Aqueduct System for Vallecito, Panama

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Michigan Technological University

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Comisión de Agua Corriente

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Aqueduct System for Vallecito, Panama

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Disclaimer:

CDAC's final report shows the efforts of undergraduate students in the Civil and Environmental Engineering Department of Michigan Technological University. While we 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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1.0 Executive Summary

The International Senior Design Program offered at Michigan Technological University allows students to travel to communities across the globe to help these communities in designing appropriate infrastructure systems. The community of Vallecito, located in Panama, has been working with a Peace Corps Volunteer, Siobhan Girling, over the past year in developing preliminary design ideas for their aqueduct system. In order to best serve the community, two different water systems will be developed in order to serve the northern and southern end of the area sufficiently. Comisión de Agua Corriente (CDAC) assessed the southern portion of the area and surveyed approximately 4275 meters of land.

In terms of data collection, CDAC used a water level to survey a route for the water system. The survey data was analyzed in EPANET and Excel to determine the feasibility of the proposed route. The first option is to include one main line with service lines branching off to households adjacent to the main line. The main pipeline is near the town center where a school is also present. After analyzing the elevation data, CDAC discovered that there is low pressure at the end of the system. Because the community wants the local school to be connected to this system, the Peace Corps volunteer was unsure if there would be enough pressure to supply the school with water. Therefore, a second alternative was developed.

For the second alternative, a tee will be installed near the beginning of the system so water can travel downhill towards the school. The system will be comprised of two pipelines, utilizing SDR 26 PVC pipe. After analyzing the two options in EPANET, the second design option proves to be more reliable in terms of supplying water than the initial proposed route, however; cost and construction time play crucial roles as well. After completing a cost estimate, option one would cost approximately 9,000 dollars and option two would cost roughly 15,000 dollars due to the additional pipeline.

For both alternatives, the community will be utilizing a spring source which is protected by a spring box. The spring box was constructed by a previous Peace Corps member in August of 2012. A conduction line will be built in order to connect the spring box to the storage tank. The line will be 1.5 inches in diameter and approximately 500 meters in length. Before the water goes into the storage tank, it will pass through a chlorination system with a bypass option available for the community to modify chlorine levels. The community will be using chlorine tablets provided by the Health Ministry in Panama, MINSA. Once the water goes through the chlorination system, it will feed into the storage tank. The existing storage tank is approximately 15 cubic meters in volume and will provide adequate contact time for the chlorine to react with any microbial contamination in the water.

CDAC developed test sheets for the community to use when testing the chlorine concentration in their water. Because the fate of chlorine is too complex to predict due to the high variability of the spring water, CDAC recommends the community be supplied with chlorine test kits in order to monitor the amount of residual chlorine in their system. If the level is too low or high, the community can modify the amount of water passing through the chlorinator by opening or closing the bypass valve. The system should maintain a residual chlorine concentration of 0.2 ppm in order to be considered safe drinking water [3].

In order to ensure the system and its components function properly, air release valves and break pressure tanks will be installed. Approximately 20 locations were identified along the distribution line where air release valves will be crucial in eliminating air obstructions from the pipeline. In regards to break pressure tanks, CDAC will be utilizing 3 tanks to properly dissipate high pressures at the beginning and end of the system

Finally, CDAC was able to make a final recommendation in terms of design approach. CDAC feels the initial option would be the best option because the proposed route can supply water to all households adjacent to the mainline and is less expensive in comparison to option two. Therefore, with the implementation of the new system and community's dedication in maintaining the components, CDAC believes the people living in Vallecito will find the system to their satisfaction.

2.0 Introduction

2.1 Community Background

The community of Vallecito is located within the Coclé province of Western Panama. The approximate location can be seen below in Figure 1. It is approximately 7 kilometers in length along a river valley. It is an area composed of many cultural traditions and values particular to the Latino community. People established the area approximately 70 years ago, and most are subsistence farmers. Many families can make about 5 dollars per day farming and harvesting their crops. The people currently live in wooden huts and have installed pit latrines that will last households 5 years. A school, church and small store are located in a centralized area where other community meetings and gatherings take place. Since the community is very widespread, the people must walk long distances, sometimes up to 4.5 kilometers, to come into this central area. An approximate location of Vallecito can be seen in Figure 1 below.

Figure 1: Location of Vallecito, Coclé, Panama [1]

2.2 Assessment of Community Need

Several existing water distribution systems serve individual households or small groups of homes in Vallecito. Thirteen small systems serve about 70% of the community using different springs as sources. Of these households that are served by an existing system, most draw their water via PVC pipeline from unprotected springs on private property. These systems were constructed by individual households, and either serve a single household, or are shared by several neighboring families. Furthermore, the existing PVC pipelines are often unburied as they traverse forestlands and farms. Flow occasionally stops when cows or horses trample the exposed conduit. Presently, people in homes that are not connected to a tap walk up to half a kilometer through their farms and forestlands to collect water from unprotected springs. The community is seeking a more permanent and widespread system to incorporate all households in the community. A map of the community can be seen below in Figure 2.

Another main reason for the desire to have a community wide system is potential problems with the water source for the town center. The central area and local school are connected to a temporary water distribution system. The problem with the current system is that a local farmer wants to begin using the land adjacent to the source for farming. There would be a high risk of pesticide and fertilizer contamination in the water. Also, with the increase of farming and other agricultural practices, this raises the risk for pipe lines breaking, which can cut off all water supply to the school and central area. Therefore, the community has hopes of designing a new water distribution system with the help of Peace Corps volunteers in order to meet the basic needs of the community and to offer a more permanent option that can serve the community long into the future.

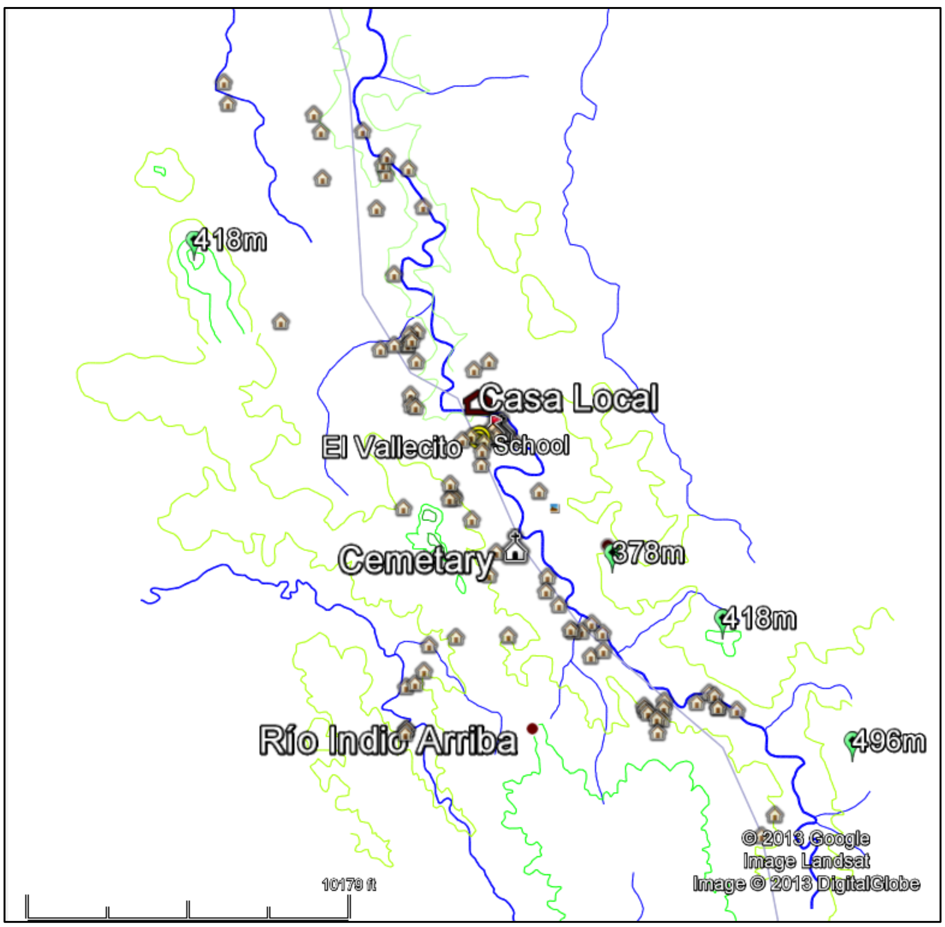


Figure 2: Map of community

The community currently has no water treatment. Based on information from their Peace Corps volunteer, Siobhan Girling, adults in Vallecito seem to suffer little from the chronic, typical symptoms of waterborne diseases, such as diarrhea and upset stomach. However, the frequency of these symptoms in children is unknown. Due to time constraints and the widespread nature of the community, the team was unable to conduct household surveys. Also, CDAC was unable to test for coliforms or E. coli at spring sources, since no springs were encountered on the survey path; however, it is assumed that there is microbial contamination in the community's drinking water. The community will be utilizing an in-line chlorination system so community members do not have to disinfect their own water.

Since all existing water pipeline was built with private funds on private property, no taxes are paid at this time for water. However, Vallecito does have a functioning water committee. This committee would be responsible for maintaining a community wide system, and it is be suggested that a fee for water usage would be collected by this committee.

2.3 Contents of Report

The final report serves as a summary of both technical and other background information regarding Vallecito. The report is to serve as a reference of information as the community begins to take its next step in the decision process. More specifically, the report will outline the various methods of collecting and analyzing data, cost estimates and construction schedules, and final project recommendations and conclusions. First, CDAC discusses the importance of the water level and how to use survey data to generate elevation plots. Elevation profiles are crucial in determining if the system will yield adequate pressures in order to assure water is flowing from the source to the end of the system. CDAC will also discuss the specific components of water distribution systems, such as chlorinators, storage tanks and spring boxes. These components are placed at the beginning of the system. As the water flows through the pipeline, households will be able to tap into the water supply using service lines and tap stands. Next, the report includes information regarding air release valves and break pressure tanks. The community will be using a large amount of air release valves due to the area's naturally hilly topography. CDAC discusses the importance of break pressure tanks at the beginning and end of the system as well. Lastly, the report covers pertinent information regarding the predicted construction time and the project's associated costs. CDAC concludes with final recommendations based on the data and cost estimate.

3.0 Methods

3.1 Data Collection

An aqueduct system for the entire community was not feasible due to the terrain. Instead two water systems are to be designed. CDAC collected data while in Panama to design a system for the southern half of Vallecito. Survey and GPS data for the pipeline, flow rate data from the water source, and community water use data were collected to design the aqueduct system. Survey data for the entire 4 km length of the pipeline was collected using a water level. The water level was used instead of an Abney level because the water level could provide more accurate survey data. A house near the end of the system has an elevation that is close to the elevation of the existing storage tank. The more accurate survey data was needed to ensure that the elevation of this house is below the tank so water can be provided to the household.

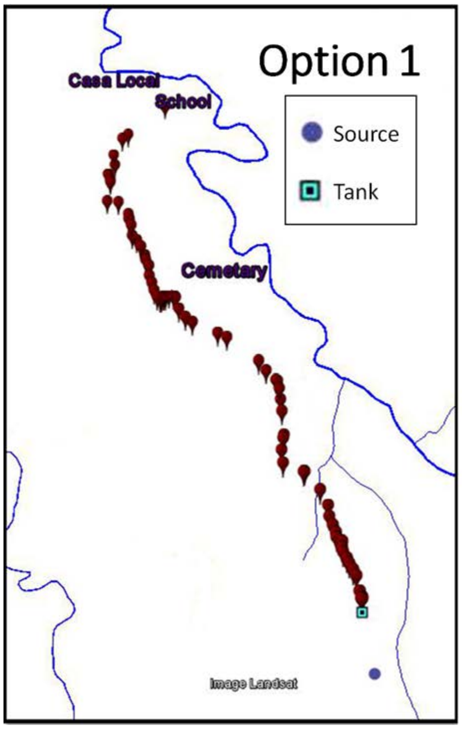
The Peace Corps volunteer in Vallecito had a simple water level that consisted of a PVC pipe and clear plastic tubing. The clear tubing runs along the ground for a certain distance before running up a stick with a measurement tape. An image of the water level can be seen in Figure 3. Although the water level can be more accurate than the Abney level, it has some limitations. The distance between recorded points using the water level is limited by the length of the clear tubing which was 7m. In areas with steep elevation changes, the water level is only able to move a meter or two between points. If the water level is moved too far in these areas, the water level would be too high to read and/or come out the top of the tube (requiring a new benchmark).

Figure 3: Water level used for topographic survey

Latitude and longitudinal data were taken using a Garmin GPS. Waypoints were taken at distinctive landmarks, such as a fence or house, along the route that was surveyed. Along with GPS data, compass bearing readings were recorded at every point along the route.
This collected survey data was used along with flow and demand data provided by Siobhan Girling for the basis of the design.

3.2 Piping System Routes

CDAC has completed the design for two possible routes for a water distribution system in Vallecito. Both of the designs call for gravity-fed systems. In CDAC's design, the main line of the system is called the "high line". This line has several service lines connected to it, but the only one defined by name is the Cemetery Line. Maps of the two options can be seen in Figure 4 below or Appendix C. The first route runs from the spring to the tank and then all the way along the surveyed route to the town center. This option will have service lines branching off of the high line to serve all the homes located south of the town center. The profile for this option can be found in Appendix A, Figure 17.



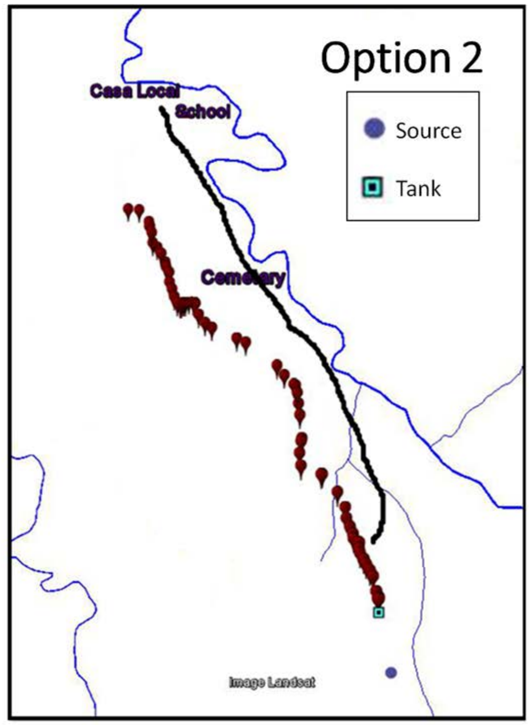


Figure 4: Route options

The second route runs from the spring to the tank and then to a house located 3.6km from the source. This house is located 130m uphill from the town center. For this option, the high line route does not run down to the town center. The main line of this system will tee into an existing system located about 1000m from the source. This existing system currently serves some of the houses on the south side of the town center. The system will be extended to serve the town center. The high line route of this system will only serve 6 houses. The profile for this option can be found in Appendix A, Figure 18.

With both options there are still many significant elevation changes. The main line of the system starts at about 420m, with a low point of 296m and a high point of 385m. While surveying the route, alternative routes to avoid severe changes in elevation were noted. The system was designed using the route that was surveyed but would probably be built to moderate many of the significant changes in elevation between the source and the high point of the system located 3536m from the source.

4.0 Components of Project Design

4.1 EPANET Distribution System Model

A total of 666 survey points were collected in Vallecito, providing distances and elevations between the aqueduct's source and the town center. This survey was conducted along the high line of the system. This data was reduced to less than 100 data points to represent the elevation changes over the distance as well as possible. A figure with the original data profile and reduced data profile is found in Appendix A, Figure 16. The reduced data includes all of the major elevation changes, including maximum and minimum elevations.

Surveyed data for the cemetery line, a service line off of the highline, was also collected in Panama and modified. Profile views of the original data and reduced data for the cemetery line can be found in Appendix A, Figure 19.

The reduced data for the High line and the Cemetery line were entered into EPANET to determine pipe sizes and pressures. The topography of the region is very hilly, which has large effects on pressure. About 1750m from the source there is a low point in the system of 295m elevation. Pressures at this location will be very high, but a pressure break tank cannot be used at this location because there is a house near the end of the system with an elevation of 390m. If a break pressure tank were used, there would not be enough pressure in the system to travel uphill. However, Option 1 has two pressure break tanks on the last descent to the town center. The location of these break tanks, along with locations of air release valves, can be found in Appendix A, Figure 20. Break pressure tanks and air release valves were also needed along the cemetery service line. The locations of these can be seen in Appendix A, Figure 21.

EPANET was also used to determine pipe sizes. Appendix A, Figure 17 shows the location of significant points along the pipeline for Option 1. This option uses two inch pipe for the entire system. The line at the altitude of 290m shows the static pressure limit for PVC SDR 26 pipe. The pipeline never crosses this line except toward the end when the system is descending into town and pressure break tanks can be used. For the design of Option 1, two inch PVC SDR 26 pipes are used. The line at the elevation of 340m shows the pressure limit for taps. Dionicio Sanchez's house and the point where the Cemetery line connects to the High line are below the pressure limit line. It is not advised to connect service lines to the system or install taps with this amount of head. The connection point for the Cemetery line will need to be moved further uphill and then have one or more break pressure tanks installed along it, so the line does not risk breaking due to high pressures.

Appendix A, Figure 18 shows the location of significant points along the pipeline for Option 2. Most of the features are the same. However, Option 2 has a connection off the High line to an existing system located approximately 1100m from the source. This connection location is above the pressure limit line for taps, so there should be no problems connecting to the existing system at this location. Pipe information for both of these options can be seen in Tables 1 and 2 below.

Table 1: Option 1 Pipe Information

Option 1: Pipe Information			
Section of Pipe	Distance (m)	Nominal Size (in.)	SDR
Conduction Line	463	1 1/2	13.5
High Line	3810	2	26
Cemetery Service Line	534	1/2	13.5
Other Service Lines	-	1/2	13.5

Table 2: Option 2 Pipe Information

Option 2: Pipe Information			
Section of Pipe	Distance (m)	Nominal Size (in.)	SDR
Conduction Line	463	1 1/2	13.5
High Line to connection to existing system	602.2	3	26
Rest of High Line	3299.1	2	26
Cemetery Service Line	534	1/2	13.5
Other Service Lines	-	1/2	13.5

4.2 Improved Source: Spring Box

Located at the source is a spring box as shown in Figures 3 and 4. The spring box appears to have been constructed in the year 2012, as shown in the figure below. Because a spring box exists, it can be assumed the source is protected from surface water runoff and contamination. The spring box also appears to be in good condition. However, a conduction line has not been installed to connect the spring box to the storage tank. An appropriate conduction line needs to be designed to ensure suitable flow through the chlorinator and into the storage tank. The spring box will not be redesigned.

Figure 5: Photo of spring box interior [4]

Figure 6: Photo of spring box [4]

4.3 Conduction Line

The pipeline from the spring box to the storage tank is known as the conduction line. The pipeline will be 1.5 inch diameter PVC SDR 26 pipe [4]. The conduction line will be 463 meters in length from the spring box to the storage tank. An in-line chlorinator will be installed along the conduction line before the water enters into the storage tank.

4.4 Supply and Demand

The spring source for the proposed aqueduct is projected to supply approximately 13,000 gal of water per day. This is a dry season flow, indicating the worst case scenario, or minimum supply. The Ministerio de Salud de Panamá (MINSA) recommends a daily per person consumption rate of 30 gal. This is a quite liberal estimate of water usage, based on communication with Peace Corps volunteer Siobhan Girling. Nonetheless, assuming a need of 30 gal/person/day, the total potential persons served by the source is about 430. CDAC liberally estimates the proposed aqueduct will serve 50 households with 6 persons per household, equaling 300 persons. These figures include houses proposed for construction in the near future.

The proposed aqueduct must also be designed to serve the public facilities at the center of the community – the school, church, and *casa local*. With an estimated 120 persons eating lunch at the school per day, CDAC liberally estimates a demand of 5 gal/person/day at the school, equaling 600 gal/day demand for the school. It is important to note here that the students from the southern half of Vallecito have been counted for both a 30 gal/day demand at home *and* a 5 gal/day demand at school. This is for the sake of a conservative design, and because CDAC does not know the number of students from southern Vallecito versus the number from northern Vallecito. The taps at the church and *casa local* are used only occasionally. Because the school demand is considered generous, CDAC will assume the church and *casa local* demands are accounted for in the school demand.

Thus, the total present demand on the proposed system is estimated at 9600 gal/day, compared with a sufficient 13,000 gal/day supply. See Appendix D for supply and demand calculations.

4.5 Existing Storage Tank

A 4000 gallon (15 m^3 =15,000 L) reinforced concrete storage tank was built by the community and a previous Peace Corps volunteer, Tyler Christian Gutierrez, most likely in 2012. It is located approximately 20 m of altitude below, and 460 m away from, the spring source. The purpose of the tank is twofold: (1) to temporarily store water so that peak demands are met, and (2) to provide contact time for chlorine disinfection.

Prior to construction, Gutierrez justified the existing storage tank's size. He based the sizing on both the current and future water needs of the community, estimating Vallecito's present population as 274 persons, growing to 369 persons in twenty years (1.5% growth per year). Assuming 200 gallons/day for the school and MINSA's recommended 30/gallons/person/day, Gutierrez comes to 11,270 gallons/day peak demand in twenty years. [5]

Thus, the tank is designed for realistic population growth in Vallecito. However, for the water system itself, CDAC will continue to use its liberal estimate of 300 people served, plus public facilities. As explained in the *Supply and Demand* section, CDAC considers its population/demand estimates to be generous. Additionally, the daily supply of 13,000 gal/day calculated by CDAC is substantially greater than roughly 11,500 gal/day calculated by Gutierrez. CDAC will maintain the 13,000 gal/day threshold, because it is based on a more recent 0.57 L/s flow provided by Siobhan Girling, as compared to 8 gal/min = 0.48 L/s from Gutierrez.

With his overall supply and demand established, Gutierrez went on to divide the day into varying blocks of time based on fluctuating demands over the course of a day. This was done to find the worst case scenario supply deficit – thus necessitating a storage tank. The greatest difference between supply and demand in twenty years, as seen in the last column of Gutierrez's table below, is nearly 3000 gallons between 11:00 AM and 1:00 PM. To be conservative, Gutierrez decided to construct a 4000 gallon tank. The percentage figures of consumption in each line are from the UNICEF guide for gravity-fed water systems, *Handbook of Gravity-Flow Water Systems for Small Communities* (Jordan, 2010). A sketch of the tank is shown in Figure 5.

Table 3: Required reserve tank capacity for future use, as estimated by previous Vallecito PCV Tyler Christian Gutierrez, English translation [5]

Needed Reserve Tank Capacity for Future Use (11,270 gallons)			
Hours	Supply (gallons)	Demand (gallons)	Difference (gallons)
5 AM – 9 AM (4 hours, 10%)	960	1,127	-167
7 AM – 11AM (4 hours, 25%)	1920	2,817.5	-897.5
11 AM – 1 PM (2 hours, 35%)	960	3,944.5	-2984.5
1PM – 5 PM (4 hours, 20%)	1920	2,254	-334
5PM – 7 PM (2 hours, 10%)	960	1,127	-167

Thus, the storage tank's size was based upon the peak demand. A sketch of the tank can be seen below. Contact time for chlorine disinfection will be discussed below in the *In-Line Chlorination* section.

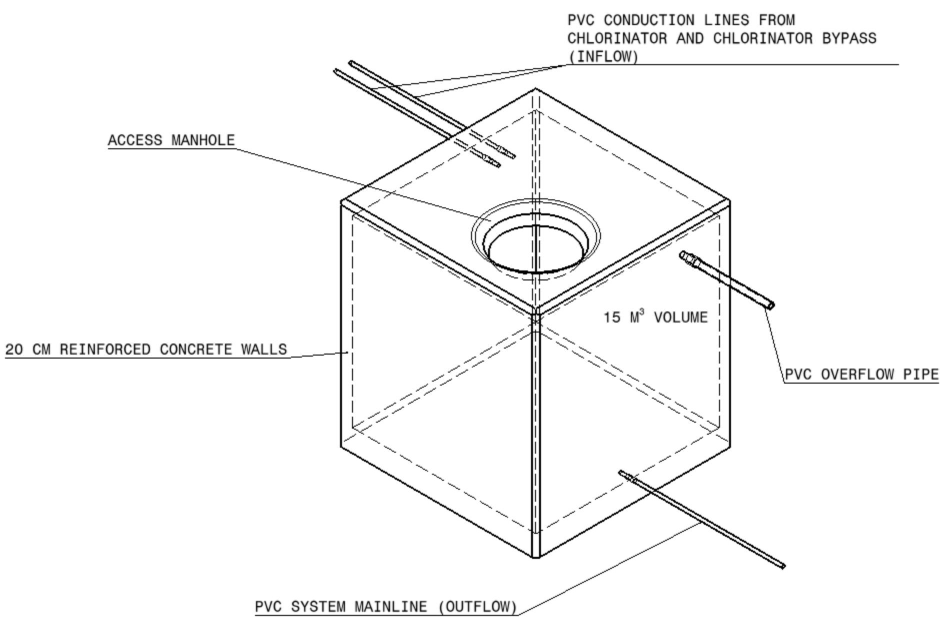


Figure 7: Storage tank sketch with outlet, inlet and overflow pipes (CDAC)

4.6 In-line Chlorination

Although the water from the spring source was never tested, CDAC can assume there is some microbial presence that may cause health problems in the community. Although the groundwater is protected by a spring box, there may be some bacteria and organic material present. In order to rid the system of bacteria, an in-line chlorinator will be installed to treat the water running through the network. The in-line chlorinator will be placed along the conduction line before the storage tank, so the chlorine has enough time to react with microbes in the water before reaching households. This is known as contact time and is dependent on the size of the storage tank and usage rate. Typically, groundwater treated with chlorine must have a contact time of 2 mg-min/L to be considered safe to drink. Contact time is determined by multiplying the chlorine concentration and the retention time of the tank. If the chlorine concentration in the storage tank is 0.2 mg/L, the retention time would need to be ten minutes. If the storage tank has 1000 gallons in reserve, the residence time within the tank for the chlorine to react is approximately 1.85 hours, which is more than enough time for the chlorine to successfully react with the water. [9]

The Ministry of Health in Panama (MINSA) provides communities with chlorinators, along with chlorine tablets for communities to use in their water systems. However, because the MINSA chlorinator design is difficult to adjust and dimensions are unknown to CDAC, the team will design for the CTI 8 model, as shown below in Figures 8 and 9. [6]

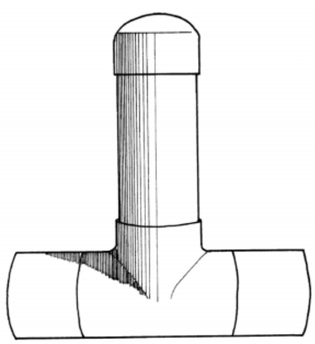


Figure 8: CTI 8 in-line chlorinator model [6]

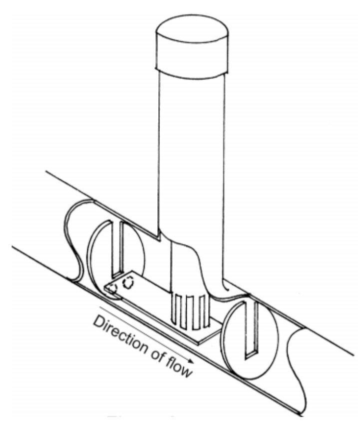


Figure 9: Schematic of CTI 8 model [6]

4.6.1 *Limitations & Recommendations*

The chlorinator poses some limitations. First, the tablets provided to the community do not last for long periods of time. Approximately two tablets may dissolve within a week, dependent upon the flow. [6] Therefore, in order to maximize the life of each tablet, several things must be taken into consideration. In terms of pressure, if there is a sufficient amount of pressure difference between the source and the in-line chlorinator, the water could potentially rise in the tablet tube where multiple tablets are stored, causing the tablets to dissolve quickly. [6] In the community of Vallecito this is especially important, as the hike to the storage tank is challenging, which may make it difficult to add the tablets weekly. Thus, CDAC plans to install a pressure break tank between the existing spring box and existing storage tank to minimize the pressure in the chlorinator. In terms of flow, the chlorinator can only withstand flows between 0.13 and 1.3 liters/second. [6] The flow coming from the spring source is approximately 0.57 liters/second, which will be suitable for the device.

Regarding operation, as the water is traveling in the conduction line towards the chlorinator, the water will eventually hit an inlet baffle. The portion above the support plate directs the flow into the middle of the chlorinator. The two holes below the support plate allow some water to bypass the chlorine tablets. As seen in Figure 9, the slits in the tube, resting on the support plate, allow for a controlled chlorine release. Possible modifications can be made to the slits in order to increase or decrease the amount of chlorine released. Lastly, the weir towards the end of the chlorinator helps ensure mixing of the chlorinated and bypassed water.

The amount of chlorine dissolved into the water can be modified in two additional ways. As shown in Figure 10 below, the addition of the bypass valve and its design can alter the amount of water flowing through the chlorinator. Installing valves and spacer discs into the chlorinator will also help control the amount of chlorine released into the water. If the amount of chlorine added to the system is too large, the isolation valve can be utilized to decrease the amount of water flowing through the chlorinator, which will decrease the amount of chlorine dissolved. Another alternative is the implementation of spacer discs. The spacer discs can be placed underneath the chlorine tablets to reduce the amount of tablet exposed to the water. Typically one spacer disc is used for every 0.13 liters/second of flow. [6] At higher flow rates, more spacer discs can be used.

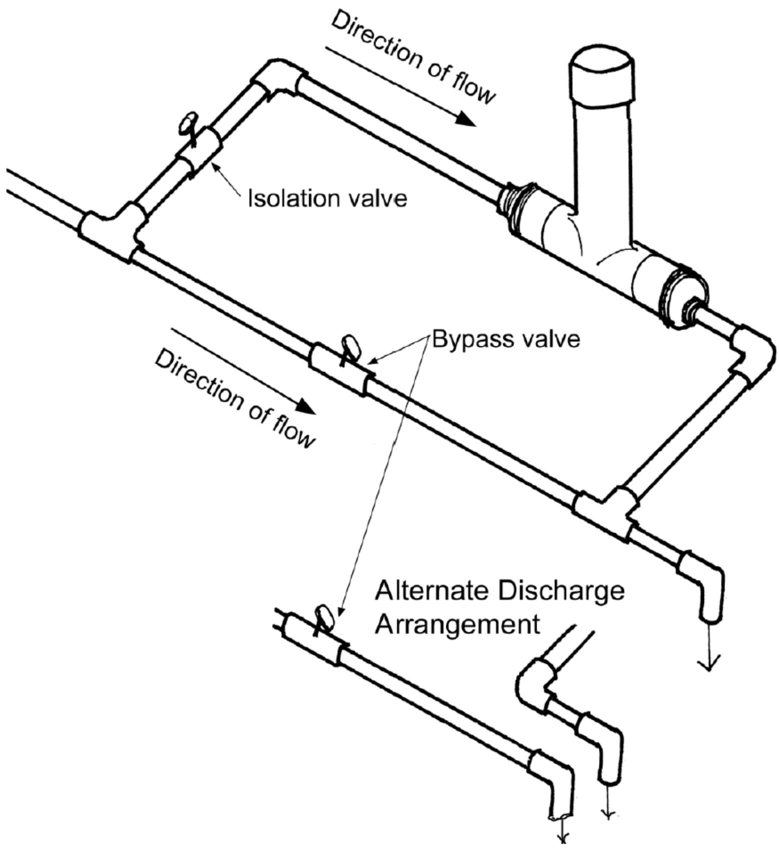


Figure 10: In-line chlorination water route design [6]

4.6.2 *Maintenance*

The manufacturer of the CTI 8 in-line chlorinator suggests the chlorinator be monitored daily, at least for the first month of use. Possible reasons include checking for proper installation and becoming familiar with the device. During the next three months, the CTI manufacturer suggests the chlorine be monitored on a weekly basis. After the first four months, the chlorinator should be checked periodically. The number of times the chlorinator will need to be checked is dependent upon the flow, and whether or not the tablets tend to dislodge and move up in the column frequently due to water pressure. In terms of cleaning the chlorinator, the device should be checked and cleaned periodically to ensure there is no accumulation of organic material or sediment that may interfere with chlorine dissolution. [6]

In order to protect the chlorinator from destructive processes, a protective encasement is often used. The encasement is usually in the form of a concrete box that has a locked panel for community members to access the chlorinator for maintenance. [6]

4.6.3 *Modeling*

Another concern is modeling the in-line chlorinator in EPANET. Due to many unknown variables, modeling the device has proven to be difficult and will likely yield inaccurate results. Chemically, the bulk decay coefficient is important in understanding how the chlorine will react with the bulk water in the pipes. The rate at which chlorine will decay depends on the amount of organic material and bacteria present. This variable is unknown because CDAC was unable to test for the coefficient in Panama using the source water. The bulk decay coefficient is determined experimentally using the source water because temperature, pH, inorganic and organic compound concentrations specific to the source will affect the coefficient. Because the coefficient is crucial in EPANET, CDAC will not be modeling the chemical properties of the disinfectant. Please reference the Chlorine Concentration Testing section below for alternative methods to testing the chlorine levels in the water system.

Additionally, the way in which the chlorinator is constructed poses major difficulties in modeling. The chlorinator is usually constructed with additional piping, as seen in Figure 10. The flow will vary based on the closing and opening of the valves. Additionally, because the chlorinator has many components like slits, a baffle, a support plate and a weir plate, the headloss through the device will also vary. Because the flow rate constantly varies with the addition of valves and component parts, modeling such a device is difficult. Therefore, CDAC does not plan to model the chlorinator in EPANET but instead has developed chlorine test sheets for the community to use. See Appendix E for these sheets.

4.6.4 *Chlorine Concentration Testing*

Residual chlorine concentration is measured to determine if the concentration is adequate for the entire system. On average, a residual concentration of 0.2 ppm is acceptable and can be determined by using a color comparator or colorimeter. [6] In order to ensure sufficient testing, the concentration should be measured at two locations along the water distribution system and at the chlorinator. [6] The concentration at the chlorinator will be higher than along the system. A residual chlorine concentration of 0.2 ppm throughout the system, is generally considered acceptable. [3]

Additional methods could involve taste and odor tests. The community should evaluate acceptable levels of chlorine based on the way the water tastes and smells. If the water tastes or smells strongly of chlorine, the community should decrease the dosage. High chlorine concentrations, greater than 0.6 ppm, are also harmful to the community’s health. The community can report to the water committee if they feel the chlorine is overwhelming. The water committee can modify the chlorine output through use of the bypass valve.

4.7 Air Release Valves [7]

CDAC used the elevation profile to determine the most feasible points in the system to install air release valves. Air release valves are intended to immediately relieve the pipe of air obstructions that may have accumulated along the undulating hills in the area. These are mainly placed at high points along the system. In terms of operation, the valve is normally closed as water moves through the pipe. When large air pockets come into contact with the valve, the floating ball will move around the device, allowing the air to be pushed out of the air release valve. If there are no air accumulations, the ball will remain floating on top of the water. In order to properly maintain the valve, a shut off-valve can be installed so water can bypass the device when the valve is repaired or cleaned. Figure 11 below is an example of a simple air release valve

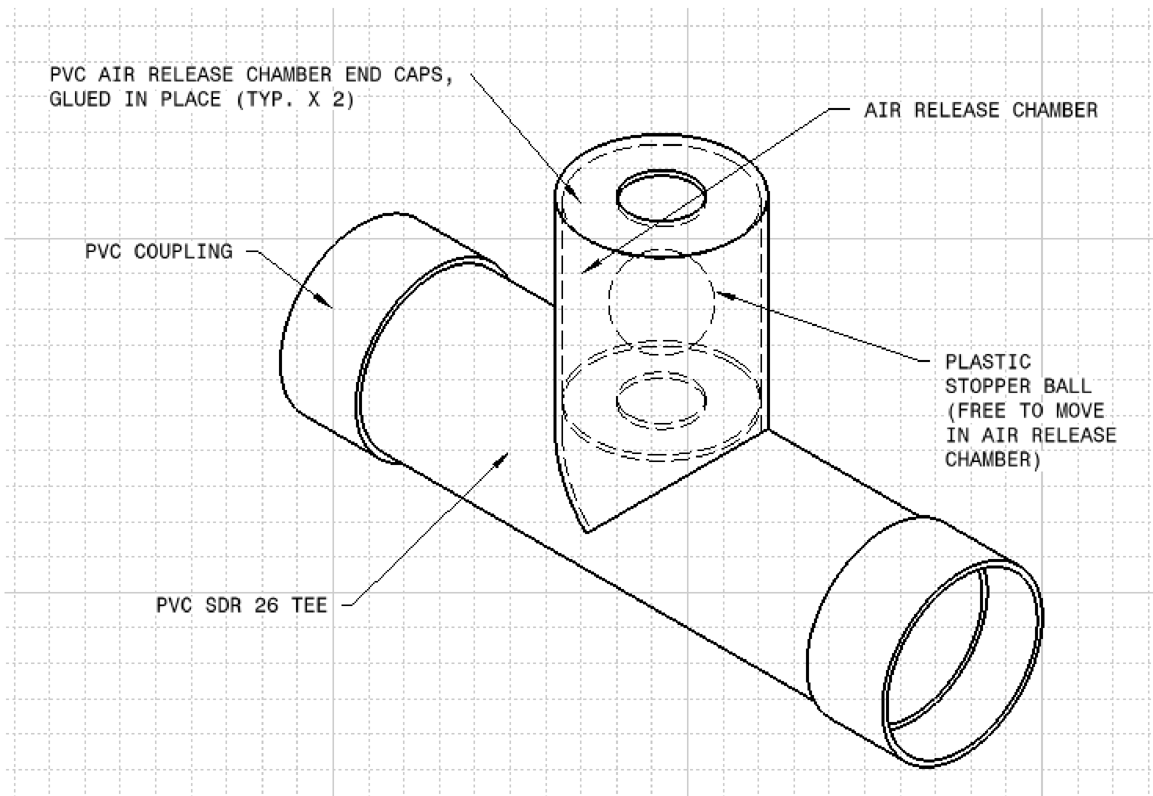


Figure 11: Air release mechanism (CDAC)

4.8 Break Pressure Tanks [8]

As previously explained in the *EPANET Distribution Modeling* section, CDAC used EPANET to determine the most feasible points in the system to install break pressure tanks. As the system experiences large drops in elevation, large amounts of static pressure are produced in the system which can be catastrophic to pipes. In order to dissipate the high pressures, pressure break tanks are used along the line to expose the water to atmospheric pressure. In a pressure break tank, water flows into a large chamber and then is redirected into the pipeline. Figure 12 below outlines a typical pressure break tank using overflow and draining components. Figure 13 below shows the design employed by CDAC for Vallecito.

Figure 12: Typical break pressure tank model [2]

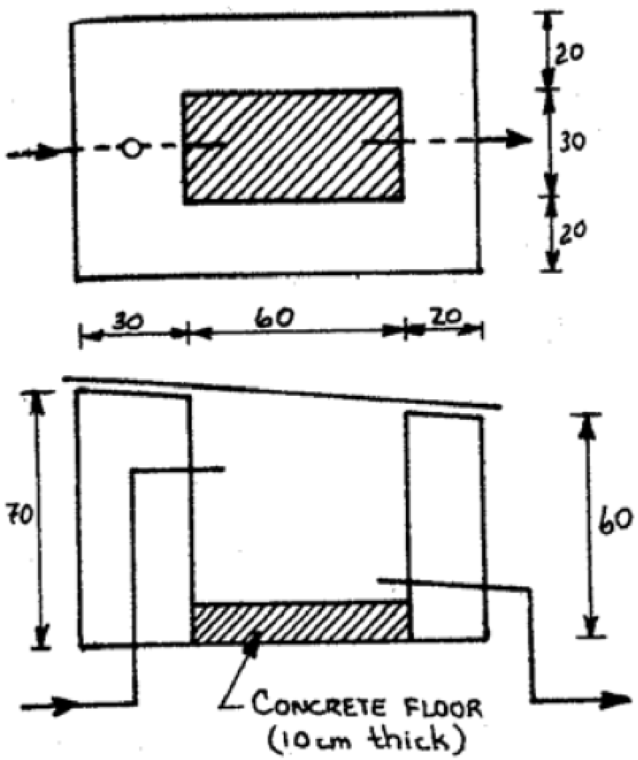


Figure 13: Break pressure tank design for Vallecito, taken from UNICEF *Handbook of Gravity-Flow Water Systems for Small Communities* (Jordan, 2010)

4.9 Tap Stands

DAC plans to serve Vallecito households using tap stands standard for central Panama. A tap stand consists of the incoming PVC service line (0.5” nominal diameter) connected to a vertical pipe with a spigot. While the pipes and 90˚ angles are PVC, the spigot is plastic or steel and may require a special connector. See Figures 11 and 12 below for a rendering of a typical tap stand. The tap stand will be supported by a wooden stake or an existing home’s wall, tied to the back of the PVC pipe. See Figures 14 and 15 below.

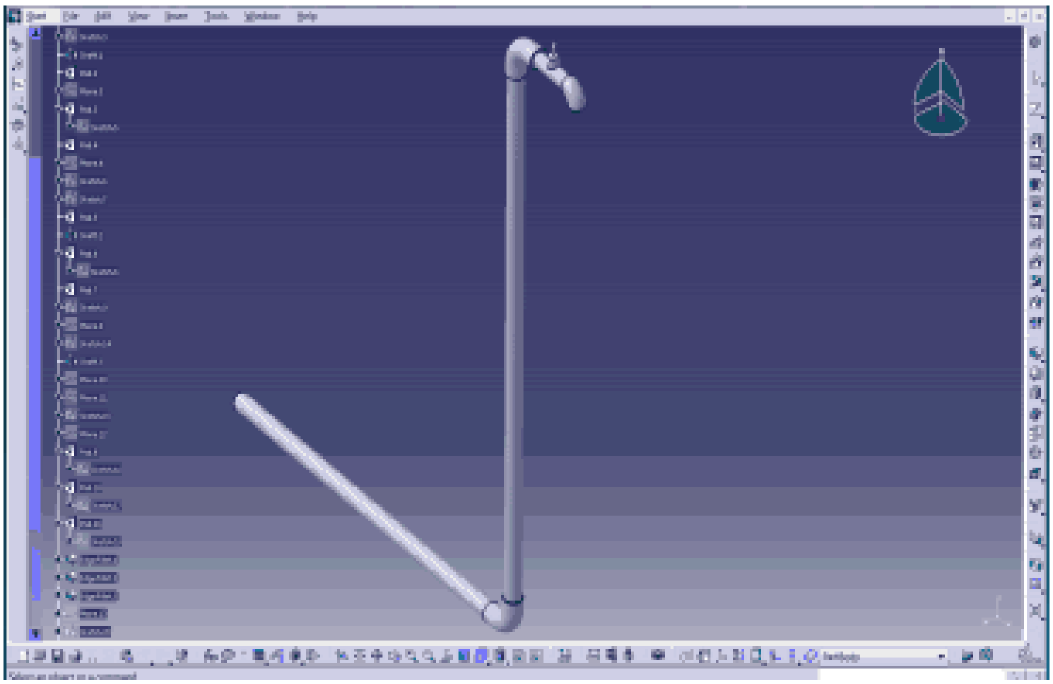


Figure 14: Typical tap stand used in Vallecito (CDAC)

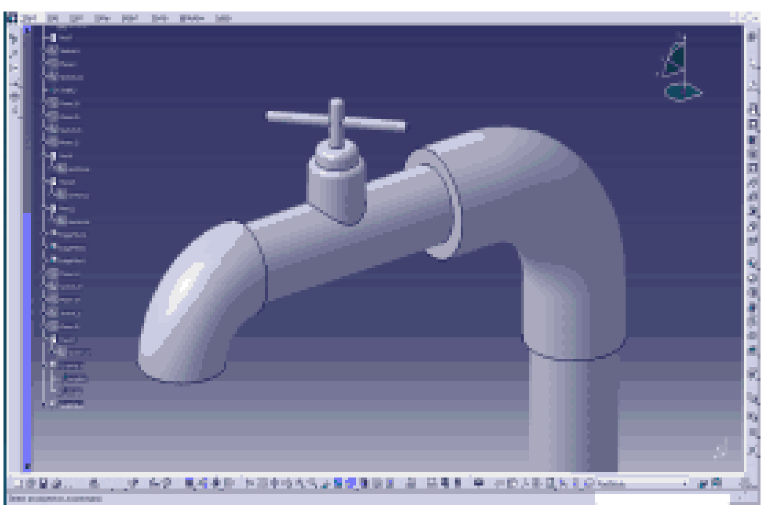


Figure 15: Close up of Spigot (CDAC

5.0 Construction Schedule

For Option 1, construction is scheduled for completion in 7 months. For Option 2, construction is scheduled for completion in 9.5 months. See Tables 4 and 5 below for the major tasks and their durations, and see Appendix F for the full breakdown of tasks and subtasks. See Appendix G for justification of the durations of the tasks.

Table 4: Construction schedule for Option 1

Task Name	Duration	Start	Finish	Predecessors
Procure materials	14 days	Thu 1/2/14	Tue 1/21/14	
Construct break pressure tanks	**8 days**	**Mon 1/20/14**	**Wed 1/29/14**	
Chlorinator	**47 days**	**Wed 1/22/14**	**Thu 3/27/14**	
Air release valves	**152 days**	**Fri 1/24/14**	**Mon 8/25/14**	
Construct conduction line, high line, cemetery service line	**132 days**	**Fri 2/21/14**	**Mon 8/25/14**	**6**
Construct service lines	**56 days**	**Fri 7/25/14**	**Fri 10/10/14**	
Tapstands	49 days	Tue 8/5/14	Fri 10/10/14	

Table 5: Construction schedule for Option 2

Task Name	Duration	Start	Finish	Predecessors
Procure materials	14 days	Thu 1/2/14	Tue 1/21/14	
Construct break pressure tanks	**24 days**	**Mon 1/20/14**	**Thu 2/20/14**	
Chlorinator	**47 days**	**Thu 1/2/14**	**Fri 3/7/14**	
Air release valves	**101 days**	**Fri 1/24/14**	**Fri 6/13/14**	
Construct conduction line, high line, cemetery service line	**81 days**	**Fri 2/21/14**	**Fri 6/13/14**	**6**
Construct service lines	**56 days**	**Tue 5/13/14**	**Tue 7/29/14**	
Tapstands	49 days	Thu 5/22/14	Tue 7/29/14	

6.0 Cost Estimate

CDAC has completed a cost estimate for both options. The two tables below summarize the final cost estimates for the projects. (See Appendix H for the plenary estimates for both options.) Based on the final results, Option 1 is less expensive. Option 2 consists of an extra 3 kilometers of pipeline routed to the town center. The extra pipe greatly increases the costs of Option 2. A design and cost estimate contingency were incorporated in the cost estimate to prevent underestimating the financial costs of the project. The results of the estimate greatly influence the type of design the community will be able to implement.

Table 6: Option 1 cost estimate summary table

Design Component	Estimated Cost ($)
Conduction Line	469
Chlorinator	55
Main Line Pipe	4560
Service Line (Cemetery) Pipe	217
Tapstand	171
Air Release Valve	119
Break Pressure Tank	182
Miscellaneous	1888
Design Contingency (10%)	766
Estimate Contingency (8%)	613
Total Estimated Cost	9039

Table 7: Option 2 cost estimate summary table

Design Component	Estimated Cost ($)
Conduction Line	469
Chlorinator	55
Main Line Pipe	9324
Service Line (Cemetery) Pipe	217
Tapstand	171
Air Release Valve	110
Break Pressure Tank	67
Miscellaneous	1888
Design Contingency (10%)	1230
Estimate Contingency (8%)	984
Total Estimated Cost	1416

7.0 Conclusions & Recommendations

7.1 Conclusions

CDAC initially surveyed one route for the proposed main line, running from the spring source to the school. Due to somewhat unreliable pressures at the end of the system, a second design option was developed to ensure a more reliable amount of water be distributed to the school. However, based on the cost estimate and EPANET results, CDAC feels the initial design is the best option for the community. The pressures at the end of the system are large enough to ensure water is flowing to the school so long as people are not letting their taps run continuously throughout the day. Additionally, the first option is much less expensive.

The design incorporates an existing spring box, constructed in August of 2012. The community will also be installing a chlorinator. CDAC recommends, however, that the community instead use a more expensive type of chlorination system, known as the CTI 8 model, which would allow them to better control the amount of chlorine in the system with the introduction of baffles, weirs and a bypass pipe. The water will flow into the existing storage tank and then through approximately 4000 meters of pipeline to households and the local town center. The distribution system will use 1.5 and 2-inch diameter SDR 26 PVC pipe. To avoid air blockages along the line, air release valves will be installed. Lastly, pressure break tanks will be used at the very beginning of the system to account for the chlorinator and along the end of the system due to the steep hill in the initial design.

7.2 Recommendations

In order for the system to sustain the growing population, a more organized water committee must be put into place. The committee must be informed of potential tax collections, pipeline location and maintenance procedures, and chlorine monitoring procedures. If the water committee and community members can cooperate with one another and dedicate time to maintaining the system, the community will be supplied with plenty of water for years to come.

During the construction process, if the initial design proves to supply inadequate water to the households at the end of the system, CDAC recommends investing in Option 2. If there are sufficient pressures at the end of the system, CDAC recommends continuing construction of the pipeline to the town center. Lastly, if the CTI 8 chlorination system proves too difficult to construct and maintain, CDAC recommends installing the chlorinators provided for free from the Ministry of Health in Panama.

8.0 Acknowledgements

Team Comisión de Agua Corriente would like to thank the following people for their help with completing the design of an aqueduct system for Vallecito.

Peace Corps Volunteers
Siobhan Girling
Danielle Renzi

Senior Design Professors
David Watkins, Ph.D., PE
Michael Drewyor, PE, PS

9.0 References

[1] Map of Panama. http://www.educatecentralamerica.org/images/panama-map-col.jpg

[2] "Agua Y Desarrollo Comunitario." *ADEC*. N.p., n.d. Web. 15 Nov. 2013. <http://adechonduras.org/2013/10/update-water-project-santa-cruz-san-manuel-de-colohete-lempira/>.

[3] *Centers for Disease Control and Prevention*. Centers for Disease Control and Prevention, 21 Mar. 2012. Web. 14 Nov. 2013. <http://www.cdc.gov/safewater/chlorine-residual-testing.html>.

[4] Girling, Siobhan. Personal Interview. 11 October 2013.

[5] Gutierrez, Tyler Christian. “Aqueduct Analysis: Vallecito, Coclé.” English translation by Victor Boron from original Spanish.

[6] Jacob, Fred, and Charles Taflin. "The CTI 8 Chlorinator." Manual of Information, Maintenance & Operation. N.p., n.d. Web. 1 Nov. 2013.

[7] "Air Release Valve Series 38, 45, 50 (Compound Lever Type)." Operation, Maintenance and Installation Manual. ValMatic. Valve and Manufacturing Corp., n.d. Web. 1 Nov. 2013. http://www.valmatic.com/pdfs/ARCL-OM1-1.pdf

[8] McNabola, A., P. Coughlan, and A.P. Williams. "The Technical & Economic Feasibility of Energy Recovery in Water Supply Networks." Department of Civil, Structural & Environmental Engineering, n.d. Web. 1 Nov. 2013.http://www.icrepq.com/icrepq'11/569-mcnabola.pdf

[9] "TECHNICAL GUIDELINES FOR DETERMINING DISINFECTION “CT” WHEN USING CHLORINE FOR DISINFECTION OF GROUNDWATER SOURCES OF SUPPLY." *STATE OF CONNECTICUT DEPARTMENT OF PUBLIC HEALTH DRINKING WATER SECTION*. N.p., 8 Apr. 2010. Web. <http://www.ct.gov/dph/lib/dph/drinking_water/pdf/Chlorination_Technical_Guidelines.pdf>.

10.0 Appendices

Table of Appendices

Appendix A: Profile Drawings

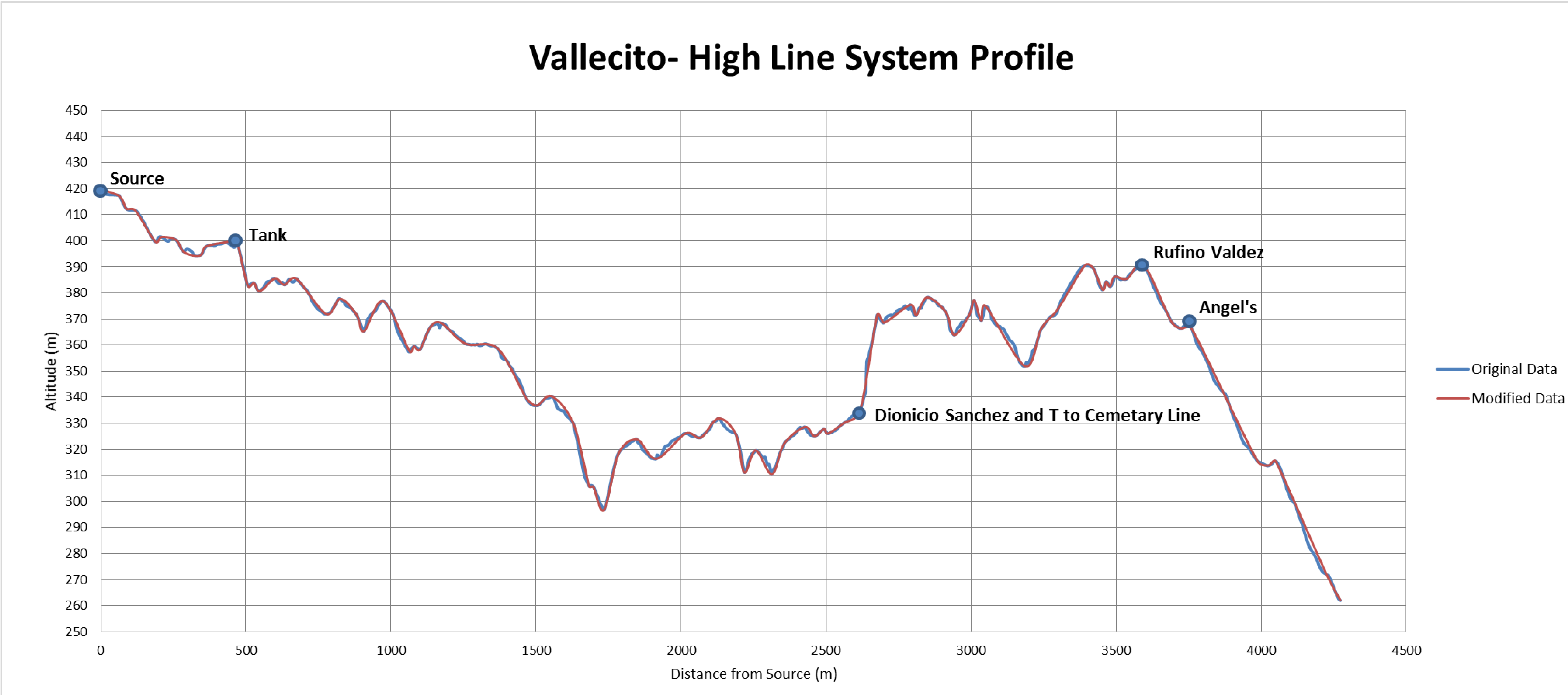


Figure 16: Original survey data, elevation data

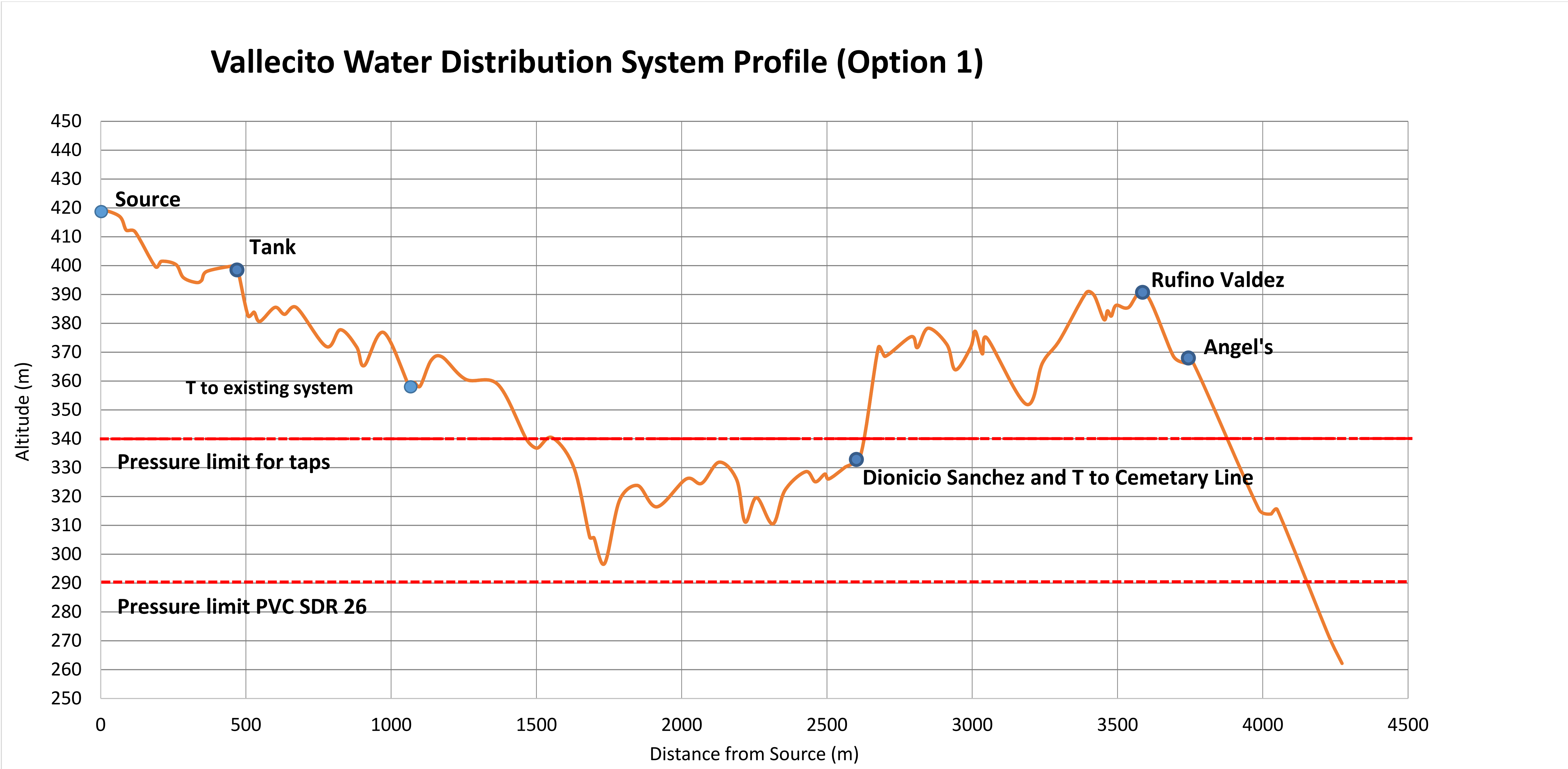


Figure 17: Option 1, high line route

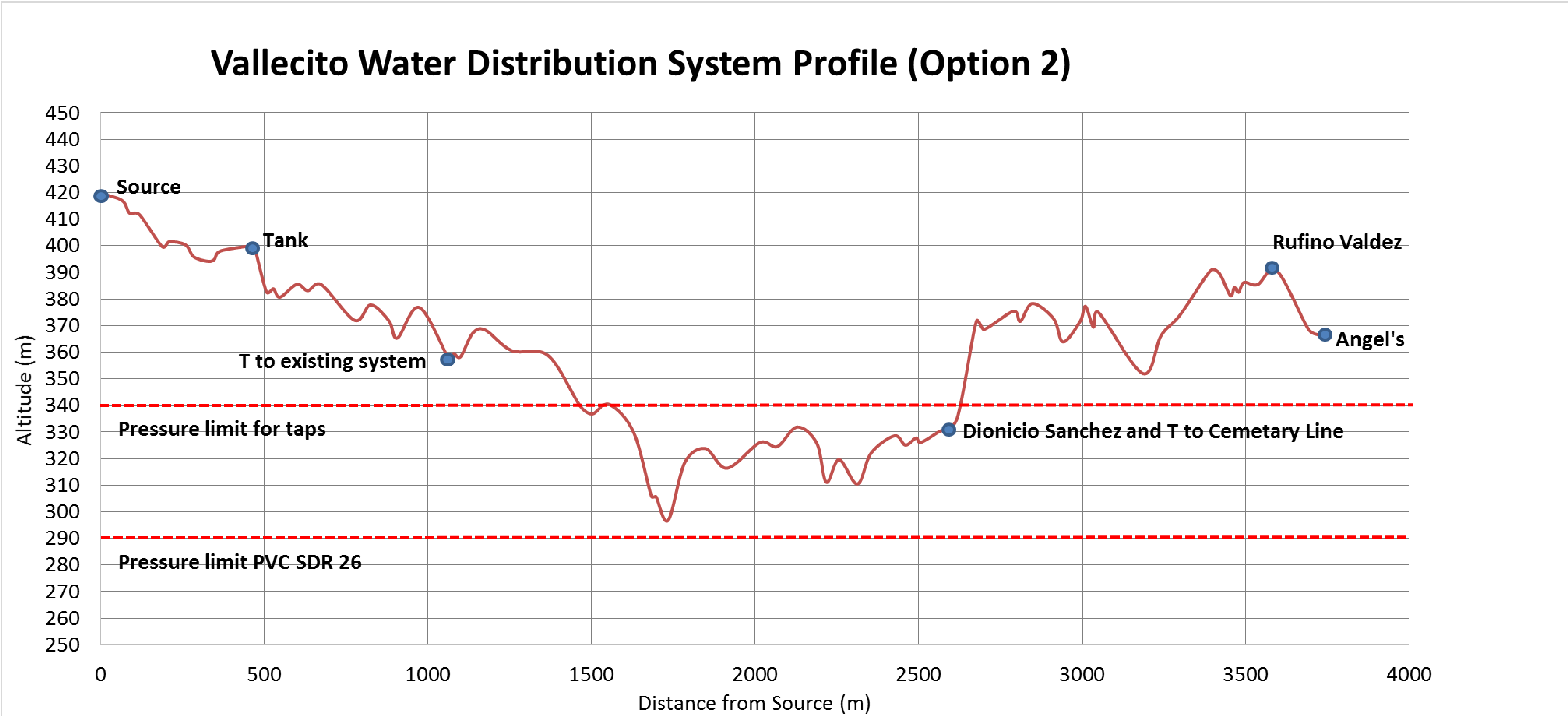


Figure 18: Option 2, high line route

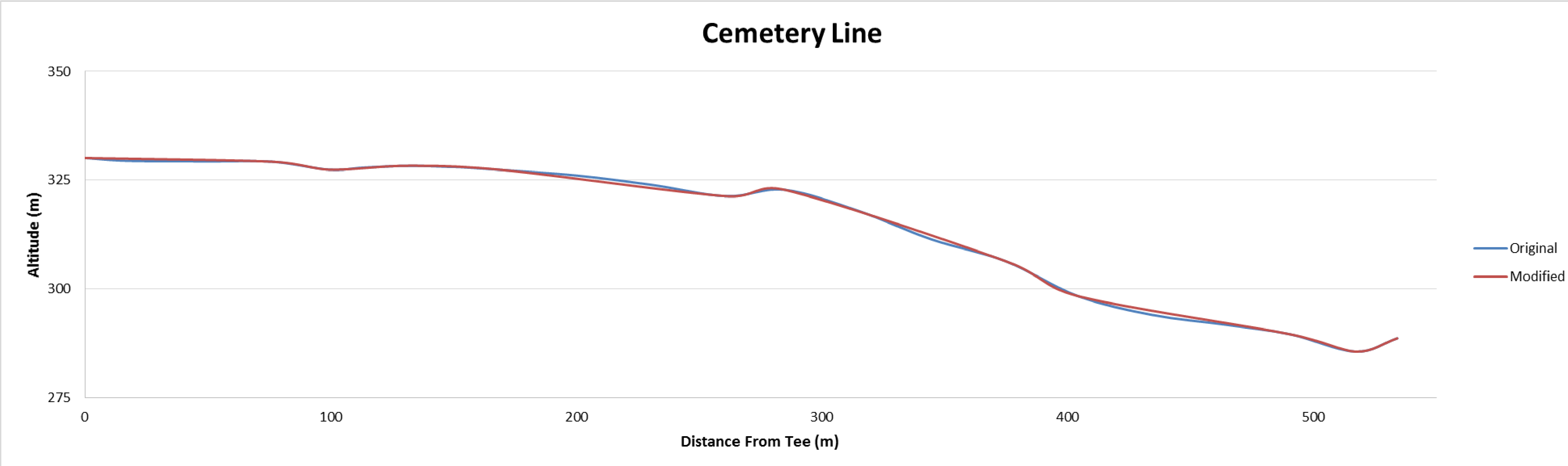


Figure 19: Original survey data, cemetery service line

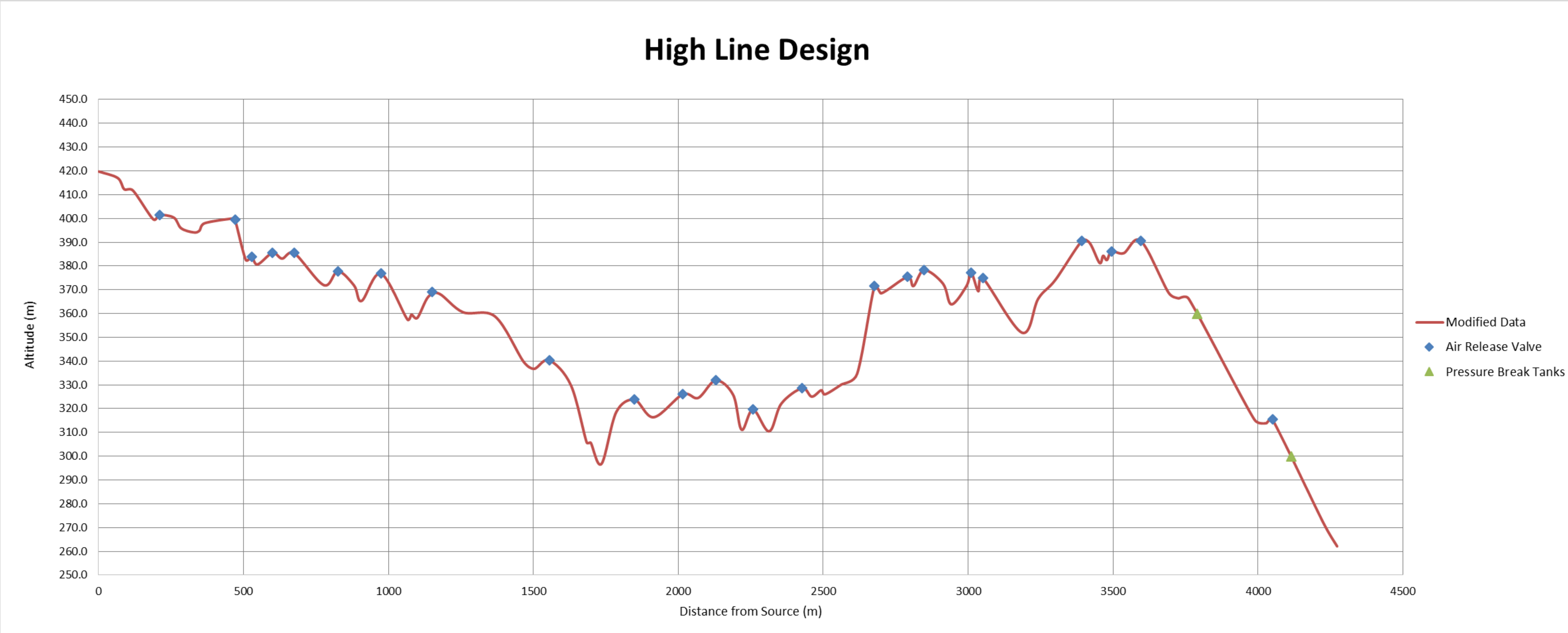


Figure 20: Elevation profile for high line with air release valves and break pressure tanks noted

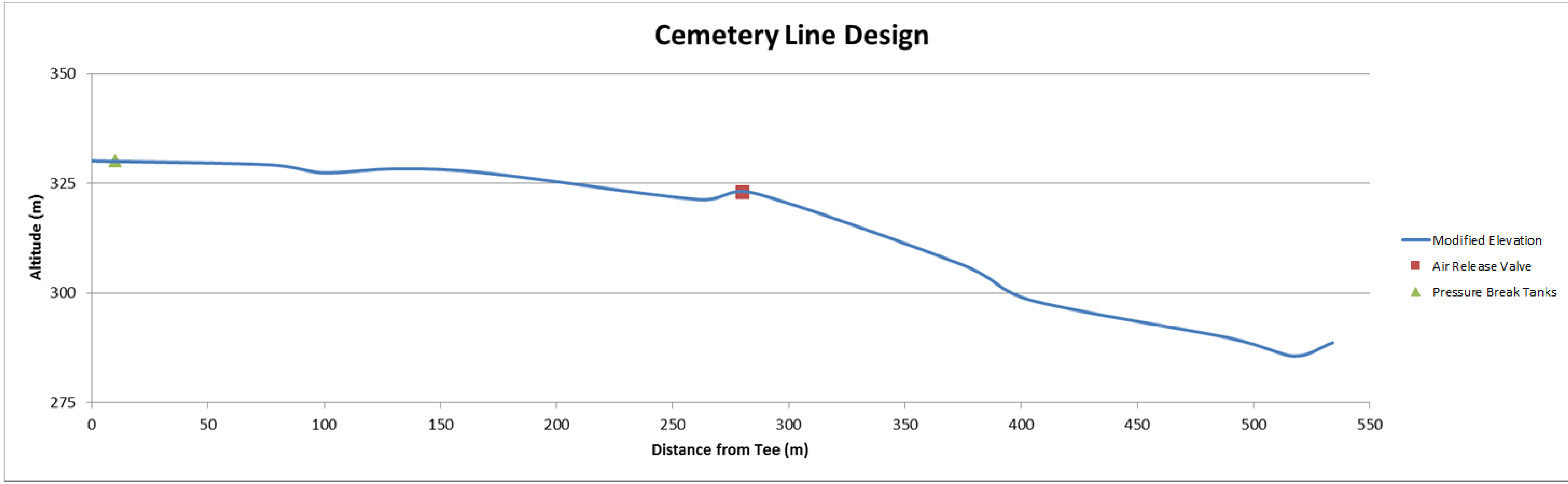


Figure 21: Elevation profile for cemetery line with air release valves and break pressure tanks noted

Appendix B: Plan Drawings

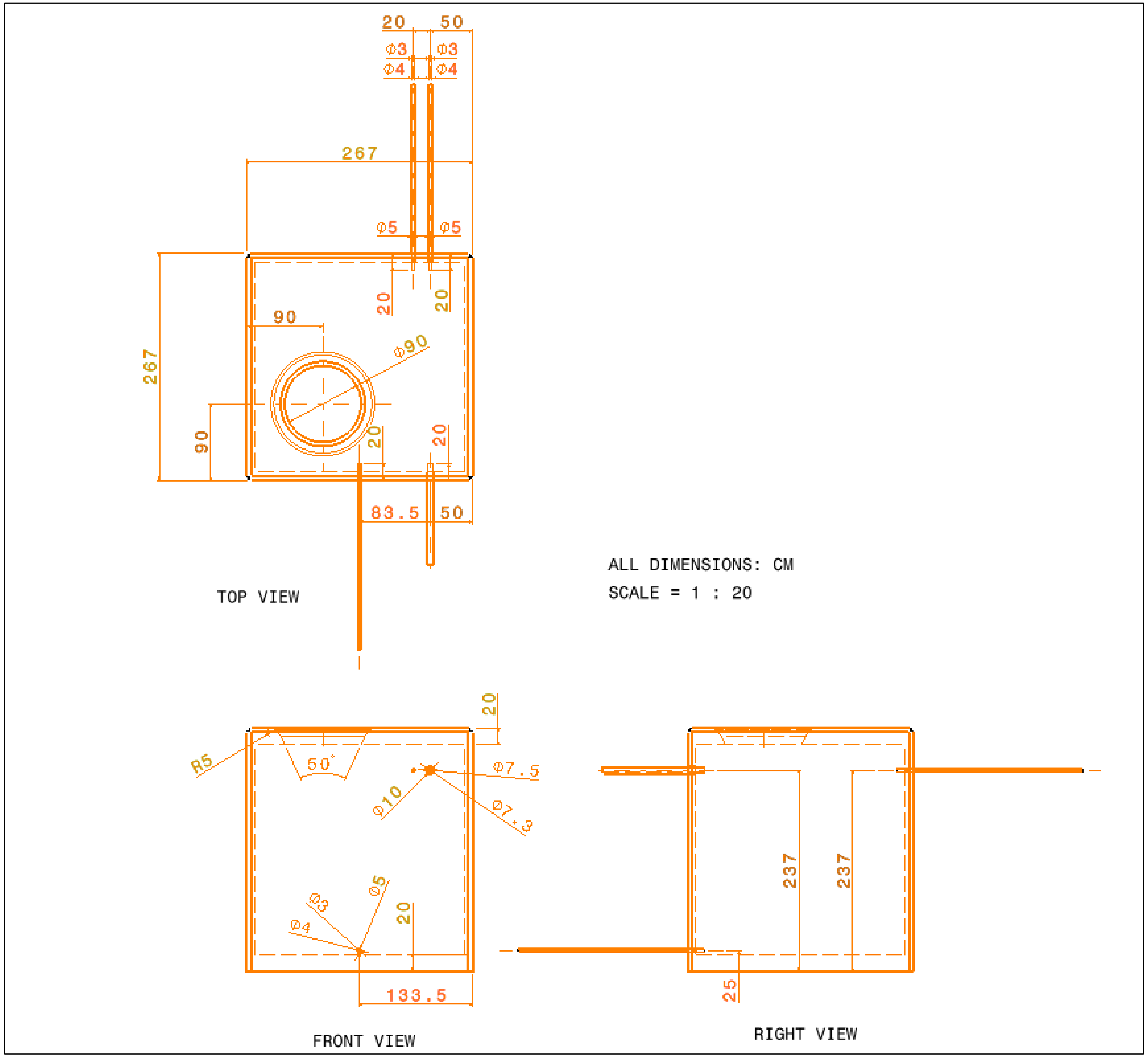


Figure 22: Plans for storage tank

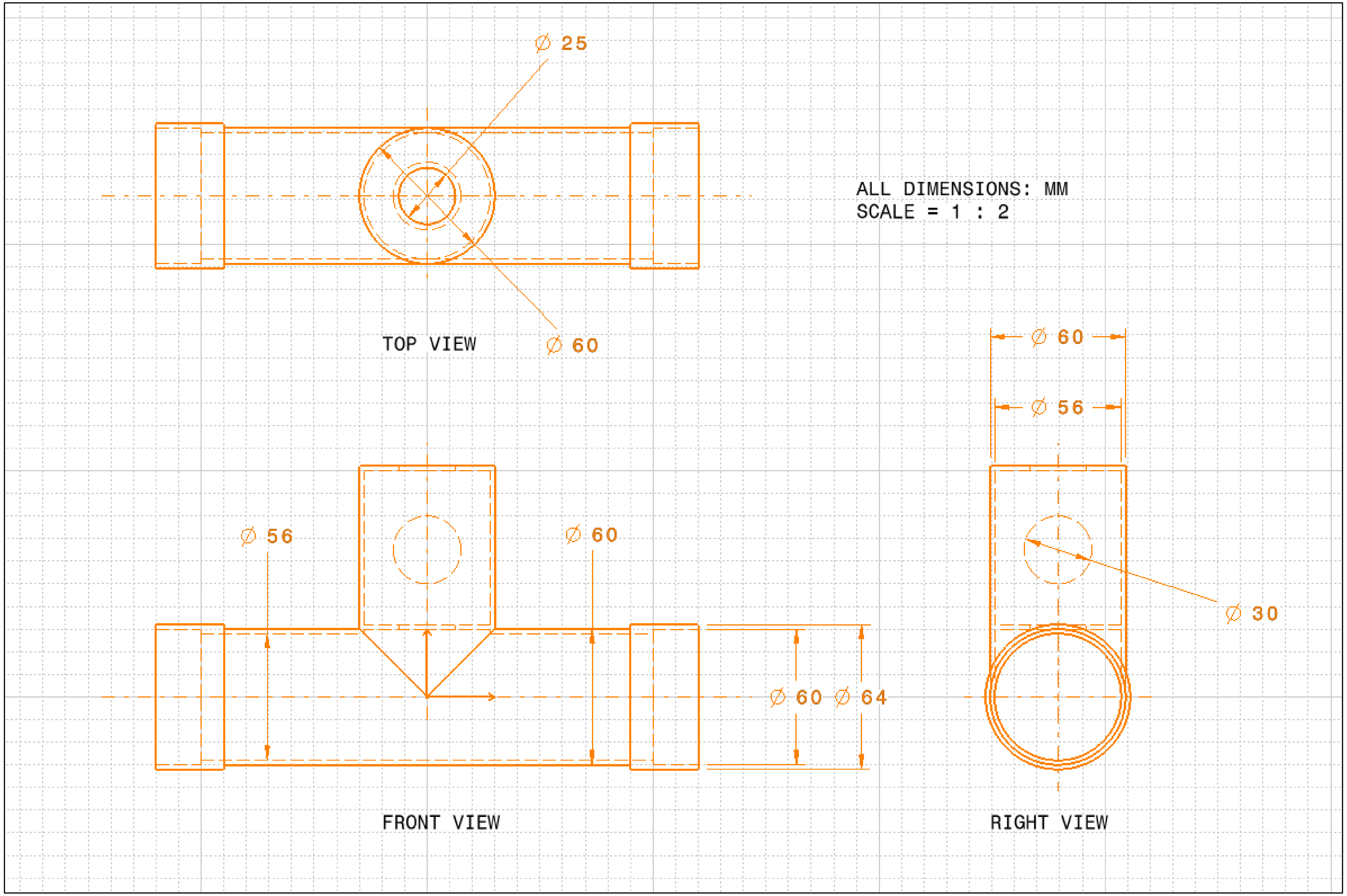


Figure 23: Plans for air release valve

Appendix C: Route Maps

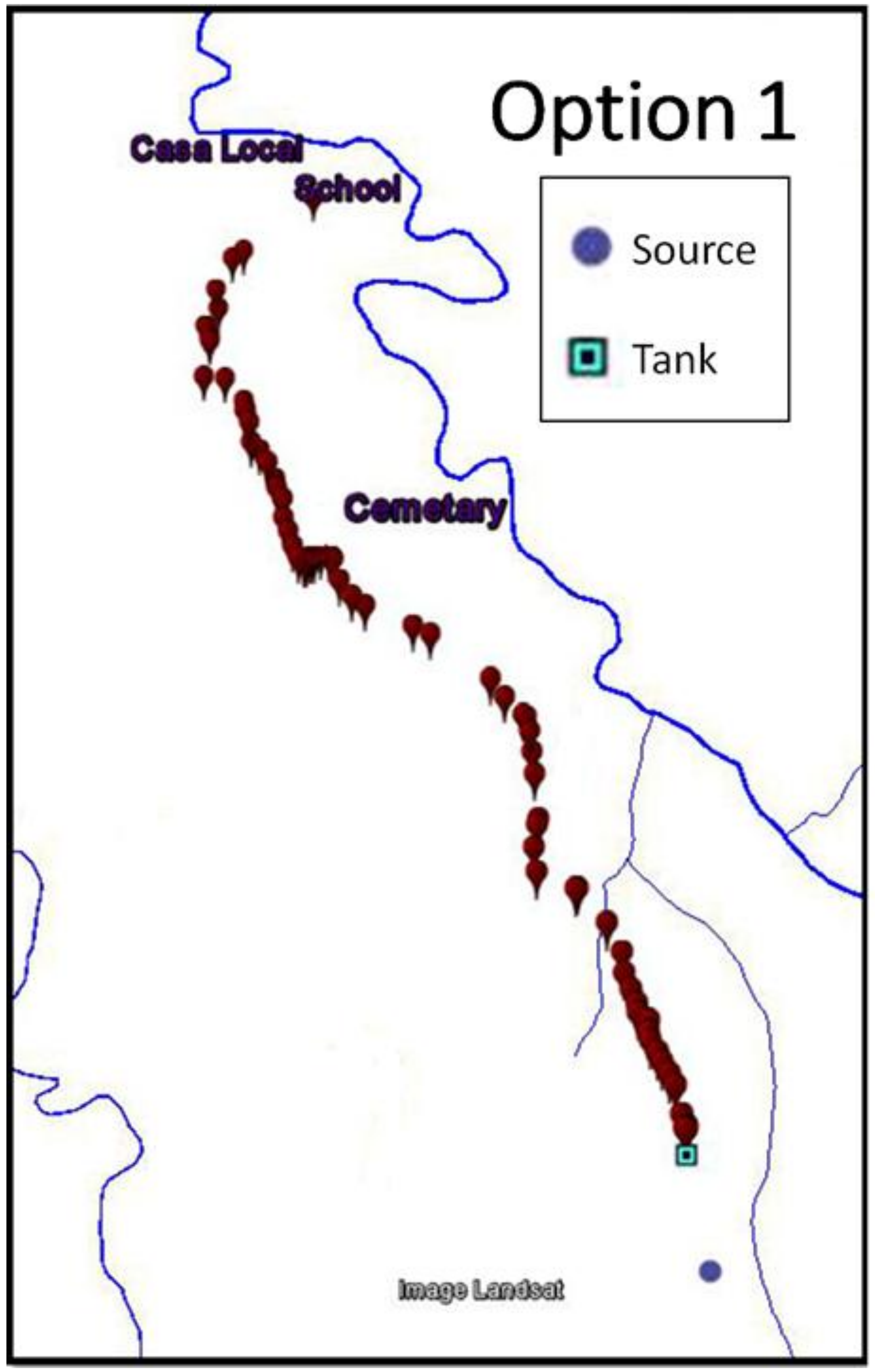


Figure 24: Map of option 1

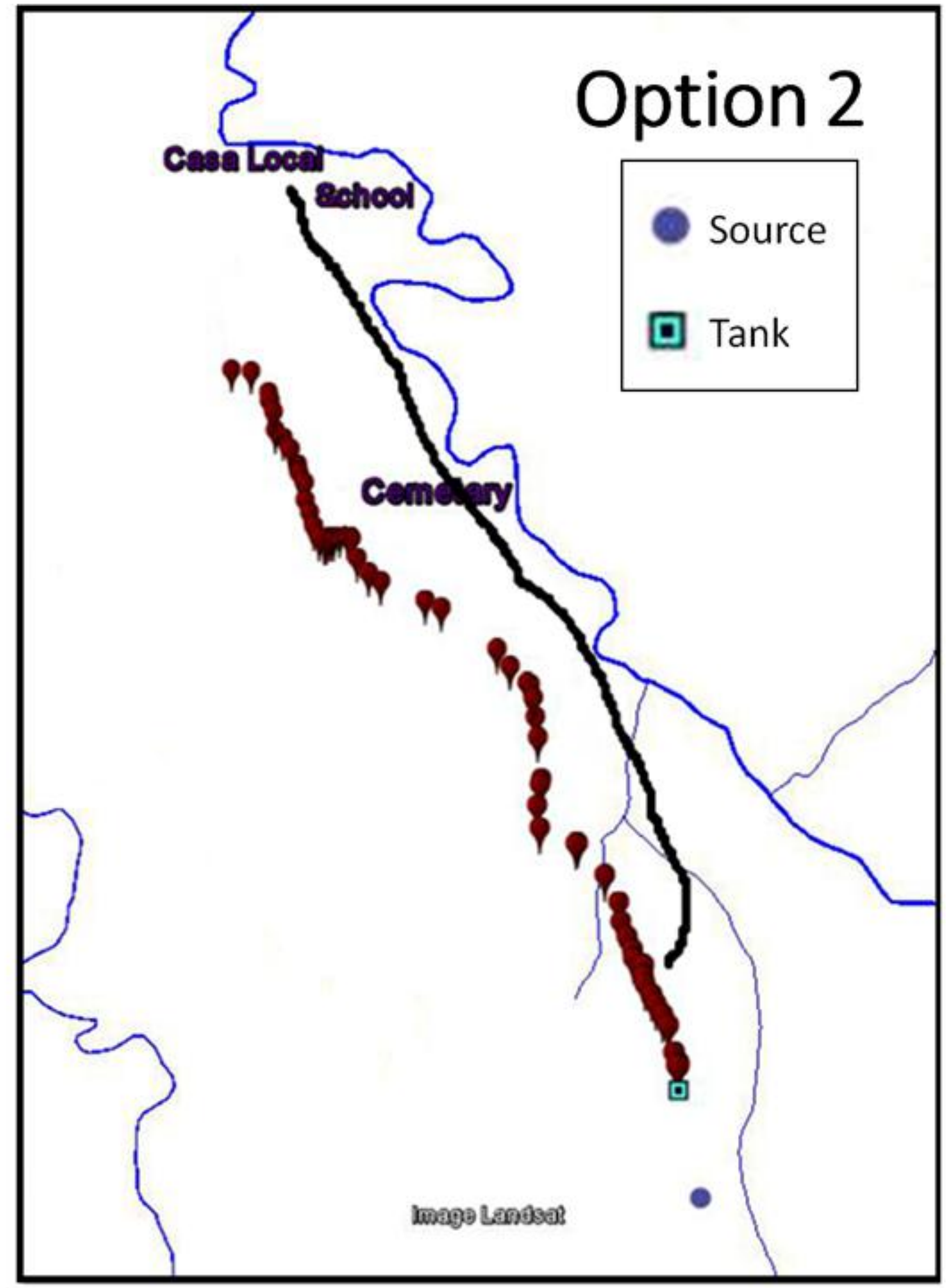


Figure 25: Map of option 2

Appendix D: Tank Calculations

Supply and Demand

of households served by proposed aqueduct (including proposed houses) = 50 households

Average persons per household = 6 persons

$$Total\ persons\ served = 50\ households\ x\ \frac{6\ persons}{household} = 300\ persons$$

Recommended rate of water consumption (MINSA) = 30 gal/person/day

$$Total\ daily\ residential\ demand = \frac{30\frac{gal}{person}}{day}\ x\ 300\ persons = 9000\ gal/day$$

$$Total\ daily\ school\ demand = 120\ persons\ x\ 5\ gal/person = 600\ gal/day$$

$$Total\ daily\ community\ demand = 9000\ gal/day + 600\ gal/day = 9600\ gal/day$$

Total dry season daily supply of source:

$$Q = 0.57\frac{L}{s}\ x\ 86{,}400\frac{s}{day}\ x\ \frac{1}{3.785}\frac{L}{gal} = 13{,}011\frac{gal}{day}$$

$$Total\ potential\ people\ served\ by\ Source\ 1 = 13{,}011\frac{gal}{day}\ x\ \frac{day}{30\frac{gal}{person}} = 433\ persons$$

Appendix E: Supplemental Chlorine Test Sheets & Instructions

Due to the lack of reliable information regarding the level of chlorine coming from the chlorinator into the storage tank and then through the rest of the water line, CDAC believes the best alternative is community involvement. If the community chooses to invest in the testing devices, CDAC developed personalized chlorine testing sheets. The community can designate test locations that best suit their interests by changing the text listed in the tables below. A test sheet for the storage tank and a sample location sheet are presented below.

Testing the water as it is leaving the storage tank will allow the community to set a baseline standard that best meets the recommended target standard of approximately 0.2 ppm for the remainder of the system. The community should continue to test the water until they meet a consensus based on personal and safety standards. The committee members can take water samples at tap stand locations and use a color wheel or colorimeter to test the concentration of chlorine. The committee can also test the water at locations where air release valves are located, for easy access to the system. Lastly, the community can note any strong odors in the water and record if the water tastes too strongly of chlorine. Based on results, the community can modify their chlorine output or invest in a second in-line chlorination system if the levels prove to be insufficient.

Table 8: Storage tank chlorine test sheet

Chlorine Concentrations: Water Leaving Storage Tank				
Date	**Test Conductor**	**Chlorine Test Results**	**Tablets**	**Notes**
mm/dd/yyyy	Name	Chlorine Concentration (ppm)	# of Tablets	Taste & Odor

Table 9: Site location test sheet 1

Test 1. Chlorine Concentrations: Along Water Line: Tap # 1				
Date	**Test Conductor**	**Test Site Location**	**Meets Standard?**	**Notes**
mm/dd/yyyy	Name	Chlorine Concentration (ppm)	Yes/No **|** 0.2-0.4 ppm	Taste & Odor

Option 1

	Task Name	Duration	Start	Finish	Predecessors
1	**Procure materials**	**14 days**	**Thu 1/2/14**	**Tue 1/21/14**	
2	**Construct break pressure tanks**	**24 days**	**Mon 1/20/14**	**Thu 2/20/14**	
3	Excavate, sand base, level	6 days	Mon 1/20/14	Mon 1/27/14	
4	Forming and rebar for concrete floor	6 days	Tue 1/28/14	Tue 2/4/14	3
5	Mixing and pouring concrete floor	6 days	Wed 2/5/14	Wed 2/12/14	4
6	Masonry and roof	6 days	Thu 2/13/14	Thu 2/20/14	5
7	**Chlorinator**	**47 days**	**Thu 1/2/14**	**Fri 3/7/14**	
8	Construct	2 days	Wed 1/22/14	Thu 1/23/14	1
9	Install	2 days	Thu 3/6/14	Fri 3/7/14	8
10	**Air release valves**	**101 days**	**Fri 1/24/14**	**Fri 6/13/14**	
11	Construct	10 days	Fri 1/24/14	Thu 2/6/14	8
12	Install	81 days	Fri 2/21/14	Fri 6/13/14	11
13	**Construct conduction line, high line, cemetery service line**	**81 days**	**Fri 2/21/14**	**Fri 6/13/14**	6
14	Excavate trench	81 days	Fri 2/21/14	Fri 6/13/14	
15	Lay pipe	81 days	Fri 2/21/14	Fri 6/13/14	
16	Backfill trench	81 days	Fri 2/21/14	Fri 6/13/14	
17	**Construct service lines**	**56 days**	**Tue 5/13/14**	**Tue 7/29/14**	
18	Excavate trench	56 days	Tue 5/13/14	Tue 7/29/14	
19	Lay pipe	56 days	Tue 5/13/14	Tue 7/29/14	
20	Backfill trench	56 days	Tue 5/13/14	Tue 7/29/14	
21	**Tapstands**	**49 days**	**Thu 5/22/14**	**Tue 7/29/14**	

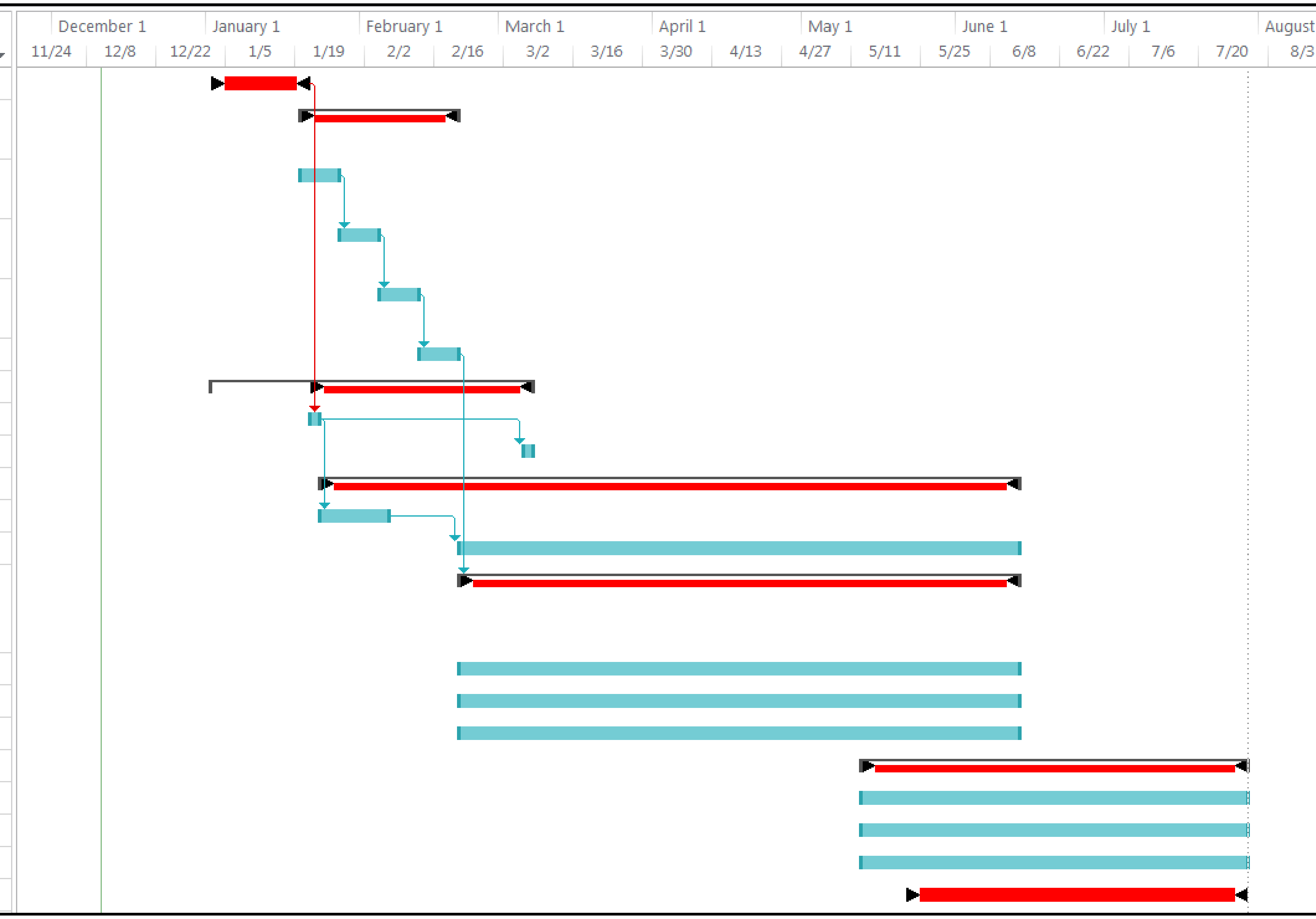


Figure 26: Option 1 construction schedule

Option 2

	Task Name	Duration	Start	Finish	Predecessors
1	**Procure materials**	14 days	Thu 1/2/14	Tue 1/21/14	
2	**Construct break pressure tanks**	**8 days**	**Mon 1/20/14**	**Wed 1/29/14**	
3	Excavate, sand base, level	2 days	Mon 1/20/14	Tue 1/21/14	
4	Forming and rebar for concrete floor	2 days	Wed 1/22/14	Thu 1/23/14	3
5	Mixing and pouring concrete floor	2 days	Fri 1/24/14	Mon 1/27/14	4
6	Masonry and roof	2 days	Tue 1/28/14	Wed 1/29/14	5
7	**Chlorinator**	**47 days**	**Wed 1/22/14**	**Thu 3/27/14**	
8	Construct	2 days	Wed 1/22/14	Thu 1/23/14	1
9	Install	2 days	Thu 3/6/14	Fri 3/7/14	8
10	**Air release valves**	**152 days**	**Fri 1/24/14**	**Mon 8/25/14**	
11	Construct	10 days	Fri 1/24/14	Thu 2/6/14	8
12	Install	132 days	Fri 2/21/14	Mon 8/25/14	11
13	**Construct conduction line, high line, cemetery service line**	**132 days**	**Fri 2/21/14**	**Mon 8/25/14**	6
14	Excavate trench	132 days	Fri 2/21/14	Mon 8/25/14	
15	Lay pipe	132 days	Fri 2/21/14	Mon 8/25/14	
16	Backfill trench	132 days	Fri 2/21/14	Mon 8/25/14	
17	**Construct service lines**	**56 days**	**Fri 7/25/14**	**Fri 10/10/14**	
18	Excavate trench	56 days	Fri 7/25/14	Fri 10/10/14	
19	Lay pipe	56 days	Fri 7/25/14	Fri 10/10/14	
20	Backfill trench	56 days	Fri 7/25/14	Fri 10/10/14	
21	**Tapstands**	49 days	Tue 8/5/14	Fri 10/10/14	

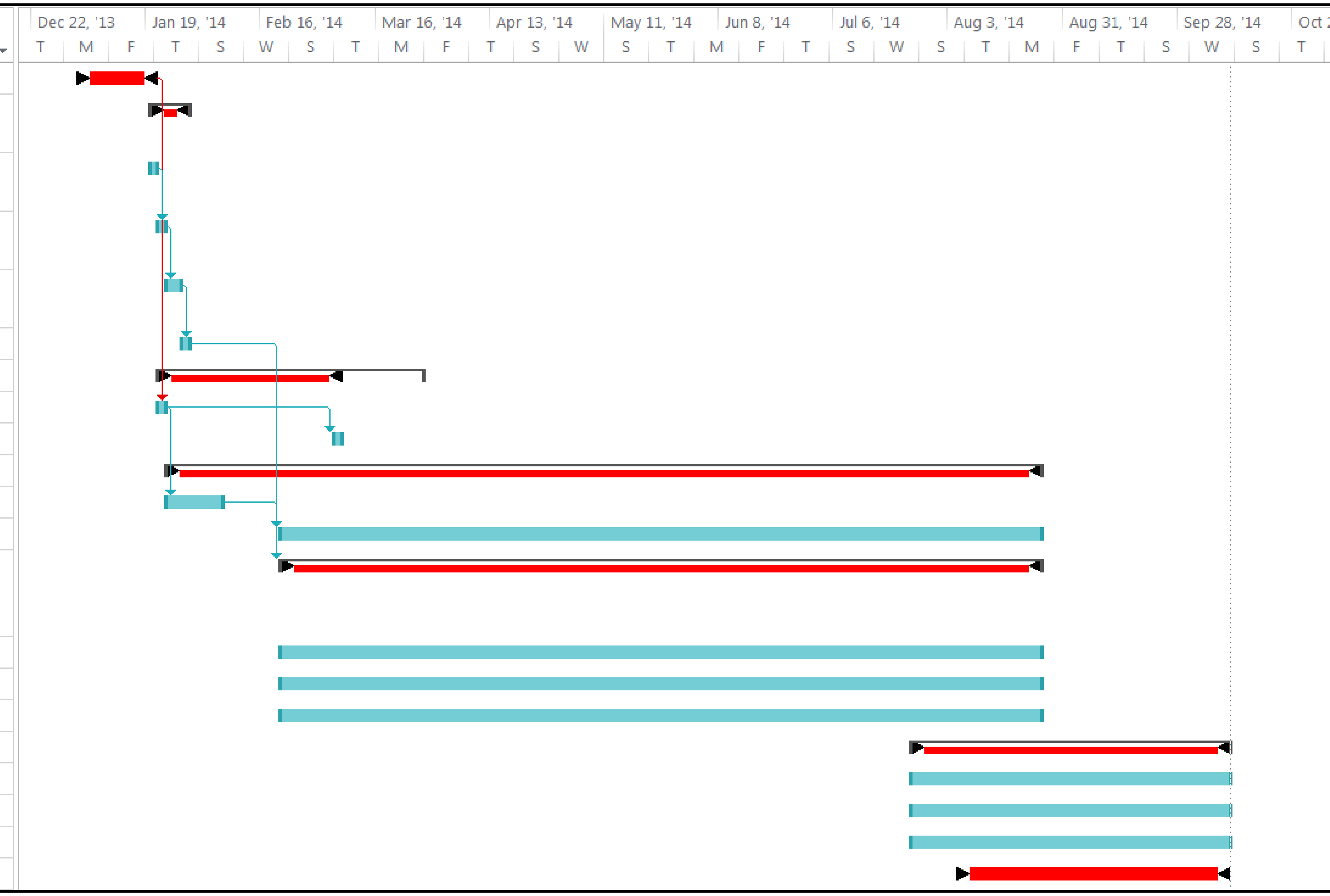


Figure 27: Option 2 construction schedule

Appendix G: Construction Schedule Details

Option 1

- **Procure Materials:** In La Chorrera, would presumably take several trips there and back by the Peace Corps volunteer and several community members, and using hired transportation ($$$)

- **Construct break pressure tanks:** all 3 tanks

    Excavate, sand base, level: 2 days per tank, 2 men per day per tank. Need to haul sand ($$$) up steep grades to tank locations. Shovels ($$$)

    Forming and rebar for floor: 2 days per tank, 2 men per day per tank. Need to haul wood and bars up steep grades to tank locations. Nails, hammers, pliers, wood, rebar, and rebar ties ($$$)

    Mixing and pouring, concrete floor: 2 days per tank, 2 men per day per tank. Need to haul cement, fine/coarse aggregate, water up steep grades to tank locations. Shovels, cement, aggregate ($$$)

    Masonry and roof: 2 days per tank, 2 men per day per tank. Need to haul bricks, corrugated sheet metal, cement, sand, water (for mortar) up steep grades to tank locations. Shovels, cement, sand, bricks, corrugated sheet metal ($$$)

- **Chlorinator**

    Construct: Can be done by 1 or 2 men, 2 days, at casa local. Pipe, connections, primer, glue ($$$)

    Install: 2 men, 2 days, need to haul chlorinator up steep grades to location near tank.

- **Air release Valves**

    Construct: Can be done by 2 or 3 men, 10 days, at casa local. Pipe, connections, primer, glue ($$$)

    Install: (during pipe laying of main lines, = 81 days as below)

- **Construct conduction line, high line, and cemetery service line (4807 m for these lines)**

    Excavate trench: Assuming 15 min/meter trench, 5 men per day, 3 hours per day = 12 m/man/day = 60 m/day = 81 days. Pickaxes and trench shovels ($$$)

    Lay pipe: Placing pipe and gluing connections. Assuming 5 men per day, 3 hours per day. = 81 days as above. Need to haul pipe and connections up steep grades. Pipe, connections, primer, glue ($$$)

Backfill trench: Pour dirt back on top of placed pipe. Assuming 5 men per day, 3 hours per day. = 81 days as above. Shovels ($$$)

- **Construct service lines (4000 m estimate)**

  Excavate trench: Assuming 10 min/meter trench, 3 men per day, 4 hours per day = 56 days. Pickaxes and trench shovels ($$$)

  Lay pipe: Placing pipe and gluing connections. Assuming 3 men per day, 4 hours per day. = 56 days as above. Need to haul pipe and connections up steep grades. Pipe, connections, primer, glue ($$$)

  Backfill trench: Pour dirt back on top of placed pipe. Assuming 3 men per day, 4 hours per day. = 56 days as above. Shovels ($$$)

- **Tapstands**

  Construct: Assuming 2 men per tapstand, 59 taps, 1 hour per tap (includes travel time to each tap – households are far-flung). = 49 of the 56 days above. Need to haul materials to far-flung houses. Pipe,
  connections, spigots, primer, glue ($$$)

Some updates/other notes from Val from the cost estimate: 1 connector every 5 m; 1 elbow every 100 m; other service lines = 4000 m now; tee to existing systems/town center for Option 2 = 3000 m

Option 2

- **Procure Materials:** In La Chorrera, would presumably take several trips there and back by the Peace Corps volunteer and several community members, and using hired transportation ($$$)

- **Construct break pressure tanks:** only the tank before the chlorinator

  Excavate, sand base, level: 2 days, 2 men per day. Need to haul sand ($$$) up steep grades to tank locations. Shovels ($$$)

  Forming and rebar for floor: 2 days, 2 men per day. Need to haul wood and bars up steep grades to tank locations. Nails, hammers, pliers, wood, rebar, and rebar ties ($$$)

  Mixing and pouring, concrete floor: 2 days, 2 men per day. Need to haul cement, fine/coarse aggregate, water up steep grades to tank locations. Shovels, cement, aggregate ($$$)

  Masonry and roof: 2 days, 2 men per day. Need to haul bricks, corrugated sheet metal, cement, sand, water (for mortar) up steep grades to tank locations. Shovels, cement, sand, bricks, corrugated sheet metal ($$$)

- **Chlorinator**

  Construct: Can be done by 1 or 2 men, 2 days, at casa local. Pipe, connections, primer, glue ($$$)

  Install: 2 men, 2 days, need to haul chlorinator up steep grades to location near tank.

- **Air release Valves**

  Construct: Can be done by 2 or 3 men, 10 days, at casa local. Pipe, connections, primer, glue ($$$)

  Install: (during pipe laying of main lines, = 132 days as below)

- **Construct conduction line, high line to connection to existing system, rest of high line, cemetery service line, and tee to existing systems/town center (7898 m for these lines)**

  Excavate trench: Assuming 15 min/meter trench, 5 men per day, 3 hours per day = 12 m/man/day = 60 m/day = 132 days. Pickaxes and trench shovels ($$$)

  Lay pipe: Placing pipe and gluing connections. Assuming 5 men per day, 3 hours per day. = 132 days as above. Need to haul pipe and connections up steep grades. Pipe, connections, primer, glue ($$$)

  Backfill trench: Pour dirt back on top of placed pipe. Assuming 5 men per day, 3 hours per day. = 132 days as above. Shovels ($$$)

- **Construct service lines (4000 m estimate)**

  Excavate trench: Assuming 10 min/meter trench, 3 men per day, 4 hours per day = 56 days. Pickaxes and trench shovels ($$$)

  Lay pipe: Placing pipe and gluing connections. Assuming 3 men per day, 4 hours per day. = 56 days as above. Need to haul pipe and connections up steep grades. Pipe, connections, primer, glue ($$$)

  Backfill trench: Pour dirt back on top of placed pipe. Assuming 3 men per day, 4 hours per day. = 56 days as above. Shovels ($$$)

- **Tapstands**

  Construct: Assuming 2 men per tapstand, 59 taps, 1 hour per tap (includes travel time to each tap tap – households are far-flung). = 49 of the 56 days above. Need to haul materials to far-flung houses. Pipe,
  connections, spigots, primer, glue ($$$)

Appendix H: Cost Estimate Tables

Below are summary tables for a more complete cost estimate analysis.

Table 10: Option 1 Cost Estimate Tables

Design Component	Cost/Unit	Quantity	Estimated Cost ($)
Main Line			
2-inch diameter PVC pipe SDR 26	$1.08/m pipe	6299	6803
2-inch diameter, 45 degree elbow PVC	$0.89/elbow	68	61
3-inch diameter PVC pipe SDR 26	$2.42/m pipe	602	1457
3-inch diameter, 45 degree elbow PVC	$1.60/elbow	6	10
3-inch diameter PVC connector	$2.15/connect	120	258
2 -inch diameter PVC connector	$0.54/connect	1362	735
		Subtotal ($)	9324

Design Component	Cost/Unit	Quantity	Estimated Cost ($)
Service Line (Cemetery)			
0.5-inch diameter PVC pipe SDR 13.5	$0.38/m pipe	534	203
0.5-inch diameter, 45 degree elbow	$0.19/elbow	5	1
Reducing PVC (2 in - 0.5 in diameter)	$0.82/reducer	1	1
0.5" diameter PVC connector	$0.10/connect	107	11
2-inch diameter Tee (PVC)	$1.45/tee	1	2.0
		Subtotal ($)	218

Design Component	Cost/Unit	Quantity	Estimated Cost ($)
Conduction Line			
1.5-inch diameter, PVC pipe SDR 26	$0.92/m pipe	463	426
1.5 inch diameter, 45 degree elbow	$0.38/elbow	4	2
1.5 inch diameter PVC connector	$0.45/connect	93	42
		Subtotal ($)	469

Design Component	Cost/Unit	Quantity	Estimated Cost ($)
Chlorination System (CTI 8 Model)			
4-inch PVC Tee	$7.70/tee	1	8
9-cm PVC couplings	$3.15/coupling	2	6
4" diameter PVC riser section pipe	$6.33/m pipe	0.5	3
4" diameter PVC cap	$2.80/cap	1	3
3" diameter PVC pipe section	$2.42/m pipe	0.5	1
1.5" diameter PVC SDR 26 pipe	$0.92/m pipe	2	2
1.5" PVC Ball Valves	$6.63/valve	2	13
1.5" diameter , 90 degree elbow	$0.85/elbow	2	2
PVC Glue	$9.15/can	1	9
Sheet metal scews #4 0.5", stainless steel	$0.034/screw	11	0
Reducing PVC (2"-1.5" diameter)	$0.60/reducer	2	1
Reducing PVC (4"-2" diameter)	$3.00/reducer	2	6
		Subtotal ($)	55

Design Component	Cost/Unit	Quantity	Estimated Cost ($)
Tapstand			
0.5" diameter, 90 degree elbow	$0.49/elbow	118	58
0.5" diameter PVC SDR 13.5 pipe	$0.38/m pipe	88.5	34
0.5" diameter PVC spigot	$1.25/spigot	59	74
0.5" diameter PVC connector	$0.10/connect	59	6
		Subtotal ($)	171

Design Component	Cost/Unit	Quantity	Estimated Cost ($)
Air Release Valves			
2" PVC Tee	$1.45/tee	21	30
2" PVC couplings	$0.54/coupling	42	23
Ping Pong Ball	$0.47/ball	21	10
1/4" Sheet PVC (144 square inches)	$7.90/sheet	6	47
		Subtotal ($)	110

Design Component	Cost/Unit	Quantity	Estimated Cost ($)
Break Pressure Tanks			
General Use Cement	$9.15/bag	4	37
2" screws	$0.10/screw	35	4
3/8" diameter, 30 feet in length rebar	$4.47/30ft bar	1	4
Hammer	$5.95/hammer	2	12
Corrugated Sheet Metal (42"x6ft)	$10.74/sheet	1	11
		Subtotal ($)	67

Design Component	Cost/Unit	Quantity	Estimated Cost ($)
Miscellaneous			
Shovels	$6.99/shovel	5	35
Hacksaw	$4.75/saw	2	10
Pickaxe	$18.97/axe	8	152
Drill bits (3/32")	$1.97/bit	1	2
Drill bits (3/8")	$2.47/bit	1	2
Cordless drill	$59.97/drill	1	60
Coping saw	$7.48/saw	2	15
Sandpaper (coarse)	$3.97/150slips	1	4
0.5" diameter PVC pipe 13.5	$0.38/m pipe	4000	1520
0.5" diameter, 45 degree elbow	$0.19/elbow	40	8
0.5" PVC connector	$0.10/connect	800	80
		Subtotal ($)	1887

Table 11: Option 2 Cost Estimate Tables

Design Component	Cost/Unit	Quantity	Estimated Cost ($)
Main Line			
2-inch diameter PVC pipe SDR 26	$1.08/m pipe	6299	6803
2-inch diameter, 45 degree elbow PVC	$0.89/elbow	68	61
3-inch diameter PVC pipe SDR 26	$2.42/m pipe	602	1457
3-inch diameter, 45 degree elbow PVC	$1.60/elbow	6	10
3-inch diameter PVC connector	$2.15/connect	120	258
2 -inch diameter PVC connector	$0.54/connect	1362	735
		Subtotal ($)	9324

Design Component	Cost/Unit	Quantity	Estimated Cost ($)
Service Line (Cemetery)			
0.5-inch diameter PVC pipe SDR 13.5	$0.38/m pipe	534	203
0.5-inch diameter, 45 degree elbow	$0.19/elbow	5	1
Reducing PVC (2 in - 0.5 in diameter)	$0.82/reducer	1	1
0.5" diameter PVC connector	$0.10/connect	107	11
2-inch diameter Tee (PVC)	$1.45/tee	1	2.0
		Subtotal ($)	218

Design Component	Cost/Unit	Quantity	Estimated Cost ($)
Chlorination System (CTI 8 Model)			
4-inch PVC Tee	$7.70/tee	1	8
9-cm PVC couplings	$3.15/coupling	2	6
4" diameter PVC riser section pipe	$6.33/m pipe	0.5	3
4" diameter PVC cap	$2.80/cap	1	3
3" diameter PVC pipe section	$2.42/m pipe	0.5	1
1.5" diameter PVC SDR 26 pipe	$0.92/m pipe	2	2
1.5" PVC Ball Valves	$6.63/valve	2	13
1.5" diameter , 90 degree elbow	$0.85/elbow	2	2
PVC Glue	$9.15/can	1	9
Sheet metal scews #4 0.5", stainless steel	$0.034/screw	11	0
Reducing PVC (2"-1.5" diameter)	$0.60/reducer	2	1
Reducing PVC (4"-2" diameter)	$3.00/reducer	2	6
		Subtotal ($)	55

Design Component	Cost/Unit	Quantity	Estimated Cost ($)
Conduction Line			
1.5-inch diameter, PVC pipe SDR 26	$0.92/m pipe	463	426
1.5 inch diameter, 45 degree elbow	$0.38/elbow	4	2
1.5 inch diameter PVC connector	$0.45/connect	93	42
		Subtotal ($)	469

Design Component	Cost/Unit	Quantity	Estimated Cost ($)
Tapstand			
0.5" diameter, 90 degree elbow	$0.49/elbow	118	58
0.5" diameter PVC SDR 13.5 pipe	$0.38/m pipe	88.5	34
0.5" diameter PVC spigot	$1.25/spigot	59	74
0.5" diameter PVC connector	$0.10/connect	59	6
		Subtotal ($)	171

Design Component	Cost/Unit	Quantity	Estimated Cost ($)
Air Release Valves			
2" PVC Tee	$1.45/tee	21	30
2" PVC couplings	$0.54/coupling	42	23
Ping Pong Ball	$0.47/ball	21	10
1/4" Sheet PVC (144 square inches)	$7.90/sheet	6	47
		Subtotal ($)	110

Design Component	Cost/Unit	Quantity	Estimated Cost ($)
Break Pressure Tanks			
General Use Cement	$9.15/bag	4	37
2" screws	$0.10/screw	35	4
3/8" diameter, 30 feet in length rebar	$4.47/30ft bar	1	4
Hammer	$5.95/hammer	2	12
Corrugated Sheet Metal (42"x6ft)	$10.74/sheet	1	11
		Subtotal ($)	67

Design Component	Cost/Unit	Quantity	Estimated Cost ($)
Miscellaneous			
Shovels	$6.99/shovel	5	35
Hacksaw	$4.75/saw	2	10
Pickaxe	$18.97/axe	8	152
Drill bits (3/32")	$1.97/bit	1	2
Drill bits (3/8")	$2.47/bit	1	2
Cordless drill	$59.97/drill	1	60
Coping saw	$7.48/saw	2	15
Sandpaper (coarse)	$3.97/150slips	1	4
0.5" diameter PVC pipe 13.5	$0.38/m pipe	4000	1520
0.5" diameter, 45 degree elbow	$0.19/elbow	40	8
0.5" PVC connector	$0.10/connect	800	80
		Subtotal ($)	1887

Appendix I: Survey Data

Table 12: Original highline survey data

Pt. ID	Dist (m)	BM (cm)	Recorded Elev. (cm)	Elev. Change (m)	Dist Cumulative (m)	Altitude (m)	Comments
	0				0.0	400.0	
0	7.16	87.9	131.6	-43.7	7.2	399.6	starting at tank, ranch land
1	1.83	80	147.4	-67.4	9.0	398.9	
2	2.06	61.8	144.5	-82.7	11.0	398.1	
3	1.75	61.8	142	-80.2	12.8	397.3	
4	1.65	61.8	146.2	-84.4	14.5	396.4	
5	1.85	61.8	149.5	-87.7	16.3	395.5	
6	1.73	61.8	137.7	-75.9	18.0	394.8	
7	2.06	61.8	144.3	-82.5	20.1	394.0	
8	1.68	61.8	145.3	-83.5	21.8	393.1	
9	1.55	61.8	146.8	-85	23.3	392.3	
10	1.70	61.8	147.9	-86.1	25.0	391.4	
11	1.91	61.8	143.8	-82	26.9	390.6	
12	1.85	61.8	149.5	-87.7	28.8	389.7	
13	1.55	61.8	144.8	-83	30.3	388.9	
14	2.77	55.88	204.47	-148.59	33.1	387.4	
15	3.43	55.88	222.25	-166.37	36.5	385.7	
16	3.40	55.88	213.995	-158.115	39.9	384.2	
17	4.22	55.88	210.82	-154.94	44.1	382.6	
18	6.99	55.88	120.65	64.77	51.1	383.2	
19	7.04	55.88	99.06	43.18	58.2	383.7	
20	6.43	55.88	73.66	17.78	64.6	383.9	
21	7.01	55.88	181.61	-125.73	71.6	382.6	
22	6.35	55.88	212.09	-156.21	78.0	381.0	
23	6.83	55.88	95.25	-39.37	84.8	380.6	
24	6.60	55.88	135.89	80.01	91.4	381.4	
25	7.01	55.88	107.95	52.07	98.4	382.0	
26	4.42	54.61	185.42	130.81	102.8	383.3	
27	6.63	54.61	151.13	96.52	109.4	384.2	
28	6.55	54.61	73.66	19.05	116.0	384.4	
29	6.96	54.61	71.12	16.51	123.0	384.6	
30	6.93	54.61	137.16	82.55	129.9	385.4	
31	6.55	54.61	62.23	7.62	136.4	385.5	
32	5.87	54.61	147.32	-92.71	142.3	384.6	

Pt. ID	Dist (m)	BM (cm)	Recorded Elev. (cm)	Elev. Change (m)	Dist Cumulative (m)	Altitude (m)	Comments
33	7.01	54.61	138.43	-83.82	149.3	383.7	crossing fence
34	6.93	54.61	78.74	-24.13	156.3	383.5	
35	6.68	54.61	114.3	59.69	162.9	384.1	
36	7.16	54.61	153.67	-99.06	170.1	383.1	
37	6.91	54.61	113.03	58.42	177.0	383.7	
38	6.91	54.61	187.96	133.35	183.9	385.0	
39	6.73	54.61	44.45	-10.16	190.7	384.9	
40	6.78	54.61	133.35	-78.74	197.4	384.1	
41	6.78	54.61	90.17	35.56	204.2	384.5	enter brushy area
42	7.11	54.61	148.59	93.98	211.3	385.4	
43	6.73	54.61	130.81	-76.2	218.1	384.7	
44	6.93	54.61	143.51	-88.9	225.0	383.8	
45	6.88	54.61	157.48	-102.87	231.9	382.7	
46	6.96	54.61	142.24	-87.63	238.8	381.9	
47	7.06	54.61	111.76	-57.15	245.9	381.3	
48	6.99	54.61	198.12	-143.51	252.9	379.9	
49	6.91	54.61	189.23	-134.62	259.8	378.5	
50	5.18	54.61	215.9	-161.29	265.0	376.9	
51	7.01	54.61	175.26	-120.65	272.0	375.7	
52	6.71	54.61	154.94	-100.33	278.7	374.7	
53	6.93	54.61	144.78	-90.17	285.6	373.8	
54	6.86	54.61	110.49	-55.88	292.5	373.2	
55	6.78	54.61	107.95	-53.34	299.3	372.7	
56	7.01	54.61	121.92	-67.31	306.3	372.0	at fence, francesco sanchez land
57	7.01	54.61	60.96	-6.35	313.3	372.0	
58	6.76	54.61	44.45	10.16	320.0	372.1	
59	6.91	54.61	92.71	38.1	326.9	372.4	
60	4.62	54.61	92.71	38.1	331.6	372.8	
61	5.94	54.61	190.5	135.89	337.5	374.2	at fence, francesco sanchez land since 56
62	6.58	54.61	154.94	100.33	344.1	375.2	
63	5.89	54.61	184.15	129.54	350.0	376.5	
64	5.51	54.61	180.34	125.73	355.5	377.7	
65	6.93	54.61	57.15	2.54	362.4	377.8	cut some alt by going around side of hill
66	6.86	54.61	139.7	-85.09	369.3	376.9	
67	6.88	54.61	107.95	-53.34	376.2	376.4	
68	6.91	54.61	186.69	-132.08	383.1	375.1	

Pt. ID	Dist (m)	BM (cm)	Recorded Elev. (cm)	Elev. Change (m)	Dist Cumulative (m)	Altitude (m)	Comments
69	7.11	54.61	83.82	-29.21	390.2	374.8	
70	6.99	54.61	91.44	-36.83	397.2	374.4	
71	6.99	54.61	127	-72.39	404.2	373.7	
72	6.93	54.61	165.1	-110.49	411.1	372.6	
73	6.78	54.61	132.08	-77.47	417.9	371.8	
74	5.23	54.61	177.8	-123.19	423.1	370.6	
75	4.32	54.61	193.04	-138.43	427.4	369.2	
76	4.88	54.61	165.1	-110.49	432.3	368.1	
77	5.49	54.61	210.82	-156.21	437.8	366.5	
78	6.22	54.61	172.72	-118.11	444.0	365.3	before fence, middle of cabrada
79	4.45	54.61	210.82	156.21	448.5	366.9	
80	3.38	54.61	196.85	142.24	451.8	368.3	
81	3.78	54.61	199.39	144.78	455.6	369.8	
82	6.99	54.61	157.48	102.87	462.6	370.8	
83	7.01	54.61	167.64	113.03	469.6	371.9	
84	7.14	54.61	115.57	60.96	476.8	372.5	
85	7.01	54.61	116.84	62.23	483.8	373.2	
86	6.63	54.61	176.53	121.92	490.4	374.4	
87	6.68	54.61	187.96	133.35	497.1	375.7	
88	6.86	54.61	148.59	93.98	503.9	376.6	
89	7.14	54.61	69.85	15.24	511.1	376.8	level, saddle of hill
90	5.92	54.61	90.17	-35.56	517.0	376.4	
91	7.01	54.61	173.99	-119.38	524.0	375.2	
92	7.11	54.61	162.56	-107.95	531.1	374.2	
93	7.24	54.61	166.37	-111.76	538.4	373.1	
94	6.48	54.61	200.66	-146.05	544.8	371.6	
95	3.15	54.61	190.5	-135.89	548.0	370.2	
96	3.48	54.61	203.2	-148.59	551.5	368.7	
97	3.05	54.61	200.66	-146.05	554.5	367.3	
98	4.11	54.61	219.71	-165.1	558.6	365.6	
99	5.46	54.61	195.58	-140.97	564.1	364.2	
100	6.58	54.61	200.66	-146.05	570.7	362.8	
101	7.21	54.61	189.23	-134.62	577.9	361.4	
102	6.96	54.61	209.55	-154.94	584.8	359.9	
103	5.97	54.61	160.02	-105.41	590.8	358.8	
104	7.11	54.61	180.34	-125.73	597.9	357.6	see existing system, potential tee point
105	4.11	54.61	59.69	-5.08	602.0	357.5	

Pt. ID	Dist (m)	BM (cm)	Recorded Elev. (cm)	Elev. Change (m)	Dist Cumulative (m)	Altitude (m)	Comments
106	7.21	52.07	172.72	120.65	609.2	358.7	fence, end of sanchez, start domingo
107	6.53	52.07	134.62	82.55	615.8	359.5	
108	6.60	52.07	29.21	-22.86	622.4	359.3	
109	6.93	52.07	110.49	-58.42	629.3	358.7	
110	7.06	52.07	104.14	-52.07	636.4	358.2	
111	6.63	52.07	189.23	137.16	643.0	359.6	
112	5.69	52.07	204.47	152.4	648.7	361.1	
113	6.35	52.07	208.28	156.21	655.0	362.7	
114	5.84	52.07	213.36	161.29	660.9	364.3	
115	6.12	52.07	207.01	154.94	667.0	365.8	
116	7.14	52.07	179.07	127	674.1	367.1	
117	7.14	52.07	115.57	63.5	681.3	367.7	
118	7.09	52.07	68.58	16.51	688.4	367.9	
119	6.78	52.07	93.98	41.91	695.1	368.3	
120	6.81	52.07	142.24	-90.17	702.0	367.4	
121	3.10	52.07	125.73	-73.66	705.1	366.7	fence
122	7.09	52.07	218.44	166.37	712.1	368.3	
123	6.88	40	79	-39	719.0	367.9	
124	7	40	67.8	-27.8	726.0	367.7	
125	4.99	38	135.5	-97.5	731.0	366.7	
126	6.87	38	134.3	-96.3	737.9	365.7	
127	6.94	38	69.5	-31.5	744.8	365.4	
128	7.03	38	99.6	-61.6	751.8	364.8	
129	6.92	38	133.5	-95.5	758.8	363.8	
130	6.94	38	99	-61	765.7	363.2	
131	7	38	84.5	-46.5	772.7	362.8	
132	6.84	38	91	-53	779.5	362.2	
133	7.03	38	107	-69	786.6	361.6	
134	6.82	38	135.5	-97.5	793.4	360.6	
135	7	38	60.8	-22.8	800.4	360.3	
136	7.02	38	41.8	-3.8	807.4	360.3	
137	7.05	38	58	-20	814.5	360.1	
138	7.01	38	27.5	10.5	821.5	360.2	
139	6.33	38	48.5	-10.5	827.8	360.1	
140	7.04	38	14	24	834.8	360.4	
141	6.82	38	96.6	-58.6	841.7	359.8	at fence low point in path
142	7.1	38	24.5	13.5	848.8	359.9	
143	6.8	38	73.5	35.5	855.6	360.3	

Pt. ID	Dist (m)	BM (cm)	Recorded Elev. (cm)	Elev. Change (m)	Dist Cumulative (m)	Altitude (m)	Comments
144	7	38	66	28	862.6	360.5	
145	7	38	15.5	-22.5	869.6	360.3	
146	7	38	80	-42	876.6	359.9	
147	7.08	38	75.2	-37.2	883.6	359.5	
148	7.05	38	22.5	15.5	890.7	359.7	
149	7.15	38	88.8	-50.8	897.8	359.2	
150	6.95	38	81.3	-43.3	904.8	358.7	
151	7.07	38	164	-126	911.9	357.5	crossing fence end domingo land
152	3.7	38	143.7	-105.7	915.6	356.4	cross path
153	2.6	38	148	-110	918.2	355.3	
154	4.75	38	93.8	-55.8	922.9	354.8	begin emilio land, cross fence
155	6.9	38	76.4	-38.4	929.8	354.4	
156	6.75	38	71.7	-33.7	936.6	354.0	
157	5.9	38	148.5	-110.5	942.5	352.9	
158	6	38	165	-127	948.5	351.7	
159	6.98	38	120	-82	955.4	350.8	
160	6.35	38	194	-156	961.8	349.3	
161	6.9	38	168	-130	968.7	348.0	
162	6.9	38	139.5	-101.5	975.6	347.0	
163	5.8	38	177	-139	981.4	345.6	
164	4.65	38	144	-106	986.0	344.5	
165	3.55	38	149.5	-111.5	989.6	343.4	
166	3.37	40.5	150	-109.5	993.0	342.3	
167	4	40.5	164	-123.5	997.0	341.1	
168	5.7	40.5	171	-130.5	1002.7	339.8	
169	4.9	40.5	139.5	-99	1007.6	338.8	
170	5.67	40.5	123	-82.5	1013.2	338.0	at fence low point in path
171	6.85	40.5	108.5	-68	1020.1	337.3	after fence
172	6.65	40.5	80	-39.5	1026.7	336.9	
173	6.95	40.5	53.5	-13	1033.7	336.7	at fence
174	5.16	40.5	41	-0.5	1038.8	336.7	measurement through fence
175	6.28	40.5	31	9.5	1045.1	336.8	
176	6.75	40.5	103.7	63.2	1051.9	337.5	
177	6.83	40.5	130	89.5	1058.7	338.4	
178	7	40.5	119.5	79	1065.7	339.2	
179	6.8	40.5	84	43.5	1072.5	339.6	measurement along fence
180	6.85	40.5	52	11.5	1079.4	339.7	measurement along fence

Pt. ID	Dist (m)	BM (cm)	Recorded Elev. (cm)	Elev. Change (m)	Dist Cumulative (m)	Altitude (m)	Comments
181	5.93	40.5	61	20.5	1085.3	339.9	measurement along fence, at corner
182	6.32	40.5	83.5	43	1091.6	340.3	end emilio, begin domingo pasture, crossed fence
183	6.74	40.5	109	-68.5	1098.3	339.7	
184	4.55	40.5	170	-129.5	1102.9	338.4	
185	3.84	40.5	168	-127.5	1106.7	337.1	
186	5.55	40.5	171	-130.5	1112.3	335.8	
187	6.9	40.5	101.5	-61	1119.2	335.2	
188	6.7	40.5	69.3	-28.8	1125.9	334.9	
189	6.75	40.5	52.3	-11.8	1132.6	334.8	
190	5.8	40.5	171	-130.5	1138.4	333.5	
191	6.95	40.5	133	-92.5	1145.4	332.5	
192	6.8	40.5	103	-62.5	1152.2	331.9	
193	6.95	40.5	133.7	-93.2	1159.1	331.0	
194	7.1	40.5	155	-114.5	1166.2	329.8	
195	3.05	40.5	205	-164.5	1169.3	328.2	
196	3.2	40.5	201	-160.5	1172.5	326.6	
197	2.6	40.5	165	-124.5	1175.1	325.3	
198	2.9	40.5	171.5	-131	1178.0	324.0	
199	1.9	40.5	143.7	-103.2	1179.9	323.0	
200	2.3	40.5	190	-149.5	1182.2	321.5	
201	2.9	40.5	192	-151.5	1185.1	320.0	
202	2.69	40.5	208	-167.5	1187.8	318.3	
203	3	40.5	195	-154.5	1190.8	316.8	
204	3	40.5	193.5	-153	1193.8	315.2	
205	2.86	40.5	160	-119.5	1196.6	314.0	
206	1.9	40.5	168	-127.5	1198.5	312.8	
207	2.7	40.5	165	-124.5	1201.2	311.5	
208	1.95	40.5	163	-122.5	1203.2	310.3	
209	3.8	40.5	181	-140.5	1207.0	308.9	
210	6.79	40.5	192	-151.5	1213.8	307.4	bottom of hill, picture taken
211	6.75	40.5	196.5	-156	1220.5	305.8	
212	7	40.5	80.6	40.1	1227.5	306.2	
213	6.9	40.5	91.5	-51	1234.4	305.7	
214	4.87	40.5	144	-103.5	1239.3	304.7	crossed fence to forest
215	5	40.5	198	-157.5	1244.3	303.1	
216	4.94	40.5	143	-102.5	1249.2	302.1	
217	4.56	40.5	180	-139.5	1253.8	300.7	

Pt. ID	Dist (m)	BM (cm)	Recorded Elev. (cm)	Elev. Change (m)	Dist Cumulative (m)	Altitude (m)	Comments
218	4.34	40.5	170	-129.5	1258.1	299.4	
219	6.67	40.5	184	-143.5	1264.8	297.9	
220	6.8	40.5	157	-116.5	1271.6	296.8	crossing stream
221	3.7	40.5	178	137.5	1275.3	298.2	
222	3.9	40.5	163	122.5	1279.2	299.4	
223	2.9	40.5	168	127.5	1282.1	300.7	
224	2.8	40.5	180	139.5	1284.9	302.0	
225	2.47	40.5	183	142.5	1287.4	303.5	
226	2.76	40.5	170	129.5	1290.1	304.8	
227	2.35	40.5	170	129.5	1292.5	306.1	
228	2.58	40.5	180	139.5	1295.1	307.5	
229	2.6	40.5	185	144.5	1297.7	308.9	
230	2.75	40.5	176	135.5	1300.4	310.3	
231	2.9	40.5	185	144.5	1303.3	311.7	
232	3.34	40.5	202	161.5	1306.7	313.3	
233	3.42	40.5	190	149.5	1310.1	314.8	
234	4.06	40.5	197	156.5	1314.1	316.4	
235	4.38	40.5	193	152.5	1318.5	317.9	
236	4.14	37.2	108.5	71.3	1322.7	318.6	at fence
237	6.62	37.2	155	117.8	1329.3	319.8	at fence of dionicio land
238	7	37.2	96.3	59.1	1336.3	320.4	
239	7.12	37.2	111.5	74.3	1343.4	321.1	
240	6.85	37.2	66.5	29.3	1350.2	321.4	
241	6.8	37.2	92.7	55.5	1357.0	322.0	
242	6.92	37.2	131	93.8	1364.0	322.9	
243	7.03	37.2	57.5	20.3	1371.0	323.1	
244	6.97	37.2	92.5	55.3	1378.0	323.7	
245	6.89	37.2	49	11.8	1384.9	323.8	
246	4.2	37.2	167	-129.8	1389.1	322.5	
247	6.5	37.2	55.5	-18.3	1395.6	322.3	
248	4.5	37.2	153	-115.8	1400.1	321.2	tree
249	4.1	37.2	175	-137.8	1404.2	319.8	
250	6.8	37.2	95	-57.8	1411.0	319.2	
251	6.8	37.2	105	-67.8	1417.8	318.5	
252	6.6	37.2	98	-60.8	1424.4	317.9	
253	6.9	37.2	150	-112.8	1431.3	316.8	
254	6.8	37.2	60	-22.8	1438.1	316.6	
255	6.8	37.2	22.5	-14.7	1444.9	316.4	
256	6.8	37.2	37	-0.2	1451.7	316.4	

Pt. ID	Dist (m)	BM (cm)	Recorded Elev. (cm)	Elev. Change (m)	Dist Cumulative (m)	Altitude (m)	Comments
257	3.73	28.5	174	145.5	1455.4	317.9	
258	6.55	28.5	112.5	-84	1461.9	317.0	
259	6.8	28.5	96	67.5	1468.7	317.7	
260	2.7	28.5	90	61.5	1471.4	318.3	at tree
261	5	28.5	182	153.5	1476.4	319.8	
262	6.57	28.5	164	135.5	1483.0	321.2	
263	6.9	28.5	52	23.5	1489.9	321.4	
264	6.97	28.5	81	52.5	1496.9	322.0	
265	6.92	28.5	139	110.5	1503.8	323.1	
266	6.83	28.5	67.5	39	1510.6	323.5	
267	6.78	28.5	64.5	36	1517.4	323.8	
268	6.86	28.5	94.7	66.2	1524.3	324.5	
269	6.95	28.5	43	14.5	1531.2	324.6	
270	6.92	28.5	77.5	49	1538.1	325.1	
271	6.99	28.5	104.2	75.7	1545.1	325.9	
272	7	28.5	44.5	16	1552.1	326.0	
273	6.7	28.5	25	-3.5	1558.8	326.0	
274	6.45	28.5	64.5	-36	1565.3	325.6	
275	6.6	28.5	76.5	-48	1571.9	325.2	
276	6.8	28.5	64.5	-36	1578.7	324.8	
277	6.7	28.5	63	34.5	1585.4	325.1	
278	6.7	28.5	83	-54.5	1592.1	324.6	
279	6.7	28.5	39.2	-10.7	1598.8	324.5	
280	6.7	28.5	23.5	5	1605.5	324.5	
281	6.88	28.5	114.5	86	1612.4	325.4	
282	6.86	28.5	103.5	75	1619.2	326.1	
283	6.64	28.5	87.5	59	1625.9	326.7	
284	6.9	28.5	92.5	64	1632.8	327.4	
285	6.82	28.5	141	112.5	1639.6	328.5	
286	5.82	28.5	194	165.5	1645.4	330.2	still in jungle
287	6.84	28.5	75	46.5	1652.2	330.6	
288	6.73	28.5	64	35.5	1659.0	331.0	
289	6.9	28.5	116.5	88	1665.9	331.9	
290	6.55	28.5	67	-38.5	1672.4	331.5	
291	6.25	28.5	175	-146.5	1678.7	330.0	
292	6.9	27.2	115.3	-88.1	1685.6	329.1	jungle
293	6.85	27.2	125.5	-98.3	1692.4	328.1	
294	6.85	27.2	97.2	-70	1699.3	327.4	
295	6.8	27.2	75	-47.8	1706.1	327.0	

Pt. ID	Dist (m)	BM (cm)	Recorded Elev. (cm)	Elev. Change (m)	Dist Cumulative (m)	Altitude (m)	Comments
296	6.65	27.2	62	-34.8	1712.7	326.6	
297	6.95	27.2	43.2	-16	1719.7	326.5	
298	6.25	27.2	92	-64.8	1725.9	325.8	
299	5.4	27.2	190	-162.8	1731.3	324.2	approaching steep hill
300	4	27.2	197	-169.8	1735.3	322.5	
301	3.15	27.2	178	-150.8	1738.5	321.0	
302	3	27.2	198	-170.8	1741.5	319.3	
303	2.8	27.2	189	-161.8	1744.3	317.6	
304	2.7	27.2	187	-159.8	1747.0	316.0	
305	2.4	27.2	189	-161.8	1749.4	314.4	
306	2.55	27.2	182	-154.8	1751.9	312.9	
307	3.1	27.2	203	-175.8	1755.0	311.1	
308	6.57	27.2	116.5	89.3	1761.6	312.0	bottom of hill
309	4	27.2	189	161.8	1765.6	313.6	uphill end dionecio martinez
310	3.4	27.2	184	156.8	1769.0	315.2	begin david at clearing
311	4.49	27.2	177	149.8	1773.5	316.7	
312	6.93	27.2	178	150.8	1780.4	318.2	
313	7.04	27.2	69.5	42.3	1787.4	318.6	
314	6.88	27.2	123.5	96.3	1794.3	319.6	
315	6.39	27.2	56.2	-29	1800.7	319.3	
316	6.85	27.2	117.5	-90.3	1807.6	318.4	
317	5.7	27.2	97	-69.8	1813.3	317.7	
318	6.9	27.2	128.5	-101.3	1820.2	316.7	
319	5.53	27.2	74	46.8	1825.7	317.2	
320	4.9	27.2	181.5	-154.3	1830.6	315.6	
321	4.7	27.2	190	-162.8	1835.3	314.0	
322	4.9	27.2	54.5	27.3	1840.2	314.3	
323	4.22	27.2	202	-174.8	1844.4	312.5	
324	1.85	27.2	191	-163.8	1846.3	310.9	
325	4	27.2	67.5	-40.3	1850.3	310.5	crossed above small quebrada (cabrada)
326	5.65	27.2	203	175.8	1855.9	312.2	
327	6.97	27.2	133	105.8	1862.9	313.3	
328	5.39	27.2	202	174.8	1868.3	315.0	
329	3.36	27.2	177	149.8	1871.6	316.5	
330	4.42	27.2	187	159.8	1876.1	318.1	
331	6.27	27.2	170	142.8	1882.3	319.6	
332	6.83	27.2	140.5	113.3	1889.2	320.7	
333	3.14	27.2	171	143.8	1892.3	322.1	

Pt. ID	Dist (m)	BM (cm)	Recorded Elev. (cm)	Elev. Change (m)	Dist Cumulative (m)	Altitude (m)	Comments
334	6.7	27.2	131	103.8	1899.0	323.2	
335	6.84	27.2	73	45.8	1905.8	323.6	
336	6.87	27.2	107.5	80.3	1912.7	324.4	
337	6.89	27.2	99	71.8	1919.6	325.1	picture of big tree with vines
338	6.97	27.2	62	34.8	1926.6	325.5	
339	7	27.2	112	84.8	1933.6	326.3	
340	6.93	27.2	160	132.8	1940.5	327.7	
341	6.96	27.2	103.5	76.3	1947.5	328.4	
342	6.35	27.2	61	-33.8	1953.8	328.1	over log
343	3.6	27.2	20.5	6.7	1957.4	328.2	
344	6.3	27.2	68	40.8	1963.7	328.6	see path/ crossing it
345	6.8	27.2	173	-145.8	1970.5	327.1	
346	6.5	27.2	108	-80.8	1977.0	326.3	
347	6.7	27.2	111	-83.8	1983.7	325.5	
348	6.6	27.2	36	-8.8	1990.3	325.4	
349	6.6	27.2	58.5	-31.3	1996.9	325.1	
350	6.5	27.2	55	27.8	2003.4	325.3	
351	6.93	27.2	76.5	49.3	2010.3	325.8	
352	6.56	27.2	116.5	89.3	2016.9	326.7	
353	6.95	27.2	86	58.8	2023.8	327.3	
354	5.98	27.2	70	42.8	2029.8	327.7	through dionecio sanchez cornfield
355	6.8	27.2	134.3	-107.1	2036.6	326.7	
356	6.6	27.2	89.7	-62.5	2043.2	326.1	near swamp
357	6.9	27.2	11.5	15.7	2050.1	326.2	
358	6.87	27.2	67	39.8	2057.0	326.6	
359	6.99	27.2	71	43.8	2064.0	327.0	
360	7.01	27.2	49	21.8	2071.0	327.3	
361	6.89	27.2	124.5	97.3	2077.9	328.2	
362	7.07	27.2	107	79.8	2085.0	329.0	
363	6.9	27.2	76.5	49.3	2091.9	329.5	
364	7.02	27.2	84.6	57.4	2098.9	330.1	house, dionecio sanchez/ end swamp
365	6.72	38.5	83	44.5	2105.6	330.5	starting at house
366	6.86	38.5	88.5	50	2112.5	331.0	
367	6.88	38.5	135.8	97.3	2119.3	332.0	turn uphill
368	6.89	38.5	102	63.5	2126.2	332.7	
369	6.9	38.5	95.2	56.7	2133.1	333.2	at 312 cm
370	6.9	38.5	68	29.5	2140.0	333.5	

Pt. ID	Dist (m)	BM (cm)	Recorded Elev. (cm)	Elev. Change (m)	Dist Cumulative (m)	Altitude (m)	Comments
371	6.95	38.5	87	48.5	2147.0	334.0	
372	6.75	38.5	106	67.5	2153.7	334.7	
373	5.05	38.5	198	159.5	2158.8	336.3	at 305 cm
374	3.03	38.5	185	146.5	2161.8	337.7	
375	3.15	38.5	183	144.5	2165.0	339.2	at 291 cm
376	4.45	38.5	182.5	144	2169.4	340.6	
377	3.4	38.5	198.5	160	2172.8	342.2	at 304 cm
378	4.5	38.5	1179	1140.5	2177.3	353.6	
379	5	38.5	194.5	156	2182.3	355.2	at 296.5 cm
380	3.6	38.5	209	170.5	2185.9	356.9	
381	3.7	38.5	184	145.5	2189.6	358.3	at 316 cm
382	2.85	38.5	176.5	138	2192.5	359.7	
383	2.9	38.5	204	165.5	2195.4	361.4	at 303.5 cm
384	3.8	38.5	190	151.5	2199.2	362.9	
385	2.45	38.5	195	156.5	2201.6	364.5	at 308 cm
386	1.98	38.5	168	129.5	2203.6	365.8	
387	2.55	38.5	187	148.5	2206.1	367.2	at 278 cm
388	3	38.5	199	160.5	2209.1	368.8	
389	2.38	38.5	191	152.5	2211.5	370.4	at 313 cm
390	2.15	38.5	156	117.5	2213.7	371.5	end of assent
391	6.45	38.5	108.5	-70	2220.1	370.8	
392	4.73	38.5	150	-111.5	2224.8	369.7	
393	6.3	38.5	142	-103.5	2231.1	368.7	
394	5.7	38.5	56.5	-18	2236.8	368.5	
395	4.5	38.5	191	152.5	2241.3	370.0	
396	7.02	38.5	133.5	95	2248.4	371.0	
397	5.57	38.5	69	30.5	2253.9	371.3	
398	7.04	38.5	61.5	23	2261.0	371.5	
399	7.03	38.5	21	-17.5	2268.0	371.4	
400	6.89	38.5	126.5	88	2274.9	372.2	
401	6.89	38.5	121	82.5	2281.8	373.1	
402	6.94	38.5	103	64.5	2288.7	373.7	
403	6.9	38.5	40	1.5	2295.6	373.7	
404	6.65	38.5	90.5	52	2302.3	374.2	
405	6.64	38.5	116	77.5	2308.9	375.0	
406	6.65	38.5	80.5	-42	2315.6	374.6	
407	5.7	38.5	130	-91.5	2321.3	373.7	Mallell's mother land, really steap slope
408	2.2	38.5	172	133.5	2323.5	375.0	

Pt. ID	Dist (m)	BM (cm)	Recorded Elev. (cm)	Elev. Change (m)	Dist Cumulative (m)	Altitude (m)	Comments
409	3.45	38.5	73	34.5	2326.9	375.4	
410	5.09	38.5	197	-158.5	2332.0	373.8	
411	4.8	38	151	-113	2336.8	372.6	
412	6.03	38	155	-117	2342.8	371.5	
413	5.25	38	27	11	2348.1	371.6	
414	5.75	37.4	189	151.6	2353.8	373.1	
415	4.5	37.4	153	115.6	2358.3	374.3	
416	6.7	37.4	43	5.6	2365.0	374.3	
417	6.7	37.4	204	166.6	2371.7	376.0	
418	6.45	37.4	183	145.6	2378.2	377.4	
419	6.95	37.4	123	85.6	2385.1	378.3	
420	6.9	37.4	27	-10.4	2392.0	378.2	
421	6.38	37.4	71	-33.6	2398.4	377.8	
422	6.67	37.4	110	-72.6	2405.1	377.1	
423	5.02	37.4	40	-2.6	2410.1	377.1	
424	6.7	37.4	103.5	-66.1	2416.8	376.4	
425	6.68	37.4	160	-122.6	2423.5	375.2	
426	6.7	37.4	60.5	-23.1	2430.2	375.0	
427	6.7	37.4	85.5	-48.1	2436.9	374.5	
428	6.61	37.4	130	-92.6	2443.5	373.6	
429	6.5	37.4	137.5	-100.1	2450.0	372.6	
430	4.94	37.4	166	-128.6	2454.9	371.3	entering bananna plantation
431	3.35	38.4	193	-154.6	2458.3	369.7	
432	2.79	38.4	174.5	-136.1	2461.1	368.4	
433	2.2	38.4	177.5	-139.1	2463.3	367.0	dropping into plantation from steep hill
434	2.1	38.4	184	-145.6	2465.4	365.5	
435	6.84	38.4	131.5	-93.1	2472.2	364.6	
436	6.77	38.4	111	-72.6	2479.0	363.9	
437	6.8	38.4	161	122.6	2485.8	365.1	
438	5.14	38.4	200	161.6	2490.9	366.7	
439	6.97	38.4	92	53.6	2497.9	367.3	
440	6.1	38.4	187	148.6	2504.0	368.7	
441	6.45	38.4	26	-12.4	2510.4	368.6	
442	6.8	38.4	117.4	79	2517.2	369.4	
443	6.8	38.4	159	120.6	2524.0	370.6	
444	6.8	38.4	130	91.6	2530.8	371.5	
445	4.8	38.4	191	152.6	2535.6	373.1	
446	3.3	38.1	181	142.9	2538.9	374.5	

Pt. ID	Dist (m)	BM (cm)	Recorded Elev. (cm)	Elev. Change (m)	Dist Cumulative (m)	Altitude (m)	Comments
447	3.35	38.1	185	146.9	2542.3	375.9	
448	4.9	38.1	166	127.9	2547.2	377.2	high point, begin decent
449	3.61	38.1	190	-151.9	2550.8	375.7	
450	1.91	38.1	186	-147.9	2552.7	374.2	
451	2.06	38.1	178	-139.9	2554.8	372.8	
452	4.4	38.1	188	-149.9	2559.2	371.3	
453	5.79	38.1	131	-92.9	2565.0	370.4	
454	6.9	38.1	139	-100.9	2571.9	369.4	
455	5.2	38.1	180	141.9	2577.1	370.8	
456	2.77	38.1	185	146.9	2579.8	372.3	
457	2.8	38.1	166	127.9	2582.6	373.6	
458	4.8	38.1	171	132.9	2587.4	374.9	high point, entering wooded area
459	6.7	38.1	83.5	-45.4	2594.1	374.4	
460	5.87	38.1	170	-131.9	2600.0	373.1	
461	3.62	38.1	187	-148.9	2603.6	371.6	
462	1.55	38.3	168	-129.7	2605.2	370.3	
463	6.7	38.3	136	-97.7	2611.9	369.4	
464	5.58	38.3	130	-91.7	2617.5	368.4	
465	6.8	38.3	117	-78.7	2624.3	367.6	
466	6.7	38.3	87	-48.7	2631.0	367.2	
467	5.26	38.3	35	3.3	2636.2	367.2	
468	3.85	38.3	111.5	-73.2	2640.1	366.5	
469	6.54	38.3	44.5	-6.2	2646.6	366.4	
470	5.84	38.3	124.5	-86.2	2652.4	365.5	
471	5.24	38.3	170	-131.7	2657.7	364.2	
472	6.05	38.3	145	-106.7	2663.7	363.2	
473	6.06	38.3	166	-127.7	2669.8	361.9	
474	6.9	38.3	89.5	-51.2	2676.7	361.4	
475	6.7	38.3	130	-91.7	2683.4	360.4	
476	4.68	38.3	170	-131.7	2688.1	359.1	
477	3.44	38.3	176	-137.7	2691.5	357.8	
478	3.32	38.3	176.5	-138.2	2694.8	356.4	
479	3.72	38.3	187.5	-149.2	2698.6	354.9	
480	4.28	38.3	160	-121.7	2702.8	353.7	
481	6.75	38.3	129.5	-91.2	2709.6	352.8	
482	6.79	38.3	116.5	-78.2	2716.4	352.0	
483	6.67	38.3	42	-3.7	2723.0	351.9	
484	4.45	39	180.5	141.5	2727.5	353.3	

Pt. ID	Dist (m)	BM (cm)	Recorded Elev. (cm)	Elev. Change (m)	Dist Cumulative (m)	Altitude (m)	Comments
485	6.54	39	62	-23	2734.0	353.1	
486	6.9	39	177	138	2740.9	354.5	
487	3.5	39	202	163	2744.4	356.1	
488	4.3	39	194	155	2748.7	357.7	
489	6.87	39	121.6	82.6	2755.6	358.5	
490	5.6	39	190	151	2761.2	360.0	
491	2.5	39	134	95	2763.7	361.0	
492	2.5	39	158	119	2766.2	362.2	
493	4.45	39	171	132	2770.7	363.5	
494	3	39	170	131	2773.7	364.8	
495	5	39	187	148	2778.7	366.3	
496	6.98	39	137	98	2785.6	367.2	
497	6.95	39	137	98	2792.6	368.2	
498	6.8	39	158	119	2799.4	369.4	
499	6.8	39	138	99	2806.2	370.4	
500	6.4	39	107.5	68.5	2812.6	371.1	
501	6.8	39	37	-2	2819.4	371.1	
502	6.8	39	94	55	2826.2	371.6	
503	6.69	39	131.5	92.5	2832.9	372.5	
504	4.4	39	194	155	2837.3	374.1	
505	4.1	39	182	143	2841.4	375.5	
506	5.6	39	185	146	2847.0	377.0	
507	6.95	39	181	142	2853.9	378.4	
508	6.77	39	184	145	2860.7	379.9	
509	6.8	39	157	118	2867.5	381.0	
510	6.62	39	162	123	2874.1	382.3	entering path
511	6.85	39	182	143	2881.0	383.7	
512	6.77	39	157	118	2887.7	384.9	
513	6.9	39	162	123	2894.6	386.1	
514	6.95	39	164	125	2901.6	387.4	
515	6.95	39	164	125	2908.5	388.6	
516	6.95	39	128	89	2915.5	389.5	
517	6.95	39	105.5	66.5	2922.4	390.2	
518	6.95	39	83	44	2929.4	390.6	
519	6.8	39	32.5	-6.5	2936.2	390.5	
520	6.9	39	48.5	-9.5	2943.1	390.4	
521	6.94	39	84	-45	2950.0	390.0	
522	6.75	39	76	-37	2956.8	389.6	
523	6.55	39	158	-119	2963.3	388.4	

Pt. ID	Dist (m)	BM (cm)	Recorded Elev. (cm)	Elev. Change (m)	Dist Cumulative (m)	Altitude (m)	Comments
524	5.05	37.7	200	-162.3	2968.4	386.8	
525	5	37.7	204	-166.3	2973.4	385.1	
526	3.45	37.7	188	-150.3	2976.8	383.6	
527	6.65	37.7	211	-173.3	2983.5	381.9	
528	6.7	37.7	101	-63.3	2990.2	381.3	
529	6.48	37.7	189	151.3	2996.7	382.8	
530	5.8	37.7	193	155.3	3002.5	384.3	
531	6.76	37.7	114	-76.3	3009.2	383.6	
532	6.26	37.7	149	-111.3	3015.5	382.5	
533	6.95	37.7	108	70.3	3022.4	383.2	
534	5.06	37.7	179	141.3	3027.5	384.6	
535	4.39	37.7	196	158.3	3031.9	386.2	
536	6.67	37.7	36.5	1.2	3038.5	386.2	
537	6.95	37.7	102	-64.3	3045.5	385.5	
538	6.98	37.7	78.5	-40.8	3052.5	385.1	
539	6.9	37.7	57	19.3	3059.4	385.3	
540	7.1	37.7	26.5	-11.2	3066.5	385.2	
541	6.95	37.7	61	23.3	3073.4	385.4	
542	7	37.7	176	138.3	3080.4	386.8	
543	6.95	37.7	102	64.3	3087.4	387.5	pluma positioning, rufino house
544	6.9	37.7	121.5	83.8	3094.3	388.3	
545	6.67	37.7	100	62.3	3100.9	388.9	
546	6.98	37.7	96.5	58.8	3107.9	389.5	
547	6.95	37.7	59.5	21.8	3114.9	389.7	
548	6.95	37.7	67.4	29.7	3121.8	390.0	
549	6.75	37.7	73	35.3	3128.6	390.4	at pluma
550	4.38	37.7	53	15.3	3133.0	390.5	at fence
551	6.5	37.7	148	-110.3	3139.5	389.4	
552	5.65	37.7	170	-132.3	3145.1	388.1	
553	5.13	37.7	174	-136.3	3150.2	386.7	
554	6.07	37.7	184	-146.3	3156.3	385.3	
555	4.93	37.7	194	-156.3	3161.2	383.7	
556	5.39	37.7	182	-144.3	3166.6	382.3	
557	6.36	37.7	182	-144.3	3173.0	380.8	
558	5.8	37.7	197	-159.3	3178.8	379.2	
559	4.88	37.7	181	-143.3	3183.7	377.8	
560	6.86	37.7	183	-145.3	3190.5	376.4	
561	6.68	37.7	153	-115.3	3197.2	375.2	

Pt. ID	Dist (m)	BM (cm)	Recorded Elev. (cm)	Elev. Change (m)	Dist Cumulative (m)	Altitude (m)	Comments
562	6.65	37.7	132	-94.3	3203.9	374.3	
563	6.1	37.7	182	-144.3	3210.0	372.8	
564	6.65	37.7	152	-114.3	3216.6	371.7	at fence of Angel house
565	5.28	37.7	185	-147.3	3221.9	370.2	
566	6.7	37.7	189	-151.3	3228.6	368.7	
567	6.84	37.7	100	-62.3	3235.4	368.1	
568	6.86	37.7	109	-71.3	3242.3	367.4	
569	6.86	37.7	72	-34.3	3249.1	367.0	
570	6.83	37.7	97	-59.3	3256.0	366.4	
571	6.95	37.7	39	1.3	3262.9	366.4	
572	6.95	37.7	126.5	88.8	3269.9	367.3	
573	6.75	37.7	95	57.3	3276.6	367.9	
574	6.9	37.7	45	-7.3	3283.5	367.8	
575	6.92	37.7	94	-56.3	3290.4	367.3	tee point possible between houses
576	6.87	37.7	132	-94.3	3297.3	366.3	
577	5	37.7	184	-146.3	3302.3	364.8	
578	4.62	37.7	188	-150.3	3306.9	363.3	
579	3.1	37.7	159	-121.3	3310.0	362.1	
580	4.8	37.7	190	-152.3	3314.8	360.6	
581	6.85	37.7	170	-132.3	3321.7	359.3	
582	6.9	37.7	160	-122.3	3328.6	358.1	
583	6.95	37.7	148	-110.3	3335.5	357.0	
584	6.35	37.7	188	-150.3	3341.9	355.5	
585	5.55	37.7	152	-114.3	3347.4	354.3	
586	6.95	37.7	205	-167.3	3354.4	352.6	
587	5.3	37.7	179	-141.3	3359.7	351.2	
588	3.7	37.7	199	-161.3	3363.4	349.6	
589	4.73	37.7	182	-144.3	3368.1	348.2	
590	5.15	37.7	178	-140.3	3373.3	346.8	
591	6.95	37.7	170	-132.3	3380.2	345.4	
592	6.95	37.7	132	-94.3	3387.2	344.5	
593	6.35	37.7	138	-100.3	3393.5	343.5	
594	6.8	37.7	138	-100.3	3400.3	342.5	
595	6.75	37.7	103	-65.3	3407.1	341.8	
596	6.3	37.7	99	-61.3	3413.4	341.2	
597	4.8	37.7	179	-141.3	3418.2	339.8	
598	4.94	37.7	197	-159.3	3423.1	338.2	
599	4.04	37.7	169	-131.3	3427.1	336.9	

Pt. ID	Dist (m)	BM (cm)	Recorded Elev. (cm)	Elev. Change (m)	Dist Cumulative (m)	Altitude (m)	Comments
600	4.25	37.7	180	-142.3	3431.4	335.5	part way downhill btwn. Angel and Tienda
601	4.8	37.7	187	-149.3	3436.2	334.0	
602	5.2	37.7	183	-145.3	3441.4	332.5	
603	4.8	37.7	181	-143.3	3446.2	331.1	
604	5.4	37.7	144	-106.3	3451.6	330.0	
605	4.26	37.7	184	-146.3	3455.9	328.6	
606	4.42	37.3	204	-166.7	3460.3	326.9	meet other path
607	4.45	37.3	175	-137.7	3464.7	325.5	
608	5.03	37.3	181	-143.7	3469.8	324.1	
609	6.3	37.3	196	-158.7	3476.1	322.5	
610	6.8	37.3	121	-83.7	3482.9	321.7	
611	7	37.3	107	-69.7	3489.9	321.0	
612	6.95	37.3	134	-96.7	3496.8	320.0	
613	6.9	37.3	161	-123.7	3503.7	318.8	
614	6.87	37.3	152	-114.7	3510.6	317.6	
615	6.88	37.3	151	-113.7	3517.5	316.5	
616	6.9	37.3	148	-110.7	3524.4	315.4	
617	6.86	37.3	68	-30.7	3531.2	315.1	
618	7	37.3	76	-38.7	3538.2	314.7	
619	6.95	37.3	75	-37.7	3545.2	314.3	
620	6.95	37.3	77	-39.7	3552.1	313.9	
621	6.95	37.3	60.5	-23.2	3559.1	313.7	
622	6.95	37.3	54	16.7	3566.0	313.9	
623	6.95	37.3	90	52.7	3573.0	314.4	
624	6.95	37.3	124	86.7	3579.9	315.2	
625	6.95	37.3	57.5	20.2	3586.9	315.4	
626	6.88	37.3	111	-73.7	3593.7	314.7	
627	6.1	37.3	171	-133.7	3599.8	313.4	
628	5.52	37.3	189	-151.7	3605.4	311.9	
629	3.87	37.3	184	-146.7	3609.2	310.4	
630	4.16	37.3	192	-154.7	3613.4	308.8	
631	4	37.3	177	-139.7	3617.4	307.4	
632	4.01	37.3	185	-147.7	3621.4	306.0	
633	4.02	37.3	182	-144.7	3625.4	304.5	
634	5.64	37.3	165	-127.7	3631.1	303.2	
635	5.15	37.3	190	-152.7	3636.2	301.7	
636	6.86	37.3	166	-128.7	3643.1	300.4	
637	6.87	37.3	126	-88.7	3649.9	299.5	

Pt. ID	Dist (m)	BM (cm)	Recorded Elev. (cm)	Elev. Change (m)	Dist Cumulative (m)	Altitude (m)	Comments
638	5.13	37.3	146	-108.7	3655.1	298.5	
639	5.32	37.3	200	-162.7	3660.4	296.8	
640	4.17	37.3	187	-149.7	3664.6	295.3	
641	4.66	37.3	180	-142.7	3669.2	293.9	
642	5.27	37.3	200	-162.7	3674.5	292.3	
643	4.77	37.3	181	-143.7	3679.3	290.8	
644	3.55	37.3	190	-152.7	3682.8	289.3	
645	3.48	37.3	173	-135.7	3686.3	288.0	
646	4.16	37.3	175	-137.7	3690.5	286.6	
647	4.08	37.3	175	-137.7	3694.5	285.2	
648	4.43	37.3	183	-145.7	3699.0	283.7	
649	5.06	37.3	175	-137.7	3704.0	282.4	
650	6.89	37.3	172	-134.7	3710.9	281.0	
651	6.84	37.3	141	-103.7	3717.8	280.0	
652	6.96	37.3	180	-142.7	3724.7	278.6	
653	6.28	37.3	185	-147.7	3731.0	277.1	
654	4.27	37.3	180	-142.7	3735.3	275.7	
655	6.34	37.3	176	-138.7	3741.6	274.3	
656	6.85	29.2	152	-122.8	3748.5	273.0	
657	6.96	29.2	88	-58.8	3755.4	272.5	
658	6.97	29.2	73	-43.8	3762.4	272.0	
659	6.94	29.2	84	-54.8	3769.3	271.5	
660	6.45	29.2	176	-146.8	3775.8	270.0	
661	5.16	29.2	157	-127.8	3780.9	268.7	
662	5.33	29.2	176	-146.8	3786.3	267.3	
663	5.34	29.2	190	-160.8	3791.6	265.6	
664	5.85	29.2	174	-144.8	3797.5	264.2	
665	6.12	29.2	180	-150.8	3803.6	262.7	
666	6.18	29.2	93	-63.8	3809.8	262.1	at tree by Tienda

Table 13: Cemetery line survey data

Point	Distance (m)	Vertical Distance	Vertical Distance (m)	Cumulative Distance (m)	Elevation (m)
0	0.0	0.0	0.00	0.0	330.1
1	17.5	-2.2	-0.66	17.5	329.4
2	30.5	-0.4	-0.13	48.0	329.3
3	28.3	-0.3	-0.08	76.3	329.2
4	23.2	-6.0	-1.82	99.4	327.4
5	14.1	1.5	0.47	113.5	327.9
6	18.1	1.4	0.42	131.6	328.3
7	15.9	-0.8	-0.23	147.5	328.1
8	5.9	-0.3	-0.10	153.3	328.0
9	16.6	-2.1	-0.63	170.0	327.3
10	30.5	-4.2	-1.29	200.4	326.0
11	30.5	-7.0	-2.13	230.8	323.9
12	30.5	-8.6	-2.61	261.2	321.3
13	23.6	4.8	1.48	284.8	322.8
14	30.5	-15.9	-4.86	314.9	317.9
15	30.5	-21.5	-6.55	344.6	311.4
16	30.5	-16.4	-4.99	374.7	306.4
17	30.5	-26.3	-8.02	404.1	298.4
18	30.5	-14.2	-4.33	434.3	294.0
19	30.5	-7.6	-2.30	464.7	291.7
20	25.9	-7.0	-2.15	490.5	289.6
21	26.9	-13.2	-4.02	517.1	285.6
22	17.3	10.1	3.08	534.1	288.7