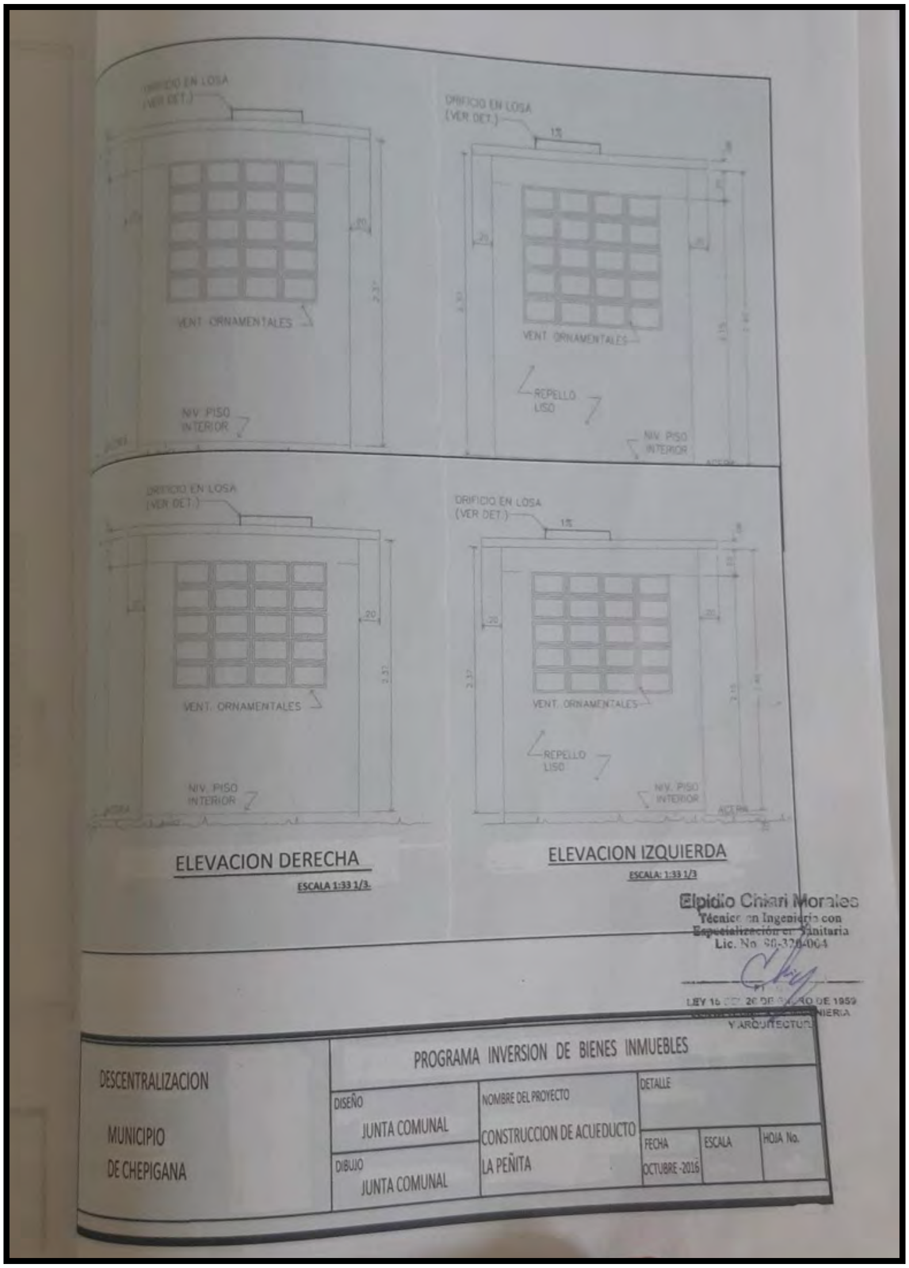

Figure B7. Control Booth Elevations

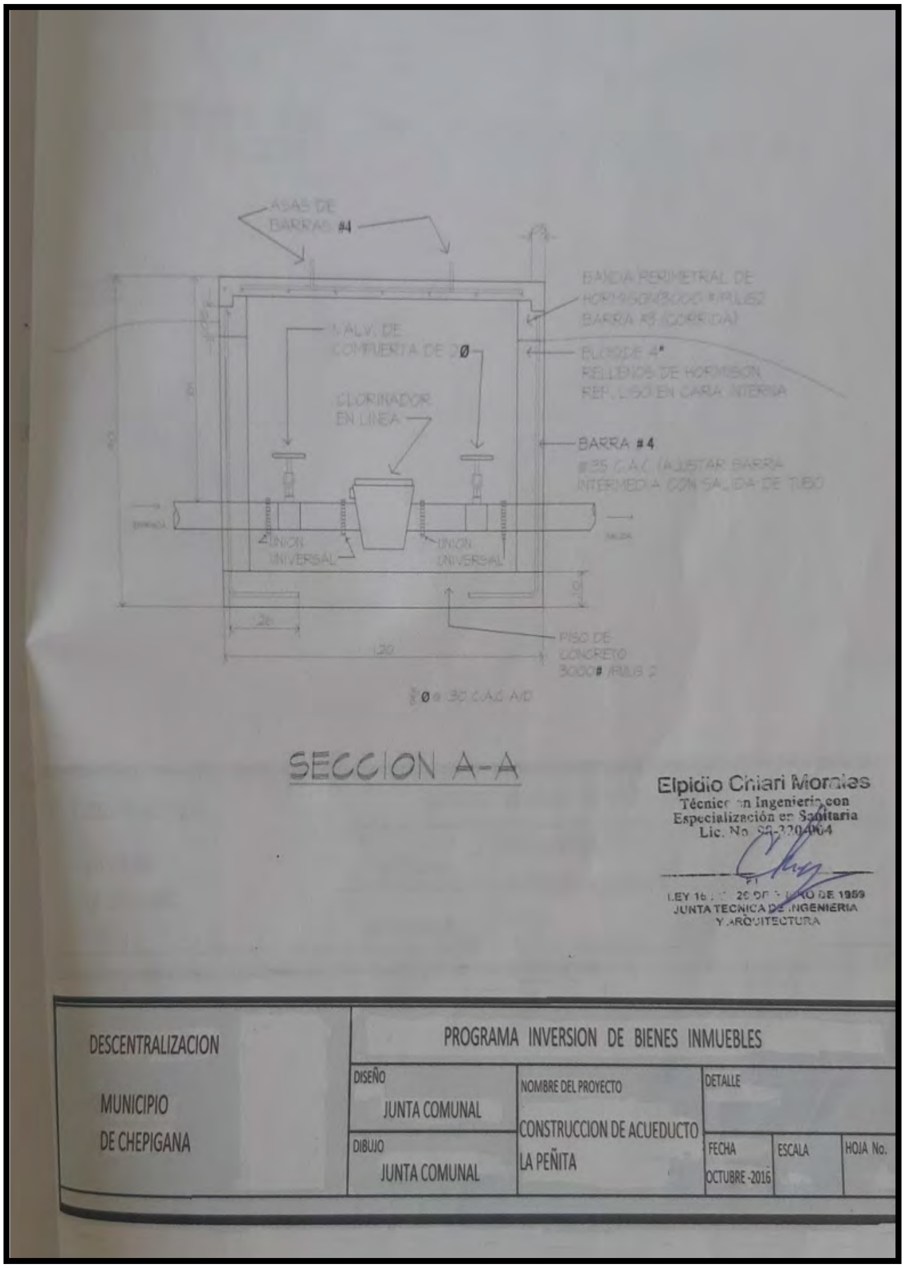

Figure B8. Chlorination System Within Storage Structure

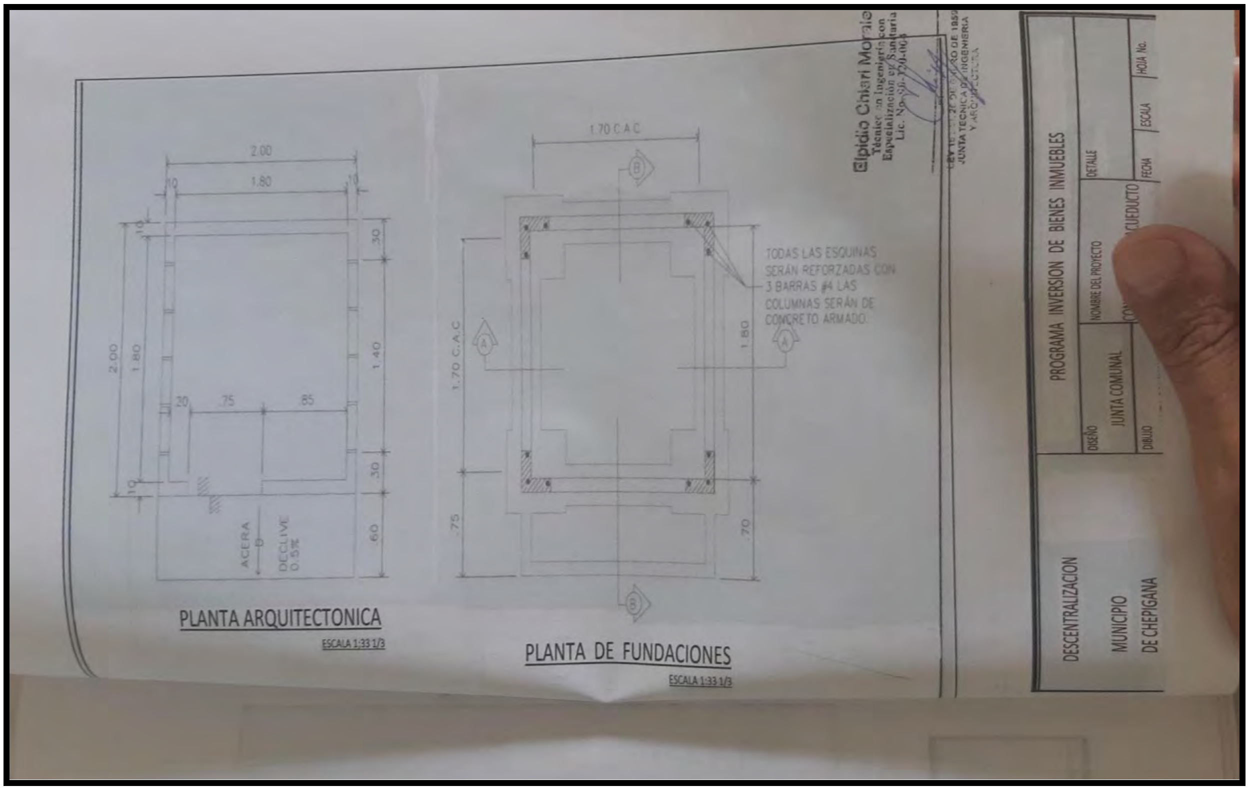

Figure B9. Architectural Plan

KSG WaterWays

Appendix C. Demographic Data

MTU expanded on the preliminary FPP demographic survey (Table C1). The survey results totaled to 161 residents, 99 adults and 62 children. The resulting average La Peñita household size is 3.31 people per home. The demographic data for five homes is missing from the survey. Therefore, as per the calculation below, the estimated total count of La Peñita residents is 177.

161+3.31*5=177 residents

A 20 year design life was considered for the La Peñita water distribution system. A population growth rate of 2% per year was factored in so that the system may continue to fulfill the community water demand throughout the design life of the system. Equation 1 is used to calculate the future community population.

$$Population = C_0(1+r)^n \quad (1)$$

$$C_0 = initial\ population$$

$$r = growth\ rate$$

$$n = time$$

The population of the community, as determined by the FPP and supplemental MTU demographic survey data, is 177. Therefore, $C_0 = 177$. A growth rate of 2% per year is to be considered, so $r = 0.02$, and a design life of 20 years is to be considered, so $n = 20$.

$$177\ people\ (1 + .02)^{20} = 263\ people \quad (1)$$

Based on the World Health Organization (WHO) recommendation and previous projects implemented in Panama, designing for a water demand of 21 gallons per capita per day is ideal.

$$263\ people \times \frac{21\ gallons}{person \cdot day} = 5,500\frac{gallons}{day}$$

WHO has a similar second computational method in which 21 gallons per capita per day is considered for adults and a lower demand of 16 gallons per capita per day is considered for children. According to the FPP and MTU data, of the 177 members of the community, 109 are adults and 68 are children.

$$109\ adults\ (1 + .02)^{20} = 162\ adults \quad (1)$$

$$68\ children\ (1 + .02)^{20} = 101\ children \quad (1)$$

$$162\ adults \times \frac{21\ gallons}{adult \cdot day} + 101\ children \times \frac{16\ gallons}{child \cdot day} = 5,000\ \frac{gallons}{day}$$

The second WHO design demand calculation result is lower than the $5,500 \frac{gallons}{day}$, at a volume of 5,000 $\frac{gallons}{day}$. The system was conservatively designed to sustain the higher $5,500\ \frac{gallon}{day}$ demand.

Table C1. La Peñita Demographic Data

FPP point	MTU point	Name	Adults	Children	Total
PL-1	208	Rodriguez Porfilio	3	1	4
PL-2	204	Asprilla Melida	2	0	2
PL-3	203	Rodriguez Arixa	1	1	2
PL-4	276	Olea Jorge	3	4	7
PL-5	2	Olea Cristino	3	2	5
PL-6	207	Daysel Deyaisa			
PL-7	205	Rodriguez Porfilio Hijo	1	0	1
PL-8	199	Rodriguez Nareth	2	0	2
PL-9	206	Ayala Jose			
PL-10	200	Morales Javier			
PL-11	348	Asprilla Maikel	2	4	6
PL-12	213	Tomasa Hilario	2	5	7
PL-13	212	Tomasa Plinio	2	2	4
PL-14	215	De Gracia Anatolio	1	0	1
PL-15	218	Cabrera Jose	3	0	3
PL-16	269	Asprilla Delis	1	0	1
PL-17	270	Asprilla Ana	3	0	3
PL-19	273	Vallesteros Ilberto	1	0	1
PL-20	221	Arauz Maida	2	1	3
PL-21	332	Moreno Emelinda	9	2	11

PL-22	239	Biquerra Pedro	1	0	1
PL-23	240	Rodriguez Lucy	2	2	4
PL-24	245	Marinez Alejandro	2	0	2
PL-25	247	Teucama Eida	2	0	2
PL-26	248	Corrales Gabriela	2	0	2
PL-27	250	Lino Mariela	2	2	4
PL-28	252	Bugama Bertalicio	2	3	5
PL-29	255	Contrera Alexander	2	6	8
PL-30	254	Contrera Serrano papa	1	2	3
PL-31	253	Tumasa Luis	2	0	2
PL-32		Chami Osiris	1	0	1
PL-33	243	Asprilla Pedro			
PL-34	242	Chami Irisaldo	2	1	3
PL-35	228	Barragona Julio	3	0	3
PL-36	227	Arrollo Cesar	2	4	6
PL-37	224	Valencia Elis	2	3	5
PL-38	231	Chajito Ivan	2	5	7
PL-39	239	Vallerino Mezua	2	0	2
PL-40	320	Vallestero Arsenio	1	3	4
A	211	Dumasa Jorge	1	0	1
B	318	Cabrera Marisol	1	3	4
C	223	Moises Gomez	2	0	2
D	229	Acosta Tomas	2	3	5
E	225	Contrera Yaneth	2	1	3
F	232	Gomez Sedon	1	0	1
G	235	Zamudio Elias	1	2	3
H	330	Snachez Joseph	4	0	4
I	272	Osmet Asprilla	1	0	1
J	246	Lino Teucama	2	0	2
K	337	Contrera Ludaris	1	0	1
L	258	Salazar Camilo	3	0	3
M	260	Store			
N	3	Olea Anilda	2	0	2
O	274	Miguel Mourusa	2	0	2

P	268	unknown			
Q	233	Church-2			
P-02	249	(EST-1(L)/ (Senafron/Military Trailer))			0
CR-1	277	Community Bank			0
CR-2	244	Military/Behind Vaccination Tent			0
ESC-1	220	School			0
IGL-1	226	Church-1			0

Appendix D. Summary of EPANet Inputs and Outputs

D1.0 EPANet Model Inputs

Table D1. EPANet Schematic Pipe Length, Diameter, and Roughness Inputs

Link ID	Length (ft)	Diameter (in)	Roughness
Pipe 3	75	0.5	150
Pipe 5	25	1	150
Pipe 21	24.6	0.5	150
Pipe 22	29.4	0.5	150
Pipe 24	34.3	0.5	150
Pipe 28	31.7	0.5	150
Pipe 30	25	0.5	150
Pipe 31	31	0.5	150
Pipe 34	20	2	150
Pipe 15	57	0.5	150
Pipe 27	38	0.5	150
Pipe 29	63	0.5	150
Pipe 37	68	0.5	150
Pipe 38	35	0.5	150
Pipe 41	13	0.5	150
Pipe 44	42	0.5	150
Pipe 45	64	0.5	150
Pipe 46	38	0.5	150
Pipe 47	49.5	0.5	150
Pipe 48	50	0.5	150
Pipe 49	25	0.5	150
Pipe 50	32	0.5	150
Pipe 52	71	0.5	100
Pipe 53	45	0.5	150
Pipe 56	21	0.5	150
Pipe 58	70	0.5	150
Pipe 59	64	0.5	150
Pipe 60	22	0.5	150
Pipe 64	50	1	150
Pipe 67	20	1	150

Pipe 69	28	1	150
Pipe 80	47	1	150
Pipe 83	30	1	150
Pipe 87	5	1	150
Pipe 88	40	1	150
Pipe 92	46	1	150
Pipe 93	73	1	150
Pipe 81	35	1	150
Pipe 96	12	1	150
Pipe 98	55	1	150
Pipe 99	28	1	150
Pipe 100	32	1	150
Pipe 101	100	0.5	150
Pipe 103	10	1	150
Pipe 104	16	0.5	150
Pipe 105	95	1	150
Pipe 106	33	1	150
Pipe 107	80	1	150
Pipe 108	26	0.5	150
Pipe 109	60	1	150
Pipe 6	44	1	150
Pipe 25	130	1	150
Pipe 26	36	1	150
Pipe 32	30	1	150
Pipe 11	92	0.5	150
Pipe 277	57	0.5	150
Pipe 63	36	0.5	150
Pipe 68	50	1	150
Pipe 74	21	0.5	150
Pipe 79	39	0.5	150
Pipe 102	100	1	150
Pipe 110	104	0.5	150
Pipe 111	89	0.5	150
Pipe 61	22	0.5	150

Pipe 130	54	0.5	150
Pipe 131	60	0.5	150
Pipe 132	55	0.5	150
Pipe 136	47	0.5	150
Pipe 137	49	0.5	150
Pipe 138	53	0.5	150
Pipe 13	24	1	150
Pipe 17	26	1	150
Pipe 18	46	0.5	150
Pipe 20	55	1	150
Pipe 23	41	0.5	150
Pipe 42	40	1	150
Pipe 51	70	1	150
Pipe 54	18	1	150
Pipe 55	64	0.5	150
Pipe 82	5	1	150
Pipe 139	47	0.5	150
Pipe 143	63	1	150
Pipe 145	15	1	150
Pipe 147	61	0.5	150
Pipe 148	104	0.5	150
Pipe 149	82	1	150
Pipe 150	42	1	150
Pipe 152	44	1	150
Pipe 153	25	1	150
Pipe 154	30	0.5	150
Pipe 155	35	1	150
Pipe 156	37	1	150
Pipe 157	37	1	150
Pipe 158	32	1	150
Pipe 159	30	0.5	150
Pipe 160	72	0.2	150
Pipe 161	32	0.5	150
Pipe 163	64	1	150

Pipe 164	15	1	150
Pipe 165	50	1	150
Pipe 166	112	0.5	150
Pipe 167	62	1	150
Pipe 168	43	1	150
Pipe 169	35	0.5	150
Pipe 170	40	1	150
Pipe 171	86	1	150
Pipe 172	35	1	150
Pipe rdschool220	38.4	0.5	150
Pipe 173	25	1	150
Pipe 174	25	1	150
Pipe 176	1000	1	150
Pipe 178	95	0.5	150
Pipe 184	63	0.5	150
Pipe 185	58	1	150
Pipe 187	100	0.5	150
Pipe 189	60	1	150
Pipe 190	116	1	150
Pipe 1	50	1	150
Pipe 4	10	1	150
Pipe 7	57	0.5	150
Pipe 16	100	1	150
Pipe 19	102	1	150
Pipe 12	80	0.5	150
Pipe 39	65	0.5	150
Pipe 8	180	1	150
Pipe 40	20	1	150
Pipe 43	110	1	150
Pipe 62	75	1	150
Pipe 2	50	2	150
Pipe 9	19	2	150
Pipe 10	23	2	150

Pipe 33	26	2	150
Pipe 57	85	2	150
Pipe 65	229	2	150
Pipe 66	180	2	150
Pipe 70	110	2	150
Pipe 71	100	2	150
Pipe 72	50	2	150

Table D2. Node Elevations and Base Demands

Node ID	Elevation (ft)	Base Demand (GPM)
Junc 273	33.5	0.015
Junc 276	33	0.105
Junc 2-271	28.5	0.075
Junc 272	26.5	0.015
Junc 205	31	0.015
Junc 203	32	0.03
Junc 204	32	0.03
Junc 200	25	0.06
Junc 206	25	0.06
Junc 199	31.8	0.03
Junc 207	27.5	0.06
Junc 208	27.5	0.06
Junc 270	26.5	0.045
Junc 269	26.5	0.015
Junc bank	32	0.15
Junc 210	31.5	0.09
Junc 213	24.5	0.105
Junc 215	30.5	0.015
Junc 218	30	3
Junc school	32	0.465
Junc 2266	23.5	0
Junc rd3	16.5	0
Junc rd5	16.5	0
Junc rd6	22	0

Junc 1799	25	0
Junc rd207208	17.5	0
Junc rd206	15	0
Junc 2366	15	0
Junc 11	22	0
Junc 12	21	0
Junc 221	37	0.045
Junc 240	32.7	0.06
Junc 245	33.5	0.03
Junc 248	24.5	0.03
Junc 250	26.5	0.06
Junc 257	21	0.045
Junc 239	32.7	0.045
Junc 243	30	0.06
Junc 242	30	0.045
Junc 223	29.5	0.03
Junc 224	30	0.075
Junc 225	31	0.045
Junc 229	33	0.075
Junc 231	33	0.105
Junc church2.233	29	1.125
Junc 1899	16.5	0
Junc 1900	16.7	0
Junc vac.clinic	32.5	0.75
Junc 2111	21	0
Junc 2099	16.5	0
Junc 2100	14.5	0
Junc 2088	14.5	0
Junc 2044	20	0
Junc 20444	20	0
Junc 234	26.5	0.06
Junc 235	26.7	0.045
Junc rd229231	23	0

Junc 1844	21	0
Junc rd224	20	0
Junc 1833	19.5	0
Junc 1966	27	0
Junc 2011	22.7	0
Junc 2700	22.5	0
Junc 2022	22.7	0
Junc 2711	23.5	0
Junc rdchurch2	19	0
Junc 1788	20	0
Junc rd215	16.5	0
Junc rd213	14.5	0
Junc 1588	21.5	0
Junc 211	32.43	1
Junc 2544	22.43	0
Junc 212	32.25	4
Junc 2555	22.25	0
Junc riversedge	6.52	0
Junc tankplatformground	24	0
Junc 232	30	0.015
Junc intersection185	22	0
Junc 5	23	0
Junc rd210	21.5	0
Junc 217	29.5	0.06
Junc 1777	19.5	0
Junc 182	18	0
Junc 187	25	0
Junc church1.226	30.5	1.125
Junc 2188	20	0
Junc senafront249	30	0.18

Junc 247	23	0.03
Junc 2199	13	0
Junc 268	10	0.045
Junc 15	21	0
Junc 16	20.69	0
Junc 19	9	0
Junc 20	13	0
Junc 21	40.44	0
Junc 22	12.28	0
Junc 23	10.7	0
Junc 24	11.47	0
Junc 41	11.35	0
Junc 258	31	0.045
Junc 260	31	0.06
Junc 259	24	0.045
Junc 253	24.5	0.03
Junc 256	24	0.045
Junc 254	24.5	0.045
Junc 2177	22.92	0
Junc 220	0	0
Junc 2077	20.5	0
Junc 246	30.5	0.03
Junc 2000	22.7	0
Junc 189	18	0
Junc 190	18	0
Junc 227	28	0.09
Junc 228	28	0.045
Junc 2033	22.7	0
Junc 241	32.7	0.045
Junc 237	37	0.06
Junc 236	37	0.165
Junc 238	37	0.06
Junc rd237	27	0
Junc rd236	27	0

Junc rd238	27	0
Junc 53	20.5	0
Junc 54	21.8	0
Junc 55	22	0
Junc rd219	17	0
Junc rd209	19	0
Junc 209	19	0.06
Junc 60	16.5	0
Junc 2255	18.5	0
Junc 21000	14.5	0
Junc 252	24.5	0.075
Junc 191	19	0
Junc 320	32	0.06
Junc 33	24.5	0.03
Junc 1	16.5	0
Resvr river	4	#N/A
Tank tank	44	#N/A

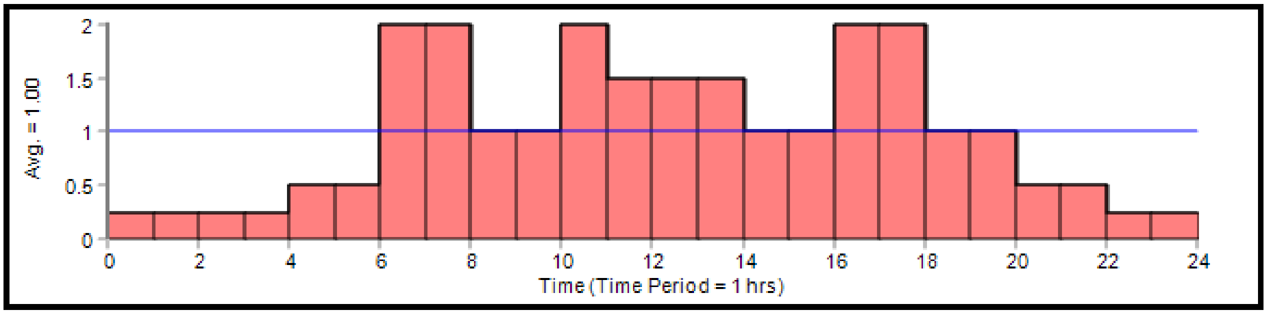

Figure D1. Home Demand Pattern

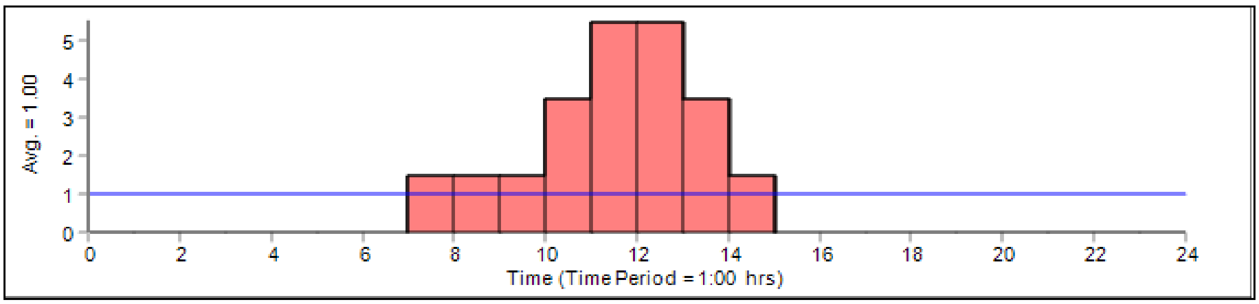

Figure D2. School Demand Pattern

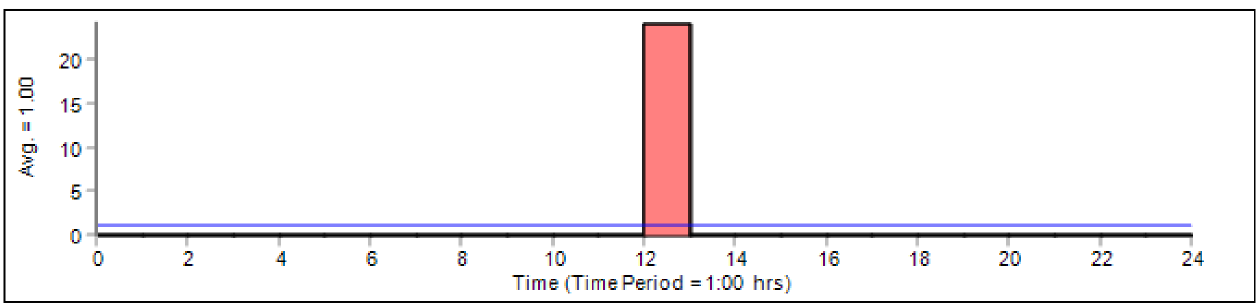

Figure D3. Bank Demand Pattern

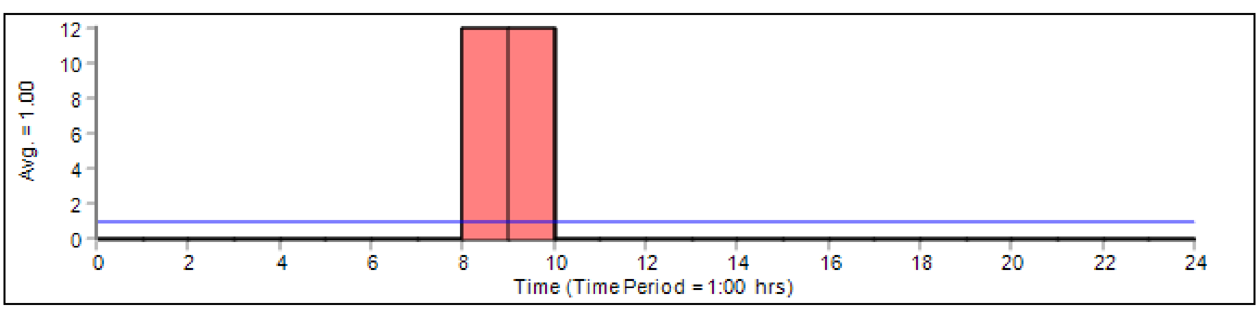

Figure D4. Church Demand Pattern

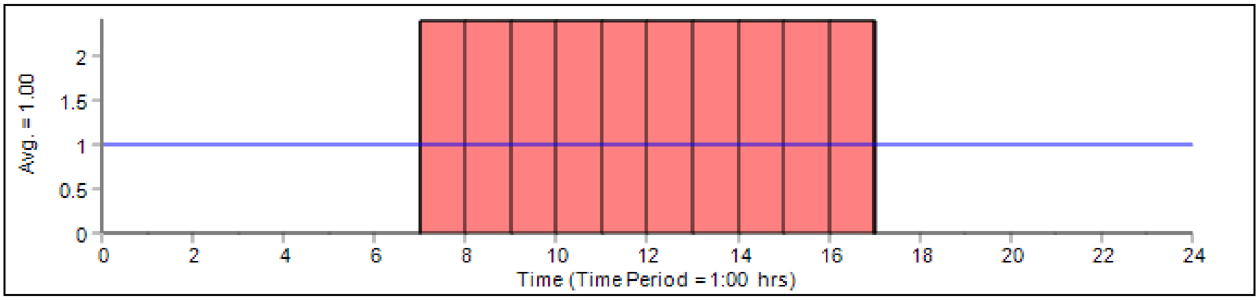

Figure D5. Clinic Demand Pattern

The following plot was used to find the pressure loss (psi) through the filter when the water is filling the tank at 25 GPM. The loss coefficient was calculated based on the following equation (D.1).

$$H_L = K\,\frac{V^2}{2g} \tag{D.1}$$

$$\frac{0.5psi}{0.43psi/ft} = K\,\frac{(2.14\,ft/s)^2}{2(\frac{32.2ft}{s^2})}$$

$$K = 16.35$$

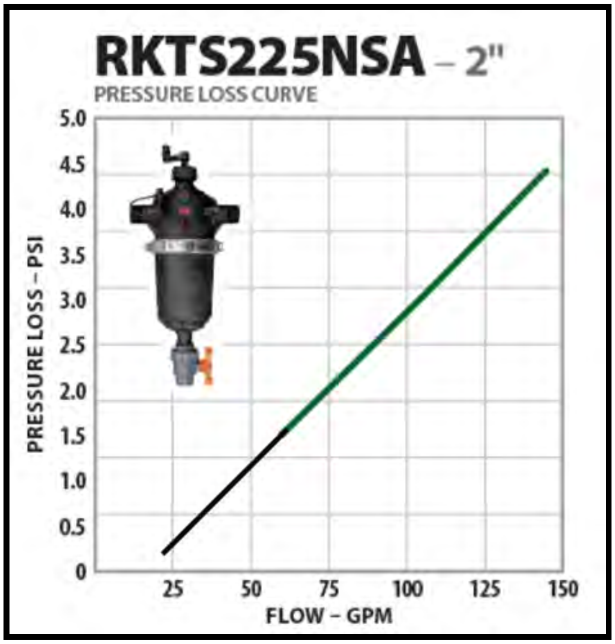

Figure D6. Pressure Loss Curve [5]

D2.0 EPANet Model Outputs

Table D3. Node Pressures at 12:00 (peak usage)

Node ID	Pressure (psi)
Junc 273	0.87
Junc 276	4.17
Junc 2-271	3.04
Junc 272	3.86
Junc 205	5.07
Junc 203	4.64
Junc 204	4.64
Junc 200	7.67
Junc 206	7.51
Junc 199	4.88
Junc 207	6.29
Junc 208	6.29
Junc 270	3.74
Junc 269	3.63
Junc bank	0.01
Junc 210	5.08
Junc 213	6.65
Junc 215	3.64
Junc 218	0.05
Junc school	0.03
Junc 2266	5.2
Junc rd3	8.08
Junc rd5	7.97
Junc rd6	5.54
Junc 1799	4.21
Junc rd207208	10.63
Junc rd206	11.85
Junc 2366	12.01
Junc 11	8.97
Junc 12	9.41

Junc 221	-1.58
Junc 240	0.1
Junc 245	-0.28
Junc 248	3.56
Junc 250	2.68
Junc 257	4.98
Junc 239	0.1
Junc 243	1.26
Junc 242	1.26
Junc 223	1.63
Junc 224	1.39
Junc 225	0.92
Junc 229	0.03
Junc 231	0.02
Junc church2.233	1.74
Junc 1899	7.15
Junc 1900	7.05
Junc vac.clinic	0.01
Junc 2111	5.05
Junc 2099	7.02
Junc 2100	7.87
Junc 2088	7.9
Junc 2044	5.6
Junc 20444	5.6
Junc 234	2.79
Junc 235	2.71
Junc rd229231	4.36
Junc 1844	5.26
Junc rd224	5.73
Junc 1833	5.97
Junc 1966	2.75
Junc 2011	4.43
Junc 2700	4.51

Junc 2022	4.43
Junc 2711	4.05
Junc rdchurch2	6.08
Junc 1788	6.56
Junc rd215	9.71
Junc rd213	10.99
Junc 1588	9.58
Junc 211	3.65
Junc 2544	9.82
Junc 212	0.02
Junc 2555	9.75
Junc riversedge	18.54
Junc tankplatformground	10.97
Junc 232	1.3
Junc intersection185	4.79
Junc 5	8.54
Junc rd210	9.42
Junc 217	3.59
Junc 1777	7.92
Junc 182	6.71
Junc 187	3.49
Junc church1.226	1.17
Junc 2188	5.52
Junc senafront249	1.16
Junc 247	4.22
Junc 2199	8.55
Junc 268	9.85
Junc 15	12.27
Junc 16	12.4
Junc 19	17.47

Junc 20	15.73
Junc 21	3.84
Junc 22	16.05
Junc 23	16.73
Junc 24	16.4
Junc 41	16.45
Junc 258	0.63
Junc 260	0.64
Junc 259	3.66
Junc 253	3.52
Junc 256	3.73
Junc 254	3.51
Junc 2177	4.26
Junc 220	14.19
Junc 2077	5.34
Junc 246	1.01
Junc 2000	4.44
Junc 189	6.48
Junc 190	6.48
Junc 227	2.13
Junc 228	2.14
Junc 2033	4.43
Junc 241	0.09
Junc 237	-1.63
Junc 236	-1.67
Junc 238	-1.72
Junc rd237	2.71
Junc rd236	2.66
Junc rd238	2.61
Junc 53	5.5
Junc 54	9.22
Junc 55	5.27
Junc rd219	10.91
Junc rd209	7.56

Junc 209	7.55
Junc 60	8.2
Junc 2255	7.37
Junc 21000	7.87
Junc 252	3.53
Junc 191	6.04
Junc 320	0.42
Junc 33	3.54
Junc 1	8.24
Resvr river	0
Tank tank	2.3

Table D4. Pipe Flows at 12:00 (peak usage)

Link ID	Flow (GPM)
Pipe 3	0.02
Pipe 5	-2.22
Pipe 21	0.09
Pipe 22	0.09
Pipe 24	0.09
Pipe 28	0.09
Pipe 30	0.05
Pipe 31	0.05
Pipe 34	0
Pipe 15	0.29
Pipe 27	0.09
Pipe 29	0.05
Pipe 37	0.09
Pipe 38	-0.07
Pipe 41	0.07
Pipe 44	0
Pipe 45	0
Pipe 46	0.05
Pipe 47	0.11
Pipe 48	0.07

Pipe 49	0.11
Pipe 50	0.16
Pipe 52	0.09
Pipe 53	0.07
Pipe 56	0.16
Pipe 58	1.5
Pipe 59	2.82
Pipe 60	3.08
Pipe 64	2.82
Pipe 67	10.34
Pipe 69	6.81
Pipe 80	-0.69
Pipe 83	-0.04
Pipe 87	1.76
Pipe 88	1.19
Pipe 92	0.72
Pipe 93	0.63
Pipe 81	1.25
Pipe 96	-0.26
Pipe 98	-2.83
Pipe 99	0.27
Pipe 100	0.18
Pipe 101	0.16
Pipe 103	7.1
Pipe 104	0.14
Pipe 105	6.97
Pipe 106	6.79
Pipe 107	6.7
Pipe 108	0.09
Pipe 109	2.25
Pipe 6	-1.81
Pipe 25	1.29
Pipe 26	0.8
Pipe 32	14.66

Pipe 11	0.02
Pipe 277	1.33
Pipe 63	0.02
Pipe 68	0.02
Pipe 74	0.02
Pipe 79	0.56
Pipe 102	0.11
Pipe 110	0.11
Pipe 111	0
Pipe 61	0.27
Pipe 130	0.14
Pipe 131	0.09
Pipe 132	0.07
Pipe 136	0.18
Pipe 137	0.07
Pipe 138	0.07
Pipe 13	-0.77
Pipe 17	0.38
Pipe 18	0.05
Pipe 20	0.07
Pipe 23	0.07
Pipe 42	0.11
Pipe 51	-1.15
Pipe 54	-1.19
Pipe 55	0.05
Pipe 82	1.72
Pipe 139	0.09
Pipe 143	0.69
Pipe 145	0.39
Pipe 147	0.14
Pipe 148	0.07
Pipe 149	0.6
Pipe 150	0.53
Pipe 152	-0.1

Pipe 153	-0.17
Pipe 154	0.07
Pipe 155	1.81
Pipe 156	1.81
Pipe 157	1.81
Pipe 158	1.81
Pipe 159	0
Pipe 160	0
Pipe 161	0
Pipe 163	1.07
Pipe 164	1.14
Pipe 165	1.14
Pipe 166	0
Pipe 167	3.24
Pipe 168	3.19
Pipe 169	0.05
Pipe 170	-3.62
Pipe 171	-3.1
Pipe 172	-4.52
Pipe rdschool220	1.42
Pipe 173	2.74
Pipe 174	2.74
Pipe 176	2.56
Pipe 178	0.09
Pipe 184	0.07
Pipe 185	-2.31
Pipe 187	0.02
Pipe 189	0.02
Pipe 190	0.11
Pipe 1	-0.29
Pipe 4	-0.45
Pipe 7	0.11
Pipe 16	-0.33

Pipe 19	-0.33
Pipe 12	0.09
Pipe 39	0.05
Pipe 8	2.47
Pipe 40	2.34
Pipe 43	0.14
Pipe 62	0.9
Pipe 2	0
Pipe 9	0
Pipe 10	0
Pipe 33	0
Pipe 57	0
Pipe 65	0
Pipe 66	0
Pipe 70	0
Pipe 71	0
Pipe 72	0

Appendix E. Pumping Cost Calculations

Pumping per day:

$$5,500\frac{gal}{day} \times \frac{1\ min}{20\ gal} \times \frac{1\ hr}{60\ min} = 4.6\frac{hr}{day}$$

Annual power usage assuming 50% efficiency:

$$4.6\frac{hr}{day} \times 1.5\ hp \times \frac{745.7\ W}{1\ hp} \times \frac{1\ kW}{1{,}000\ W} \times 365\ day \times 2 = 3,742\ kW * h$$

Annual cost:

$$3,742\ kW * h \times \frac{\$0.17}{1\ kW * h} = \$640$$

Appendix F. Chlorine Dose, Detention Time, and Chlorine Contact Time Calculations

The following detention time was calculated based on a 2,000 gallon tank.

$$detention\ time,\ min = \frac{tank\ volume,\ gal}{flow\ rate,\ gpm}$$

$$detention\ time,\ min = \frac{\Pi r^2 h}{flow\ rate}$$

$$detention\ time,\ min = \frac{\Pi(7.5/2ft)^2(6\ ft)*7.5gal/ft^3}{20.16\ gpm}$$

$$detention\ time,\ min = 98.6\ min$$

The following contact time was calculated based on a 0.3 baffling factor.

$$contact\ time\ =\ detention\ time\ *\ baffling\ factor$$

$$contact\ time\ =\ 98.6\ min\ *\ 0.3$$

$$contact\ time\ =\ 29.6\ min$$

The following contact time calculation (CT calc) was determined based on the previous results and an expected concentration of free chlorine to be 2mg/L [6]. It is recommended that expected free chlorine concentration is tested in the field and reevaluated if necessary.

$$CT\ calc\ =\ concentration\ of\ free\ chlorine\ *\ contact\ time$$

$$CT\ calc\ =\ 2\frac{mg}{L} * 29.6\ min$$

$$CT\ calc\ =\ 59.2\ \frac{mg-min}{L}\ >\ 15\ \frac{mg-min}{L}$$

Appendix G: Cost Estimate

Table G1. Project Cost Breakdown

Item	Units	Quantity	Unit Price	Total Cost	Additional Comments
TRUNK LINES					
1" PVC pipe	each	230	7	1610	SDR-21, 20' length
PVC primer	each	9	6	54	8 oz can
PVC glue	each	9	4.25	38.25	8 oz can
1" PVC ball valve	each	13	7.75	100.75	
BUILDING CONNECTIONS					
1"x1"x1" PVC tee connection	each	52	2.25	117	
1-1/2" PVC reducer	each	52	1.25	65	
1/2" PVC pipe	each	177	4.5	796.5	SDR-40, 20' length
1/2" PVC 90 deg elbow	each	60	0.5	30	
3/4" galvanized metal pipe strap	roll	3	18.25	54.75	100' length
#12-1/2x2" Galvanized Steel Nails	box	1	5	5	#12-1/2 x 2 in. 6-Penny Hot-Galvanized Steel Nails (1 lb.-Pack=236 nails)
1/2" ball valve handle spigot	each	60	8.75	525	
TANK ROOF					
Zinc roof panel	each	33	30	990	2' x 4' panels= 8 sft
Metal Poles	each	3	170	510	20' Lengths
Metal Studs	each	29	10	290	12' Lengths
Nail Anchors	each	1	30	30	50 per box
Soft metal shields	each	1	30	30	50 per box
Concrete screw	each	1	30	30	75 per box
Post Bracket	each	7	30	210	
Sheet metal	each	6	22	132	For gusset plates, 2'x3'
Self-tapping screws	each	1	45	45	80 per box
Gravel	bag	35	3	105	0.5cft/bag
METERING					
Water meter	each	60	55	3300	1/2" NPT connection size
Water meter box	each	60	41	2460	14in. x 19in. x 12in.
1/2" ball valve	each	180	1.5	270	
1/2" PVC female adapter	each	120	0.5	60	SDR-40
1/2"x1/2"x1/2" PVC tee connection	each	120	0.75	90	SDR-40
1/2" PVC 90 deg elbow	each	120	0.5	60	SDR-40
Zip Ties	bag	3	14	42	7.2mm. x 18in.
Teflon tape	roll	10	3	30	1/2in. x 520in.

Note: 10% contingency is built for each material

Appendix H: Operations and Maintenance Recommendations

I1.0 Operations

Annual pump costs are anticipated to be about $640. Annual water treatment costs are estimated to be $110. For water filtration, three chlorine tablets will be added every 1 to 2 weeks for proper disinfection. The water filter will need to be backwashed once every 3 to 5 weeks and replacement of the media should be done once per year approximately. The community should be prepared for additional intermittent maintenance costs as the system will require repair on occasion. KSG WaterWays recommends the La Peñita water committee collect fees according to water usage, as recorded by the water meters, to cover the operating and maintenance costs.

I1.2 Maintenance

If one or more homes is not receiving water there may be a break in the PVC line. The pipe leading up to the first home without water will need to be dug up to identify the location of the break in the line. The water to that line may then be turned off by closing the nearest upstream trunkline valve. Once the water supply is shut off to the affected area, the section of broken line will be cut out and replaced using the appropriate adapters, primer, and glue. Before backfilling, the valves should be opened, allowing the water to flow, to make sure the system is operating properly. Upon confirmation that the leak has been successfully repaired, the trench may be backfilled. Finally, the system should be flushed to evacuate any contaminants that entered while the system was under maintenance. All valves that have not been used in a month should be turned at least once per month to prevent any future additional maintenance and plumbing issues.

Water quality will need to be monitored at all times at each house. Any presence of solids, high turbidity, change in color and even strong chlorine odors are signs of poor water quality. Immediately, the water has to be tested and analyzed before continuing to drink. If a pressure drop is detected across the system, the operation of the backwash filter needs to be verified. A pressure drop can imply a saturation of the filter media and therefore, the filter needs to be properly backwashed to have a regular operation. If bacteria is found in the water reaching the houses, shocking the system with household bleach is recommended to kill bacteria and eliminate any buildup material inside the piping network.

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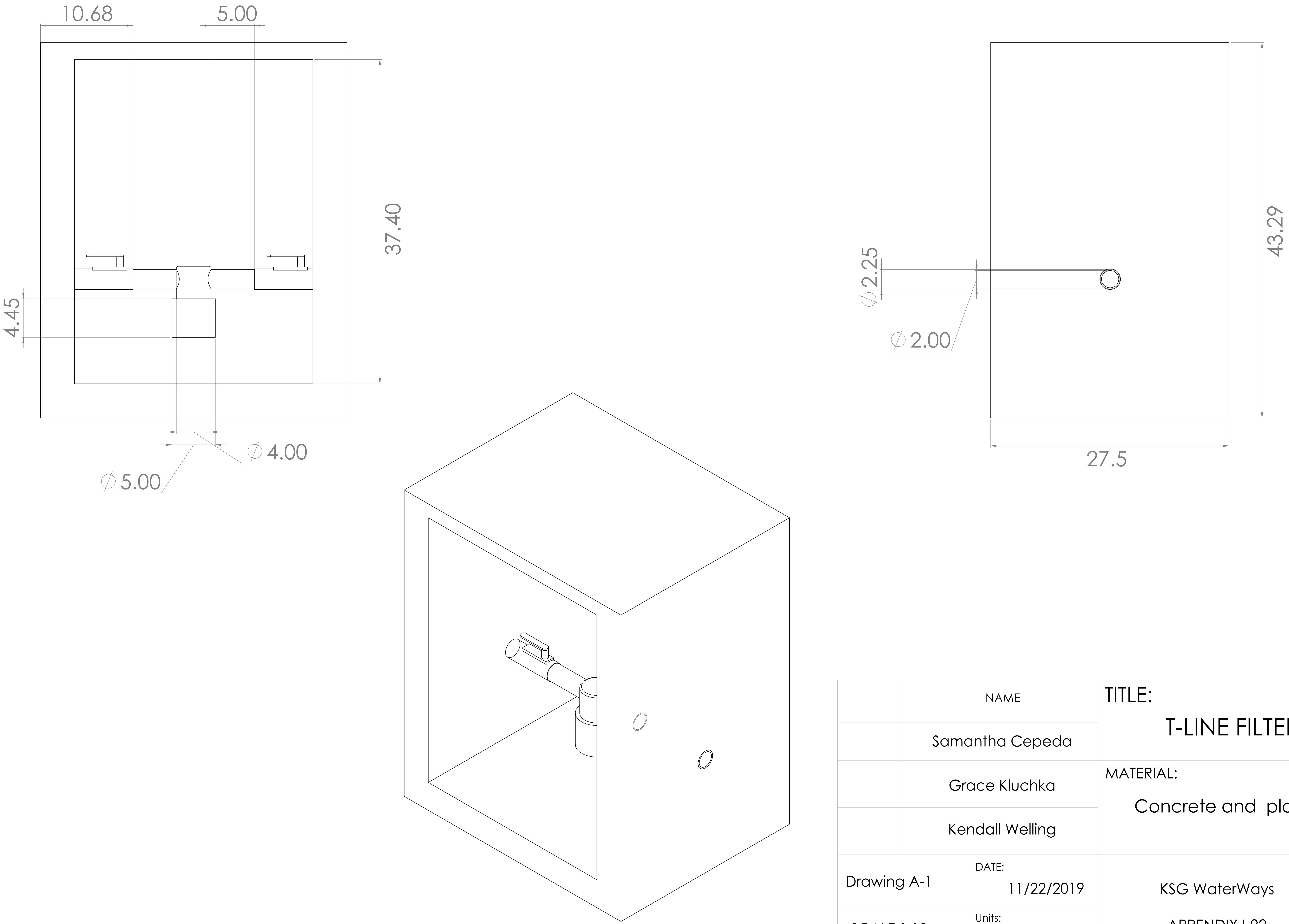
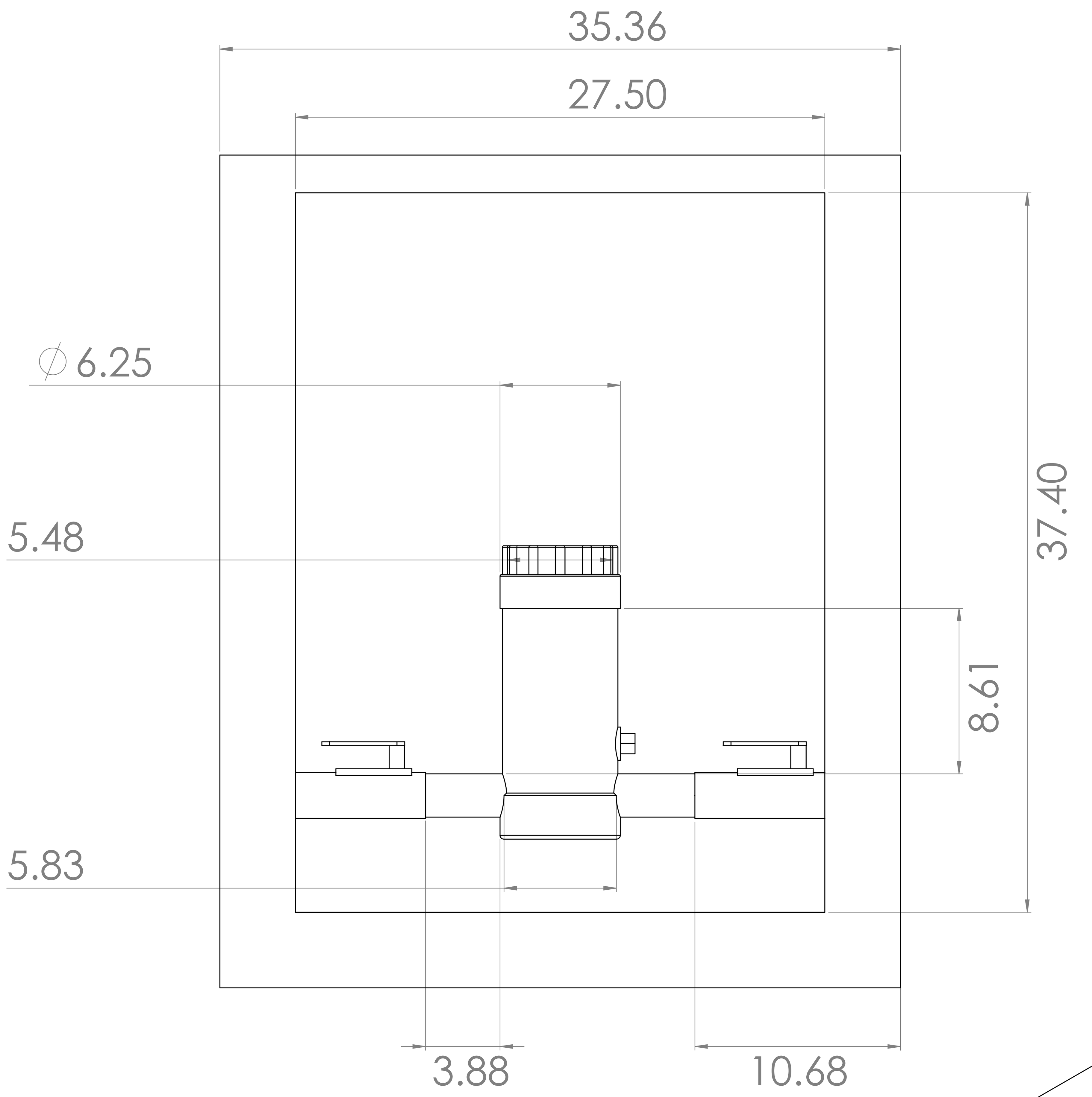
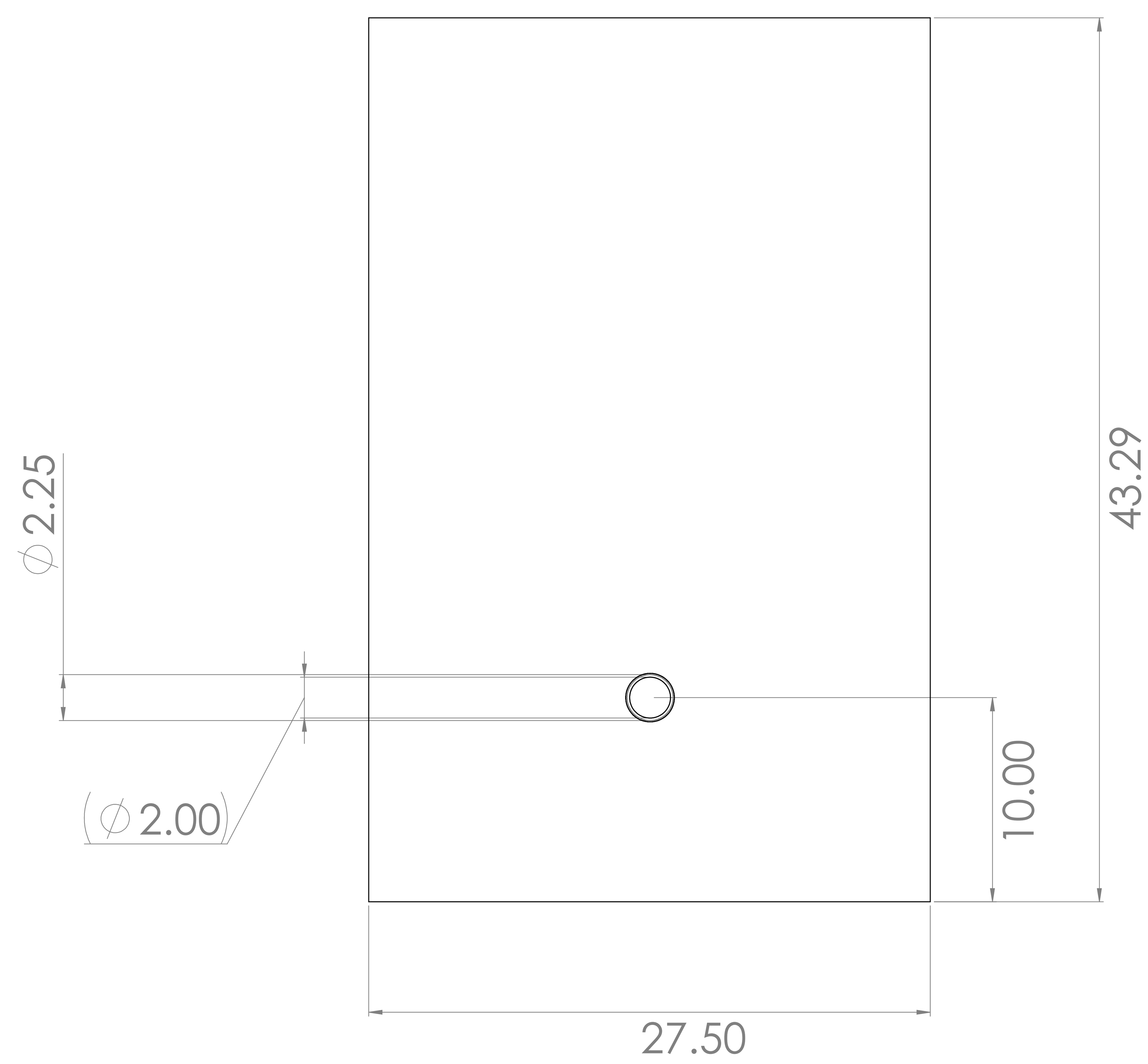
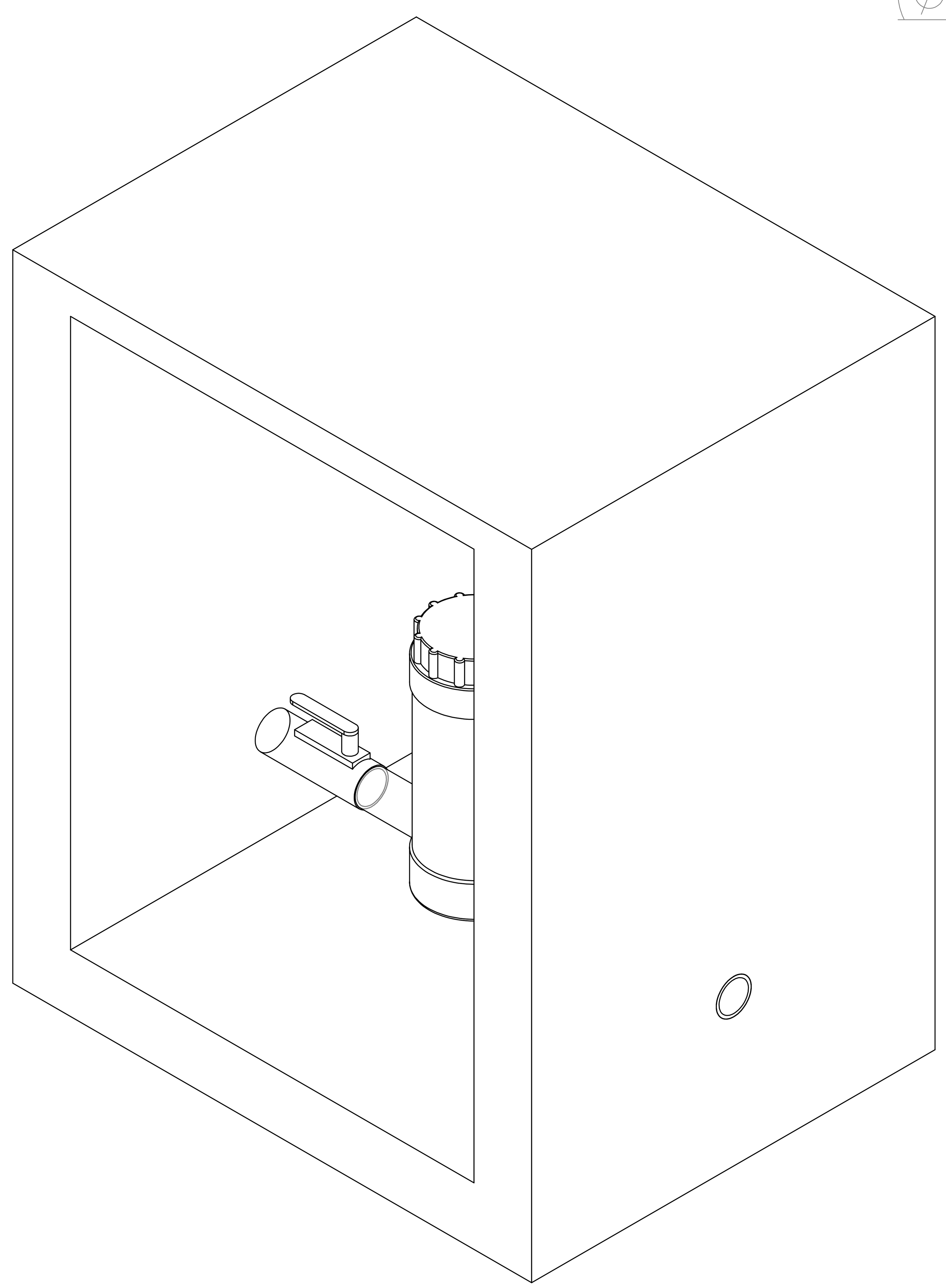
Appendix I. T-Line Filter and In-Line Chlorinator Drawings



	NAME	TITLE: T-LINE FILTER
	Samantha Cepeda	
	Grace Kluchka	MATERIAL: Concrete and plastic
	Kendall Welling	
Drawing A-1	DATE: 11/22/2019	KSG WaterWays
SCALE:1:10	Units: Inches	APPENDIX I-92



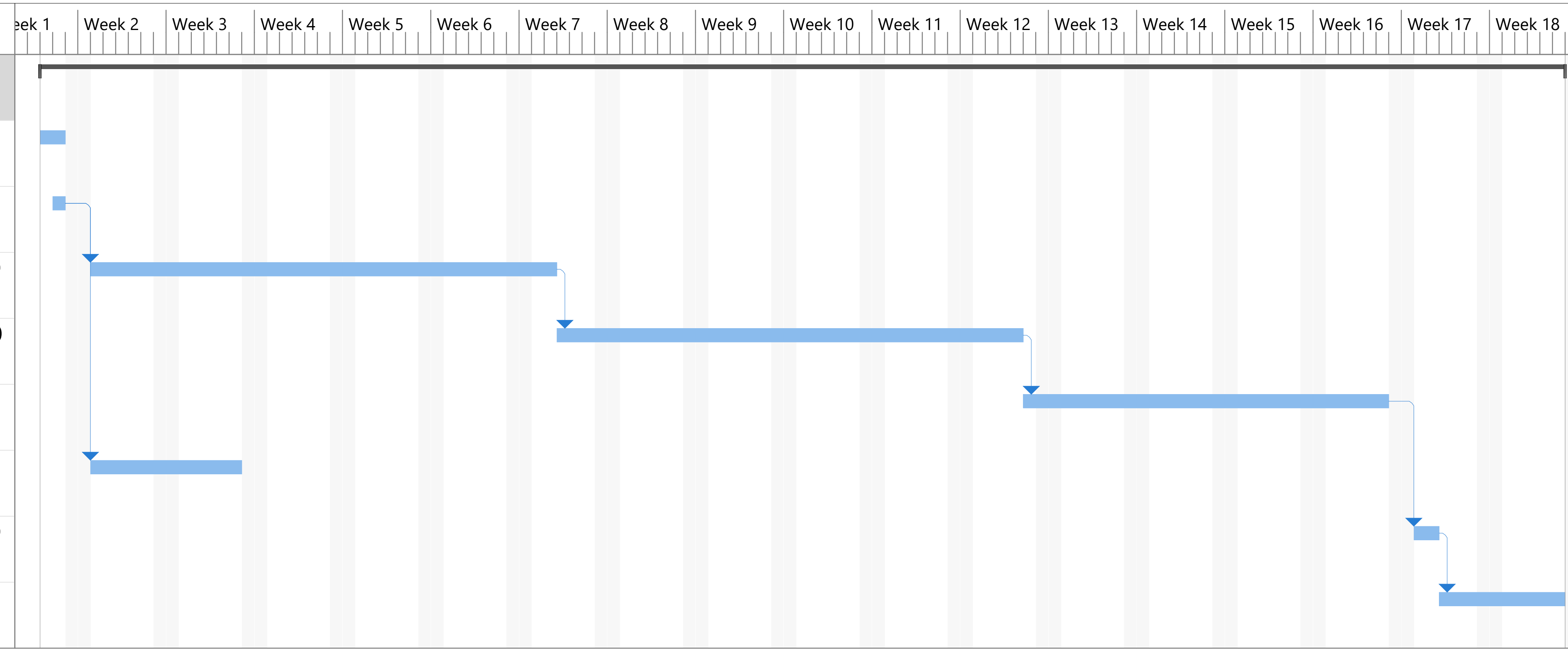




	NAME	TITLE: IN-LINE CHLORINATOR
	Samantha Cepeda	
	Grace Kluchka	MATERIAL: Concrete and plastic
	Kendall Welling	
Inches	DATE: 11/22/2019	KSG WaterWays
SCALE:1:5	Units: Inches	APPENDIX I-93

Appendix J: Construction Schedule

ID	Task Name	Duration	Start	Finish
1	La Penita Water Distribtion	87 days	Thu 1/2/20	Fri 5/1/20
2	Transportation	2 days	Thu 1/2/20	Fri 1/3/20
3	Safety and Instructional Training	1 day	Fri 1/3/20	Fri 1/3/20
4	Trunklines	27 days	Mon 1/6/20	Tue 2/11/20
5	Branchlines	27 days	Wed 2/12/20	Thu 3/19/20
6	Meter Instalation	21 days	Fri 3/20/20	Fri 4/17/20
7	Tank Roof	10 days	Mon 1/6/20	Fri 1/17/20
8	Flush and Test	2 days	Mon 4/20/20	Tue 4/21/20
9	Contingency Days	8 days	Wed 4/22/20	Fri 5/1/20



Project: La Penita Construction
Date: 12/13/2019

Task | Summary | Project Summary