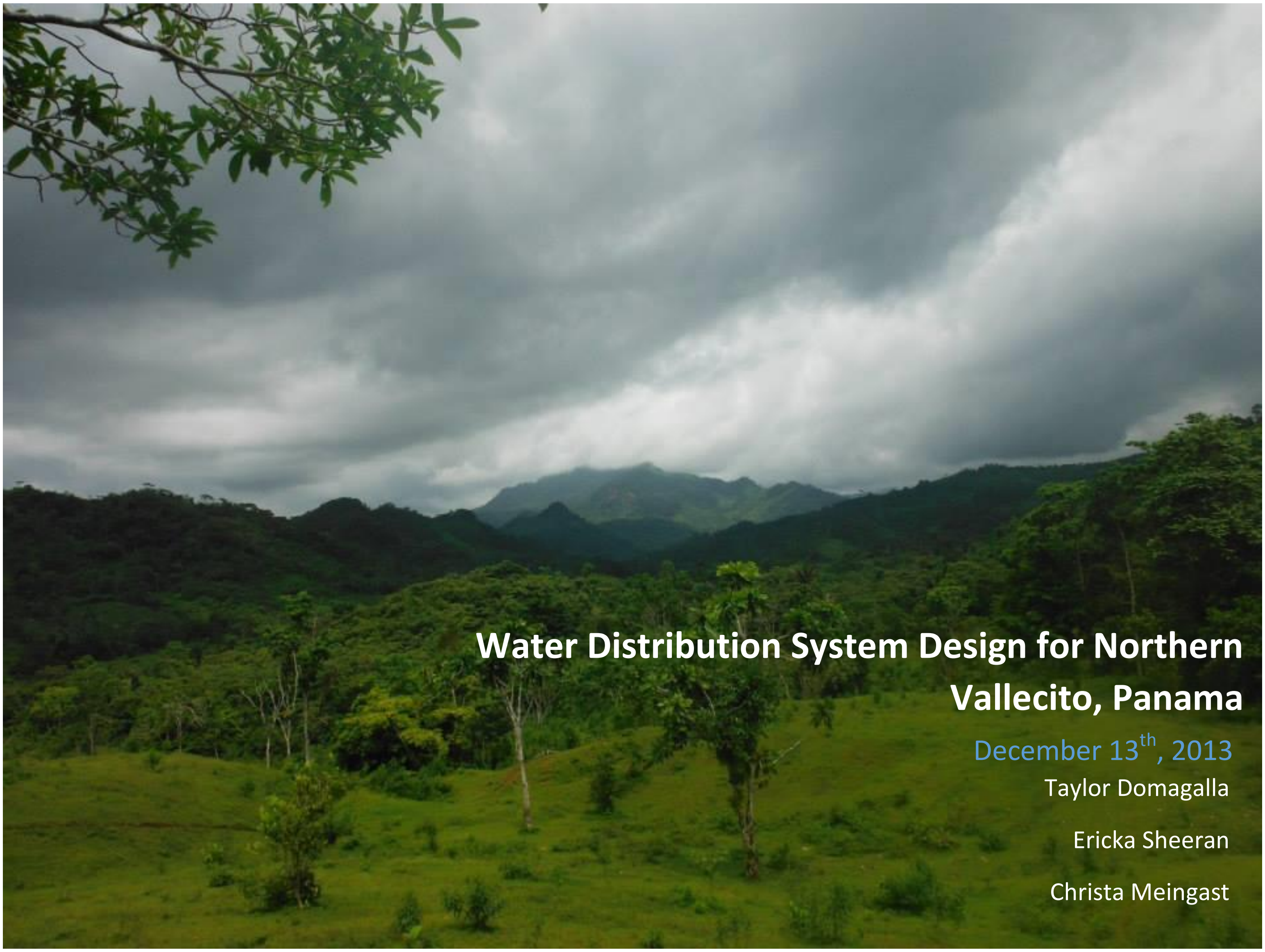

Water Distribution System Design for Northern Vallecito, Panama

December 13th, 2013

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Mission Statement:

The mission of Agua de Abajo Engineering is to improve the quality of life in developing communities of Panama by designing sustainable low-cost, low-maintenance aqueduct systems to carry potable water to those who are interested and invested in supporting the systems.

Purpose

Agua de Abajo Engineering is part of the International Senior Design program at Michigan Tech. The team traveled to Vallecito, Panama this past summer to collect data so that a water distribution system could be designed during the Fall Semester of 2013. Now, a sustainable and affordable system has been designed that meets the needs and wants of the community as best as physical constraints allow. A proposed design and several alternatives are included.

Acknowledgements

Agua de Abajo Engineering would like to show gratitude to all of those who helped the team with this project, from data collection through design.

MTU Professors:
Dr. David Watkins-Course Advisor
Mr. Mike Drewyor-Course Advisor
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Ms. Norma Veurink

Peace Corps Volunteers:
Siobhan Girling-Vallecito PCV
Kerri Smyth
Alex Masarie
Danielle Renzi

Vallecito Water Committee Community Guides:
Epifanio Valdez
Felix Martinez and his hospitable family
Roberto Reyes
Magdaleno
Clemente Alveo

Other iDesign Team Members

Disclaimer:

This report, titled “Water Distribution for Northern Vallecito, Panama”, represents the efforts of Agua de Abajo Engineering, an International Senior Design group 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

Agua de Abajo Engineering is a group of civil and environmental engineering students who travelled to Vallecito, Panama during August of 2013 for International Senior Design in order to collect data for the design of a gravity fed water distribution system. Agua de Abajo worked in the northern region of the community while another senior design group, CDAC, worked in the southern region. Vallecito has existing water systems, but according to the community's Peace Corps Volunteer, Siobhan Girling, around 30 percent of the community is not served. Residents from 10 households of Northern Vallecito requested the construction of a water system to serve them. These houses contain approximately 40 people, which is nearly half of the estimated population without an improved water source.

Agua de Abajo collected elevation data, coordinate data, flow rates from two springs (*tomas*), and water quality data to base the system design on. This data was analyzed when Agua de Abajo returned to Michigan Tech, and it showed that the Northern Vallecito residents would be best served if split into two groups and both tomas were utilized. Three design options were developed for each group. The designs using the northernmost spring, Toma 1, include (1) distribution system along the original surveyed route, (2) a system along route partially based on topographic map readings, and (3) a distribution system to the second-to-last house on the line with a rainwater harvesting system at the last house. All of the Toma 1 options contain a bridge to cross the Rio Indio. The second group of people lives above both tomas, but closer to Toma 2. The designs for this group include (1) using a solar-powered pump to deliver water to household taps, (2) a gravity fed water distribution system that ends in a communal tap about 30 meters from the houses, and (3) rainwater harvesting systems at each of the houses. The designs for each toma have been ranked based on the following criteria: cost, community perspective, ease of maintenance, potential lifespan, quality of delivered water, convenience, and supply reliability. Agua de Abajo Engineering recommends that Vallecito utilizes the partial reroute for the Toma 1 System and the gravity fed line to a communal tap for the Toma 2.

The cost to transport these materials and to construct these systems will be approximately $9,400. Some work needs to be done to ensure the suitability of the recommended Toma 1 System. The portion of the Toma 1 System line that was routed based on a topographic map will need to be surveyed and analyzed to ensure that this system route will adequately supply water to the last house on the line. The results of this survey may change the cost of the system. Agua de Abajo Engineering considers these two water distribution system designs to be a financially feasible and physically sustainable solution to the Northern Vallecito community's desire for accessible potable water.

1.0 Introduction

Vallecito is a remote, rural community in the Coclé province of western Panama. It is made up of approximately 300 Spanish-speaking Latino persons who rely primarily on subsistence farming. The community has essentially no electricity and limited water supply infrastructure. The Peace Corps has a presence in the community. Siobhan Girling, the community's current Peace Corps Volunteer, is working to develop water infrastructure. About 30 percent of community members do not have access to an improved water source—instead, they drink surface water from streams or a river. Approximately 13 percent of these under-served people live in the northern region of the community in ten households. They have requested the design and implementation of a gravity-fed water distribution system to meet their potable water needs. This report describes Agua de Abajo Engineering's data collection, analysis, and design of water distribution systems in order to assist Northern Vallecito.

1.1 Community Background

Vallecito is located about 75 kilometers southwest of Panama City on the border of the Coclé and Panama provinces and in a mountainous region. The location can be seen below in Figure 1. This community is not located far from Panama City; however, the terrain and heavy rainstorms make it a remote location. The trip requires a 45-minute bus ride to La Chorrera, 1.5 hours in a chiva—a pick-up truck whose bed has been converted to seating and covered—through the rolling hills to El Harino, and finally an hour hike over steep clay hills, farmland, creeks and a rushing river.

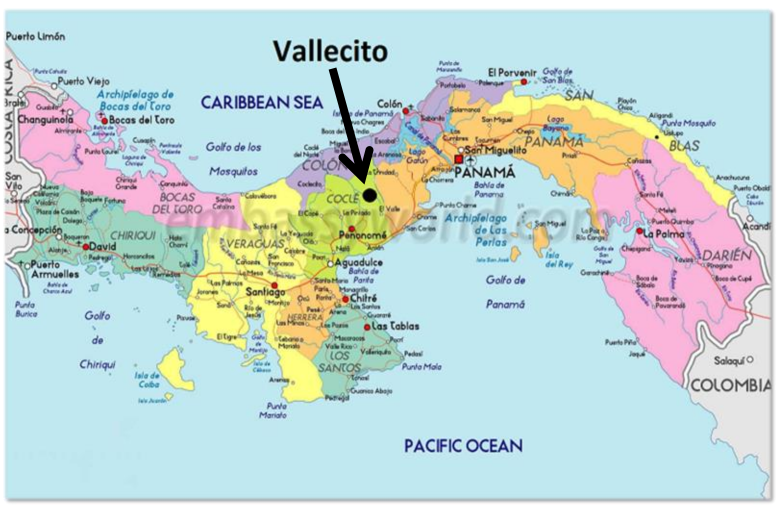


Figure 1. Map of Panama. Black dot shows approximate location of Vallecito.

This area was settled in the early 1940s because of the fertile land. It has been built along 7 kilometers of the river, Rio Indio. The river serves as a useful reference point for community members. The downstream area of the river is referred to as Abajo—meaning lower—and the upstream area of the river was referred to as Arriba—meaning upper. Rio Indio flows north, so the "lower" region of the community is actually north while the "upper" region is south. Maps are displayed in the community with the northern direction pointing downward so the orientation matches the community members' reference point. Agua de Abajo Engineering took its name from this convention; Agua de Abajo means "water from below," and the team worked in the northern part of the community. The layout of the community, including an estimate of the division between "Arriba" and "Abajo" areas, is shown in Figure 2.

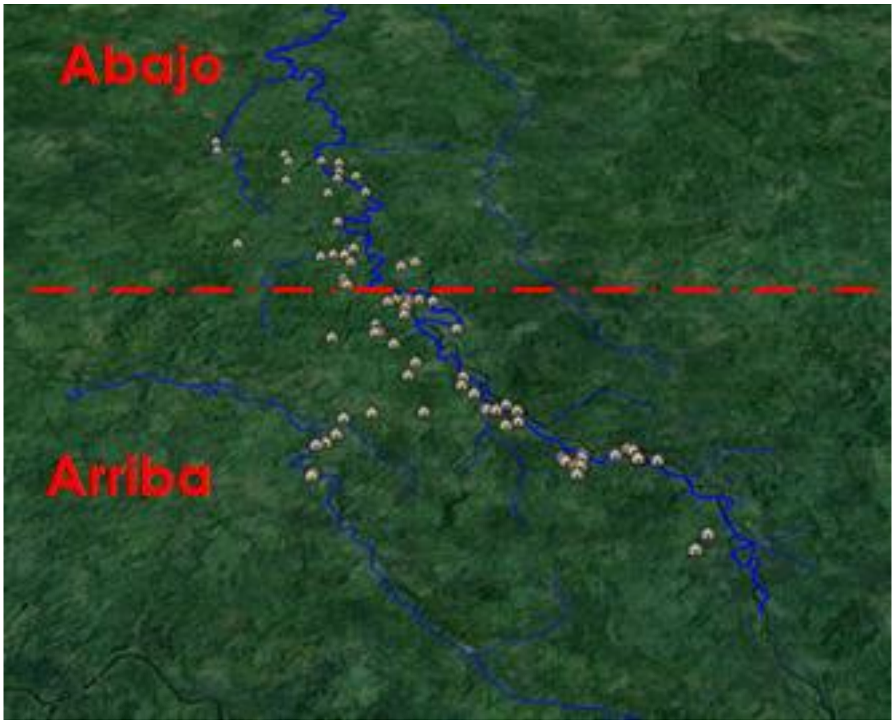


Figure 2. Map of Vallecito community layout. GoogleEarth file used provided by Siobhan Girling.

The people of Vallecito survive on subsistence farming. Community members grow rice, corn, yucca (a popular local root vegetable), coffee, oranges, bananas, and coconuts. They also raise many chickens and cattle. Horses are also fairly common in the community for transportation of goods into and around the community. Other forms of work for community members include construction work in nearby cities and working as farm hands for neighbors for approximately $5/day.

The community center (approximately where the dividing red line is in Figure 2) consists of a church, community building, school, and a small store. These buildings in the community center were made of concrete block, which was common before the community gained access to chainsaws. The community building where Agua de Abajo engineers stayed was built in the 1980s and had a concrete floor, pillars, and a zinc roof. The houses usually consisted of wooden huts with dirt floors and palm thatch roofs. In addition, every house visited on this trip had a pit latrine—all with similar design and construction—surrounded by wood walls and a metal roof. These were built as part of a recent Peace Corps project. Agua de Abajo Engineering is confident the community has some construction skills and that it is capable of successfully completing development projects to improve health.

In addition, the community is well organized and in favor of a water distribution system. This is evident for many reasons. First, the existing systems are inadequate and aging, most approximately 20 years old. Therefore, the community has experience with this technology and they are capable of keeping the technology working for the design life. The second reason is the organization and dedication of the water committee. This committee is a group of people who are very passionate about providing potable water in the community. Every day, during our visit the committee arranged for community guides to help us survey and navigate the community. They also coordinated with several other committees to cook for all visiting International Senior Design students and Peace Corps Volunteers every night of the trip. The president of the water committee guided Agua de Abajo through the community himself for a few days and was very interested in learning how to use the surveying equipment. Finally and most importantly, the water committee has a constitution prepared for water distribution systems. This constitution can be seen in Appendix A in both Spanish and roughly translated English. It contains information about maintenance plans, user rules, and a billing system. All of these factors ensure that Vallecito is truly dedicated to meeting its water needs and is capable of maintaining a water distribution system when a suitable design is offered.

1.2 Problem Description

Vallecito has existing water distribution systems, but the community has several problems with them. Many of the systems and issues are more relevant to the Arriba section of the community. However, there are some shared concerns and concerns specific to the Abajo region of Vallecito. Currently, there are several small systems reaching from a spring source to only a few houses. The community has a strong desire to unify these systems, partially so that in-line chlorination can be utilized. The complaints associated with the existing system include frequent pipeline breakage due to livestock stepping on unburied or shallowly buried pipe, and pipes being washed out at river crossings by high flood waters and floating debris. Both of these problems cause interruption in water supply and require significant effort to repair.

While these interruptions are certainly a concern, approximately 30 percent of the community is not connected to a water system at all. These people obtain water from other sources such as unprotected springs, the river, small streams, or neighbors' water systems. The first three sources mentioned are not protected and are subject to contamination from animal feces and agricultural runoff, which could result in serious health problems. Nearly half of the people who do not have access to their own tap live in the Abajo region and are interested in having access to a water distribution system. Community members from ten houses have requested to have a water distribution system designed and implemented in the Abajo region that will serve about 40 people.

1.3 Project Objectives

The goal of Agua de Abajo Engineering for this project is to design a financially feasible and sustainable water distribution system (or systems) that will serve all interested households in Northern Vallecito. The system should be gravity-fed because there is no electricity infrastructure in Vallecito. It should provide 30 gallons of water for every person on the line every day, which is a standard of the Panamanian Health Ministry (MINSA). The design should also be as unified as possible to simplify chlorination. The community members also expect a tap at each house. Finally, where these objectives cannot be met, reasonable alternatives should be offered.

2.0 Data Collection and Preliminary Analysis

Agua de Abajo Engineering traveled to Vallecito during August of 2013 to gather data for the water distribution system design. Survey data, map coordinate data, water demand, water supply, and water quality data were obtained to assist in the design.

2.1 Site Description

Agua de Abajo Engineering surveyed to ten houses in Northern Vallecito under the direction of Siobhan Girling and the community guides. Two water sources have been proposed to supply water for a public gravity fed water distribution system to connect these houses. The layout of these houses and Tomas can be seen in Figure 3.

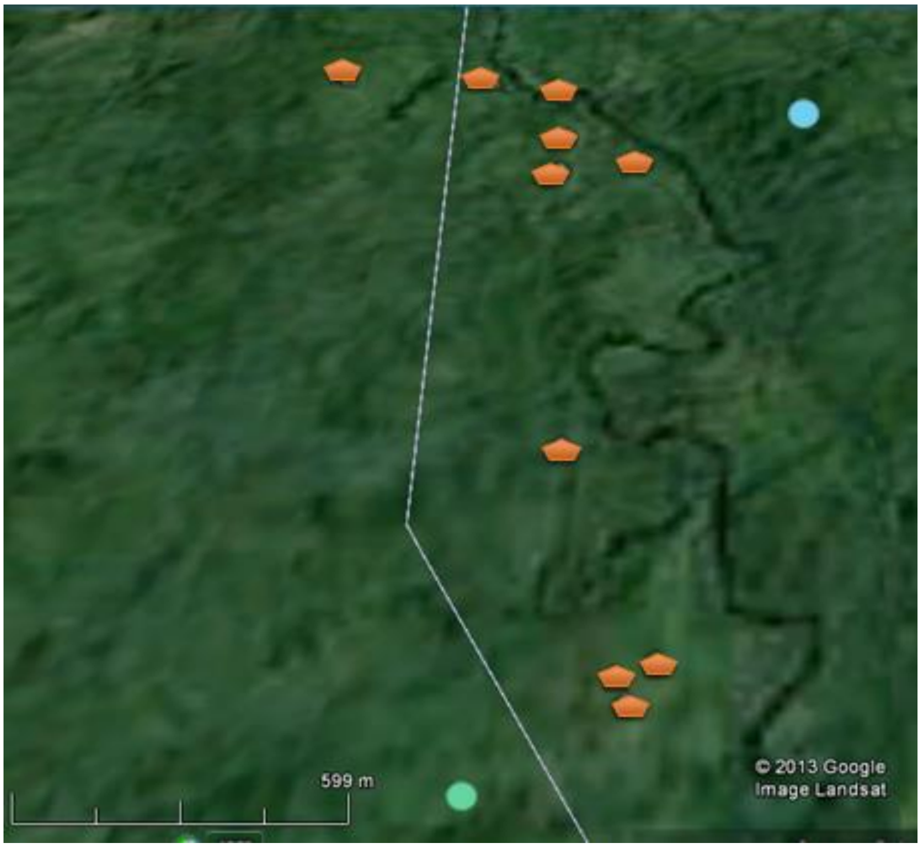


Figure 3. Map showing layout of houses that want to be connected to a water system and the available supplies. The orange pentagons represent houses, the bright blue circle represents Toma 1, and the light green circle represents Toma 2. This map has been created from the GoogleEarth file provided by Siobhan Girling.

2.2 Surveying

Abney levels were used to find the elevation changes within the system. Abney levels are small, easy to carry through rough terrain, durable, and do not require batteries. These characteristics make Abney levels a great tool to use in the field, particularly in developing communities. To perform a survey with an Abney level, one needs two sticks of the same height, two Abney levels, a tape measure, and at least one partner. First, one person stakes into the starting point with one stick, then their partner walks down the survey path and places their stick onto the ground. The distance between the sticks is measured. Next, the Abney level is used to measure the angle between the tops of the sticks. The person reading in the direction of motion down the survey route reads the forward angle and the person who has to turn around to face towards the starting direction is reading the back angle. For this project, the two readings needed to be within 30 minutes of each other to be considered accurate. When an accurate reading is obtained, the person who read the forward angle moves to the spot the person who read the back angle was at the last reading, and the back angle reader can move forward to the next point to repeat the process. Trigonometry can be used to analyze the angle and the distance measured between the two points to solve for the elevation change. After these elevations are all calculated, a full profile map of the system can be created to show the changing elevation throughout the system. The elevation profiles generated are shown in the design sections of this report.

This surveying was performed over about four kilometers in Vallecito for this project. After finishing the survey for the distribution route that connects all houses to Toma 1, Siobhan had us survey from the southernmost houses of the system to Toma 2. She stated that the elevation of those houses may be higher than Toma 1, so surveying an alternative route would be recommended.

Agua de Abajo used a GPS device to record the X, Y-coordinate information. GPS data was collected at every survey point. This GPS data was then used to create a detailed system map which can be found in Appendix C. Siobhan Girling also sent a Google Earth file that has been used to create many of the maps Agua de Abajo has been using. Finally, after arriving back in the United States, a topographic map of the region was also ordered.

2.3 Water Demand

The design of a water distribution system depends greatly on the water needs of the community and the available flow from water sources, so the demand of the community at the end of the design life of the system must be accounted for. The total number of people in need of water in Northern Vallecito is 41, but it is more helpful to know how many people live in each house so the demand of each house on the system can be considered. The population projection for each house has been calculated and is tabulated in Table 1. The sample calculation shown below is for one particular household. The population growth rate for Panama was 2.2 percent in the 1980s and 1.9 percent in the first half of the 1990s (countrystudies.us). The growth rate used for this analysis is 2.2 percent to be conservative, and the design life chosen is 15 years.

$$P_N = 5\ people\left(1 + \frac{2.2\frac{people}{year} \times 15\ years}{100}\right) = 7\ people$$

(Eqn. 1)

Multiplying the design population by the amount of water required by each person gives the demand on the system. The MINSA the water requirement is 30 gallons of water per person per day (0.0013 Liters per person per second).

$$Average\ Daily\ Usage = 7\ people \times 0.0013\frac{L}{s \times person} = 0.0091\frac{L}{s}$$

$$0.0091\frac{L}{s} \times \frac{3600\ s}{1\ hr} \times \frac{24\ hr}{1\ d} = 790\ Liters\ per\ day$$

(Eqn. 2)

Table 1. Design Demands for each household.

Household Head	People per House	Design Population per House	Design Demand per House (L/s)
Magdaleno	5	6.65	0.00875
Benjamin	1	1.33	0.00175
Eufemio	5	6.65	0.00875
Roberto	10	13.3	0.0175
Felix	7	9.31	0.0122
Martina	1	1.33	0.00175
Clemente	3	3.99	0.00524
Laurino	1	1.33	0.00175
Ismael	5	6.65	0.00874
Luis Moran	3	3.99	0.00524

This approach was used for every household. The summation of these demands results in a net demand of 0.072 L/s (6200 L/d).

In addition to finding the average daily, the hourly demand should be modeled as well to ensure that water supply will be sufficient throughout the day. When asked about a demand pattern, Siobhan Girling said via email, "It'll be highest early morning and early evening, when cooking and bathing coincide. Exact numbers are not available." Figure 4 shows the demand pattern used in Agua de Abajo's analysis. It represents the usage fluctuations throughout the day and is used by multiplying the value for each hour by the average hourly flow.

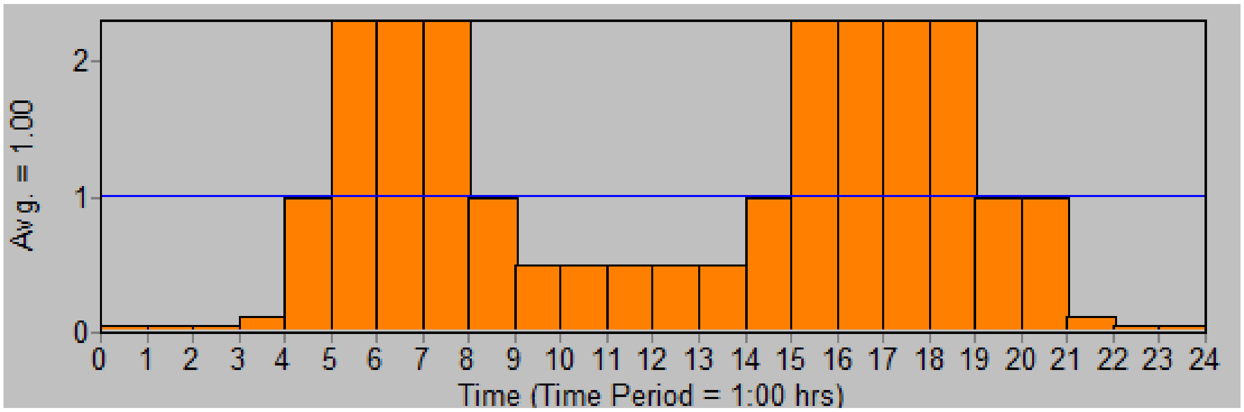


Figure 4. Typical Daily Usage Water Demand Pattern.

2.4 Water Supply

The flow rate of each toma was measured using the volume-time method. The amount of time it took to fill a 1-L water bottle was used for Toma 1. The amount of time it took to fill a 5-L water jug was used for Toma 2, as its flow was much higher. The Toma 2 measurement was taken from the overflow of the toma's storage tank as the spring already has a functioning spring box, conduction line, and storage tank.

The flow from Toma 1 was measured in August 2013 to be 0.29 L/s, and Siobhan Girling provided data indicating that the flow rate for the dry season was 0.24 L/s. The toma could provide three times as much water at this flow rate as is necessary for the projected population of Northern Vallecito. This makes Agua de Abajo Engineering confident that the supply will be more than sufficient for Northern Vallecito's design needs year-round, despite only having two measurements available.

The flow from Toma 2 was 0.83 L/s. Peace Corps records do not contain dry season flow data for this toma, so this measured value during the rainy season is the only value available. It is more than an order of magnitude larger than the projected demand on the system. This makes Agua de Abajo Engineering confident that water supply in Northern Vallecito far outpaces water demand, which will help ensure the system is sustainable over the life of the project.

2.5 Water Quality

Water quality tests were performed on the Toma 1 spring source for the system as well as the river. 3M petrifilms were used to test for *E.coli* and *total coliforms*, using body heat to incubate the films. The tests showed that Toma 1 had 140 cfu/mL and the river had 97 cfu/mL. These results were not expected since groundwater springs are supposed to be much cleaner than surface water. But as seen in Figure 5, this spring source was not protected so there was contamination. If the source were protected, this contamination would most likely be eliminated. The measured contamination reveals how poor the water quality of available sources can be.

Figure 5. Toma 1 is currently open to surface water and is contaminated.

Agua de Abajo Engineering had attempted to test the water quality at Toma 2 and at the tapstand near the community building, but the 3M petrifilms were ruined by exposure to water before this could be done, either from humidity, rain, or an accidental dip while crossing Rio Indio.

3.0 System Design

The best design in the eyes of the community members would be a single, unified system that reaches all houses individually using gravity. Unfortunately, the topography of Northern Vallecito and the placement of the houses does not allow for a single gravity-fed system with taps at every house. Siobhan's intuition that three southernmost houses are above the elevation of Toma 1 was correct. Analysis of the survey data shows that these houses are actually above the elevation of both Toma 1 and Toma 2. Agua de Abajo Engineering chose to utilize Toma 2 to serve these houses because it is significantly closer to the houses and because the path from Toma 1 to these houses would require an additional bridge crossing, which would have added a substantial amount (roughly $2,000) to the total system cost. In addition, there are several high points in the Toma 1 line that could seriously reduce the supply reliability at these houses if it were used. This dual system design does not match exactly what the community wanted, but physical limitations of the landscape and house layout make a single gravity-fed system impossible along the surveyed route. Figure 6 shows which houses will be served by each toma.

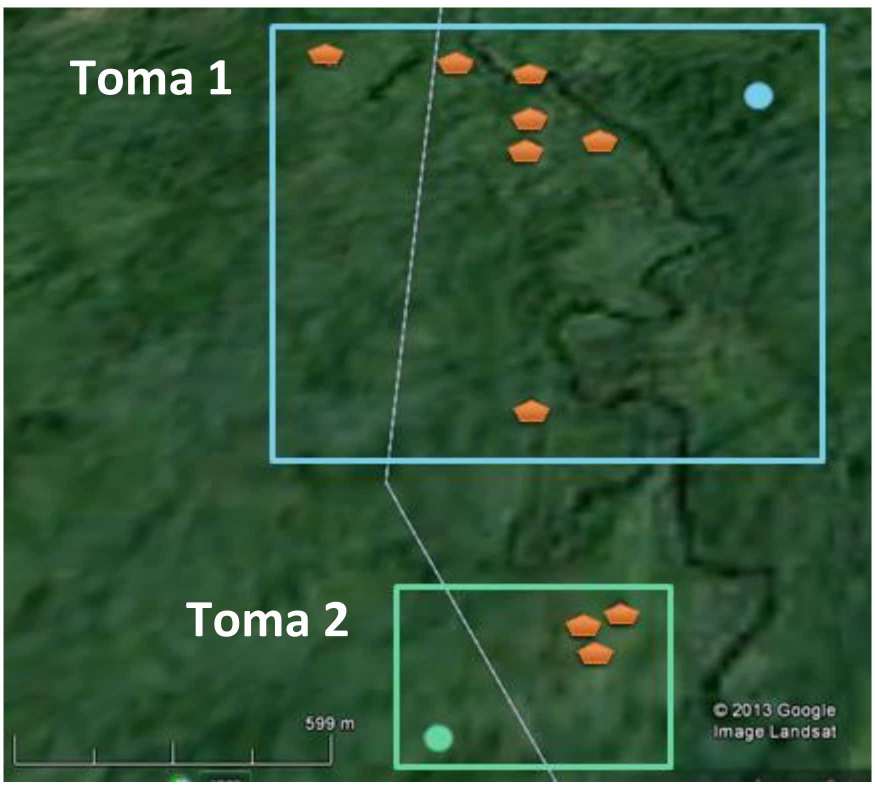


Figure 6. Map showing which houses will be served by each toma in Northern Vallecito.

4.0 Toma 1 System Design

The Toma 1 system will serve the current population of 32 in seven houses, but is designed for 43 people. A daily flow rate of 4833 L/d is needed to provide the MINSA standard of water to 43 people. This flow rate was found by adding up all but the last three households' demand in Table 1. This system design starts from scratch, so it includes all design components. Three design options have been evaluated, detailed in section 4.2, and a final recommendation for the system is made in section 4.3.

Since this system is completely undeveloped, all system components have been included in the design. Though three alternatives for the distribution system are discussed in section 4.2, all share the same design from Toma 1 to the second-to-last house on the line. Therefore, all design components described in this section are relevant to every alternative design for the Toma 1 system. The chosen proposed design is the full reroute system. The elevation profile for this design is shown in Appendix E.

4.1 Design Components

4.1.1 Spring Box

Figure 7 illustrates a spring box design for a spring on a hill, which represents the setting of Toma 1. The spring water will flow through a filter of rocks and sand into a collection box. A capture area will be sized around the spring in relation to the size of the spring veins. After the water runs through the capture area, it will arrive at the primary filter. The primary filter consists of large rocks to filter out any large materials contained in the spring water. The next component of the filter contains sand, which will filter out smaller particles in the spring water. The sand filter will clean the water substantially, reducing the risk of sedimentation of particles in the retention tank and conduction line as well as contamination present in the water.

The design of an effective spring box requires several detailed components. First, the design will have wingwalls on either side of the collection box to capture water from the spring source. This will allow more water to be diverted to the spring box, increasing the flow available for the system. A diversion ditch and soil berm will be constructed on either side of the concrete box in order to divert surface runoff. Next, a compacted clay layer will be placed on top of the filter system in order to create an impervious layer to stop surface water from entering the box. Beneath the clay layer, gravel and large rocks will create a water filter. The collection box itself will be made out of ferrocement. The cover will be sloping and overhanging in order to divert surface water. There will be an outflow pipe to ensure water does not back up into spring, discharging to the spring's natural drainage path. This pipe will have a screen covering to protect from bugs, animals and other contamination sources. The outlet pipe will be designed above the bottom of the tank to prevent sediment from entering the pipes, assuming regular cleaning.

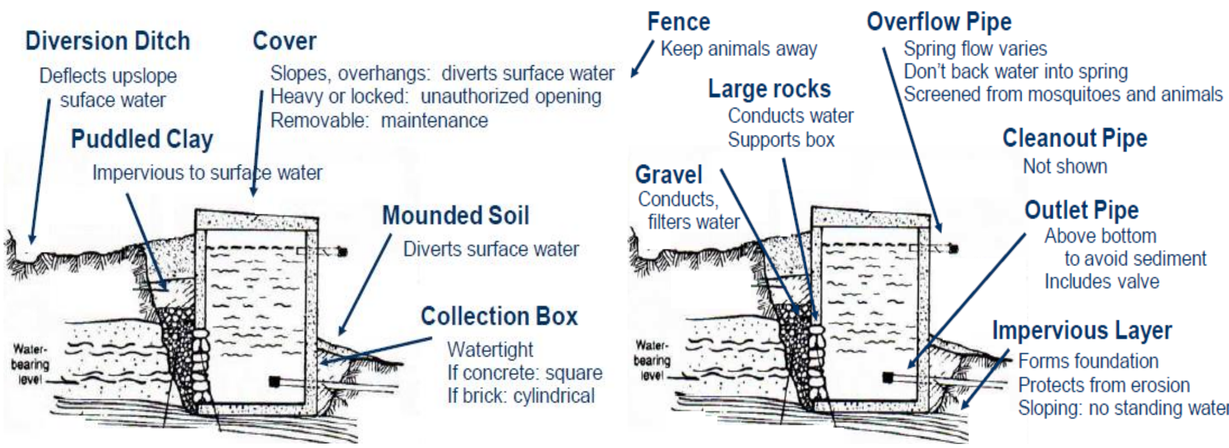


Figure 7. Spring box design (Niemann 2013).

The size of the sand filter of the spring box must allow for an adequate flow rate to the storage tank in order to meet the maximum daily demand. The necessary flow rate for the water flowing into the storage tank is calculated below. The storage tank design calls for a volume of 6m^3 (See section 4.1-3 for details).

$$Flow\ Rate = 6\,\frac{m^3}{day} * \frac{day}{24\ hours} * \frac{hours}{60\ minutes} * \frac{minutes}{60\ seconds} * \frac{1000L}{m^3} = 0.069\,\frac{m^3}{s}$$

(Eqn. 3)

The spring source has an average flow rate of 0.25 L/s. This is ideal because the flow rate of the spring is larger than the necessary flow rate needed to fill the storage tank, meaning that there will be enough flow to meet the maximum daily demand. To minimize clogging, the entire spring flow rate will be filtered. To find the area of the spring sand filter, a filtration rate that meets the maximum daily demand has to be determined. With this spring system, the desired filtration rate is 0.3 m^3/m^2/hr (Kaczkowski, 2012). The following calculation illustrates the computation of the area of sand for the filter.

$$A = \frac{Q}{v} = \frac{0.265\,\frac{L}{s} * 3600\,\frac{s}{hour} * 1\,\frac{m^3}{1000L}}{\frac{0.3\,\frac{m^3}{m^2}}{h}} = 3.2\ m^2$$

(Eqn. 4)

The area of the sand filter will be 3.2 m^2. The spring box will not have to contain a retention tank because the storage tank will fulfill these requirements. In Appendix B, profile and plan views of the spring box are given. The concrete will be constructed from ferrocement, which is a mixture of sand and concrete plastered onto and reinforced by a wire mesh cage. The spring box will have concrete wingwalls to catch the flowing water out of the spring. These wingwalls cannot yet be sized since the dimensions of the wingwalls will depend on the area of the flowing water. This area can only be found once the spring is excavated, and construction of the spring box has begun. All other dimensions of the spring box, including the area of the sand and gravel filters, the diameter of the PVC pipes, and the volume of the tank itself are shown in the Appendix B. Water will be carried from the spring box to a chlorinator and storage tank in a 50.8-mm PVC pipe.

4.1.2 Storage Tank

The purpose of incorporating a storage tank into the design of the gravity-fed water system is to ensure that peak demands can be meet. The storage tank also maintains a positive pressure in the pipe system in order to prevent contaminants from leaking into the network (Mihelcic, 2009). The tank is designed to be 21 meters away from the spring source at an elevation of 287 m. The storage tank size was designed to have the ability to meet the maximum daily water demand value of 4833 L/d. The storage tank will be made from ferrocement because this has no practical size limitation and can hold an unlimited amount of water (Mihelcic, 2009). The calculation below illustrates the storage tank volume calculation. A safety factor of 1.25 is used to insure that the size of the storage tank will be adequate to meet any unanticipated demands.

$$Storage\ Tank\ Volume = 4833\frac{liters}{day} * 1day * 1.25 * \frac{(meter)^3}{1000\ liters} = 6\ \ m^3$$

(Eqn. 5)

The tank will be a cube with dimensions of 1.8 m by 1.8 m by 1.8 m to hold enough water for meeting the daily demand. Shown in Appendix B are the dimensions of the storage tank. The storage tank contains a screened vent pipe, an inspection hold, an inlet pipe, an outflow pipe, and a screened overflow pipe. The tank will be constructed from ferrocement that is reinforced by a wire mesh cage.

4.1.3 Chlorination

One main reason the village asked for a single community wide water distribution system is because MINSA (the Ministry of Health in Panama) provides in line chlorinators and chlorine tablets to communities developing water systems. Unfortunately, the topography does not allow for a community-wide water distribution system. Therefore, to ensure maximum benefit, the chlorinator will be placed on the line serving the most community members. Figure 8 shows a basic schematic of the in-line chlorinator provided to the community. This chlorinator will be placed before the storage tank to ensure enough contact time for effective disinfection before distribution to the community members.

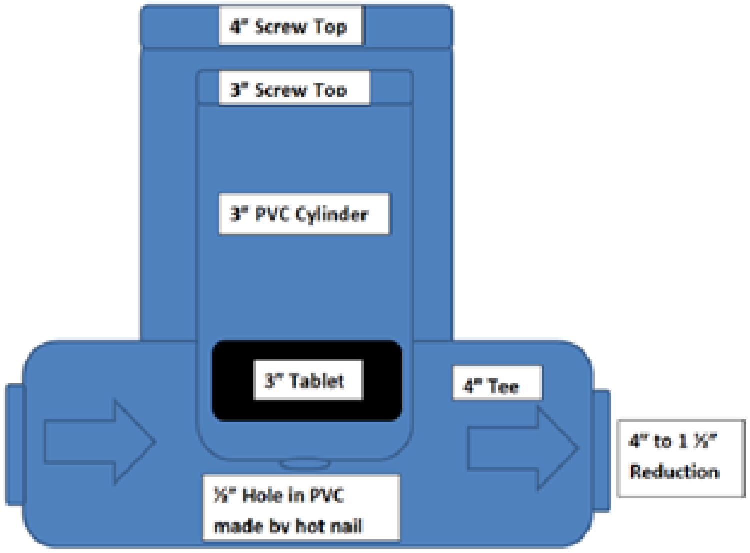


Figure 8. In-line chlorinator provided by MINSA.

According to a study done by Orner (2011) in a rural village in Panama, these tablets are reported to contain 60% calcium hypochlorite and are designed to have 2 grams dissolve in every 1,000 Liters of water. This will ensure the concentration requirement of 1mg/L is met. It is also important to ensure there is sufficient contact time to kill off bacteria before sending the water to the houses. "Ct" (concentration-time) values are used when evaluating chlorine's effectiveness in disinfection against pathogens, viruses, and protozoa, and have units of mg*min/L. This is simply chlorine concentration in the water multiplied by contact time. The Ct required to disinfect E.coli is 0.1, and it is 10 for Hepatitis A and 35 for E. histolytica (Orner, 2011). In order to ensure all pathogens are destroyed, a Ct value of 75 mg*min/L has been chosen. Assuming the MINSA chlorinator provides the concentration stated of 2mg/L (which is twice of the requirement of 1 mg/L) the contact time must be 38 minutes. Since the chlorinator will be placed directly before the storage tank, contact time is assumed equal to the residence time in the tank. The calculations are as follows.

$$Average\ Contact\ Time = Tank\ volume/Flowrate$$

Where the volume of the tank was designed to be 6 m^3 to meet system demands, and the flow rate during peak demand was calculated to be 0.13 L/s.

$$Average\ Contact\ time = 1m^3 * \frac{sec}{.13L} * \frac{1000L}{1m^3} * \frac{1\ min}{60\ sec} = 128min = 2\ hours$$

(Eqn. 6)

This estimated contact time of 2 hours during peak demand is more than sufficient to meet our design criteria of 75 mg*min/L. Therefore, the MINSA provided chlorinator will be more than sufficient for disinfecting the community's water supply.

4.1.4 Distribution Lines

The distribution lines are one of most essential parts of water distribution system design. The pipes within this system are PVC and have been modeled with a pipe roughness of 0.0015 mm (neutrium.net) using EPANET. Diameters and lengths of the pipes are variable and depend on the topography and the pressure conditions, but the main distribution line is generally 50.8 mm SDR 26, tees to houses are generally 25.4 mm SDR26, and the tap stands themselves are 12.7 mm SDR13.5 (these are 2 inch, 1 inch, and 0.5 inch pipe, respectively). The distribution pipes must be able to contain the pressures of the system without bursting. These pipes are locally available according Siobhan Girling. Of these pipes, the 12.7 mm SDR13.5 has the lowest strength; its pressure limit is 113 m head, so this has been considered the high-pressure limit. The low pressure limit is not as strict, though low pressures are susceptible to air blockages or provide trickling at the tap. The details of the pipeline are what change most in the different design options, so the elevation profiles and maps of each system representing each distribution system are shown with the design option descriptions, in subsequent sections of this report.

4.1.5 Air Release Valves

A very common problem that occurs in the operation of a water distribution system is air buildup in the pipes. Air gets trapped at high points in the pipe and can cause blockages to flow, especially if the pressure head of the water is low. The best way to minimize the problem is to install air release valves. Air release valves work by releasing air when pressures reach high levels in the system. Different kinds of air release valves are available. A spring attached to a poppet that allows air to be released when the pressure builds up. This then sinks the poppet to allow air to pass. The poppet rises from buoyancy once air is release and water is back into the system. This closes the opening so is not leaked. This operation is illustrated in Figure 14.

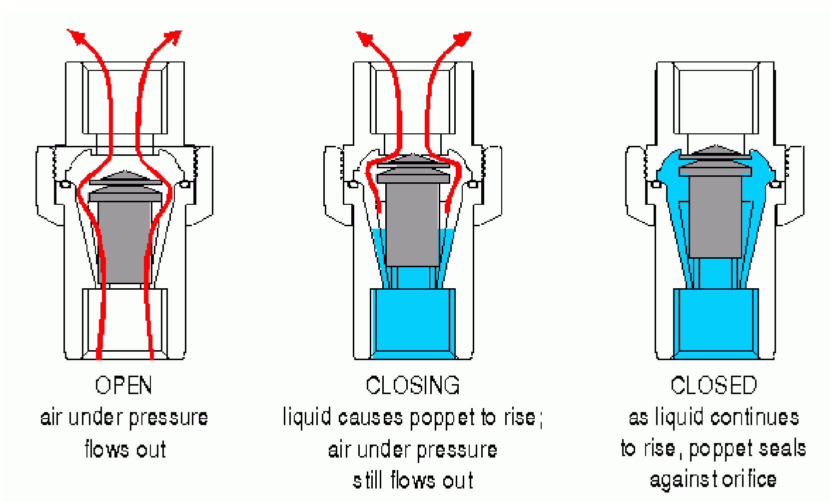


Figure 9: Air Release Valve Design

Though this design is very efficient, these air release values can be costly and are not locally available. For this reason, Agua De Abajo Engineering designed a simple air release value. This valve works in the same basic way as the one explained above. The schematic of this air release valve is shown in Figure 10.

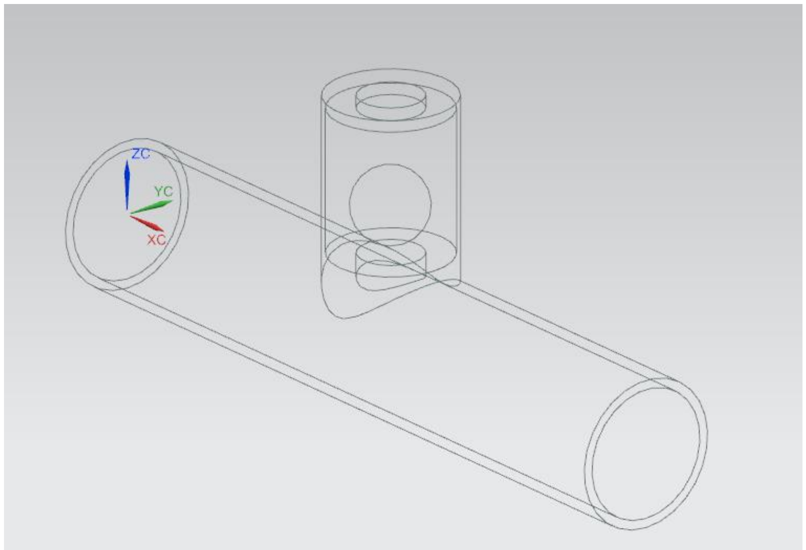


Figure 10. Schematic of simple air release valve.

The valves will be located at every high point in the design system, this includes 10 valves total. Below shows the elevation profile of the Toma 1 system with all of the air release valves included.

Figure 11: Air Release Valve Locations Toma 1.

4.1.6 Pressure Reducing Valve

Pressures of 10 m to 60 m are required at each tap stand to maintain adequate flow pressures without the pressure being so high that it could damage the system or injure users. However, there is one tap stand in the system, located at a low area of a ravine, that experiences a pressure around 80 meters. To reduce the pressure in the tap, there are a few options. First, reducing the pipe diameter will increase head losses throughout the pipe. The pipe diameter was reduced to 12.7 mm and the pressures were still too high. Second, a pressure reducing valve was designed to reduce the pressure adequtely at the tap stand. Pressure release valves are cost effective, have low mainteance and are easy to adjust. For this reason, a pressure release valve was choosen for the design.

To design for the pressure reducing valve, the amount of headloss that needed to occur in the system to reduce the pressure had to be calculated. Figure 12 shows the pressure distribution of the problem area in the system.

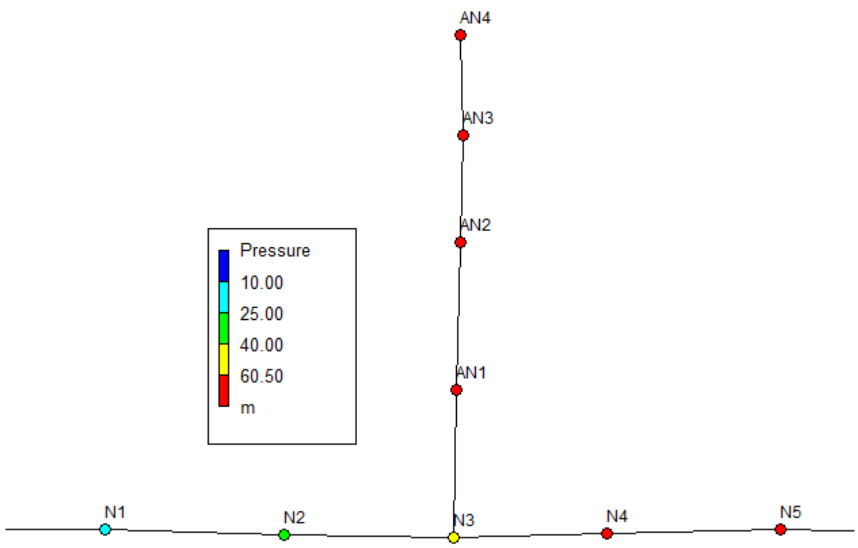


Figure 12: Pressure Distribution of High Pressure Tap Stand

The tap stand AN4 is the point that needs pressure reduction. Agua de Abajo decided to put a pressure reducing system at the node AN1 to reduce the pressure before the the water arrived at the tap stand. The node AN1 has to be reduced to a pressure of 50 m in order to obtain a pressure below 60 m at the tap stand AN4. The pressure at AN1 is 84 m, so a reduction of 34 m has to be obtained.

Figure 13 illsutrates a Series PRHM Premium performance, Complete (5-123 psi). This pressure release valve is high performance and has a heavy-duty design, perfect for using in the water distribution system. The pressure release valves in the system contain a setting of 60 m. This valve would sufficently reduce the pressures at the tap, but they are not locally available or familiar to the people.

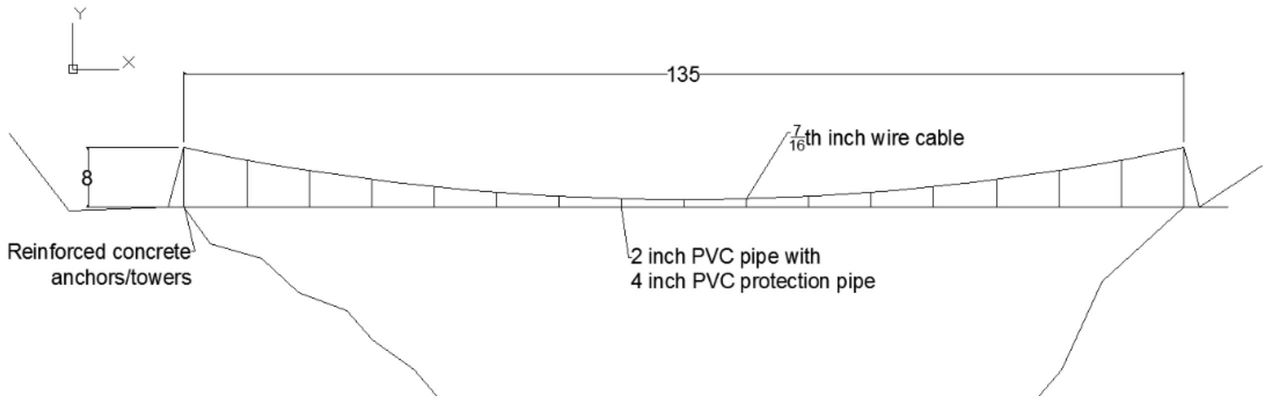
Figure 13. Presssure Release Valve http://www.plastomatic.com/pressure-regulators.html

4.1.7 Tap Stands

The people in the Abajo area of Vallecito expect to have tap stands at each house. Agua de Abajo Engineering has designed the system with this expectation in mind as much as topography will allow. To meet the minimum pressure requirements mentioned previously and to reduce cost, the tap stand will be made from 12.7 mm PVC pipe. The tap stands Agua de Abajo Engineering saw in community were supported by wooden stakes, and wooden boards were used to prevent erosion around the tap stand rather ineffectively. In Appendix B, the design of the tap stand is illustrated. The tap stand incorporates ½ inch PVC pipe, wooden stability stake, metal ties, and a concrete skirt. A concrete skirt in place of a wooden board will reduce erosion significantly.

4.1.8 River Crossing Bridge

During the rainy season, the water level of the river rises drastically and has caused several problems with past water distribution systems. The pipeline currently in place is suspended across the river by barbed wire. The high rushing waters and debris have frequently washed out water systems suspended over the river in this way. In the field, the community members established a high water mark for the river. To avoid a wash out of the proposed design, a suspension bridge was designed to hold the pipeline 3 meters above this level with a span of 135 meters. To avoid a wash out of this proposed design, a suspension bridge has been designed to hold the pipeline in place at a high level. Figure 14 is a sketch of the designed bridge. A detailed drawing of this bridge can be found in Appendix B, which also includes all of the calculations, and AutoCad drawings of the bridge and anchors. All calculations were done in feet and then converted to meters.



Units: Meters

Figure 14. AutoCAD sketch of bridge to suspend pipeline over the river. Vertical scale exaggerated 2:1

The 2-inch pipeline will be covered by a 4-inch PVC pipe to protect it from UV damage. The pipes will be suspended across the river by wire cables, supported by a 4 meter reinforced concrete towers, and anchored to the base of these towers. (Figure 14 shows 8 meters because there is a vertical exaggeration to better see the design. They are actually 4 meters tall as stated in the text). A safety factor of 2 was used throughout this design because this is a critical aspect to the design, but would not put any lives at risk if it were to fail.

Cable tensions were calculated based on the unit weight of the water-filled pipe. A 7/16in cable was determined sufficient to hold the safe load of this bridge. This cable forms a catenary curve when hanging free between the tops of the towers. This equation, listed below, was used to establish the height of the towers at 3.6 meters.

$$y = a[\cosh\left(\frac{x}{a}\right) - 1]$$

(Eqn. 7)

After these calculations were complete, the reinforced concrete anchors had to be sized. The anchors and towers are combined into one triangular structure. The cable will come over the top of the structure and connect to an eyelet at the base of the structure. To ensure the weight of the bridge would not cause the anchors to slide or overturn, the other dimensions of the base were determined by calculating the sliding and overturning moments about the base. Through these calculations, the length of the base was established at 2.14 m, with a width of 2.13 m and a height of 4 m (to include a burial of 0.4m in the ground).

Next, rebar for the anchors was determined. Assuming a concrete compressive strength of 4ksi and yield strength of 60 ksi, it was determined that 8 no. 18 bars would be placed vertically within this tower. These bars would then be tied every 0.9 meters. A visual depiction of this can be found in the Appendix B.

One difficulty with this design component is the constructability. There are steep slopes on either side of the river, and the river is deep with a strong current. PCV Siobhan Girling asserted that community members could transport concrete across the river, but the soil may make it very difficult to cast the anchors and construct the rest of the bridge. There also may be soil stability issues, especially during the rainy season. The sliding moment was determined using clay friction values; however, these may not match the soil type in Vallecito. Unfortunately, the team was unable to take soil samples while in the Panama, so this is an uncertainty and must be accounted for during construction.

4.2 Toma 1 Water Distribution Alternatives

4.2.1 Surveyed Route to last Toma 1 House

The coordinate data collected in country was used to develop the ARCGIS map shown in Figure 15. Only the data relevant to Toma 1 is shown. The original intent and the desire of the community was to follow the surveyed route, following a common and cleared path, so construction and maintenance would be easier.

Figure 15. ARCGIS Map of the survey route for Toma 1.

The elevation profile of the surveyed route's main line is shown below in Figure 16. The total amount of pipe needed for this system was measured at 3280 m. To provide a safety factor, approximately 10% was added to this amount to total 3600 m.

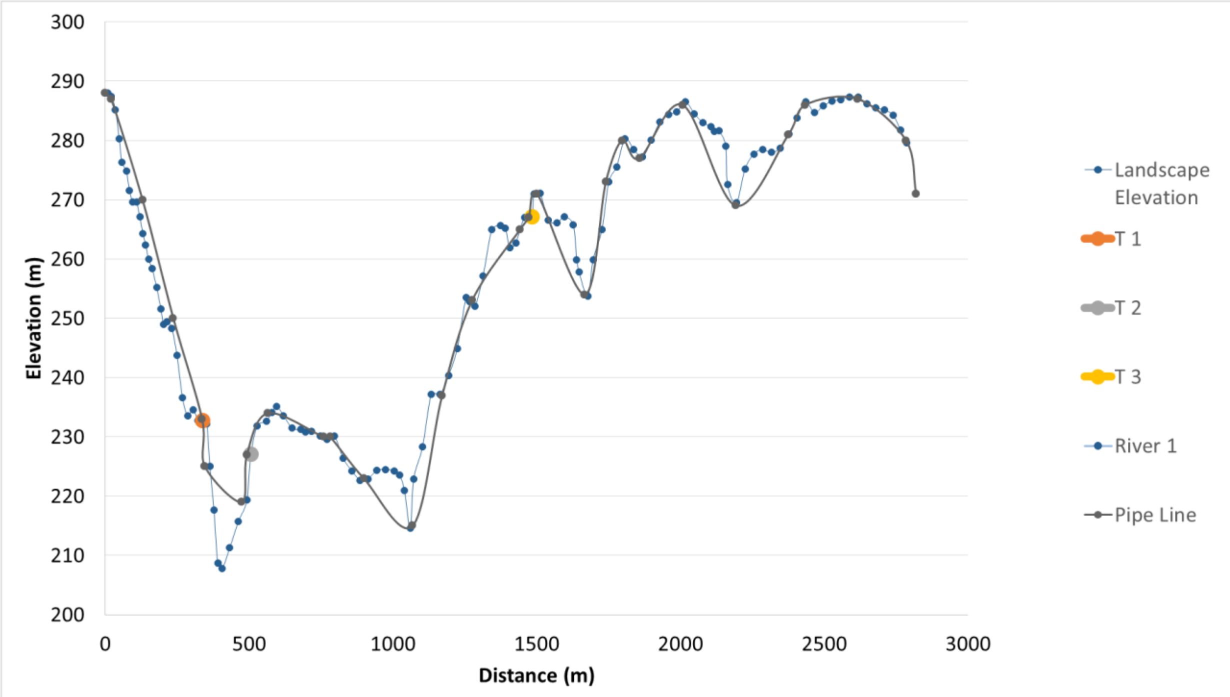


Figure 16 Elevation profile from Toma 1 to Clemente's house. Tees off of the line are shown, but their elevation profiles are not included as they would only be a few points long.

Pipe diameters for the main distribution line are 50.8 mm (2 inches). The first two branches off of the Toma 1 main line (N3 to AN4 and N6 to BN1) are 12.7 mm (1/2 inch) in diameter and the remaining branches (N7 to CN5 and N9 to DN1) have diameters of 25.4 mm (1 inch). Figure 17 provides a spatial representation of these nodes. This is not a true representation of the layout of the houses, but it gives an indication of how the system works.

The topography shown in the elevation profile below displays the pressures throughout the system. This pressure distribution determines whether or not the system will function properly. Pressures must be low enough to ensure that pipes will not burst or people will not be injured at the taps, but must be high enough to keep the water moving without significant risk of air blockage. A pressure reducing valve has been modeled on the first tee to reduce high pressures, as mentioned in section 4.1-6. The pressures within the system are shown at the nodes in the EPANET model schematic below.

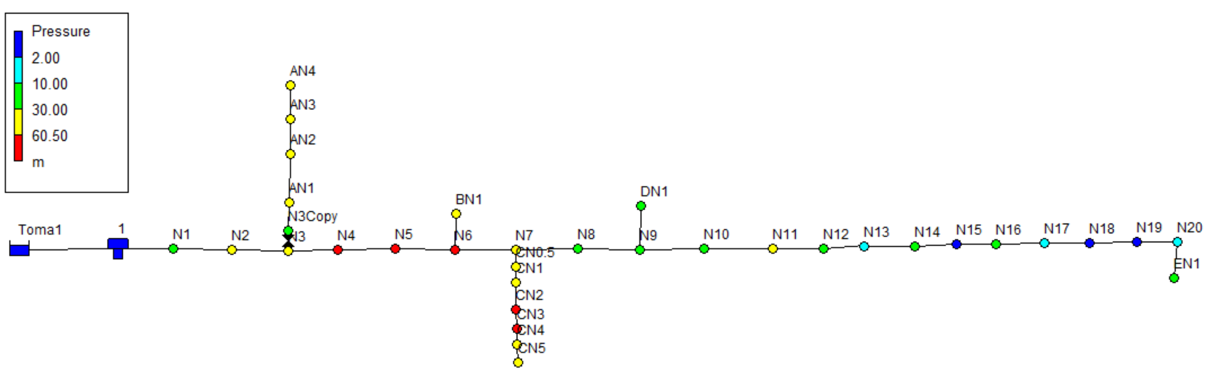


Figure 17 EPANET model representation for the surveyed route Toma 1 system. Each node is labelled with its ID and is colored according to the pressure at the junction (scale at top left). These pressures are instantaneous, showing the pressures for 12:00 AM, but the variation throughout the day does not make significant differences in the pressures. All nodes fall within the same range throughout the simulation.

As shown in Figure 17, the nodes with highest pressures are N4, N5, N6, CN3, and CN4. All pressures are below 75 m, so the chosen PVC pipes are more than strong enough to handle the maximum pressures in the system. The only problem in this system is low pressure. The elevation profile, Figure 16, shows points at or near the same elevation as the source after 2000 m, which result in low pressures at nodes N15, N18, and N19. While none of the pressures are negative or zero, they are at or below 2 m, so air blockages are likely.

This route is along a common path so that it would be easy for the community members to construct and maintain a water distribution system. However, the very low pressures after 2000 m make it a poor choice from an engineering standpoint, as service interruption at the last house on the line is likely. Most of the line should be buried about 1 m below the ground surface (Mihelcic, 2009). If these high pressure points along the distribution line could be excavated a significant depth below that or rerouted 5 to 10 m downhill, this path could be feasible.

4.2.2 Topographic Reroute to Last Toma 1 House

Due to the low pressures in Design Option 1, Agua de Abajo Engineering decided to reroute the path of the distribution line. This eliminated the problem of low pressure values at peaks in the original system design because the peaks were avoided in the reroute. Rerouting the line was possible because the high points occurred between two houses; moving the distribution line would not affect service for any other community members. Figure 18 shows the reroute along with the original survey line on the backdrop of a topographic map. The reroute trails down the ravine to a lower elevation, bypassing the high points. This reroute allows the system to provide adequate water flow to the last house on the line.

Figure 18. Topographic Reroute. The red line shows all of the original Toma 1 proposed system. The black line shows the reroute of the water line, which appears to avoid peaks.

Figure 19 illustrates the approximate elevation profile for the topographic reroute. (A larger view of this profile can be found in Appendix E.) Prior to point T3, the elevation profile is identical to the surveyed route. The reroute is established from T3 to the end of the profile. The elevation along the reroute is lowered to an elevation of 230 m down a ravine, and then brought back up to T4 at an elevation of 271 m. This proposed route avoids all of the peaks which caused problems in the previous design. The total length of pipe needed on this route was measured to be 2950 m. To provide a safety factor, approximately 10% was added to this amount to total 3250 m.

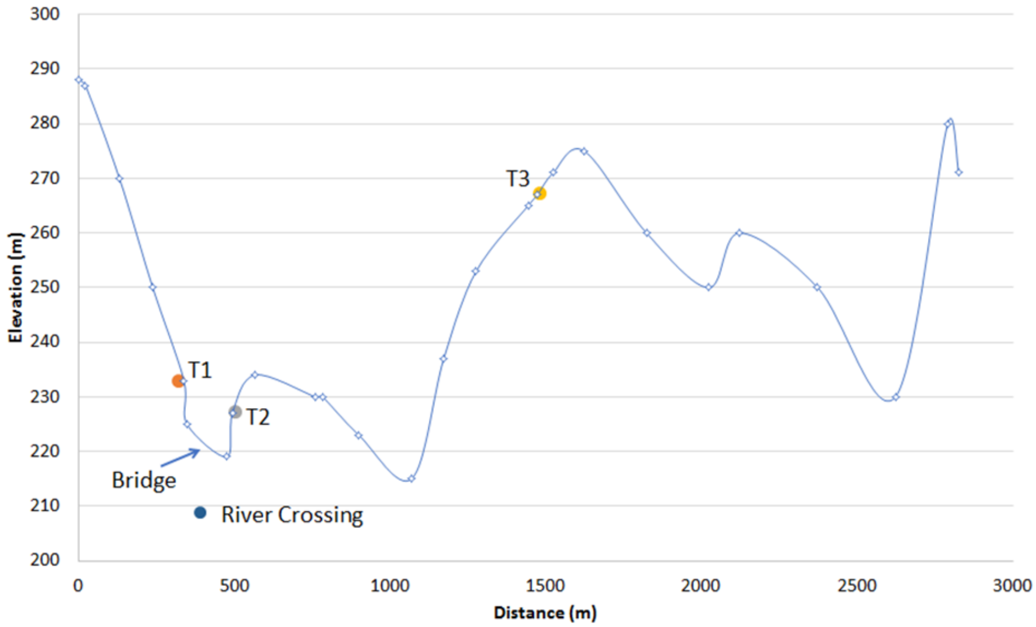


Figure 19. Pipeline Reroute Elevation Profile

Just as the elevation profile for this system is identical to the surveyed system up through N9 (shown in Figure 20), the pipe diameters are also the same. Every pipe from N9 through the end of the system is 50.8 mm, except for the pipe preceding Clemente's house, now TR7 in Figure 20. The pressures are now high enough at Clemente's house to use a 25.4 mm pipe, which is cheaper and more typical of the pipes connecting to tap stands. There are no pressure problems in this model of the system. The high pressures are similar to those shown in Figure 17; these pressures are not high enough to break the pipes and do not occur at tap stands. All pressures are above 8 m, which is significantly better than Design Option 1.

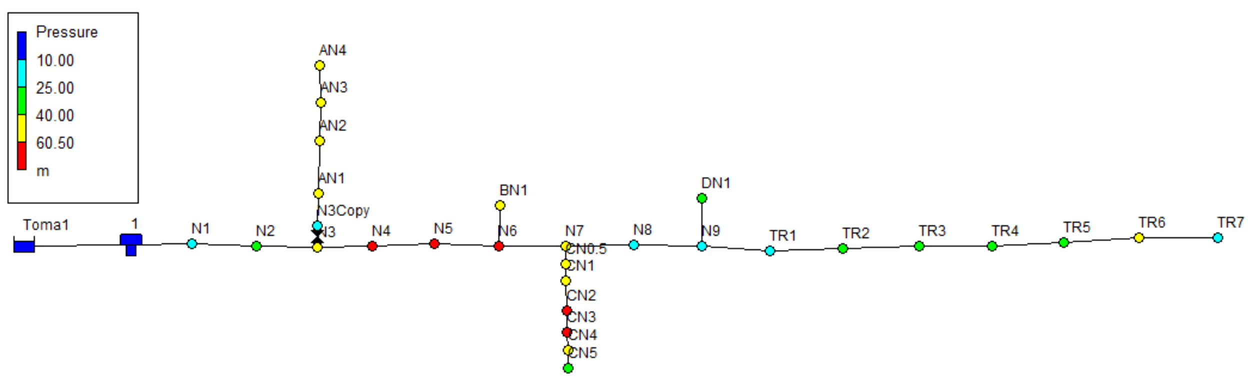


Figure 20. EPANET model representation for the topographic reroute Toma 1 system. Note the difference in the pressure scale at the top left; the pressures in this system past the storage tank are all higher than 10 m, which is a great improvement.

While this system is potentially a significant improvement from the last system hydraulically, this route will have to be surveyed to provide data for a more accurate analysis of the system. Further, it is unknown who owns the property the pipeline would cross, or if maintenance in these areas is feasible.

This proposed route could be running through agricultural fields, jungle, or both, any of which would be significantly more difficult to maintain than a distribution line along the main path.

4.2.3 Distribution System with a Rainwater Harvesting System

This option is the same as the two previous options, except the last house would have a rainwater catchment system. This would reliably provide point-of-use water access to all community members, and it would significantly reduce the amount of pipeline required. The system map, elevation profile, and pressures would be identical to the previous two designs (maps are Figures 15 and 18, elevation profiles are Figures 16 and 19, and pressure schematics are Figures 17 and 20) up to the second to last house which has been represented by N9 in the EPANET model schematics and T4 in the elevation profiles. The design for the rainwater harvesting system is detailed in section 5.2.3 since three other rainwater harvesting systems were designed for the Toma 2 group. The results show that if a metal roof were installed, this last house on the line would need a roof area of 134 m^2 and a tank volume of 16 m^3 to meet the MINSA water supply standard of 113 liters per person per day, or a roof area of 55 m^2 and a tank volume of 8 m^3 to meet the UN supply demand standard of 55 liters per person per day (unwater.org). Thatch roofs are much less efficient and are not recommended, though roof area and storage tank volume requirements have been calculated. Details of this analysis are available in Appendix F.

5.0 Toma 2 System Design

The Toma 2 system will serve the current population of 9 in three houses, but is designed for 12 people. It takes 1060 L of water each day to meet the MINSA demand for these households (the last three households' demands in Table 1). While this system is much smaller than the Toma 1 System, it presents significant challenges. An important challenge in the design for delivering water to these houses is that the houses are at higher elevations than either of the available tomas. Three design options have been developed that address this challenge and are described in section 5.2. Two use the Toma 2 spring source and the third utilizes rainwater catchment. The first two design options for Toma 2 rely on some of the same components: an existing spring box, an existing storage tank, and a tap stand (the same design should be used as is discussed in section 4.1.7). These components will not be discussed in section 5.1. The final design for Toma 2 was chosen to be a water distribution system originating from the Toma 2 spring source. The distribution system will be gravity fed and will contain one communal tap stand for all the houses on the line. The elevation profile for the Toma 2 proposed design can be found in Appendix G.

5.1 Water Distribution Alternatives

5.1.1 Individual Taps with Solar Pump

Figure 21 illustrates the elevation profile for the distribution line from Toma 2 to the three houses. Shown on the profile, the last point in the system is 12 meters higher than the initial spring source elevation. This means that to provide running water to the houses, a pump will be needed. Figure 21 illustrates the suggested location of the transfer pump and the storage tank. All the dimensions for the storage tank and the pump are contained in Appendix B. This location was chosen since it is close to the last location that water can be provided by while still having adequate pressure.

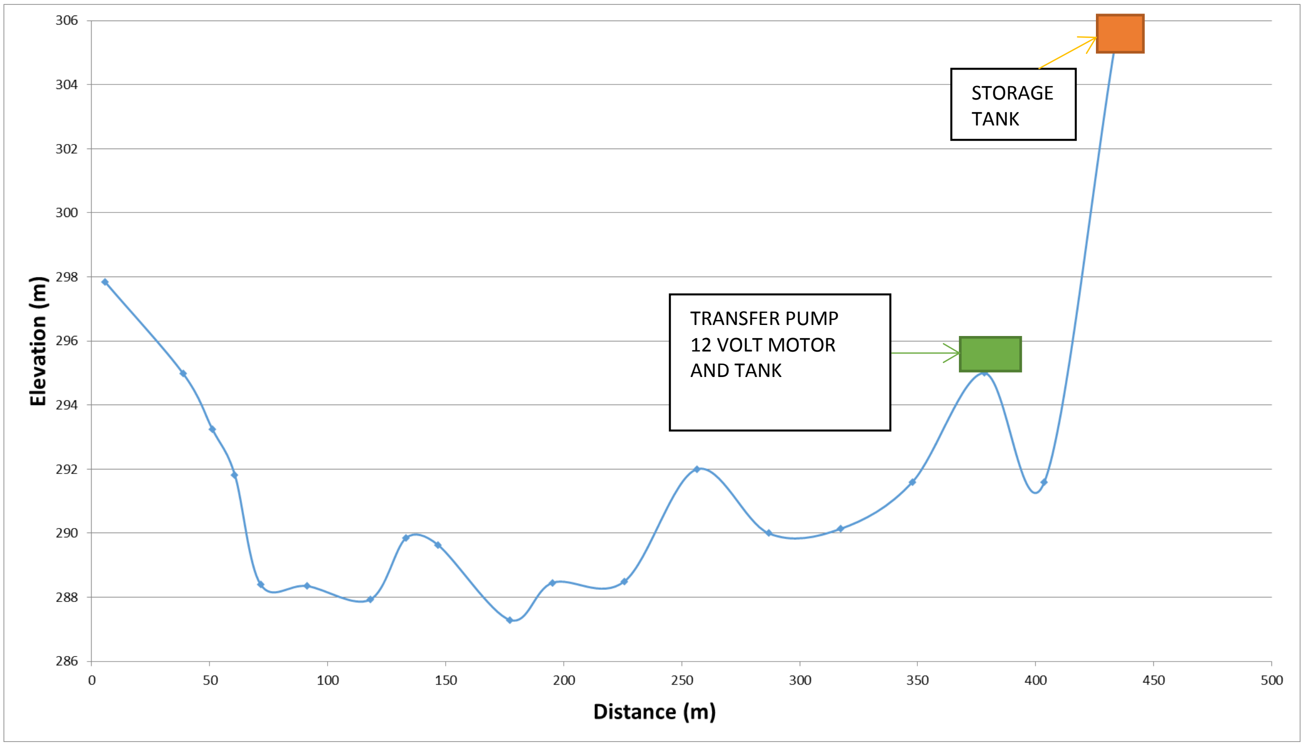


Figure 21. Toma 2 Eleveation Profile with Solar-Powered Pump

The next step in the design of the pumping system is to select a pump based on the power requirements for the design. The system has a lift of about 40 feet. The desired pumping rate is 5 gallons per minute. Next, the pump efficiency is estimated to be around 50%. With all these known values, the power requirements of the system can be determined with the following equation:

$$OUTPUT\ POWER = FLOW\ x\ TOTAL\ DYNAMIC\ HEAD$$

$$OUTPUT\ POWER\ (hp) = Q(GPM)\ x\ TDH\ (ft)/\ 3960$$

$$OUTPUT\ POWER\ (hp) = 40' * \frac{3\ gpm}{3960} =\ 0.03\ hp$$

(Eqn. 8)

$$INPUT\ POWER = \frac{OUTPUT\ POWER}{PUMP\ EFFICIENCY}$$

$$INPUT\ POWER = \frac{0.03\ hp}{0.5} = 0.06\ hp * \frac{746\ watts}{hp} = 45\ watts$$

(Eqn. 9)

The input power of the system is calculated to be 45 watts, which is around the same power that is required to use a light bulb. In order to meet the power requirements for the pumping, a solar panel and battery will be used. The solar panel used is a *Wel-Bilt 45 Watt Solar Kit with Lights — Three 15 Watt Amorphous Solar Panels, 2 12V CFL Light Bulbs.* The solar panel can be purchased from Northern Tool and Equipment. This package includes three amorphous solar panels, two 12V CPL light bulbs, a combiner cable, one DC plug, one support stand, one control box, and a set of battery clamps. Figure 22 below illustrates the solar panels and included items.

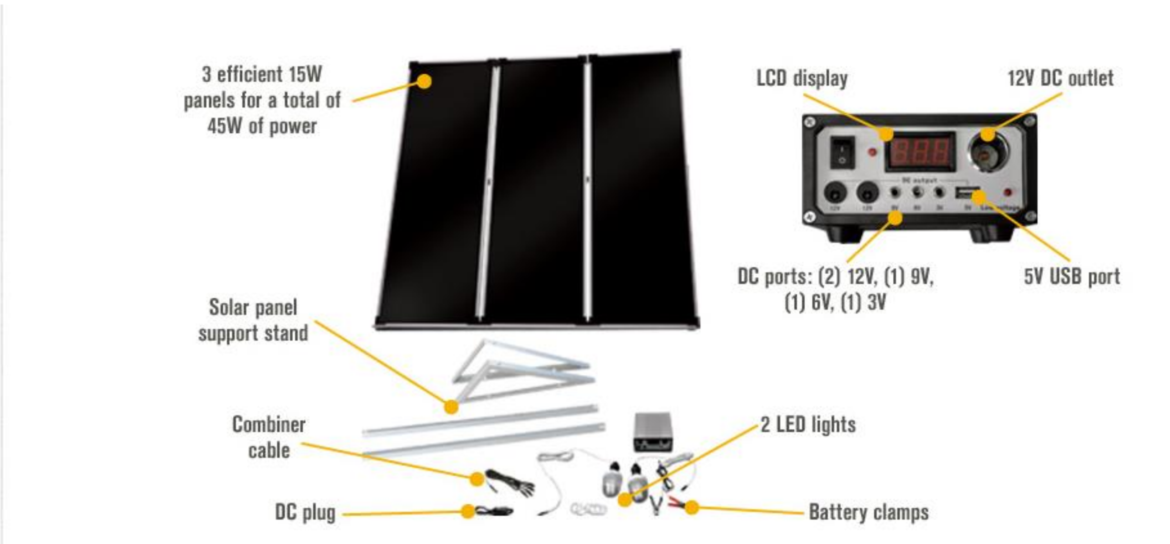


Figure 22: Solar Panel and Included Items (northerntool.com)

A rechargeable battery will be connected to the solar panel. Figure 23 shows a 12 V 5Ah SLA Rechargeable Battery that has the capability to connect to the solar panel.

Figure 23: 12 V 5Ah Rechargeable Battery (amazon.com)

The last element to add to the system is the actual pump. Figure 21 below illustrates a SURflo On-Demand Diaphragm Pump. This pump contains ½-inch ports, can produce a flow rate of 180 gallons per hour or 3 gallons per minute, and contains a 12 volt motor.

Figure 24: SHURflo On-Demand Diaphragm Pump (northerntool.com).

The pump design and water distribution system were entered into EPANET to determine the head losses and pressures at all the nodes. The system uses 25.4 mm PVC pipe before the pump and 12.7 mm diameter PVC after the pump. Figure 25 shows the system pressures in EPANET.

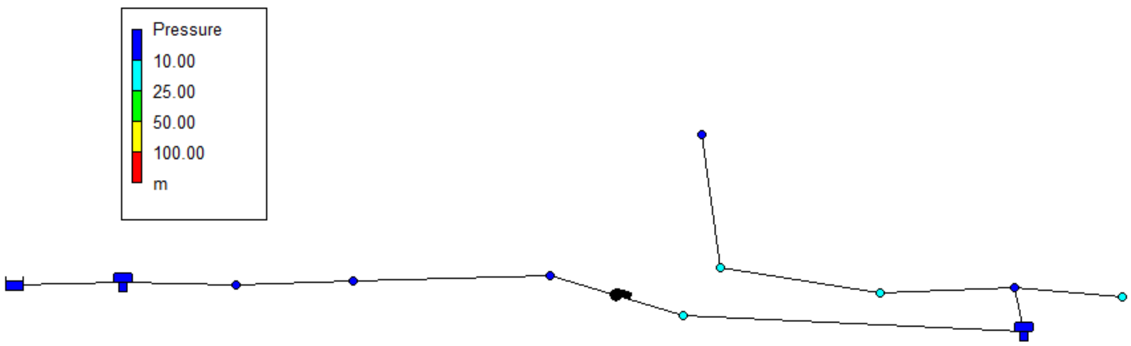


Figure 25: Toma 2 EPANET Model

From the model, the pressures at two of the tap stands at Louis Moran and Laurino's houses pressures are 9 and 4 m, respectively, which is below the recommended pressure to provide adequate flow of water. The only way to provide adequate flow of water to these houses would be to increase the tank elevation by 6 meters. The topographic map of Vallecito shows that there are no hills nearby with a higher elevation than 305 meters, which is the current elevation of the tank. The other option would be to build a 6-meter high water tower, which is prohibitively expensive. This means that if these three houses want to have water provided to their point of use via a water distribution system, the pressures will be lower than recommended.

5.1.2 Gravity Fed Communal Tap

The other option for using Toma 2 as part of a water distribution system would be to use gravity to carry water as far as it can go before too much head is lost, providing a tap stand at this node for the three houses to share. The water would be carried to node 3 of Figure 25. The elevation profile for this system is shown as Figure 26.

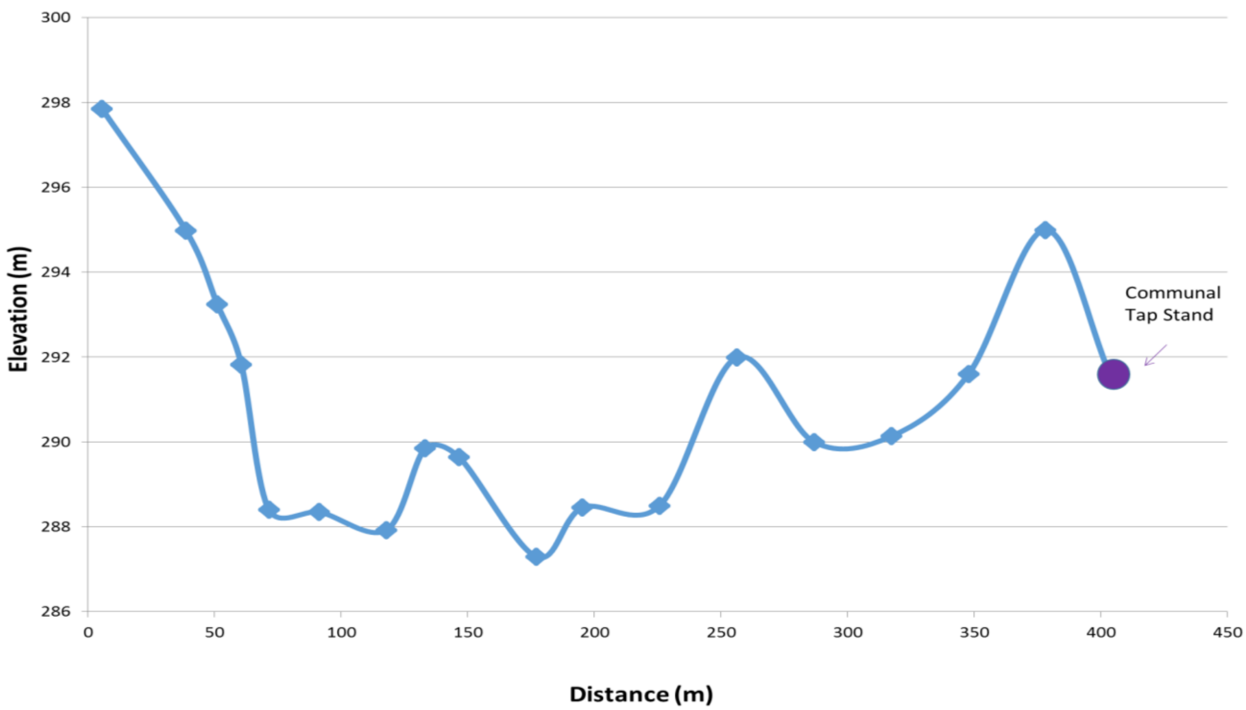


Figure 26: Elevation profile of Toma 2 gravity fed water distribution system to a communal tap.

The difference from source to communal tap in Figure 26 shows that pressure at the communal tap stand will be approximately 6 m, which is similar to the low pressures provided by the solar pump. Use of gravity cannot provide water straight to the points of use; the tap stand would exist at a walking distance of about 30 meters from each of the houses, which is not far. The alternative would be more cost-effective and more sustainable, albeit less convenient.

5.1.3 Rainwater Harvesting Systems

Rainwater harvesting systems have been designed and evaluated for four homes in the Abajo region of Vallecito. Three of these homes are higher than both spring sources (the Toma 2 group), and the fourth is significantly far from the previous house on the line (the last house on the Toma 1 line), which make these houses excellent candidates for rainwater harvesting.

Monthly precipitation averages for Vallecito were approximated using The World Bank's Climate Change Knowledge Portal. This data shows a monthly low of 59.8 mm of rain in February and an annual total of 2,795.8 mm of rain. The data from this source is shown in Figure 26. According to DTU (1987), the minimum monthly rainfall should be no less than 50 mm for half of the year (Mihelcic 2009). Thus, rainwater harvesting should be a viable water supply option for these houses.

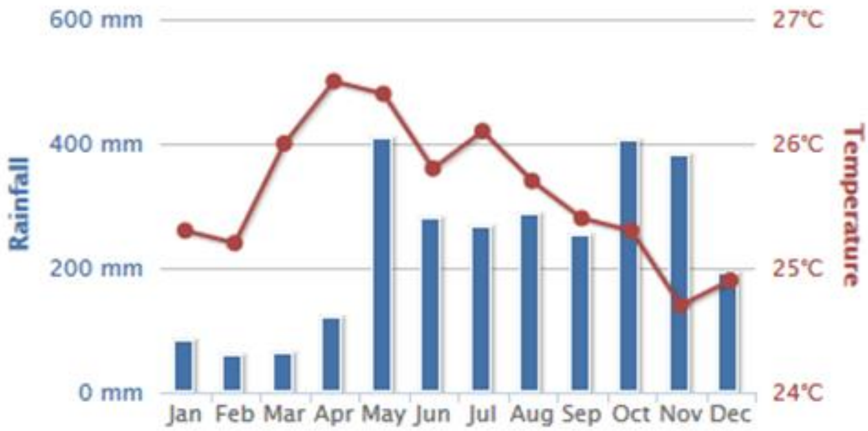


Figure 27. Monthly rainfall and temperature means near Vallecito based on 1990-2009 data. "The dataset was produced by the Climatic Research Unit (CRU) of University of East Anglia (UEA)," (The World Bank, 2013).

The water supply available can be found using the following equation, (Mihelcic, 2009):

$$S = PAC$$

(Eqn. 10)

Where S is supply, P in the precipitation volume (mm), A is the collection area of the roof, and C is the runoff coefficient, which represents the fraction of water that hits the roof and makes it to the storage tank.

The precipitation data used for each model is the precipitation data shown above. Two different values were used for C: 0.2 for the thatch roofs, which all of the houses currently have, and 0.9 for galvanized iron, which is comparable to zinc roofs that would greatly improve water supply (Waite, 2010). An initial estimate for roof area was 56 m^2 (approximately 20 ft. by 30 ft. based on a photograph), but the area was varied to meet the demands of each household. Two different demands were used for each household: the MINSA demand of 3411 liters per person per month and the UN demand of 1500 liters per person per month, based on 50 liters per person per day (unwater.org). The population was again projected 15 years into the future to calculate the demand at each house. This data can be seen below.

Table 2. MINSA and UN Demands for each potential rainwater harvesting household.

Household Head	Projected Household Population	MINSA Demand per House (L/mo)	UN Demand per House (L/mo)
Clemente	4	13610	5985
Laurino	2	4537	1995
Ismael	7	22683	9975
Louis Moran	4	13610	5985

The final sizes of the necessary roof and storage tank were determined using the following approach, outlined by Mihelcic, 2009. This example of the data analysis was performed on Laurino's household using a metal roof, the UN demand, and the precipitation data shown in Figure 27.The runoff supply was found using Equation 11, with a final roof area of 20 m^2 and runoff coefficient of 0.9. The demand used is the UN demand for a 1 person household, projected 15 years into the future. V_t is the volume of water that could be stored in the tank. It was found using the following equations:

For the first month, then $V_t = Supply - Demand$

For all consecutive months $V_t = (V_{t-1} + Supply) - Demand$

(Eqn. 11)

The V_{t-1} term in the equation for the later months accounts for storage in the tank at the end of the previous month, which would be available to meet the demand. The volume of water stored in the tank is limited to the size of the tank. In this case, that volume is 2300 liters, or 2.3 m^3. $V_{t\text{-Corrected}}$ represents the volume of water physically in the tank, constrained by being empty or overflowing. The % Demand Met shows how much of the demand is met by both the current month's rainfall and the previous month's storage. If was found using this equation:

$$\%\ Demand\ Met = \frac{V_{t-1} + Supply}{Demand} \times 100$$

(Eqn. 12)

The roof area and storage tank size were adjusted until 100 percent of monthly demand was met after the first few months. The first months of the year are during the dry season, so demand is left unmet without storage from previous months. Results for subsequent years (shown in Appendix F) assure that the roof area and tank size are sufficient to meet the household demand under typical circumstances, even during the dry season.

Table 3. Data analysis to determine appropriate roof area and storage tank size for Laurino's house using a metal roof and the UN demand standard.

	Rain (mm)	Supply (L)	Demand (L/mo)	V_t (L)	$V_{t\text{-Corrected}}$ (L)	% Demand Met
Jan.	82.8	1490.4	1995	-505	0	75
Feb.	59.8	1076.4	1995	-919	0	54
Mar.	63.8	1148.4	1995	-847	0	58
Apr.	118.9	2140.2	1995	145	145	107
May	408.4	7351.2	1995	5501	2300	376

The same analysis was performed for all roof material and demand combinations for each household. The results are shown in Table 4. The extended table of calculations to support each of these results can be seen in Appendix F. Each roof size and tank size have designed so that 100 percent of the demand at each house is met throughout the year.

Table 4. Summary of rainwater harvesting analysis results, showing roof area and storage tank size as a function of roof material and demand combinations. Specific demands for each house are shown in Table 2.

		Thatch Roofs Results		Metal Roof Results	
		MINSA	UN	MINSA	UN
Laurino	Roof Area (m^2)	200	56	56	20
	Tank Size (m^3)	5.5	4.35	3.5	2.3
Clemente & Louis Moran	Roof Area (m^2)	530	250	134	55
	Tank Size (m^3)	20	7.7	16	8
Ismael	Roof Area (m^2)	1175	306	260	85
	Tank Size (m^3)	20	20	20	15

While thatch roofs are most common in Vallecito, these roofs do not support rainwater harvesting systems for two reasons: the catchment area required is absurdly large, and rainwater harvested from organic roofs is not recommended for drinking (Mihelcic, 2009). If rainwater harvesting systems are implemented, the roofs of each of the houses should be replaced or topped with galvanized iron or locally available zinc roofing to improve water supply quantity and quality. Even with this improvement, rainwater harvesting requires a significant roof area to supply the MINSA demand of 113 liters per person per day. All of these households currently get their water from surface sources, so the people are unlikely to use this much water per day; the UN demand of 50 liters per person per day is likely more realistic for the area. Modeling the systems with a metal roof and considering UN demand yields reasonable roof area and storage tank requirements for three of the four houses. Ismael's house requires a roof area of 85 m^2 and a tank of 15 m^3, which are both a little larger than desirable for the area but are necessary to provide water for the projected population of 7 in the home. These roof areas and tank sizes may be reasonable for the four properties, but measurements of existing roof areas and space available for tanks should be obtained before a commitment to rainwater harvesting is made.

The guttering for each house will be made of 200 mm wide sheet metal bent in the center to 90 degrees. A first flush pipe will be included in the guttering layout prior to water entering the tank to ensure that the roof is clean by the time water reaches the tank.

If rainwater harvesting is chosen, systems will look similar Figure 27, with the exception that cost estimates were based on cylindrical ferrocement tanks.

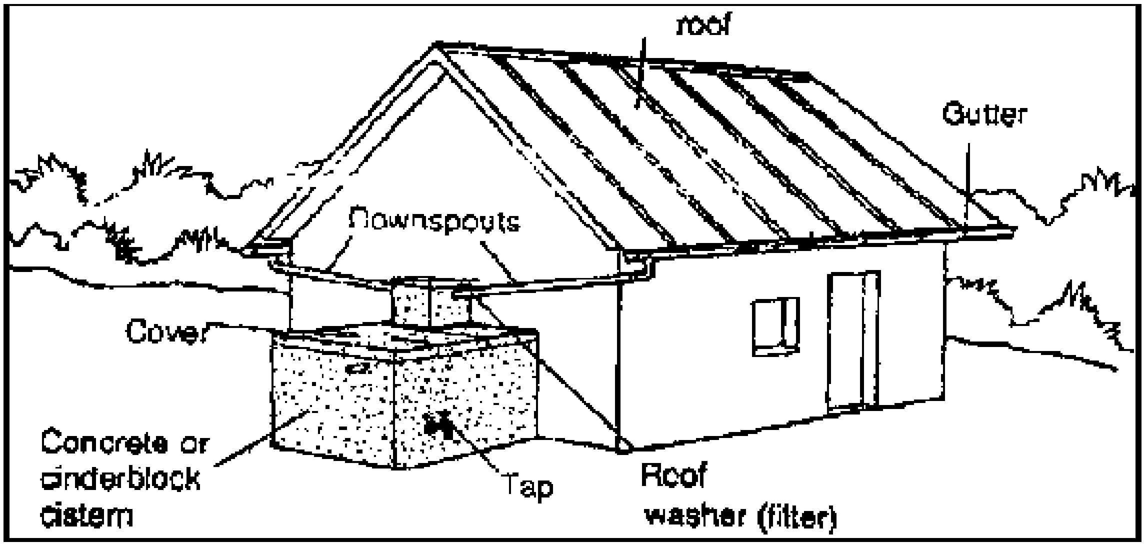


Figure 28. Rainwater harvesting schematic (http://www.oas.org/dsd/publications/Unit/oea59e/p034.GIF).

6.0 Alternatives Analysis and Final Recommendation

Decision matrices were used by Agua De Abajo Engineering to determine the best of the alternatives for suppling water to the Northern area of Vallecito. Based on the following decision matrices, the recommended designs are the “Topographic Reroute to Last Toma 1 House” (described in section 4.2.2) for the Toma 1 System and “Gravity Fed Communal Tap” (described in section 5.1.2) for the Toma 2 system. This design will be the most cost-effective, and most accepted by the community.

The cost column is based on the calculations in the cost estimate (seciton 7). Community perspective is based off information provided by the PCV Siobhan Girling. Ease of maintenance is based on how simple the design components are to maintain, and potential lifespan is based on the design life due to the sustainability of the materials and components. Quality of water delivered is rated high for water that is clean, both by design and by the perception of cleanliness. Convenience is based on ease of construction, location of water source in relation to homes, and the need for any additional assessment work. Finally, supply reliability is based on how much the community can rely on the given system to provide a sufficient amount of water throughout the year and flow on a daily basis.

Weights for the decision matrix were based on the importance of each component to the community, based on information from the PCV Siobhan Girling. Cost, ease of maintenance, and supply reliability are most important because there represent limited resources in the community. Community perspective and quality of water delivery are next because these are necessary to have a successful system shared by multiple families. Potential lifespan and convenience are still important, but are less necessary, which is why they are given a weight of two.

Table 5. Decision Matrix for Toma 1 Options.

Criteria	Cost	Community Perspective	Ease of maintenance	Potential Lifespan	Quality of water delivered	Convenience	Supply Reliability	
Weight of Criteria	4	3	4	2	3	2	4	**Total**
Surveyed Full System	6	10	8	7	9	9	5	**165**
Reroute Full System	7	9	8	7	9	6	9	**176**
System to Felix's, rainwater for Clemente	9	5	8	8	7	8	7	**164**

Table 6: Decision Matrix for Toma 2 Options.

Criteria	Cost	Community Perspective	Ease of maintenance	Potential Lifespan	Quality of water delivered	Convenience	Supply Reliability	
Weight of Criteria	4	3	4	2	3	2	4	**Total**
Rainwater catchment for all	3	4	8	9	7	8	7	**139**
Gravity Fed Communal Tap	9	6	6	8	8	5	8	**160**
Solar pump	5	9	2	2	8	9	8	**133**

The final recommendations of Agua de Abajo Engineering for this project have been sketched onto a map from the Google Earth file Siobhan Girling sent, shown as Figure 29.

Figure 29. Map of Northern Vallecito showing the recommended design options for Toma 1 and Toma 2 Systems. The red line represents "Topographic Reroute to Last Toma 1 House" (described in section 4.2.2) for the Toma 1 System and "Gravity Fed Communal Tap" (described in section 5.1.2) for the Toma 2 System.

The designs that were explored for the Toma 1 system included the surveyed system, the topographic reroute, and the surveyed line to Felix's with a rainwater catchment system at Clemente's house. The desings reviewed for the Toma 2 system included a solar pump water distribution system, a communal tap stand gravity fed water distribution system, and rainwater catchment at all houses. Based on the decision matrices, Agua de Abajo Engineering recommends the "Topographic Reroute to Last Toma 1 House" (described in section 4.2.2) for the Toma 1 System and "Gravity Fed Communal Tap" (described in section 5.1.2). These design will be the most cost effective, and most accepted by the community.

7.0 Cost Estimates

The overall water supply system for Northern Vallecito is separated into two systems, each having three alternatives. Table 7 shows a summary of the costs for the recommended design and other alternatives. A detailed cost breakdown for each can be found in Appendix.

Transportation of all these matrials will be done by chiva, which will cost approximately $60 for each trip and is included in the cost for the recommended design. Labor to build this project will be provided by volunteers from the community, and supervision will be performed by the Peace Corps Volunteer.

As mentioned previously, the proposed system will include a rerouted gravity fed system from the first source and a gravity fed system for the second source. The estimated cost for this entire project (both systems) will be approximately $9,700. The majority of these costs come from the distribution line and bridge.

Table 7: Cost estimate for Toma 1 proposed design

Toma 1	
Component	**Cost**
Pipeline	$4,400
Spring Box	$360
Storage Tank	$343
Bridge	$2,300
Valves	$20
Tapstands	$75
Transportation	$960
Total+10%	$9,300

Table 8. Cost estimate for Toma 2 proposed design

Toma 2	
Component	**Cost**
Tapstand	$10
Pipeline	$275
Transportation	$60
Total +10%	$380

In order to determine the proposed design, a cost estimate was developed for every alternative. Below is a summary of the cost of the alternatives not chosen for each spring soruce. This information may be used if a different design is selected for implementation.

Table 9: Cost Estimates for Alternatives for Toma 1

Alternative	**Cost**
Surveyed System	$8,600
Surveyed to Felix, Rainwater for Clemente	$7,000

Table 10: Cost estimates for alternatives for Toma 2

Alternative	Cost
Rainwater Catchment	$2,000
Solar Pump	$1,200

8.0 Scheduling Estimate

After the recommended design was chosen, a construction schedule was produced for these options. The construction will begin on December 1st, 2014 and end January 22nd, 2015, which is during the dry season.

The workers needed were estimated using data from a previous iDesign report done by Uno Mas Engineering (2012). The amount of workers available in Vallecito, however, is smaller than the estimate provided in this earlier report. Vallecito's construction crews will consists of about 8 people each day. The time estimates for the construction of a pipeline show that this size crew could lay approximately 0.25 km in one day.

Table 11 Summary of Tasks and Time to Complete for Proposed Design

Task	Time to Complete
Bridge Tower Construction	6 days with 28 days for curing
Spring Box and Tank Construction	6 days
Installation of Pipeline	24 days

In the schedule that is attached and summarized in Appendix I, preparation includes clearing the area of all vegetation and acquiring appropriate tools. Transportation includes transporting the materials from the store to the chiva to the community center where the materials should be stored within the fence of the community building. The first structures to be built are the bridge towers to allow adequate time for the concrete to cure before tension cables are placed. The concrete will be mixed with a 3:2:1 ratio of gravel, sand and cement, respectively.

The next structures to be built are the spring box and the storage tank, which will both be made of ferrocement. This cement takes a ratio of 3:1 of sand to concrete. Ferrocement was chosen for these tanks due to ease of construction and because it is relatively inexpensive. Ferrocement is reinforced by a frame of wire mesh. Two double wire mesh frames will be used to create the structure of both tanks. First, double wire mesh will be formed into the desired structure of the tank. Cement will be mixed with sand to the recommended ratio and then plastered onto the frame. This process will be repeated once more to create a second layer.

After the anchors, spring box, and storage tank have been constructed, the installation of the pipeline will begin. Toma 1 pipeline will be laid in three different phases. The first section of the pipeline will be constructed in 3 days. This includes 650 meters of pipe from the spring box to the bridge. Note that the air release values, pressure reducing valves, and tap stands will be put in place during the assembly of the pipe line. The second phase of pipe installation will be from the bridge to Roberto's house, including the tee to Felix's. This section is 1,500 meters long and will take 5 days to construct. The final section of pipe will be 1,300 meters long, which will take another 5 days to assemble.

After the construction of the Toma 1 system has been completed, construction of the Toma 2 system will begin. Toma 2 includes 375 meters of pipe. Eight people can lay this section in 2 days. The prep for the pipeline includes clearing the area and confirming the appropriate route.

At the end of the project, a whole system inspection will be conducted, and then system will be ready to use. This schedule will allow Vallecito to construct their water system in approximately 2 months. By constructing the structures first, there will sufficient time for the concrete to cure before the systems will be in use. Please see the Gaant chart in Appendix I for more specifics on the construction schedule.

9.0 Maintenance and Sustainability

Agua de Abajo Engineering has provided this maintenance manual so that the community has an understanding of basic maintenance and operating procedures to extend the potential life-span of this design. All of the components were designed with sustainability in mind, but still need regular maintenance for optimum performance. Agua de Abajo Engineering also acknowledges the community's prior experience with water distribution systems and their established Aqueduct Constitution, which addresses many maintenance and sustainability issues. The Aqueduct Constitution can be found in Appendix A, first in Spanish as it was sent by PCV Siobhan Girling and then roughly translated to English.

9.1 Materials

Agua de Abajo designed this system to have minimal maintenance because the topography of Vallecito would make frequent maintenance very difficult. The proposed design contains inexpensive and mostly uniform parts. We recommend that the community keeps common materials such as an extra 20-ft section of 0.5, 1, and 2-inch PVC pipe, PVC joint Glue, spigots, and air release valve materials on hand. This will allow for a shorter repair time, as the nearest hardware store is inconveniently far.

In order to pay for these materials, a maintenance fee has been established in the Aqueduct Constitution. The fee is currently set at $5.00 per month, though it may be changed through an addendum. In order to enforce this fee, shut-off valves can be incorporated before tap stands in locked boxes. This will allow the water committee to shut off water to the houses refusing to pay the tax.

9.2 Pipeline

The existing systems experience frequent pipeline breaks due to livestock along the paths, washouts from river waters, and degradation due to sunlight. To limit these risks, Agua de Abajo recommends burying the pipeline wherever possible, implementing the suspension bridge design across the river, and using a 4-inch outer casement pipe wherever exposed to sunlight (as included in the bridge design). By taking these precautions, the community should experience drastically fewer breaks than with previous systems. However, breakages will still occur, and repair should be done as soon as possible to reduce service outages and the risk of contamination. By keeping materials on hand, as mentioned above, these repairs can be done promptly.

9.3 Spring Box

The spring boxes need to be monitored and cleaned regularly to ensure that safe water is being delivered to the system. Silt, leaves, dead animals and other things may collect in the pipes and spring box and block the pipes or contaminate the water. To minimize this risk, Agua de Abajo decided to place a wire screen on the pipe leading into the spring box. Inspecting and cleaning the screen frequently will help ensure a steady flow of clean water. The surface of the sand filter should also be inspected about every three months. If the surface of the filter is clogged, the filter will not work. The plumber should stop flow into the spring box and scrape the organic materials and a thin layer of sand from the top of the filter when water levels drop sufficiently. When the layer of sand is 0.5-0.8 m thick, the sand should be replaced (Water for the World, 1982).

9.4 Chlorine

As described earlier in the report, MINSA provides free in-line chlorinators and chlorine tables to communities implementing water distribution systems. The tablets provided are 3 inches in diameter and weigh approximately 200 g (Orner). With the demand flow of 4833 L/d and a dissolution rate of 2 g/1000 L, 2 tablets will need to be added every 40 days. It is recommended that the plumber checks the status of the tablets once a week until he or she knows how long the tablets will last.

10.0 Conclusions

The goal of Agua de Abajo Engineering for this project was to design a financially feasible and sustainable water distribution system (or systems) that will serve all interested households in Northern Vallecito. Agua de Abajo Engineering succeeded in this endeavor as the proposed Toma 1 and Toma 2 solutions together would cost less than $10,000 and scored very well in terms of sustainability criteria (evaluated in the decision matrices in section 6.0). With this design, the community will receive reliable, clean water throughout the year. The materials used throughout the system ensure that the water will be filtered and disinfected, safely protected from hazards in the environment, and delivered at acceptable rates to all interested homes in the northern area of the community.

One drawback of the design is that a single communitywide system was not feasible, which was a community desire. This shortcoming will not allow Vallecito to chlorinate all water sources using the MINSA-provided inline chlorinator, assuming only one is available to the community. The community may be able to obtain another chlorinator from MINSA. If not, the design of the original chlorinator could be copied so that water from both distribution systems is chlorinated, provided that enough chlorine tablets can be obtained.

In addition to recommending two appropriate solutions for Northern Vallecito, Agua de Abajo developed and analyzed two additional design options per water system. The development of multiple solutions demonstrates Agua de Abajo's dedication to considering different aspects affecting the design. The first option listed under each toma addresses the desires of the community the most—a system set along a main path for easy maintenance and providing each household with a tap, even if it requires extra technology or cost. The third set of options utilizes components that are cheaper or potentially easier to construct, despite the community's discomfort with rainwater harvesting. The second set of design options, the ones that were recommended, balances the desires of the community with what is physically achievable. Agua de Abajo Engineering believes the topographic reroute on the Toma 1

System and the communal tap downhill from the houses for the Toma 2 System are the best options for the community, but alternatives have been included in the event that community members or future development engineers involved with the community think differently.

If Agua de Abajo Engineering's proposed design is accepted, the next steps for the community include completing a survey of the route the team has proposed based on a topographic map. The topographic map available was not very precise, so this step should be taken before construction begins to ensure the system will work properly. While in community, Siobhan Girling mentioned that once a Peace Corps project is approved, a website can be set up to help fundraise for the community. Once the reroute survey is completed and analyzed, Peace Corps approval should be sought. Once it's obtained, the members of Agua de Abajo Engineering look forward to sharing links to help Vallecito fundraise for their water projects.

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Appendices

A: Vallecito Aqueduct Constitution

B: All Design AutoCAD Drawings

-Spring Box Profile

-Spring Box Plan

-Storage Tank Drawings

-Tap Stand

-Bridge

-Bridge Anchor

- Pump Design Drawings

C: Bridge Calculations

D: Toma 1

-EPANET Data

-GIS Map

-Elevation Profile (Toma 1 surveyed route)

E: Toma 1 Topographic Reroute Elevation Profile

F: Rainwater Catchment

G: Toma 2

-Toma 2 Elevation Profile

H: Cost Estimates

I: Schedule

Appendix A: Vallecito Aqueduct Constitution

Constitución del Acueducto de la Comunidad de Vallecito

Chiguiri Arriba, Penonomé, Provincia de Coclé

En acuerdo con el Decreto Ejecutivo Numero 40 (18-04-04) y Resolución Número 28 (31-01-94) establecido por el Ministro de Salud (MINSA) se presenta las regulaciones y normas gobernando el acueducto de la comunidad de Vallecito, dirigido por la Junta Administradora de Acueducto Rural (JAAR).

TODOS LOS USUARIOS DEL ACUEDUCTO TENDRÁN IGUAL RESPONSABILIDAD EN LA APLICACIÓN DE ESTA CONSITUCIÓN.

Sección 1: Obligaciones de la Junta Administradora de Acueducto Rural (JAAR)

a) La JAAR está obligado a prestar el servicio de aguas de forma continua e ininterrumpida, exceptuando cuando se produzcan daños en el acueducto o insuficiencia en la fuente de agua.
b) La JAAR no podrá interrumpir el suministro de agua, alegando motivos políticos, religiosos, de condición social o sexual, salvo las excepciones señaladas en la Sección 1ª.
c) La JAAR se obliga a mantener las estructuras del acueducto en condiciones sanitarias y de seguridad adecuadas para el consumo humano.

Sección 2: Uso de agua

d) Usos permitidos: para el consumo doméstico humano. Esto es, para beber, aseo personal, preparación de los alimentos, lavada de ropa y utensilios domésticos.
e) Usos no permitidos: se prohíbe usar el agua para actividades de lucro que ya están establecidas, tampoco para actividades nuevas como fábricas o industrias porquerizas, galerías de ordeño, cultivos u hortalizas, hoteles, pensiones, piscinas públicas, vivienda unifamiliar o cualquier otro tipo de construcción con fines de vivienda o negocios.
f) Se evitará el desperdicio del agua por medios pertinentes. Para la aplicación de las sanciones por desperdicio de agua se solicitará la intraversión de las autoridades administrativas.
g) Cada propietario está obligado asesorarse con el plomero/operador de la comunidad a fin de que esté proceda a la corrección de cualquier desperfecto que aumente el desperdicio del agua.

Sección 3: Aquellos usuarios que participaron en la construcción del acueducto tendrán las siguientes obligaciones:

a) Colaborar con el buen funcionamiento y mantenimiento del acueducto pagando la cuota mensual.
b) Reparar los daños del acueducto en su propiedad hasta la línea madre.
c) Evitar el desperdicio del agua.
d) Asistir a las reuniones y seminarios llamados por la JAAR.

Sección 4: Aquellos usuarios que no participaron en la construcción del acueducto tendrán estos deberes:

a) Cumplir con las responsabilidades, obligaciones y derechos en la Sección 3.
b) Aportar todos los materiales necesarios para su conexión desde la tubería madre hasta su residencia.
c) Hacer toda la excavación necesaria para esta conexión.
d) Pagar para la instalación una cantidad que se cobró para la construcción original del acueducto. *Esta cantidad se calculará por la JAAR en el fin del proyecto y se atajado en un adenda*.

Sección 5: La JAAR designará a una persona o grupo de personas plomero/operador con el objetivo de que se encargue de la operación y mantenimiento del acueducto.

a) La JAAR le puede pagar al plomero/operador por los servicios prestados dependiendo de los ingresos del acueducto. *Esta decisión se notará en un adenda.*
b) Cuando se cambie de plomero/operador debe haber un periodo de entrenamiento para plomeros/operadores nuevos.

Sección 6: Para ser plomero/operador del acueducto, la persona seleccionada se escogerá entre aquellos que tengan los siguientes requisitos:

a) Que muestre deseo de ayudar a la comunidad.
b) Que tenga conocimiento básico de mecánica o en su defecto, que haya demostrado interés y capacidad para aprender.
c) Debe prestar sus servicios con toda la dedicación y honradez y ser responsable de sus funciones ante el presidente de la JAAR y la autoridad del programa.

Sección 7: Las funciones del plomero/operador del acueducto son las siguientes:

a) Encargarse de la operación y mantenimiento del acueducto siguiendo las instrucciones escritas en el manual de operación y mantenimiento que le imparte la JAAR y la autoridad del programa.
b) Asistir a las reuniones de la JAAR.
c) Mantener buenas relaciones interpersonales con la comunidad.

Sección 8: Los gastos inherentes a costos de mayoras, mantenimiento y extensión deben ser cubiertos por la comunidad con fondos recogidos de la tarifa mensual.

a) La tarifa se debe pagar el primer día de cada mes al Secretario
b) Como alternativa se puede pagar varios meses en avanzado.
c) El Secretario entregará un recibo al usuario por cada pago.
d) Los usuarios pagarán una tarifa mensual de 5.00 balboas.
e) A gente que no vive en la comunidad de Vallecito, que no está conectada al sistema, puede llenar un tanque de 12 latas si se le cobra 5.00 Balboas.
f) Si se necesitará ajustar el nivel de la tarifa para cobrar los gastos del sistema, se debe explicar el cambio a los usuarios y se nota en un adenda.

Sección 9: Las infracciones del reglamento y sus sanciones

Las transgresiones al presente reglamento son:

a) No pagar la tarifa para el uso de agua.
b) Desperdicio del agua
c) Instalarse al acueducto sin previo autorización de la JAAR
d) Suministrar agua a vecinos sin consultar la JAAR

Los usuarios que transgredan el presente reglamento serán sancionados así:

a) Después de dos (2) meses de morosidad el usuario pagará un cargo de 10%. La JAAR comunicará un plazo de ocho (8) días para cancelar la deuda. Al terminar estos ocho (8) días sin pagar, se procederá a cortar el agua con la autorización de la JAAR.
b) Los usuarios que desperdicien el agua se les llamará la atención dos (2) veces. A la tercera infracción serán impuestos a órdenes de las autoridades.
c) Para volver a instalarse después que le corten el agua, el usuario tendrá que pagar 20.00 Balboas.
d) Se desconectará inmediatamente a toda persona que se instale al acueducto sin autorización.
e) Sanciones aplicadas por otras infracciones cometidas por los usuarios debe ser primero aprobadas por la JAAR.

Sección 10: El acueducto es un patrimonio de la comunidad ya que la misma participa activamente en la construcción y mantenimiento con el propósito de brindar salud, bienestar y mejoras nexos de unión entre sus miembros.

Sección 11: Cuando se compre un lote/propiedad que ya está instalada al acueducto, es la responsabilidad del comprador de verificar con la JAAR que la cuenta de agua esta pagada hasta la fecha actual para ese lote/propiedad.

Sección 12: La comunidad no puede cobrar bajo ningún concepto tazas de valorización a propiedades servidas o beneficiadas por el acueducto, ya que para tal propósito se requiere el respaldo legal del órgano ejecutivo.

Yo, ___________________________ he leído las reglas y normas contenidas en esta constitución del acueducto de la comunidad de Vallecito. Afirmo que entiendo estas reglas y hago todo posible para adherirme a ellas en buena fe.

Firma:________________________ Cedula:_____________________ Fecha:_________________

Esta es la Constitución del Acueducto de la Comunidad de Vallecito establecida por la JAAR el 6 de octubre 2012.

_____________________ _____________________

Presidente – Gertrudes Sanchez Fiscal – Zoila Mendoza

_____________________ _____________________

Secretario – David Rodriguez   Tesorero – Isabel Valdez

_____________________ _____________________

Vocal - Augustin Alveo   Vocal – Ana Valdez

Rough translation into English using Spanishdict.com:

Constitution of the aqueduct of the community of Vallecito
Penonomé, province of Coclé, Chiguirí up
In accordance with the Decree Executive number 40 (18-04-04), and resolution No. 28 (31-01-94) established by the Minister of health (MINSA) is presented regulations and standards governing the aqueduct of the community of Vallecito, directed by the Administrative Board of Rural Aqueduct (JAAR).
ALL USERS OF THE AQUEDUCT WILL TAKE EQUAL RESPONSIBILITY IN THE APPLICATION OF THIS CONSTITUTION.
Section 1: Obligations of the Administrative Board of Rural Aqueduct (JAAR)
(a) the JAAR is obliged to provide the service of water continuously and uninterrupted, except when damage to the aqueduct or failure in water supply.
b) La JAAR may not interrupt water supply, claiming reasons political, religious, social condition or sex, subject to the exceptions specified in section 1.
(c) the JAAR is obliged to maintain the aqueduct in sanitary conditions and safety structures suitable for human consumption.
Section 2: Use of water
(d) permitted uses: for domestic human consumption. That is, drinking, toilet staff, food preparation, washed clothes and household utensils.
(e) not permitted uses: it is forbidden to use water to non-profit activities that are already established, nor for activities such as factories or industries swine husbandry, galleries of milking, crops or vegetables, hotels, pensions, public swimming pools, single family dwelling or any other type of construction business or housing purposes.
f) will prevent the waste of water by appropriate means. The intraversion of the administrative authorities will be requested for the application of penalties for water waste.
(g) each owner is required consult with the plumber/operator of the community so that it is appropriate to correct any faults which increase the waste of water.
Section 3: Users who participated in the construction of the aqueduct will have the following obligations:
(a) collaborate with the proper functioning and maintenance of the aqueduct paying the monthly fee.
(b) to repair damage from the aqueduct on your property until the mother line.
(c) avoid the waste of water.
(d) attend meetings and seminars called by the JAAR.
Section 4: Users who did not participate in the construction of the aqueduct will have these duties:
(a) comply with the responsibilities, obligations and rights in section 3.
(b) provide all the necessary materials for your connection from the stem pipeline up to his residence.

(c) make any necessary excavation for this connection.
(d) pay an amount that it claimed for the original construction of the aqueduct for the installation. This amount is calculated by the JAAR in the end of the project and is tackled in an addendum.
Section 5: La JAAR shall designate a person or group of people plumber/operator with the objective that is responsible for the operation and maintenance of the aqueduct.
(a) the JAAR can pay the plumber/operator services rendered depending on the income of the aqueduct. This decision will be noticed in an addendum.
(b) when changing operator/plumber should be a training period for new operators/plumbers.
Section 6: To be plumber/operator of the aqueduct, the selected person choose is between those who have the following requirements:
a) which shows desire to help the community.
(b) that you have basic knowledge of mechanics or failing, that has shown interest and capacity to learn.
c) must provide their services with all the dedication and honesty and be responsible for their functions before the President of the JAAR and the authority of the program.
Section 7: The functions of the plumber/operator of the aqueduct are as follows:
(a) responsible for the operation and maintenance of the aqueduct follow the instructions written on the operation and maintenance manual that taught you the JAAR and the authority of the program.
(b) attend the meetings of the JAAR.
(c) to maintain good interpersonal relationships with the community.
Section 8: The expenses inherent to major, extension and maintenance costs should be covered by the community with funds collected from the monthly fee.
(a) the rate must be paid the first day of each month to the Secretary
(b) Alternatively you can pay several months in advanced.
(c) the Secretary will deliver a receipt to the user for each payment.
(d) users will pay a monthly fee of 5.00 dollars.
(e) to people who do not live in the community of Vallecito, which is not connected to the system, can fill a tank of 12 cans if they charge 5.00 dollars.
f) If you will need to adjust the level of the fee to collect the cost of the system, the change must be explained to users and is noted in an addendum.
Section 9: Infringements of the rules of procedure and sanctions
The transgressions to this regulation are:
(a) failure to pay

Appendix B: All AutoCAD drawings

Spring Box Profile

Spring Box Plan

Storage Tank Drawings

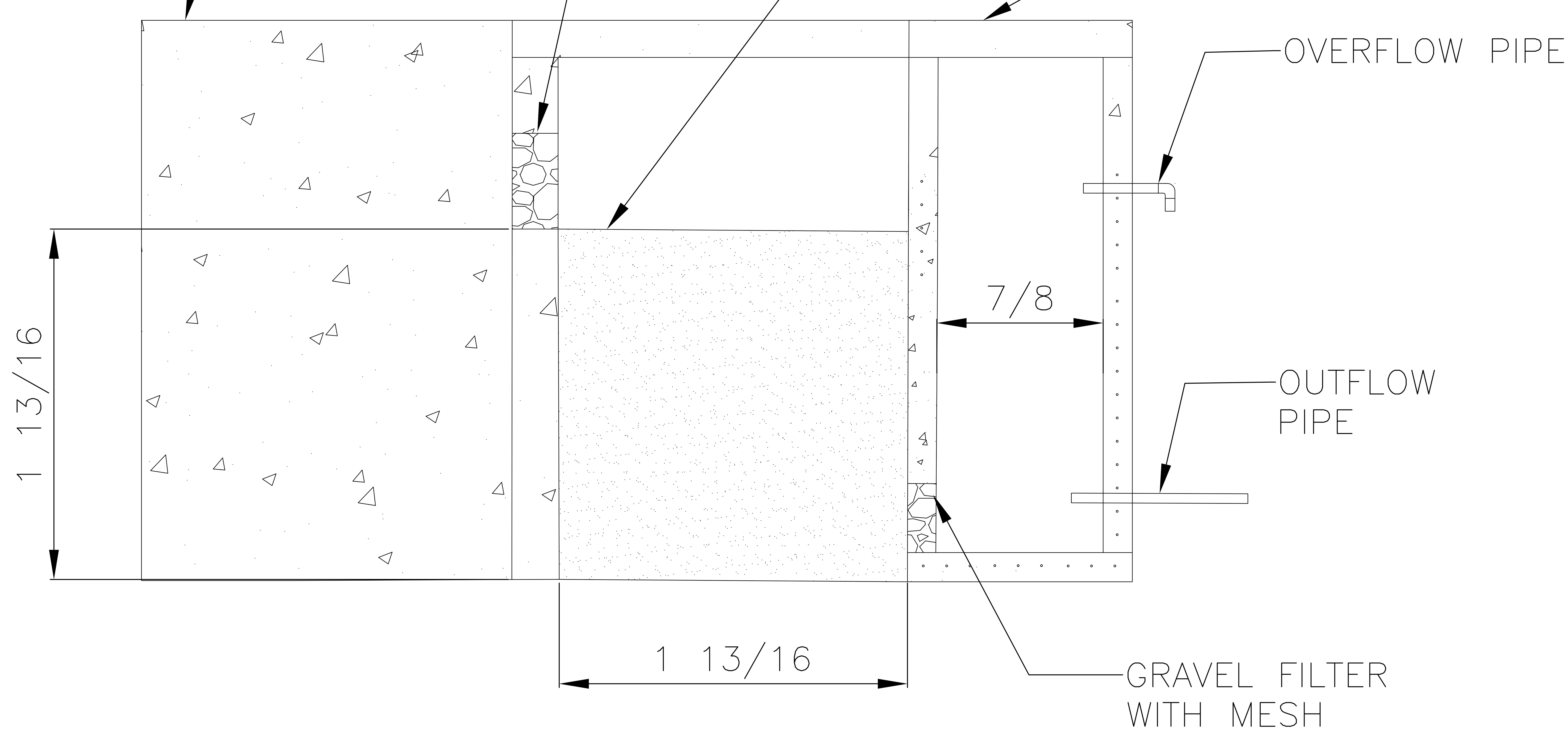
Tap Stand

Bridge

Bridge Anchor

Pump Design

◇PROFILE VIEW: SPRING BOX



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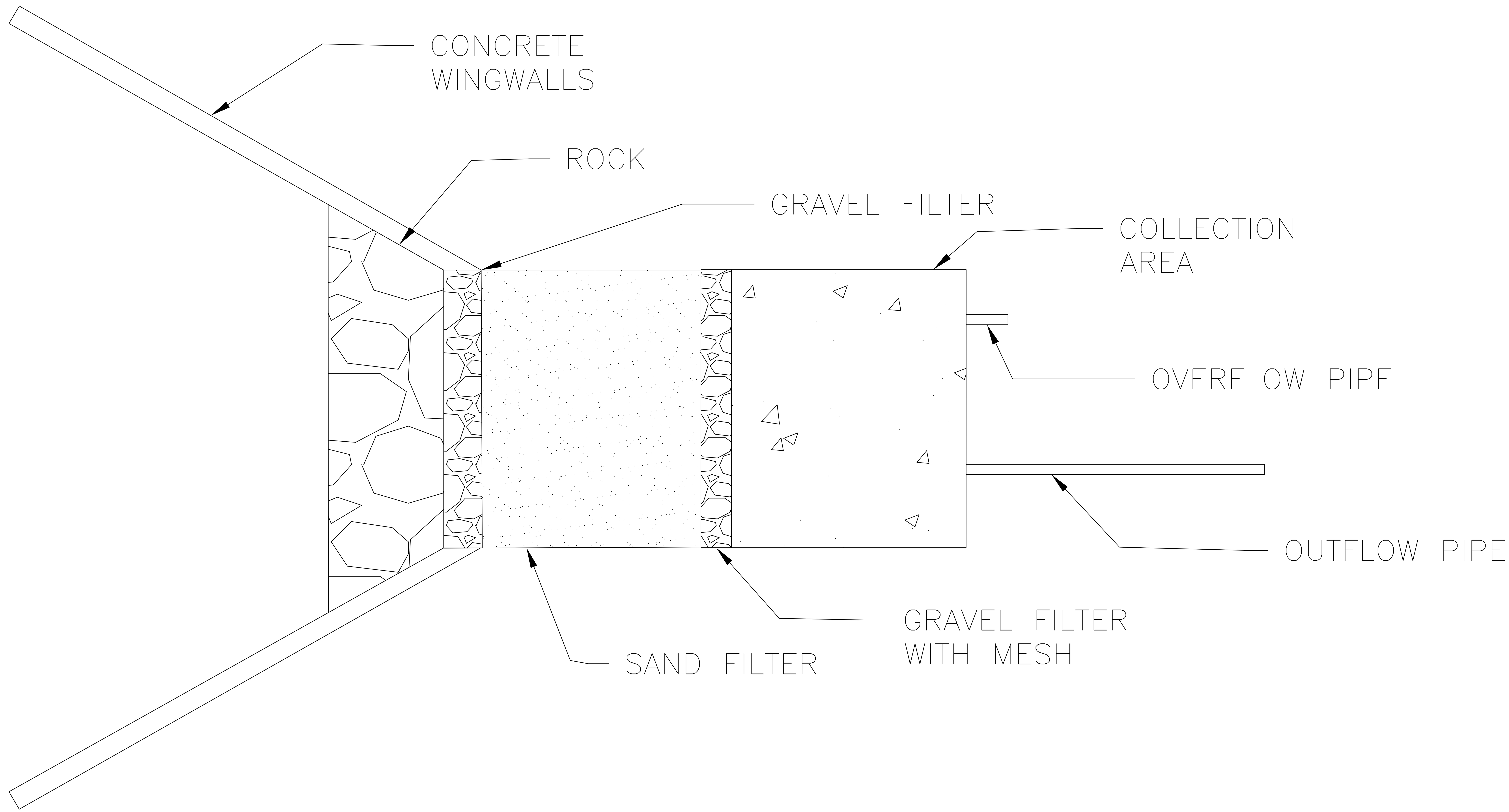
tpdomaga@mtu.edu
clmeinga@mtu.edu
easheera@mtu.edu

UNITS: METERS	DATE: 11.17.13	SHEET: 1 OF 2

◇PLAN VIEW: SPRING BOX



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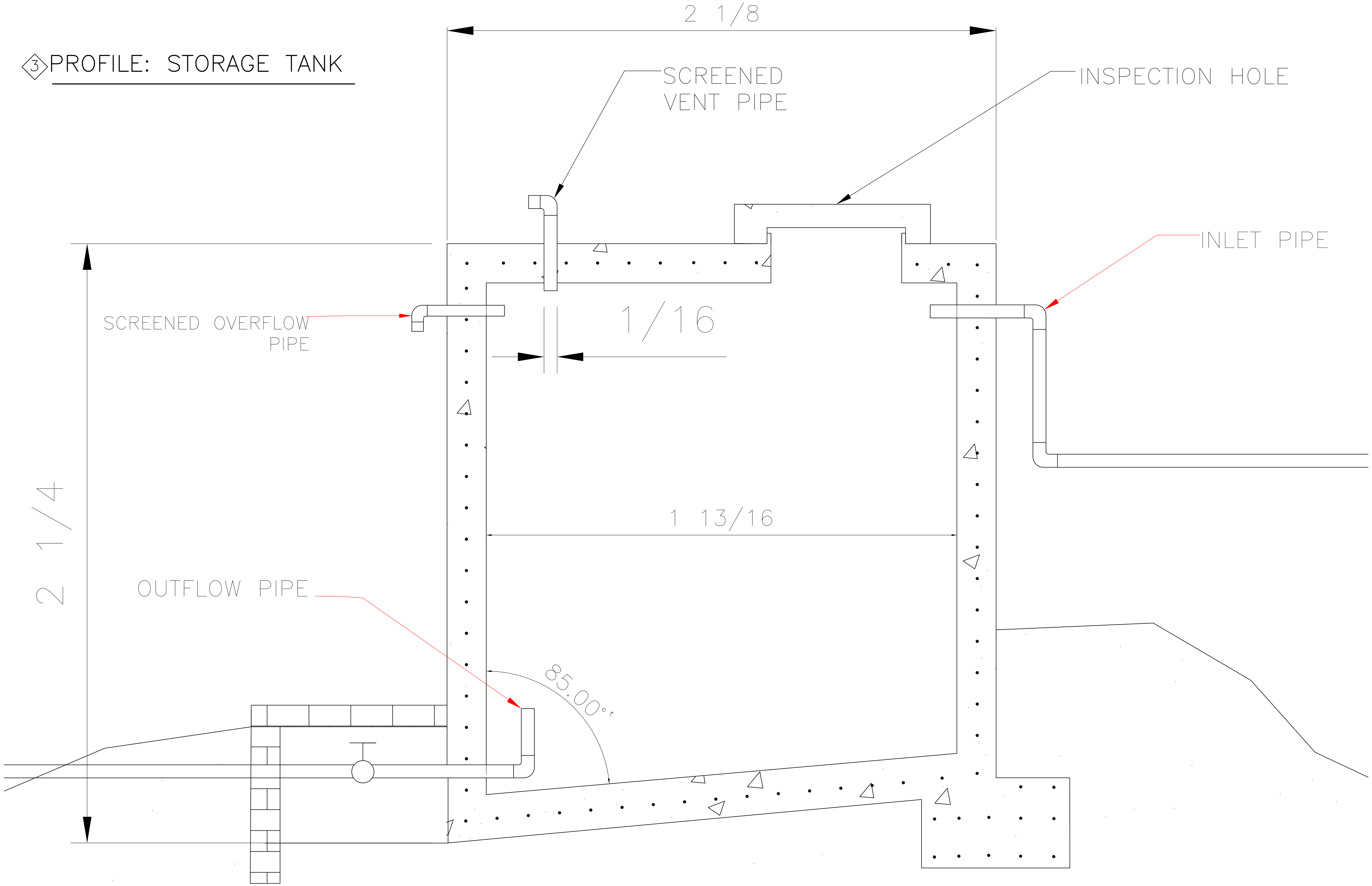
PLAN VIEW: SPRING BOX	UNITS: METERS	DATE: 10/11 /13	SHEET: 2 of 2



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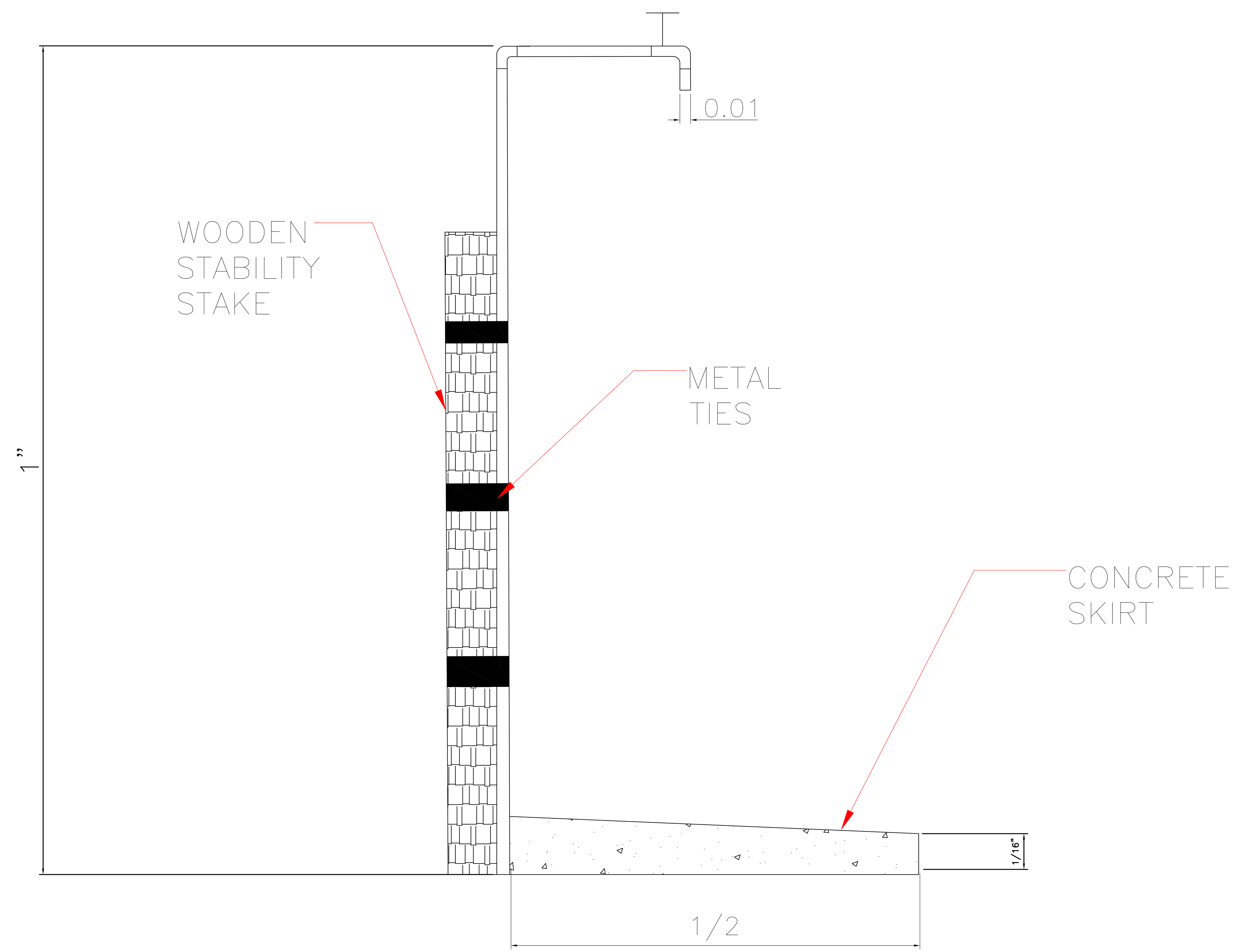
◇PROFILE VIEW: TAP STAND



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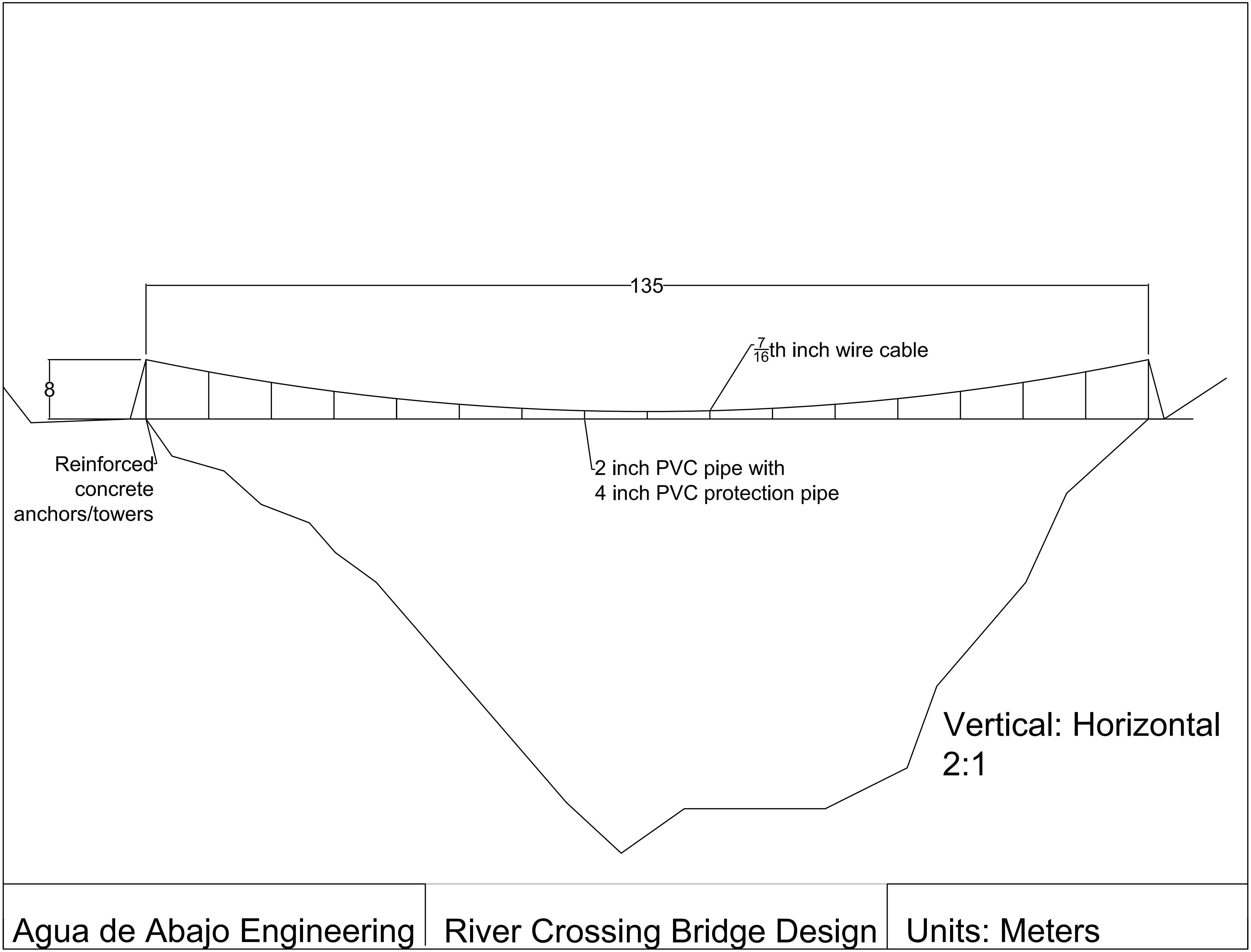
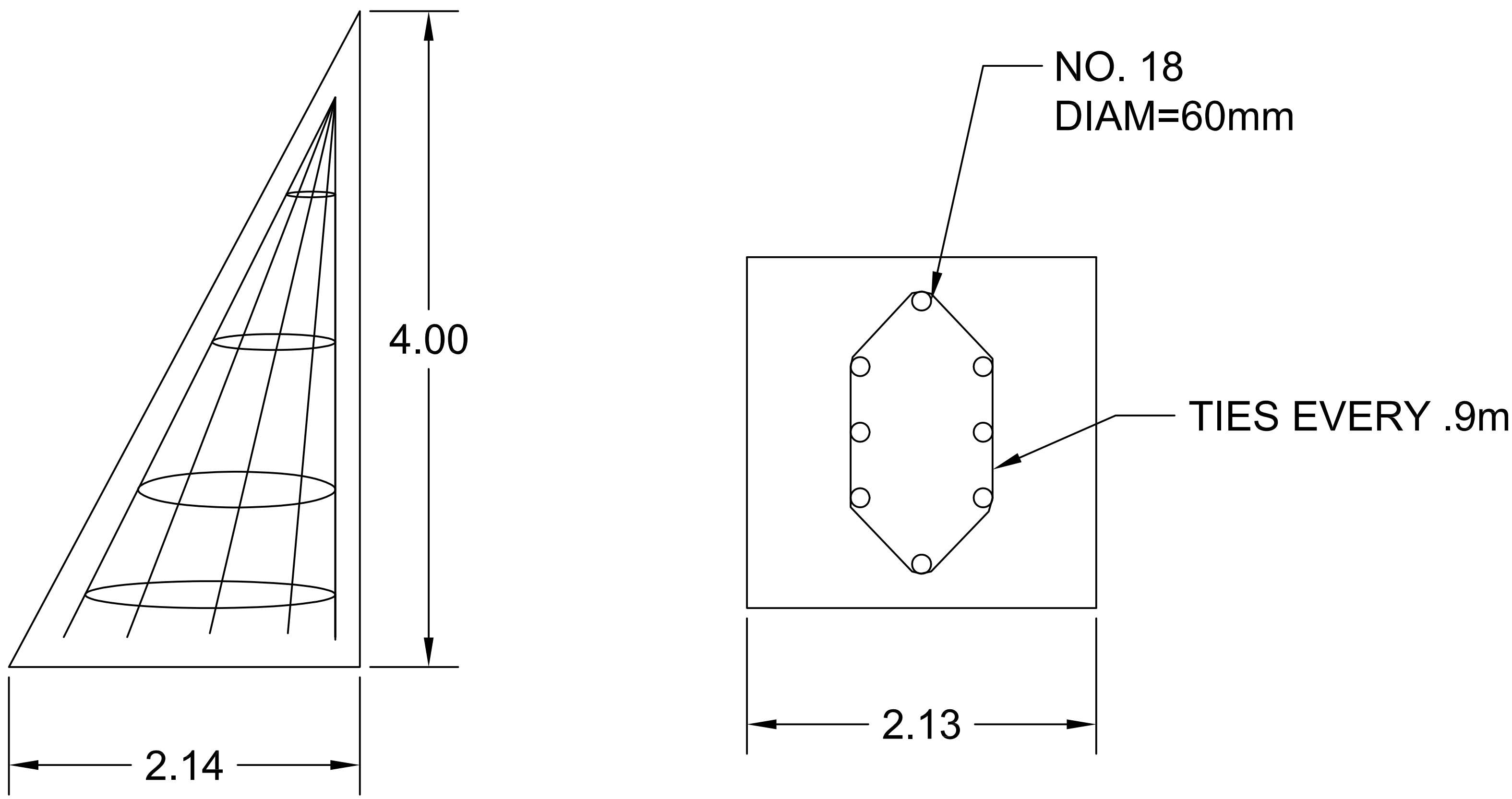
UNITS: METERS | DATE: 11.17.13 | SHEET: 2 of 2


135
$\frac{7}{16}$th inch wire cable
8
Reinforced concrete anchors/towers
2 inch PVC pipe with
4 inch PVC protection pipe
Vertical: Horizontal
2:1
Agua de Abajo Engineering
River Crossing Bridge Design
Units: Meters



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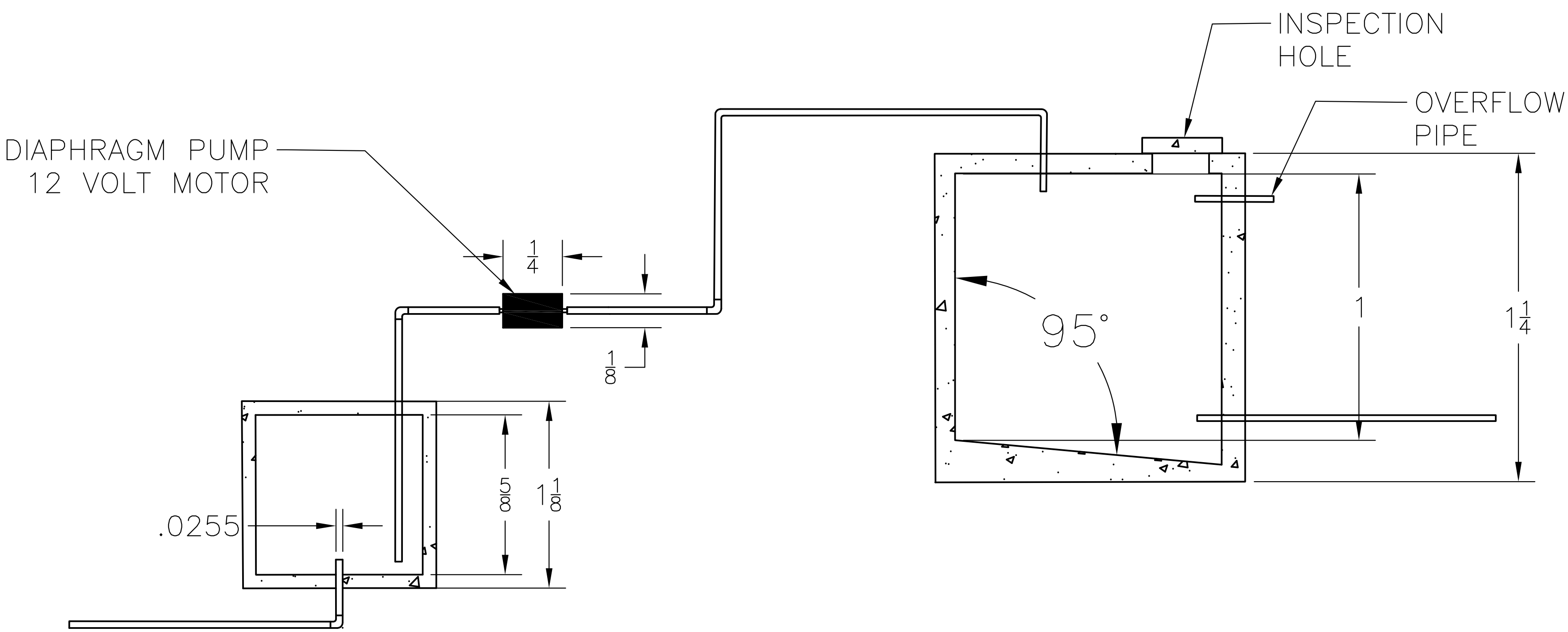
Bridge Anchors	UNITS: Meters	DATE: 12/913	SHEET: 1/1

PUMP DESIGN



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UNITS: METERS	DATE: 11.14.13	SHEET: 1

Appendix C: Bridge Calculations

See attached Sketches

Basics:

Pipe length: 135m=422.8ft

Pipe Diameter=2in

Unit weight of water=62.4 lb/ft^3

Unit Weights

Pipe: $.68\frac{lb}{ft}$

Water: $unit\ wt\ H2O * (cross\ sectional\ area\ of\ pipe)/2$

$$62.4\frac{lb}{ft^3} * \frac{pi*1^2}{2} * \frac{1ft^2}{144\,in^2} = .681\frac{lb}{ft}$$

Total= $.68\frac{\text{lb}}{\text{ft}} + .681\frac{\text{lb}}{\text{ft}} = 1.361\frac{\text{lb}}{\text{ft}}$

Horizontal Tension

w=unit weight load

L=length of pipe over river

d=estimated sag (10ft)

$$\boldsymbol{H = wL^2/8d}$$

$$\frac{\left(1.361\frac{lb}{ft}\right)*(422.8ft)^2}{8*10ft} = 3041lb$$

Total Tension

H=Horizontal Tension

$$\boldsymbol{T = \left(H^2 + \left(\frac{wL}{2}\right)^2\right)^{\frac{1}{2}}}$$

$$\left((3041lb)^2 + \frac{\left(\left(1.361\frac{lb}{ft}\right)*(422.8ft)\right)^2}{2}\right)^{\frac{1}{2}} = 3054.6lb$$

Safety Factor=2

Total Tension with Safety Factor (FS)=6109.2lb

Cable Size

$\frac{7}{16}in$ cable has a minimum breaking strength of 16540lb

Safe Load= $\frac{\boldsymbol{Min\ Break\ Strenght}}{\boldsymbol{FS}} = \frac{16540}{2} = 8270lb$

Check Sag

Safe Sag= $\frac{\boldsymbol{wL^2}}{\boldsymbol{8*cable\ safe\ load}} = \frac{\left(1.361\frac{lb}{ft}\right)*(422.8ft)^2}{8*8270lb} = 3.7ft$

Assumed sag>safe sag   10ft>3.7ft

Length of Cable

$$\boldsymbol{S = L + \frac{8d^2}{3L}} = 422.8ft + \frac{8*(10ft)^2}{3*422.8ft} = 423.43\ ft$$

Catenary Curve (used to find hanging cable lengths)

c,a=catenary curve variable

w=unit weight of cable, pipe and water=1.601 $\frac{lb}{ft}$

$$\boldsymbol{a = \frac{H}{w}} = \frac{3041lb}{1.601\frac{lb}{ft}} = 1899.4ft$$

$$\boldsymbol{y = a\left[\cosh\left(\frac{x}{a}\right) - 1\right]} = 1899.4ft\left[\cosh\left(\frac{x}{1899.4ft}\right) - 1\right]$$

See example values in the section below.

Height of the Towers

Use the catenary curve equation at different x values to find the length (y) of each cable.

At x=0 (center point between towers), y=0

At x=-211.4 and 211.4 (locations of the towers) y=11.8 ft

Therefore, the height of the towers is 11.8 ft above ground. Additional height is added to allow burial of .4 m of the tower.

Anchor size

L=triangle base of tower

h=height of tower

W=width of tower (estimated based on recommendations)

H=horizontal tension

$$\sum M = 0 = \left(\frac{1}{2}LH\right)(W)\left(\frac{1}{3}L\right)\left(150\frac{lb}{ft^3}\right) - Hh(SF)$$

$$\sum M = 0 = \left(\frac{1}{2}L * 13.12ft\right)(4.92ft)\left(\frac{1}{3}L\right)\left(150\frac{lb}{ft^3}\right) - 3041lb * 13.12ft * 2$$

Solve for L: L=7.03ft=2.14m

Check for overturning:

Sum moments around base (excluding moment from anchor weight)

The values below are the forces in the direction of the moment multiplied by the distance.

$$\sum M = 2691.6lb * 6.888ft + 2691.6lb * 13.12ft = 53{,}853\ lbft$$

In order to avoid overturning, the moment created by the weight of the object must be 2x the pervious total~=108,000.

Therefore, W must be changed to 7ft.

Check for sliding:

$$f = \mu N$$

$$= \mu * .5LWH * unit\ wt.of\ concrete = .35 * .5 * 6.888ft * 13.12ft * 7ft * 150pcf = 16{,}605.6lb$$

This above calculation shows resistance to sliding. This is four times greater than the original sum. Therefore, this design will not slide.

Appendix D: Toma 1 Design Details

EPANET Data

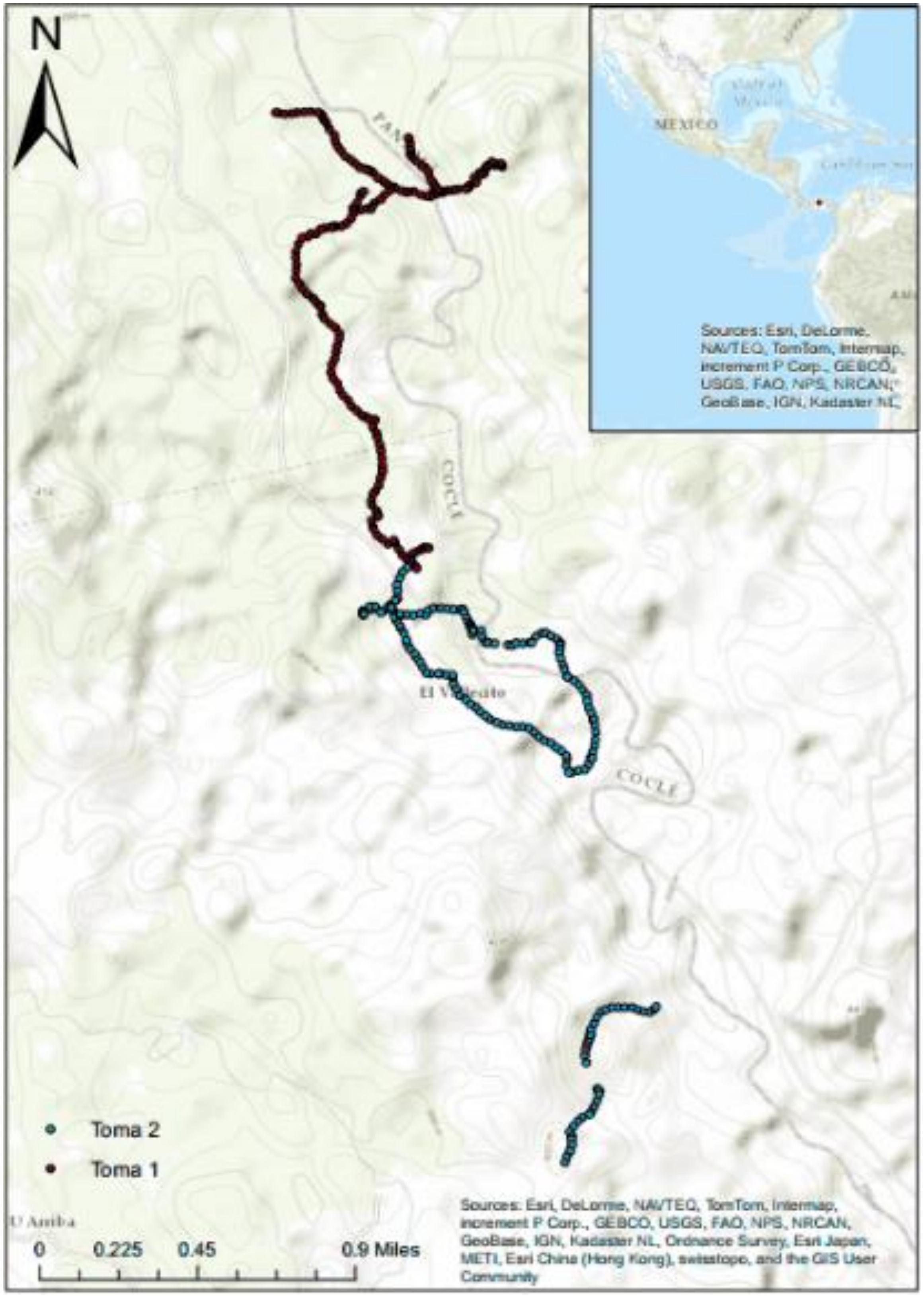
Elevation, Base Demand, Demand, Head and Pressure of each Node in Toma 1 Surveyed System at t=0.

Node ID	Elevation m	Base Demand	Demand LPS	Head m	Pressure m
Junc N1	270	0	0.00	287.90	17.90
Junc N2	250	0	0.00	287.90	37.90
Junc N3	233	0	0.00	287.90	54.90
Junc N4	225	0	0.00	287.90	62.90
Junc AN1	204	0	0.00	253.00	49.00
Junc AN2	203	0	0.00	252.99	49.99
Junc AN3	198	0	0.00	252.99	54.99
Junc AN4	209	0.00874	0.00	252.98	43.98
Junc N5	225	0	0.00	287.90	62.90
Junc N6	227	0	0.00	287.90	60.90
Junc N7	234	0	0.00	287.90	53.90
Junc BN1	228	0.00175	0.00	287.90	59.90
Junc N8	265	0	0.00	287.90	22.90
Junc N9	271	0.01224	0.00	287.90	16.90
Junc N10	271	0	0.00	287.90	16.90
Junc CN1	230	0	0.00	287.90	57.90
Junc CN2	223	0	0.00	287.90	64.90
Junc CN3	215	0	0.00	287.89	72.89
Junc CN4	237	0	0.00	287.89	50.89
Junc CN5	253	0.0175	0.00	287.89	34.89
Junc DN1	260	0.00175	0.00	287.90	27.90
Junc N11	254	0	0.00	287.90	33.90
Junc N12	273	0	0.00	287.90	14.90
Junc N13	280	0	0.00	287.90	7.90
Junc N14	277	0	0.00	287.90	10.90
Junc N15	286	0	0.00	287.90	1.90
Junc N16	269	0	0.00	287.90	18.90
Junc N17	281	0	0.00	287.90	6.90
Junc N18	286	0	0.00	287.90	1.90
Junc N19	287	0	0.00	287.90	0.90
Junc N20	280	0	0.00	287.90	7.90
Junc EN1	271	.00524	0.00	287.90	16.90
Junc CN0.5	230	0.00874	0.00	287.90	57.90
Junc N3Copy	233	0	0.00	253.00	20.00
Resvr Toma1	288	#N/A	-0.88	288.00	0.00
Tank 1	287	#N/A	0.87	287.90	0.90

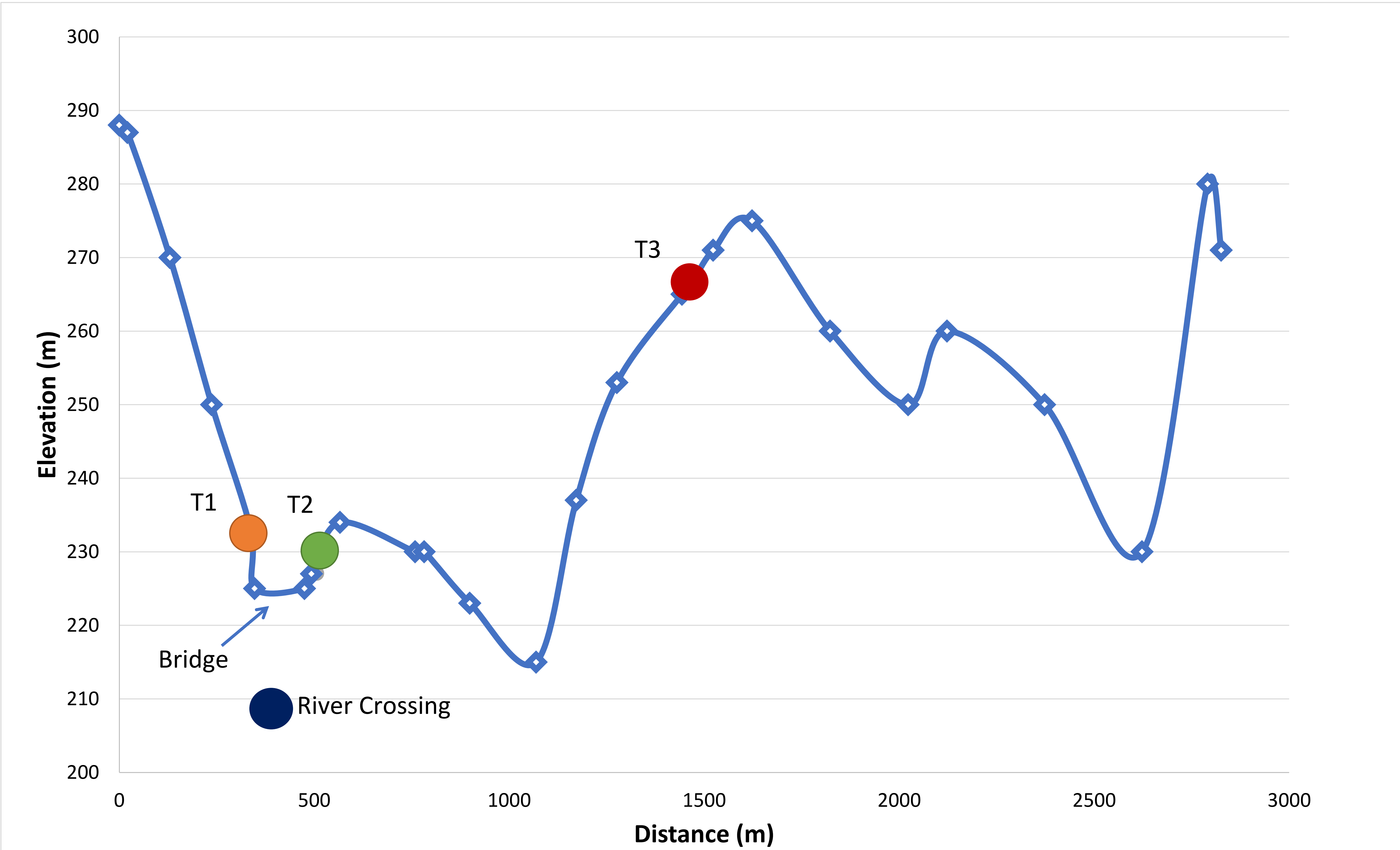
EPANET Data Continued

Node ID	Elevation m	Base Demand	Demand LPS	Head m	Pressure m
Junc N1	270	0	0.00	287.90	17.90
Junc N2	250	0	0.00	287.90	37.90
Junc N3	233	0	0.00	287.90	54.90
Junc N4	225	0	0.00	287.90	62.90
Junc AN1	204	0	0.00	253.00	49.00
Junc AN2	203	0	0.00	252.99	49.99
Junc AN3	198	0	0.00	252.99	54.99
Junc AN4	209	0.00874	0.00	252.98	43.98
Junc N5	225	0	0.00	287.90	62.90
Junc N6	227	0	0.00	287.90	60.90
Junc N7	234	0	0.00	287.90	53.90
Junc BN1	228	0.00175	0.00	287.90	59.90
Junc N8	265	0	0.00	287.90	22.90
Junc N9	271	0.01224	0.00	287.90	16.90
Junc CN1	230	0	0.00	287.90	57.90
Junc CN2	223	0	0.00	287.90	64.90
Junc CN3	215	0	0.00	287.89	72.89
Junc CN4	237	0	0.00	287.89	50.89
Junc CN5	253	0.0175	0.00	287.89	34.89
Junc DN1	260	0.00175	0.00	287.90	27.90
Junc CN0.5	230	0.00875	0.00	287.90	57.90
Junc N3Copy	233	0	0.00	253.00	20.00
Junc TR1	275	0	0.00	287.90	12.90
Junc TR2	260	0	0.00	287.90	27.90
Junc TR3	250	0	0.00	287.90	37.90
Junc TR4	260	0	0.00	287.90	27.90
Junc TR5	250	0	0.00	287.90	37.90
Junc TR6	230	0	0.00	287.90	57.90
Junc TR7	271	.00524	0.00	287.90	16.90
Resvr Toma1	288	#N/A	-0.88	288.00	0.00
Tank 1	287	#N/A	0.87	287.90	0.90

Appendix D Cont. : GIS Map of original surveyed route.



Appendix E: Toma 1 Topographic Reroute Elevation Profile



Appendix F: Rainwater Harvesting Results

Table 1. Data analysis to determine appropriate roof area and storage tank size for Laurino's house using a thatch roof and the MINSA demand standard. The corresponding roof area is 200 m^2 and storage tank size is 5.5 m^3.

	Rain (mm)	Supply (L)	Demand (L/mo)	Vt (L)	Vt (L) Corrected	% of Demand Met
Jan.	82.8	3312	4537	-1225	0	73
Feb.	59.8	2392	4537	-2145	0	53
Mar.	63.8	2552	4537	-1985	0	56
Apr.	118.9	4756	4537	219	219	105
May	408.4	16336	4537	12019	5500	365
Jun.	280.2	11208	4537	12171	5500	368
Jul.	267.6	10704	4537	11667	5500	357
Aug.	286.1	11444	4537	12407	5500	373
Sept.	252.3	10092	4537	11055	5500	344
Oct.	403.9	16156	4537	17119	5500	477
Nov.	381.7	15268	4537	16231	5500	458
Dec.	190.3	7612	4537	8575	5500	289
Jan.	82.8	3312	4537	4275	4275	194
Feb.	59.8	2392	4537	2131	2131	147
Mar.	63.8	2552	4537	146	146	103
Apr.	118.9	4756	4537	365	365	108
May	408.4	16336	4537	12165	5500	368
Jun.	280.2	11208	4537	12171	5500	368
Jul.	267.6	10704	4537	11667	5500	357
Aug.	286.1	11444	4537	12407	5500	373
Sept.	252.3	10092	4537	11055	5500	344
Oct.	403.9	16156	4537	17119	5500	477
Nov.	381.7	15268	4537	16231	5500	458
Dec.	190.3	7612	4537	8575	5500	289
Jan.	82.8	3312	4537	4275	4275	194
Feb.	59.8	2392	4537	2131	2131	147
Mar.	63.8	2552	4537	146	146	103
Apr.	118.9	4756	4537	365	365	108
May	408.4	16336	4537	12165	5500	368
Jun.	280.2	11208	4537	12171	5500	368
Jul.	267.6	10704	4537	11667	5500	357
Aug.	286.1	11444	4537	12407	5500	373
Sept.	252.3	10092	4537	11055	5500	344
Oct.	403.9	16156	4537	17119	5500	477
Nov.	381.7	15268	4537	16231	5500	458
Dec.	190.3	7612	4537	8575	5500	289

Table 2. Data analysis to determine appropriate roof area and storage tank size for Clemente's house and Louis Moran's house using a thatch roof and the MINSA demand standard. The corresponding roof area is 530 m^2 and storage tank size is 20 m^3.

	Rain (mm)	Supply (L)	Demand (L/mo)	Vt (L)	Vt (L) Corrected	% of Demand Met
Jan.	82.8	8777	13610	-4833	0	64
Feb.	59.8	6339	13610	-7271	0	47
Mar.	63.8	6763	13610	-6847	0	50
Apr.	118.9	12603	13610	-1006	0	93
May	408.4	43290	13610	29681	20000	318
Jun.	280.2	29701	13610	36091	20000	365
Jul.	267.6	28366	13610	34756	20000	355
Aug.	286.1	30327	13610	36717	20000	370
Sept.	252.3	26744	13610	33134	20000	343
Oct.	403.9	42813	13610	49204	20000	462
Nov.	381.7	40460	13610	46850	20000	444
Dec.	190.3	20172	13610	26562	20000	295
Jan.	82.8	8777	13610	15167	15167	211
Feb.	59.8	6339	13610	7896	7896	158
Mar.	63.8	6763	13610	1049	1049	108
Apr.	118.9	12603	13610	42	42	100
May	408.4	43290	13610	29723	20000	318
Jun.	280.2	29701	13610	36091	20000	365
Jul.	267.6	28366	13610	34756	20000	355
Aug.	286.1	30327	13610	36717	20000	370
Sept.	252.3	26744	13610	33134	20000	343
Oct.	403.9	42813	13610	49204	20000	462
Nov.	381.7	40460	13610	46850	20000	444
Dec.	190.3	20172	13610	26562	20000	295
Jan.	82.8	8777	13610	15167	15167	211
Feb.	59.8	6339	13610	7896	7896	158
Mar.	63.8	6763	13610	1049	1049	108
Apr.	118.9	12603	13610	42	42	100
May	408.4	43290	13610	29723	20000	318
Jun.	280.2	29701	13610	36091	20000	365
Jul.	267.6	28366	13610	34756	20000	355
Aug.	286.1	30327	13610	36717	20000	370
Sept.	252.3	26744	13610	33134	20000	343
Oct.	403.9	42813	13610	49204	20000	462
Nov.	381.7	40460	13610	46850	20000	444
Dec.	190.3	20172	13610	26562	20000	295

Table 3. Data analysis to determine appropriate roof area and storage tank size for Ismael's house using a thatch roof and the MINSA demand standard. The corresponding roof area is 1175 m^2 and storage tank size is 20 m^3.

	Rain (mm)	Supply (L)	Demand (L/mo)	Vt (L)	Vt (L) Corrected	% of Demand Met
Jan.	82.8	19458	22683	-3225	0	86
Feb.	59.8	14053	22683	-8630	0	62
Mar.	63.8	14993	22683	-7690	0	66
Apr.	118.9	27942	22683	5258	5258	123
May	408.4	95974	22683	78549	20000	446
Jun.	280.2	65847	22683	63164	20000	378
Jul.	267.6	62886	22683	60203	20000	365
Aug.	286.1	67234	22683	64550	20000	385
Sept.	252.3	59291	22683	56607	20000	350
Oct.	403.9	94917	22683	92233	20000	507
Nov.	381.7	89700	22683	87016	20000	484
Dec.	190.3	44721	22683	42037	20000	285
Jan.	82.8	19458	22683	16775	16775	174
Feb.	59.8	14053	22683	8145	8145	136
Mar.	63.8	14993	22683	455	455	102
Apr.	118.9	27942	22683	5713	5713	125
May	408.4	95974	22683	79004	20000	448
Jun.	280.2	65847	22683	63164	20000	378
Jul.	267.6	62886	22683	60203	20000	365
Aug.	286.1	67234	22683	64550	20000	385
Sept.	252.3	59291	22683	56607	20000	350
Oct.	403.9	94917	22683	92233	20000	507
Nov.	381.7	89700	22683	87016	20000	484
Dec.	190.3	44721	22683	42037	20000	285
Jan.	82.8	19458	22683	16775	16775	174
Feb.	59.8	14053	22683	8145	8145	136
Mar.	63.8	14993	22683	455	455	102
Apr.	118.9	27942	22683	5713	5713	125
May	408.4	95974	22683	79004	20000	448
Jun.	280.2	65847	22683	63164	20000	378
Jul.	267.6	62886	22683	60203	20000	365
Aug.	286.1	67234	22683	64550	20000	385
Sept.	252.3	59291	22683	56607	20000	350
Oct.	403.9	94917	22683	92233	20000	507
Nov.	381.7	89700	22683	87016	20000	484
Dec.	190.3	44721	22683	42037	20000	285

Table 4. Data analysis to determine appropriate roof area and storage tank size for Laurino's house using a thatch roof and the UN demand standard. The corresponding roof area is 56 m^2 and tank size is 4.35 m^3.

	Rain (mm)	Supply (L)	Demand (L/mo)	Vt (L)	Vt (L) Corrected	% of Demand Met
Jan.	82.8	927	1995	-1068	0	46
Feb.	59.8	670	1995	-1325	0	34
Mar.	63.8	715	1995	-1280	0	36
Apr.	118.9	1332	1995	-663	0	67
May	408.4	4574	1995	2579	2579	229
Jun.	280.2	3138	1995	3722	3722	287
Jul.	267.6	2997	1995	4724	4350	337
Aug.	286.1	3204	1995	5559	4350	379
Sept.	252.3	2826	1995	5181	4350	360
Oct.	403.9	4524	1995	6879	4350	445
Nov.	381.7	4275	1995	6630	4350	432
Dec.	190.3	2131	1995	4486	4350	325
Jan.	82.8	927	1995	3282	3282	265
Feb.	59.8	670	1995	1957	1957	198
Mar.	63.8	715	1995	677	677	134
Apr.	118.9	1332	1995	13	13	101
May	408.4	4574	1995	2592	2592	230
Jun.	280.2	3138	1995	3736	3736	287
Jul.	267.6	2997	1995	4738	4350	337
Aug.	286.1	3204	1995	5559	4350	379
Sept.	252.3	2826	1995	5181	4350	360
Oct.	403.9	4524	1995	6879	4350	445
Nov.	381.7	4275	1995	6630	4350	432
Dec.	190.3	2131	1995	4486	4350	325
Jan.	82.8	927	1995	3282	3282	265
Feb.	59.8	670	1995	1957	1957	198
Mar.	63.8	715	1995	677	677	134
Apr.	118.9	1332	1995	13	13	101
May	408.4	4574	1995	2592	2592	230
Jun.	280.2	3138	1995	3736	3736	287
Jul.	267.6	2997	1995	4738	4350	337
Aug.	286.1	3204	1995	5559	4350	379
Sept.	252.3	2826	1995	5181	4350	360
Oct.	403.9	4524	1995	6879	4350	445
Nov.	381.7	4275	1995	6630	4350	432
Dec.	190.3	2131	1995	4486	4350	325

Table 5. Data analysis to determine appropriate roof area and storage tank size for Clemente's house and Louis Moran's house using a thatch roof and the UN demand standard. The corresponding roof area is 250 m2 and tank size is 7.7 m3.

	Rain (mm)	Supply (L)	Demand (L/mo)	Vt (L)	Vt (L) Corrected	% of Demand Met
Jan.	82.8	4140	5985	-1845	0	69
Feb.	59.8	2990	5985	-2995	0	50
Mar.	63.8	3190	5985	-2795	0	53
Apr.	118.9	5945	5985	-40	0	99
May	408.4	20420	5985	14435	7700	341
Jun.	280.2	14010	5985	15725	7700	363
Jul.	267.6	13380	5985	15095	7700	352
Aug.	286.1	14305	5985	16020	7700	368
Sept.	252.3	12615	5985	14330	7700	339
Oct.	403.9	20195	5985	21910	7700	466
Nov.	381.7	19085	5985	20800	7700	448
Dec.	190.3	9515	5985	11230	7700	288
Jan.	82.8	4140	5985	5855	5855	198
Feb.	59.8	2990	5985	2860	2860	148
Mar.	63.8	3190	5985	65	65	101
Apr.	118.9	5945	5985	25	25	100
May	408.4	20420	5985	14460	7700	342
Jun.	280.2	14010	5985	15725	7700	363
Jul.	267.6	13380	5985	15095	7700	352
Aug.	286.1	14305	5985	16020	7700	368
Sept.	252.3	12615	5985	14330	7700	339
Oct.	403.9	20195	5985	21910	7700	466
Nov.	381.7	19085	5985	20800	7700	448
Dec.	190.3	9515	5985	11230	7700	288
Jan.	82.8	4140	5985	5855	5855	198
Feb.	59.8	2990	5985	2860	2860	148
Mar.	63.8	3190	5985	65	65	101
Apr.	118.9	5945	5985	25	25	100
May	408.4	20420	5985	14460	7700	342
Jun.	280.2	14010	5985	15725	7700	363
Jul.	267.6	13380	5985	15095	7700	352
Aug.	286.1	14305	5985	16020	7700	368
Sept.	252.3	12615	5985	14330	7700	339
Oct.	403.9	20195	5985	21910	7700	466
Nov.	381.7	19085	5985	20800	7700	448
Dec.	190.3	9515	5985	11230	7700	288

Table 6. Data analysis to determine appropriate roof area and storage tank size for Ismael's house using a thatch roof and the UN demand standard. The corresponding roof area is 306 m2 and tank size is 20 m3.

	Rain (mm)	Supply (L)	Demand (L/mo)	Vt (L)	Vt (L) Corrected	% of Demand Met
Jan.	82.8	5067	9975	-4908	0	51
Feb.	59.8	3660	9975	-6315	0	37
Mar.	63.8	3905	9975	-6070	0	39
Apr.	118.9	7277	9975	-2698	0	73
May	408.4	24994	9975	15019	15019	251
Jun.	280.2	17148	9975	22192	20000	322
Jul.	267.6	16377	9975	26402	20000	365
Aug.	286.1	17509	9975	27534	20000	376
Sept.	252.3	15441	9975	25466	20000	355
Oct.	403.9	24719	9975	34744	20000	448
Nov.	381.7	23360	9975	33385	20000	435
Dec.	190.3	11646	9975	21671	20000	317
Jan.	82.8	5067	9975	15092	15092	251
Feb.	59.8	3660	9975	8777	8777	188
Mar.	63.8	3905	9975	2707	2707	127
Apr.	118.9	7277	9975	8	8	100
May	408.4	24994	9975	15027	15027	251
Jun.	280.2	17148	9975	22201	20000	323
Jul.	267.6	16377	9975	26402	20000	365
Aug.	286.1	17509	9975	27534	20000	376
Sept.	252.3	15441	9975	25466	20000	355
Oct.	403.9	24719	9975	34744	20000	448
Nov.	381.7	23360	9975	33385	20000	435
Dec.	190.3	11646	9975	21671	20000	317
Jan.	82.8	5067	9975	15092	15092	251
Feb.	59.8	3660	9975	8777	8777	188
Mar.	63.8	3905	9975	2707	2707	127
Apr.	118.9	7277	9975	8	8	100
May	408.4	24994	9975	15027	15027	251
Jun.	280.2	17148	9975	22201	20000	323
Jul.	267.6	16377	9975	26402	20000	365
Aug.	286.1	17509	9975	27534	20000	376
Sept.	252.3	15441	9975	25466	20000	355
Oct.	403.9	24719	9975	34744	20000	448
Nov.	381.7	23360	9975	33385	20000	435
Dec.	190.3	11646	9975	21671	20000	317

Table 1. Data analysis to determine appropriate roof area and storage tank size for Laurino's house using a metal roof and the MINSA demand standard. The corresponding roof area is 56 m2 and tank size is 3.5 m3.

	Rain (mm)	Supply (L)	Demand (L/mo)	Vt (L)	Vt (L) Corrected	% of Demand Met
Jan.	82.8	4173	4537	-364	0	92
Feb.	59.8	3014	4537	-1523	0	66
Mar.	63.8	3216	4537	-1321	0	71
Apr.	118.9	5993	4537	1456	1456	132
May	408.4	20583	4537	17503	3500	486
Jun.	280.2	14122	4537	13085	3500	388
Jul.	267.6	13487	4537	12450	3500	374
Aug.	286.1	14419	4537	13383	3500	395
Sept.	252.3	12716	4537	11679	3500	357
Oct.	403.9	20357	4537	19320	3500	526
Nov.	381.7	19238	4537	18201	3500	501
Dec.	190.3	9591	4537	8554	3500	289
Jan.	82.8	4173	4537	3136	3136	169
Feb.	59.8	3014	4537	1614	1614	136
Mar.	63.8	3216	4537	293	293	106
Apr.	118.9	5993	4537	1749	1749	139
May	408.4	20583	4537	17795	3500	492
Jun.	280.2	14122	4537	13085	3500	388
Jul.	267.6	13487	4537	12450	3500	374
Aug.	286.1	14419	4537	13383	3500	395
Sept.	252.3	12716	4537	11679	3500	357
Oct.	403.9	20357	4537	19320	3500	526
Nov.	381.7	19238	4537	18201	3500	501
Dec.	190.3	9591	4537	8554	3500	289
Jan.	82.8	4173	4537	3136	3136	169
Feb.	59.8	3014	4537	1614	1614	136
Mar.	63.8	3216	4537	293	293	106
Apr.	118.9	5993	4537	1749	1749	139
May	408.4	20583	4537	17795	3500	492
Jun.	280.2	14122	4537	13085	3500	388
Jul.	267.6	13487	4537	12450	3500	374
Aug.	286.1	14419	4537	13383	3500	395
Sept.	252.3	12716	4537	11679	3500	357
Oct.	403.9	20357	4537	19320	3500	526
Nov.	381.7	19238	4537	18201	3500	501
Dec.	190.3	9591	4537	8554	3500	289

Table 2. Data analysis to determine appropriate roof area and storage tank size for Clemente's house and Louis Moran's house using a metal roof and the MINSA demand standard. The corresponding roof area is 134 m2 and tank size is 16 m3.

	Rain (mm)	Supply (L)	Demand (L/mo)	Vt (L)	Vt (L) Corrected	% of Demand Met
Jan.	82.8	9986	13610	-3624	0	73
Feb.	59.8	7212	13610	-6398	0	53
Mar.	63.8	7694	13610	-5916	0	57
Apr.	118.9	14339	13610	729	729	105
May	408.4	49253	13610	36373	16000	367
Jun.	280.2	33792	13610	36182	16000	366
Jul.	267.6	32273	13610	34663	16000	355
Aug.	286.1	34504	13610	36894	16000	371
Sept.	252.3	30427	13610	32817	16000	341
Oct.	403.9	48710	13610	51100	16000	475
Nov.	381.7	46033	13610	48423	16000	456
Dec.	190.3	22950	13610	25340	16000	286
Jan.	82.8	9986	13610	12376	12376	191
Feb.	59.8	7212	13610	5978	5978	144
Mar.	63.8	7694	13610	62	62	100
Apr.	118.9	14339	13610	792	792	106
May	408.4	49253	13610	36435	16000	368
Jun.	280.2	33792	13610	36182	16000	366
Jul.	267.6	32273	13610	34663	16000	355
Aug.	286.1	34504	13610	36894	16000	371
Sept.	252.3	30427	13610	32817	16000	341
Oct.	403.9	48710	13610	51100	16000	475
Nov.	381.7	46033	13610	48423	16000	456
Dec.	190.3	22950	13610	25340	16000	286
Jan.	82.8	9986	13610	12376	12376	191
Feb.	59.8	7212	13610	5978	5978	144
Mar.	63.8	7694	13610	62	62	100
Apr.	118.9	14339	13610	792	792	106
May	408.4	49253	13610	36435	16000	368
Jun.	280.2	33792	13610	36182	16000	366
Jul.	267.6	32273	13610	34663	16000	355
Aug.	286.1	34504	13610	36894	16000	371
Sept.	252.3	30427	13610	32817	16000	341
Oct.	403.9	48710	13610	51100	16000	475
Nov.	381.7	46033	13610	48423	16000	456
Dec.	190.3	22950	13610	25340	16000	286

Table 3. Data analysis to determine appropriate roof area and storage tank size for Ismael's house using a metal roof and the MINSA demand standard. The corresponding roof area is 260 m2 and tank size is 20 m3.

	Rain (mm)	Supply (L)	Demand (L/mo)	Vt (L)	Vt (L) Corrected	% of Demand Met
Jan.	82.8	19375	22683	-3308	0	85
Feb.	59.8	13993	22683	-8690	0	62
Mar.	63.8	14929	22683	-7754	0	66
Apr.	118.9	27823	22683	5139	5139	123
May	408.4	95566	22683	78022	20000	444
Jun.	280.2	65567	22683	62884	20000	377
Jul.	267.6	62618	22683	59935	20000	364
Aug.	286.1	66947	22683	64264	20000	383
Sept.	252.3	59038	22683	56355	20000	348
Oct.	403.9	94513	22683	91829	20000	505
Nov.	381.7	89318	22683	86635	20000	482
Dec.	190.3	44530	22683	41847	20000	284
Jan.	82.8	19375	22683	16692	16692	174
Feb.	59.8	13993	22683	8002	8002	135
Mar.	63.8	14929	22683	248	248	101
Apr.	118.9	27823	22683	5388	5388	124
May	408.4	95566	22683	78270	20000	445
Jun.	280.2	65567	22683	62884	20000	377
Jul.	267.6	62618	22683	59935	20000	364
Aug.	286.1	66947	22683	64264	20000	383
Sept.	252.3	59038	22683	56355	20000	348
Oct.	403.9	94513	22683	91829	20000	505
Nov.	381.7	89318	22683	86635	20000	482
Dec.	190.3	44530	22683	41847	20000	284
Jan.	82.8	19375	22683	16692	16692	174
Feb.	59.8	13993	22683	8002	8002	135
Mar.	63.8	14929	22683	248	248	101
Apr.	118.9	27823	22683	5388	5388	124
May	408.4	95566	22683	78270	20000	445
Jun.	280.2	65567	22683	62884	20000	377
Jul.	267.6	62618	22683	59935	20000	364
Aug.	286.1	66947	22683	64264	20000	383
Sept.	252.3	59038	22683	56355	20000	348
Oct.	403.9	94513	22683	91829	20000	505
Nov.	381.7	89318	22683	86635	20000	482
Dec.	190.3	44530	22683	41847	20000	284

Table 4. Data analysis to determine appropriate roof area and storage tank size for Laurino's house using a metal roof and the UN demand standard. The corresponding roof area is 20 m2 and tank size is 2.3 m3.

	Rain (mm)	Supply (L)	Demand (L/mo)	Vt (L)	Vt (L) Corrected	% of Demand Met
Jan.	82.8	1490.4	1995	-504.6	0.0	75
Feb.	59.8	1076.4	1995	-918.6	0.0	54
Mar.	63.8	1148.4	1995	-846.6	0.0	58
Apr.	118.9	2140.2	1995	145.2	145.2	107
May	408.4	7351.2	1995	5501.4	2300.0	376
Jun.	280.2	5043.6	1995	5348.6	2300.0	368
Jul.	267.6	4816.8	1995	5121.8	2300.0	357
Aug.	286.1	5149.8	1995	5454.8	2300.0	373
Sept.	252.3	4541.4	1995	4846.4	2300.0	343
Oct.	403.9	7270.2	1995	7575.2	2300.0	480
Nov.	381.7	6870.6	1995	7175.6	2300.0	460
Dec.	190.3	3425.4	1995	3730.4	2300.0	287
Jan.	82.8	1490.4	1995	1795.4	1795.4	190
Feb.	59.8	1076.4	1995	876.8	876.8	144
Mar.	63.8	1148.4	1995	30.2	30.2	102
Apr.	118.9	2140.2	1995	175.4	175.4	109
May	408.4	7351.2	1995	5531.6	2300.0	377
Jun.	280.2	5043.6	1995	5348.6	2300.0	368
Jul.	267.6	4816.8	1995	5121.8	2300.0	357
Aug.	286.1	5149.8	1995	5454.8	2300.0	373
Sept.	252.3	4541.4	1995	4846.4	2300.0	343
Oct.	403.9	7270.2	1995	7575.2	2300.0	480
Nov.	381.7	6870.6	1995	7175.6	2300.0	460
Dec.	190.3	3425.4	1995	3730.4	2300.0	287
Jan.	82.8	1490.4	1995	1795.4	1795.4	190
Feb.	59.8	1076.4	1995	876.8	876.8	144
Mar.	63.8	1148.4	1995	30.2	30.2	102
Apr.	118.9	2140.2	1995	175.4	175.4	109
May	408.4	7351.2	1995	5531.6	2300.0	377
Jun.	280.2	5043.6	1995	5348.6	2300.0	368
Jul.	267.6	4816.8	1995	5121.8	2300.0	357
Aug.	286.1	5149.8	1995	5454.8	2300.0	373
Sept.	252.3	4541.4	1995	4846.4	2300.0	343
Oct.	403.9	7270.2	1995	7575.2	2300.0	480
Nov.	381.7	6870.6	1995	7175.6	2300.0	460
Dec.	190.3	3425.4	1995	3730.4	2300.0	287

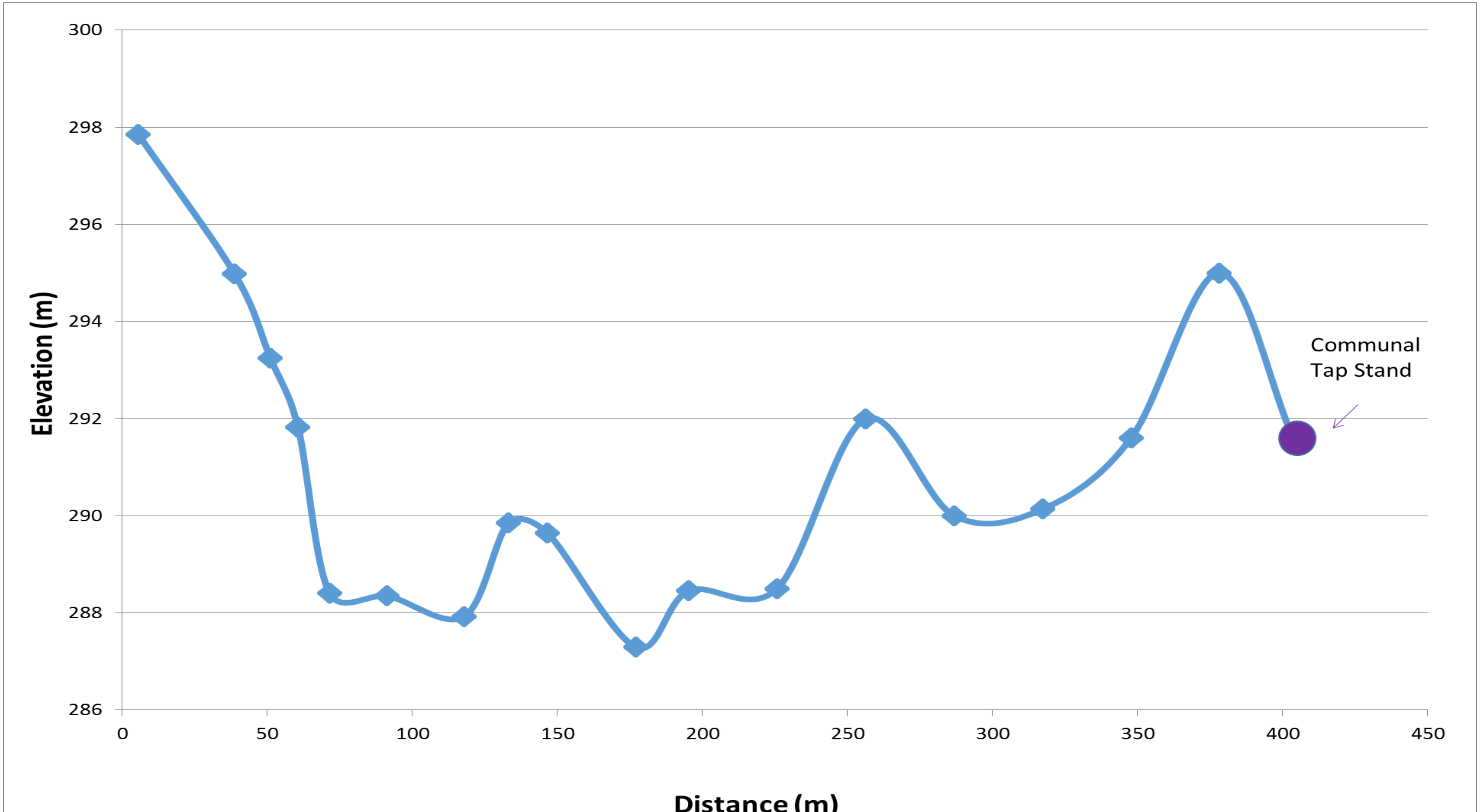
Table 5. Data analysis to determine appropriate roof area and storage tank size for Clemente's house and Louis Moran's house using a metal roof and the UN demand standard. The corresponding roof area is 55 m2 and tank size is 8 m3.

	Rain (mm)	Supply (L)	Demand (L/mo)	Vt (L)	Vt (L) Corrected	% of Demand Met
Jan.	82.8	4098.6	5985	-1886.4	0	68
Feb.	59.8	2960.1	5985	-3024.9	0	49
Mar.	63.8	3158.1	5985	-2826.9	0	53
Apr.	118.9	5885.55	5985	-99.45	0	98
May	408.4	20215.8	5985	14230.8	8000	338
Jun.	280.2	13869.9	5985	15884.9	8000	365
Jul.	267.6	13246.2	5985	15261.2	8000	355
Aug.	286.1	14161.95	5985	16177	8000	370
Sept.	252.3	12488.85	5985	14503.9	8000	342
Oct.	403.9	19993.05	5985	22008.1	8000	468
Nov.	381.7	18894.15	5985	20909.2	8000	449
Dec.	190.3	9419.85	5985	11434.9	8000	291
Jan.	82.8	4098.6	5985	6113.6	6113.6	202
Feb.	59.8	2960.1	5985	3088.7	3088.7	152
Mar.	63.8	3158.1	5985	261.8	261.8	104
Apr.	118.9	5885.55	5985	162.35	162.35	103
May	408.4	20215.8	5985	14393.2	8000	340
Jun.	280.2	13869.9	5985	15884.9	8000	365
Jul.	267.6	13246.2	5985	15261.2	8000	355
Aug.	286.1	14161.95	5985	16177	8000	370
Sept.	252.3	12488.85	5985	14503.9	8000	342
Oct.	403.9	19993.05	5985	22008.1	8000	468
Nov.	381.7	18894.15	5985	20909.2	8000	449
Dec.	190.3	9419.85	5985	11434.9	8000	291
Jan.	82.8	4098.6	5985	6113.6	6113.6	202
Feb.	59.8	2960.1	5985	3088.7	3088.7	152
Mar.	63.8	3158.1	5985	261.8	261.8	104
Apr.	118.9	5885.55	5985	162.35	162.35	103
May	408.4	20215.8	5985	14393.2	8000	340
Jun.	280.2	13869.9	5985	15884.9	8000	365
Jul.	267.6	13246.2	5985	15261.2	8000	355
Aug.	286.1	14161.95	5985	16177	8000	370
Sept.	252.3	12488.85	5985	14503.9	8000	342
Oct.	403.9	19993.05	5985	22008.1	8000	468
Nov.	381.7	18894.15	5985	20909.2	8000	449
Dec.	190.3	9419.85	5985	11434.9	8000	291

Table 6. Data analysis to determine appropriate roof area and storage tank size for Ismael's house using a metal roof and the UN demand standard. The corresponding roof area is 55 m2 and tank size is 8 m3.

	Rain (mm)	Supply (L)	Demand (L/mo)	Vt (L)	Vt (L) Corrected	% of Demand Met
Jan.	82.8	6334.2	9975	-3640.8	0	64
Feb.	59.8	4574.7	9975	-5400.3	0	46
Mar.	63.8	4880.7	9975	-5094.3	0	49
Apr.	118.9	9095.85	9975	-879.15	0	91
May	408.4	31242.6	9975	21267.6	15000	313
Jun.	280.2	21435.3	9975	26460.3	15000	365
Jul.	267.6	20471.4	9975	25496.4	15000	356
Aug.	286.1	21886.65	9975	26911.7	15000	370
Sept.	252.3	19300.95	9975	24326	15000	344
Oct.	403.9	30898.35	9975	35923.4	15000	460
Nov.	381.7	29200.05	9975	34225.1	15000	443
Dec.	190.3	14557.95	9975	19583	15000	296
Jan.	82.8	6334.2	9975	11359.2	11359.2	214
Feb.	59.8	4574.7	9975	5958.9	5958.9	160
Mar.	63.8	4880.7	9975	864.6	864.6	109
Apr.	118.9	9095.85	9975	-14.55	0	100
May	408.4	31242.6	9975	21267.6	15000	313
Jun.	280.2	21435.3	9975	26460.3	15000	365
Jul.	267.6	20471.4	9975	25496.4	15000	356
Aug.	286.1	21886.65	9975	26911.7	15000	370
Sept.	252.3	19300.95	9975	24326	15000	344
Oct.	403.9	30898.35	9975	35923.4	15000	460
Nov.	381.7	29200.05	9975	34225.1	15000	443
Dec.	190.3	14557.95	9975	19583	15000	296
Jan.	82.8	6334.2	9975	11359.2	11359.2	214
Feb.	59.8	4574.7	9975	5958.9	5958.9	160
Mar.	63.8	4880.7	9975	864.6	864.6	109
Apr.	118.9	9095.85	9975	-14.55	0	100
May	408.4	31242.6	9975	21267.6	15000	313
Jun.	280.2	21435.3	9975	26460.3	15000	365
Jul.	267.6	20471.4	9975	25496.4	15000	356
Aug.	286.1	21886.65	9975	26911.7	15000	370
Sept.	252.3	19300.95	9975	24326	15000	344
Oct.	403.9	30898.35	9975	35923.4	15000	460
Nov.	381.7	29200.05	9975	34225.1	15000	443
Dec.	190.3	14557.95	9975	19583	15000	296

Appendix G: Toma 2 Elevation Profile



Appendix H: Cost Estimate

Proposed Design Cost Estimate

Total Cost + 10% : $9,700

Toma 1

Total Cost+ 10%: $9,300

Item	Source	Unit	Quantity	Unit Price	Total	Comments
Reroute Conduction & Distribution Lines						
.5 inch PVC	Siobhan	Meter	291	$0.42	$122	
1 inch PVC	Siobhan	Meter	1252	$0.74	$926	
PVC Joint Glue	Tole	Bottle	6	$0.75	$4.50	
2 inch PVC	Siobhan	Meter	2036	$1.64	$3,339	
Total Cost					$4,392.24	
Spring Box						
Wire Mesh	Siobhan	Meter^2	60m^2	$1.19	$71	
Cement	Novey	Bag	26	$9.15	$236	42.5kg/bag
2 inch PVC	Siobhan	Meter	1	$1.64	$1.64	
Sand	Tole	5 gal pail	150	$0.3	$45	
Gravel	Tole	5 gal pail	26	$0.3	$8	
Total Cost					$361	
Storage Tank						
Wire Mesh	Siobhan	Meter^2	81	$1.19	$97	
Cement	Novey	Bag	23	$9.15	$209	42.5kg/bag
2 inch PVC	Siobhan	Meter	1	$1.64	$1.64	
Sand	Tole	5 Gal Pail	119	$0.30	$35	
Total Cost					$343	
Bridge						
2 inch PVC Pipe	Siobhan	Meter	135	$1.64	$221.40	
Protection Pipe (SDR 64, 4in)	Siobhan	Meter	135	$2.65	$357.75	
Cables	Pesqueros	Meter	135	$4.10	$554.24	
Sand	Tole	5 gal pail	64	$0.3	$95.40	
Gravel	Tole	5 gal pail	95	$0.3	$142.50	
Cement	Novey	Bag	91	$9.15	$832.65	42.5kg/bag
Rebar	Pesqueros	Bar	16	$6	$96	
Total Cost					$2,299.94	
Air Release Valves						
2 inch PVC Pipe	Siobhan	Meter	10	$1.64	$16.40	

Ping Pong Ball	local Shop	Ball	10	$0.10	$1.00	
Total Cost					$17.40	
Pressure Reducing Apparatus						
Valve	Siobhan	Valve	1	$50	$50	
Total Cost					$50	
Tap Stand						
Cement	Novey	Bag	3	$9.15	$31	42.5kg/bag
.5 inch PVC	Siobhan	Meter	7	$0.42	$2.94	
Metal Spigot	Supercentro SF	Spigot	7	$5.90	$41.30	
Total Cost					$75	

Transportation		Units	Quantity	Unit Cost	Total Cost	
Pipeline		Truckload	10	$60/truckload	$600	
Spring box/storage/bridge materials		Truckload	6	$60	$300	
Air release/pressure reducing/tap stand materails		Truckload	1	$60	$60	
Total Cost					$960	

Toma 2

Total Cost + 10%: $400

Item	Source	Unit	Quantity	Unit Cost	Total	Comments
Toma 2 without Pump						
Tap Stand	Siobhan	Tapstand	1	$11	$11	
PVC Joint Glue	Tole	Bottle	1	$0.75	$0.75	
1 inch PVC	Siobhan	Meter	375	$0.74	$277.50	
Total Cost					$307	

Transportation		Unit	Quantity	Unit Cost	Total Cost	
Pipeline		Truckload	1	$60	$60	
Total Cost					$60	

Alternatives

Toma 1: Surveyed- Full System to Clemente's

Total Cost+10% : $8,600

Item	Source	Unit	Quantity	Unit Cost	Total Cost	Comments
Surveyed Conduction & Distribution Lines						
.5 inch PVC	Siobhan	Meter	291	$0.42	$122	
1 inch PVC	Siobhan	Meter	960	$0.74	$710	
PVC Joint Glue	Tole	Bottle	6	$0.75	$4.50	
2 inch PVC	Siobhan	Meter1.64	2369	$1.64	$3,885	
Total Cost					$4,722.28	
Spring Box						
Wire Mesh	Siobhan	Meter^2	60	$1.19	$71	
Cement	Novey	Bag	26	$9.15	$236	42.5kg/bag
2 inch PVC	Siobhan	Meter	1	$1.64	$1.64	
Sand	Tole	5 gal pail	150	$0.30	$45	
Gravel	Tole	5 gal pail	27	$0.30	$8	
Total Cost					$361	
Storage Tank						
Wire Mesh	Siobhan	Meter^2100	81	$1.19	$97	
Cement	Novey	Bag	23	$9.15	$209	42.5kg/bag
2 inch PVC	Siobhan	Meter	1	$1.64	$1.64	

Sand	Tole	5 gal pail	119	$0.30	$35	
Total Cost					$343	
BRIDGE						
2 inch PVC Pipe	Siobhan	Meter	135	$1.64	$221.40	
Protection Pipe (SDR 64, 4in)	Siobhan	Meter	135	$2.65	$357.75	
Cables	Pesqueros	Meter	135.18	$4.10	$554.24	
Sand	Tole	5 gal pail	64	$0.30	$95.40	
Gravel	Tole	5 gal pail	95	$0.30	$142.50	
Cement	Novey	Bag	91	$9.15	$832.65	42.5kg/bag
Rebar	Pesqueros	Bar	16	$6	$96	
Total Cost					$2,299.94	
Air Release Valves						
2 inch PVC Pipe	Siobhan	Meter	10	$1.64	$16.40	
Ping Pong Ball	local Shop	Ball	10	$0.10	$1.00	
Total Cost					$17.40	
Pressure Reducing Apparatus						
Valve	Siobhan	Valve	1	$50	$50	
Total Cost					$50	
Tap Stand						

Cement	Novey	Bag	4	$9.15	$31	
.5 inch PVC	Siobhan	Meter	7	$0.42	$2.94	
Metal Spigot	Supercentro SF	Spigots	7	$5.90	$41.30	
Total Cost					$75	

Toma 1: System to Felix's, rainwater for Clemente

Total Cost + 10%: $7,000

Item	Source	Unit	Quantity	Unit Cost	Total	Comments
Surveyed Conduction & Distribution Lines to Felix's						
.5 inch PVC	Siobhan	Meter	291	$0.42	$122	
1 inch PVC	Siobhan	Meter	960	$0.74	$710	
PVC Joint Glue	Tole	Bottle	6	$0.75	$4.50	
2 inch PVC	Siobhan	Meter	1069	$1.64	$1,753	
Total Cost					$2,590.28	
Spring Box						
Wire Mesh	Siobhan	Meter^2	60	$1.19	$71	
Cement	Novey	Bag	26	$9.15	$236	42.5kg/bag
2 inch PVC	Siobhan	Meter	1	$1.64	$1.64	
Sand	Tole	5 gal pail	150	$0.30	$45	
Gravel	Tole	5 gal pail	27	$0.30	$8	
Total Cost					$361	
Storage Tank						
Wire Mesh	Siobhan	Meter^2	81	$1.19	$97	
Cement	Novey	Bag	23	$9.15	$209	42.5kg/bag
2 inch PVC	Siobhan	Meter	1	$1.64	$1.64	
Sand	Tole	5 gal pail	119	$0.30	$35	
Total Cost					$343	
BRIDGE						
2 inch PVC Pipe	Siobhan	Meter	135	$1.64	$221.40	
Protection Pipe (SDR 64, 4in)	Siobhan	meter	135	$2.65	$357.75	
Cables	Pesqueros	Meter	135.2	$4.10	$554.24	
Sand	Tole	5 gal pail	318	$0.30	$95.40	
Gravel	Tole	5 gal pail	475	$0.30	$142.50	

Cement	Novey	Bags	91	$9.15	$832.65	42.5kg/bag
Rebar	Pesqueros	Bar	16	$6	$96	
Air Release Valves						
2 inch PVC Pipe	Siobhan	Meter	10	$1.64	$16.40	
Ping Pong Ball	local Shop	Ball	10	$0.10	$1.00	
Total Cost					$17.40	
Pressure Reducing Apparatus						
Valve	Siobhan	Valve	1	$50	$50	
Total Cost					$2.06	
Tap Stand						
Cement	Novey	Bags	3	$9.15	$26	42.5kg/bag
.5 inch PVC	Siobhan	Meter	6	$0.42	$2.52	
Metal Spigot	Supercentro SF	Spigot	6	$5.9	$35.40	
Total Cost					$64	
Rainwater Harvesting (3 person)						
Wire Mesh	Siobhan	Meter^2	28	$1.19	$33	
Cement	Novey	Bag	15	$9.15	$138	42.5k/bag
Sand	Tole	5 gal pail	71	$0.30	$21	
Zinc Roofing	Novey	Meter^2	55	$5.55	$305	
Gutters	Novey	Meters	22	$4.50	$95	
4" PVC Pipe	Siobhan	Meters	8	$6.78	54	
Metal Spigot	Supercentro SF	Spigot	1	$5.90	$5.90	
Total Cost					$652	

Toma 2: Rainwater Catchment for All

Total Cost + 10%: $2,000

Item	Source	Unit	Quantity	Unit Cost	Total	Comments
Rainwater Harvesting (1 person)						
Wire Mesh	Siobhon	Meter^2	16	$1.19	$19	
Cement	Novey	Bag	7	$9.15	$61	42.5kg/bag
Sand	Tole	5 gal pail	31	$0.30	$9	
Zinc Roofing	Novey	Meter	20	$5.55	$111	
Gutters	Novey	Meters	14	$4.50	$60	
.5" PVC Pipe	Siobhon	Meter	8	$0.42	$3	
Metal Spigot	Supercentro SF	Spigot	1	$5.90	$5.90	
Total Cost					$270	
Total Cost +					$297	

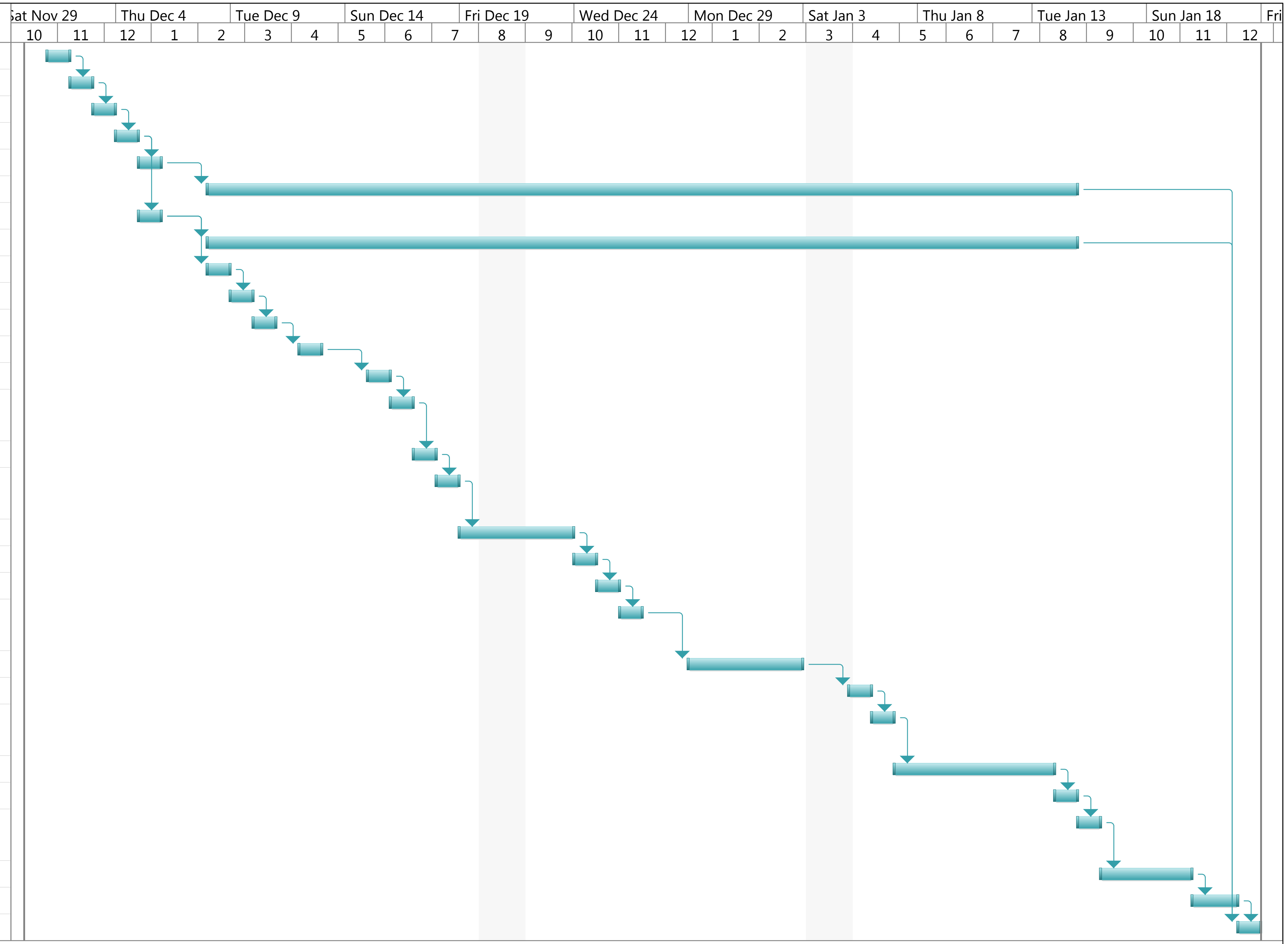
10%						
Rainwater Harvesting (3 person)						
Wire Mesh	Siobhan	Meter^2100	28	$1.19	$33	
Cement	Novey	Bag	15	$9.15	$138	42.5kg/bag
Sand	Tole	5 gal pail	71	$0.30	$21	
Zinc Roofing	Novey	Meter^2	55	$5.55	$305	
Gutters	Novey	Meter	22	$4.50	$95	
4" PVC Pipe	Siobhan	Meter	8	$6.78	54	
Metal Spigot	Supercentro SF	Spigot	1	$5.90	$5.90	
Total Cost					$652	
Rainwater Harvesting (5 person)						
Wire Mesh	Siobhan	Meter^2	44	$1.19	$52	
Cement	Novey	Bag	15	$9.15	$241	42.5kg/bag
Sand	Tole	5 gal pail	71	$0.30	$37	
Zinc Roofing	Novey	Meter^2	85	$5.55	$471	
Gutters	Novey	Meter	28	$4.50	$121	
1" PVC Pipe	Siobhan	Meter	11	$0.74	8	
Metal Spigot	Supercentro SF	Spigot	1	$5.90	$5.90	
Total Cost					$936	

Toma 2: Solar Pump and Full Line

Total Cost + 10%: 1,200

Item	Source	Unit	Quantity	Unit Cost	Total	Comments
Toma 2 with Pump						
Wire Mesh	Siobhan	Meter^2	45	$1.19	$55	
Cement	Novey	Bag	15	$9.15	$140	42.5kg/bag
1 inch PVC	Siobhan	Meter	500	$0.74	$370.00	
1/2 inch PVC	Siobhan	Meter	183	$0.42	$77.00	
Tap Stand	Supercentro SF	Meter	3	$11.1	$33.30	
Pump	Northern Tool	Pump	1	$100	$100.00	
Battery	Northern Tool	Battery	1	$14	$14.00	
Solar Panel	Northern Tool	Panel	1	$250	$250.00	
PVC Joint Glue	Tole	Bottle	1	$0.75	$0.75	
Sand	Tole	5 gal pail	80	$0.30	$24	
Total Cost					$1,064	

ID	Task Name	Duration	Start	Finish	Predecessors
1	Prep Bridge Crossing Area	1 day	Mon 12/1/14	Mon 12/1/14	
2	Dig Holes for Towers	1 day	Tue 12/2/14	Tue 12/2/14	1
3	Build Forms for Towers	1 day	Wed 12/3/14	Wed 12/3/14	2
4	Set Rebar for Towers	1 day	Thu 12/4/14	Thu 12/4/14	3
5	Pour Concrete for Tower 1	1 day	Fri 12/5/14	Fri 12/5/14	4
6	Set Time for Tower 1	28 days	Mon 12/8/14	Wed 1/14/15	5
7	Pour Concrete for Tower 2	1 day	Fri 12/5/14	Fri 12/5/14	4
8	Set Time for Tower 2	28 days	Mon 12/8/14	Wed 1/14/15	7
9	Prep Spring Box Area	1 day	Mon 12/8/14	Mon 12/8/14	7
10	Build Spring Box Forms	1 day	Tue 12/9/14	Tue 12/9/14	9
11	Construct Spring Box Concrete	1 day	Wed 12/10/14	Wed 12/10/14	10
12	Prep Storage Tank 1 Area	1 day	Fri 12/12/14	Fri 12/12/14	11
13	Build Storage Tank 1 Forms	1 day	Mon 12/15/14	Mon 12/15/14	12
14	Construct Storage Tank 1 Concrete	1 day	Tue 12/16/14	Tue 12/16/14	13
15	Prep Section 1	1 day	Wed 12/17/14	Wed 12/17/14	14
16	Transport Section 1and bridge section of Pipe to community	1 day	Thu 12/18/14	Thu 12/18/14	15
17	Construction Section 1 of Pipe	3 days	Fri 12/19/14	Tue 12/23/14	16
18	String Pipe Across Bridge	1 day	Wed 12/24/14	Wed 12/24/14	17
19	Prep Section 2	1 day	Thu 12/25/14	Thu 12/25/14	18
20	Transport Section 2 of pipe to community	1 day	Fri 12/26/14	Fri 12/26/14	19
21	Construct Section 2 of Pipe	5 days	Mon 12/29/14	Fri 1/2/15	20
22	Prep Section 3	1 day	Mon 1/5/15	Mon 1/5/15	21
23	Transport Section 3 of Pipe to community	1 day	Tue 1/6/15	Tue 1/6/15	22
24	Construct Section 3	5 days	Wed 1/7/15	Tue 1/13/15	23
25	Prep Section 4	1 day	Wed 1/14/15	Wed 1/14/15	24
26	Transport Section 4 of pipe to the community	1 day	Thu 1/15/15	Thu 1/15/15	25
27	Construct Section 4	2 days	Fri 1/16/15	Mon 1/19/15	26
28	Inspect total line	2 days	Tue 1/20/15	Wed 1/21/15	27
29	System Ready to use	1 day	Thu 1/22/15	Thu 1/22/15	28,6,8



Project: Agua de Abajo Schedule.m
Date: Mon 12/9/13

Task	Project Summary	Manual Task	Start-only	Deadline
Split	Inactive Task	Duration-only	Finish-only	Progress
Milestone	Inactive Milestone	Manual Summary Rollup	External Tasks	Manual Progress
Summary	Inactive Summary	Manual Summary	External Milestone	