Rehabilitation of Water Systems in Quebrada Miña and Calabazal, Panama

Agua Contigo Consultados

International Senior Design 2009

Rehabilitation of Water Systems in Quebrada Miña and Calabazal, Panama

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Disclaimer

Agua Contigo Consultados consists of engineering students working on a senior design project at Michigan Technological University in Houghton, MI. While the students worked under the supervision and guidance of associated faculty members, the contents of this report should not be considered professional engineering.

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Acknowledgements

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Of course we need to extend our utmost gratitude towards the **community members** of Quebrada Miña and Calabazal. None of this would be possible without them. We hope they will benefit from our work.

1.0 Executive Summary

In August of 2009, five students from Michigan Technological University formed Agua Contigo Consultados (ACC), or "Water with You Consultants," for the purpose of designing solutions to water resource problems in the Comarca District of Panama. ACC's mission statement is as follows:

> "Agua Contigo Consultados (ACC) is dedicated to providing practical water treatment solutions to the communities of Calabazal and Quebrada Miña, Panama. ACC will research and design sustainable water catchment and distribution system components that can be easily operated and maintained by the communities."

ACC is comprised of a diverse group of individuals from varying backgrounds, all studying at Michigan Technological University (MTU). It is composed of two civil engineering majors, two environmental engineering majors and one applied geophysics major. This diversity has contributed to the creativity and vision throughout the scope of the project.

The iDesign program works with developing communities lacking certified individuals capable of designing engineering solutions. This gives MTU undergraduates an opportunity to gain a cultural experience, practice with different field work techniques, and the chance to design for the needs of the people and the area.

The communities that ACC is working for are Calabazal and Quebrada Miña, Panama. Currently these communities have a water distribution system that does not contain any form of a filtration system. Problems with the water systems continue to impact the health of the community. Without improvement of the systems, these health problems will continue to be an issue.

ACC looked at several filtration and water treatment methods. Options such as a drum filter, slow and rapid sand filters, modified media drum filters, bio-filtration, and roughing filtration were all researched and weighted against each other. In the end, a rapid sand filter was chosen as the optimal solution for their needs. ACC also looked into the addition of a chlorination component to the system. This system would be added downstream of the rapid sand filtration system in the form of an access tee where the chlorine can be added when necessary prior to entering the storage tank. A piezometer (water level gauge) is also suggested for the storage tank so that the proper amount of chlorine could be added for the appropriate amount of water.

The aim of this project is to improve the water systems of the communities and decrease the number of water-related health issues. Different components were designed to remove sediment and disinfect water within both communities, and to address the maintenance issues in the current water system and the migrated spring in Calabazal. While developing a suitable design, ACC always considered the needs of the community through economic, environmental and social sustainability. ACC is submitting this design document to the Peace Corps and the members of the communities, Quebrada Miña and Calabazal, in the hope that the systems will be implemented and funded in the near future.

2.0 Background

Within the Central American country of Panama there lie two very unique Ngäbe communities: Calabazal and Quebrada Miña. Although each community has its own water capture and distribution system, there is a great deal of difference between Calabazal's 20-year-old installation and Quebrada Miña's recently constructed system.

In August of 2009, five students from Michigan Technological University formed Agua Contigo Consultados (ACC), or "Water with You Consultants," for the purpose of designing solutions to water resource problems in the Comarca District of Panama. This technical report comprises the findings and recommendations of this design team.

Figure 1: Group of students comprising ACC with their student mentor and Peace Corps volunteer.

Located approximately 7.5 miles north of San Felix, Chiriquí (Figure 2, Figure 3, and Figure 4), the community of Calabazal is hundreds of years old. Quebrada Miña, however, is newly rising, having originated in the 1990´s as a result of community sprawl from Calabazal.

Despite the newly appointed distinction, these communities are only about a 15-minute walk apart.

Figure 2: Panama in relationship to the U.S.

Figure 3: Location of the Nole-Duima District in the Nedrini región of Panama

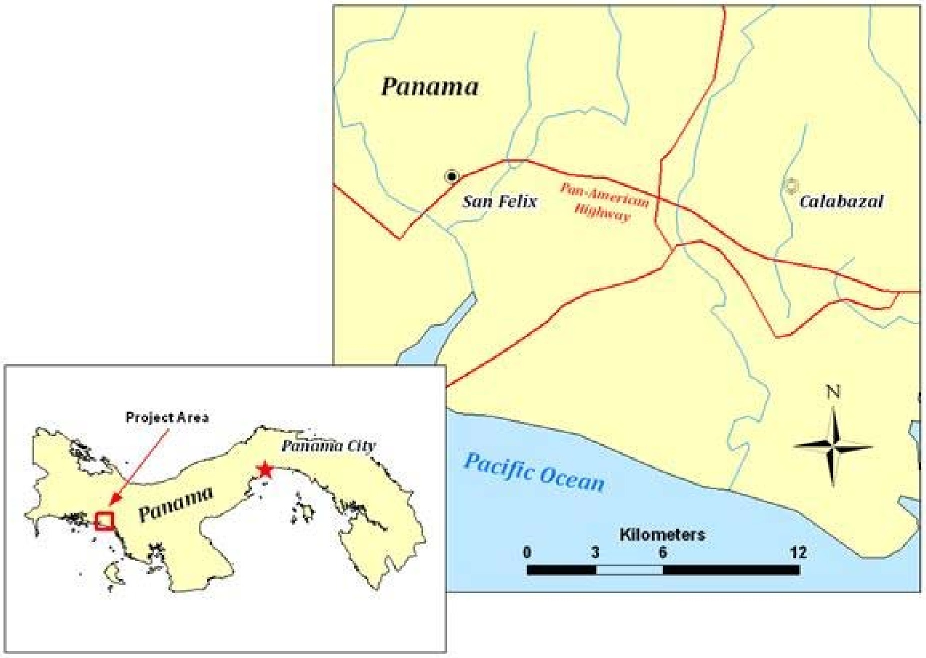

Figure 4: Location of Calabazal relative to San Felix and Panama City

Due to a larger population in Calabazal (~300 individuals) than in Quebrada Miña (~200 individuals), along with a stronger history, the government does not yet recognize Quebrada Miña as an independent community. All issues to be taken up outside of the communities must be done through Calabazal´s representatives in the district government located in Cerro Iglesias. The government has subdivided the country into provinces to better represent the people, additional subdivisions have been made to better represent the indigenous groups, these are known as *Comarcas*. The area within which Cerro Iglesias is located is known nationally as Calabazal, Región Nedrini, Districto Nole-Duima, Cerro Iglesias, Comarca Ngäbe-Buglé.

Figure 5: Tropical homes in Calabazal; built with panka roofs and bamboo walls.

2.1 Income

As with most Ngäbe communities, the people of Quebrada Miña and Calabazal are subsistence farmers with a few small-scale family-owned stores to supplement their income. Corn, rice, beans, and yucca are the main crops subsistence growers live on, but residents also enjoy wild oranges, grapefruit and other indigenous fruits.

Figure 6: Ngäbe children sharing some oranges they gathered.

Wealth is generally demonstrated by ownership of animals that are not themselves eaten. Pigs and chickens show a family is well off; a horse shows the utmost of wealth (Figure 7). The majority of the income for the community comes from work outside of the area. Many leave the community several times a year to work on other farms, mainly in the form of manual labor—harvesting coffee and *panka*, mending fences, farming animals, harvesting crops, and other activities. In the Boquete Region, along with parts of Costa Rica, work is often promised for a set period of time. Laborers in these cases are able to bring their families with them and are promised work, a place to live, and a means of traveling to and from their permanent home. Additional income has, in the past, come from welfare on a monthly basis from the government (this may change with the recent election of Ricardo Martinelli on May 3, 2009).

Figure 7: Children taking pride in their ownership of a horse.

2.2 Language and Education

The Ngäbe people sustain their ancestral language, Ngäbere, but are taught Spanish as a secondary language. English is a third language often taught in the schools. All but the elders of

Quebrada Miña and Calabazal are able to converse in Spanish. Schools are run by an educational ministry known as Meduca.

Children from Quebrada Miña, Orema, Caracole, Quebrada Pita, and Cerro Kidate are hosted by Calabazal to reduce the need for more teachers and resources. Teachers are often from Latino communities which can cause difficulties in learning due to Spanish being a secondary language for the children but a primary language for the teacher. Kindergarten through eighth grade is taught in Calabazal. Traveling farther to Cerro Iglesias, Remedios, San Felix, or Las Lajas is required for continuing education in grades nine through twelve. Fifth grade is the average education level for most of the community members. Children are taught basic courses similar to a curriculum in the United States: math, science, reading, and English, with only one unique topic of religion within their courses.

Seventh Day Adventism, a denomination of Christianity, is followed routinely as their sole religion which they attend too often. This religion is typically practiced on either Saturdays or Sundays with an additional service on Wednesdays. In most countries, Saturday is considered their day of rest and the day they attend church service. However, both Calabazal and Quebrada Miña find it important to attend all of these services with an additional service being held on Mondays. By attending church the villages are further unified similar to the characteristics of a family. They work to strengthen the bonds between households during this time and provide moral guidance and education during these religious ceremonies.

2.3 Organizations

These communities are well known for their committees and involvement. There are committees for health, sports, water, their cooperative pond and farm, as well as one called *Padres de Familía* for the school, similar to a parent teacher association in the United States. Of these, the biggest driving force is the school committee, Padres de Familía. Within this group it is decided who is going to cook, clean, and carry supplies for the school and the children. Children and their well being are considered everyone's responsibility, and they try to spread that responsibility equally.

The second biggest driving force for these communities is the water committee. Calabazal has had their water distribution and storage system for approximately 20 years. It is unknown to ACC who constructed the current system in Calabazal 20 years ago. Thanks to the work done by Julie Herrick (Peace Corps volunteer approximately May 2007-October 2009), Quebrada Miña has recently received their own water storage and distribution system serving the entire community. This system cost approximately $6300, and was funded by the NGO Waterlines. The community provided the necessary hours of labor set forth by the Peace Corps volunteer during its construction.

2.4 Modernization

Many changes have been discussed for this region of Panama. The seat of government for Nole-Duima is located relatively close to Calabazal, and there have been discussions of connecting them to the electricity grid within the next five years. If this happens, Quebrada Miña and Calabazal will also be able to connect at the same time. Additionally, paving a road to both communities has been discussed to help make the area easier to travel. Currently the clay surface makes any travel extremely hazardous, since anyone coming into the communities must walk on steep grades.

Lower-tech solutions to existing problems of sanitation have been proposed by outside organizations. For example, the Peace Corps is encouraging a specific style of composting latrines in Panama. In addition to technological changes for the area, the population is still expected to continue to grow at a rapid rate (Julie Herrick, personal communication), which will increase the demand for water, food, and other materials and supplies.

Figure 8: Example pit latrine built in Calabazal.

2.5 Health Issues

Despite the talk of technical advances, the core necessities for maintaining a healthy life are not being addressed. People in most regions, not just Quebrada Miña and Calabazal, are faced with illnesses that are not being attended to. Tuberculosis, intestinal problems caused by bad hygiene and diet, diarrhea, and many other ailments affect the daily lives of most rural Panamanians. Some of these problems are visually apparent, while others require a little more investigation. Many of the people in both communities are stricken with malnutrition which is visible in their teeth and hair. Parasites are another large problem that is barely addressed. Often children have large, protruding bellies that make them look extremely well-fed; however, it is in fact a parasite causes them to look this way. For many of these problems soft drinks are used as a remedy for the symptoms, which only makes things worse because it only provides sugar and empty calories for their diets. Since the taste of water is often undesirable, due to sediment and other debris issues, additives like sugar are often used in most drinks.

The majority of health care is free to the citizens of Panama. The biggest obstacle to receiving health care comes from the transportation required to obtain it. Often families are unable to come up with enough money to get to a health care provider. MINSA (Minestario de Salud, the Ministry of Health for Panama) is one of the larger organizations working to counteract the lack of available health care. They also help develop aqueducts, distribute fortified milk and vaccinations for infants, and more. MINSA's biggest struggle lies with being under-staffed. Currently one individual is tasked with providing for an entire district with no outside help. The only additional help that exists comes generally from the United States. Groups like Doctors without Borders, dentists, and eye doctors alike will come down and volunteer time in different areas of the country to do what they can with donated supplies.

3.0 Technical Background

Calabazal and Quebrada Miña each have their own water capture and distribution systems. Calabazal's system is showing signs of age, while Quebrada Miña's is newly constructed (within this past year). They both utilize captured water from spring boxes (protected springs) to distribute water throughout the community. The newer system in Quebrada Miña utilizes two spring boxes in order to provide a higher volume throughout the year. This higher volume of water reduces the risk of water scarcity in the dry season. Both systems, however, are in need of improvement.

Figure 9: Quebrada Miña's water storage tank.

Calabazal's system is approximately 20 years old and is starting to fail in several places. It consists of one spring box (Spring discharge of 4,565 gallons/day in November, 2007), one 6,145-gallon storage tank, over 4,000 feet of distribution lines, and approximately 21 taps. The system also suffers from a lack of clear responsibility as to who repairs the system. For example, in August 2009 there was a leak that was only taped up and continued to waste water with no additional repairs (Figure 10). There exist other problems with the system. The source has migrated, reducing the amount of water that is captured and introducing the potential for contamination. There is also contamination potential in the faulty seals of the spring box and storage tank. For instance, a snake once got into the water system and the majority of the community became ill from drinking contaminated water at a celebration. Another problem is sedimentation in the storage tank, which must be manually cleaned on occasion.

Figure 10: Depiction of leak in Calabazal's system only taped up temporarily.

Figure 11: Exposed pipe supported by barbed wire.

The system also contains a 20-foot length of pipe that is supported by barbed wire. This section is very susceptible to failure as it is only about a meter above the stream (Figure 11). The exposed pipe could potentially be knocked out by large flood debris, disrupting service to the whole system since this section is in the only line to the storage tank. The system also has limited water pressure which sometimes is too low to supply a desired flow rate.


Figure 12: One of Quebrada Mina's Spring Boxes

Quebrada Miña's system is brand new; its valve-opening ceremony happened in early July of 2009. The system consists of two spring boxes, one 2,588-gallon storage tank (Figure 9 and 12), and 15 taps. The flow rates for both springs were measured in November, 2007 by the Peace Corps volunteer present at that time. The east spring's flow rate was measured at 1,042 gallons/day, and the northwest spring's flow rate was measured at 4,565 gallons/day. The system currently has great pressure and has made the community very happy with their new system. Before it was introduced the people had to travel a great distance to the stream and bring the water back in buckets. The system contains two sections of exposed, suspended piping which are vulnerable. These sections are cased in larger diameter PVC piping and held up by a steel cable (Figure 13). The suspended piping has 90° elbow joints that provide support; at the base is a shut-off valve in case of breakage. There are other areas in the distribution system where the piping could not be buried due to rocky or gravel terrain. This exposed pipe can easily be punctured, especially after a few years of UV degradation.

Figure 13: Depiction of pipe bridging where water pipe is encased in another PVC pipe. Additionally, showing the 90° elbow joints.

4.0 Field Methods and Materials

In order to gain a better understanding of the area ACC is working with, site investigations within both communities, Calabazal and Quebrada Miña, were conducted utilizing multiple data collection techniques. Personal interviews concerning water quality and satisfaction with pit latrines were conducted in Quebrada Miña. Flow rates were measured at each tap in Quebrada Miña using a 5-gallon bucket and a stopwatch (Figure 14). Point elevations were measured at each community´s water storage tanks using a Topcon TOP-JR auto-level with a tripod mount and a Jacob´s rod. Elevations along water lines in Calabazal were measured using two different methods: differential leveling with an auto-level and by measuring the angle of elevation using a Brunton surveyor´s compass. Also described here are field techniques used for digging test pits and evaluating potential new water resources.

Figure 14: Flow rates being measured with a stop watch and 5 gallon bucket.

The personal interviews, conducted with assistance from the Peace Corps volunteer, initially consisted of a small number of questions:

1) How do you feel about your water?
2) Are there any problems with your water?
3) What would you like to change about your water system?
4) How do you feel about your pit latrine?
5) Are there any problems with your pit latrine?

These questions were carefully phrased so as not to ‘lead the witness’ or otherwise bias the answers that might be received. The answers to these questions were recorded for every household and are provided in Appendix A. Background information, such as the number of people in each household, has already been obtained by the current Peace Corps volunteer (Appendix A).

Figure 15: ACC member noting some translated responses from the Peace Corps volunteer

During the personal interviews, the Secretary of the Quebrada Miña Water Committee, Miguel Mora, suggested that more specific questions be asked. He felt that the water system in his community was so new, and he and others were so happy with it, that no one really knew how to answer such broad questions. Taking the Secretary’s advice into consideration, two new questions were generated to replace the initial two questions about water quality. The first two questions became:

1) Has the water ever been dirty?
2) Has the water ever tasted bad?

As personal interviews were being conducted, measurements of flow rate were taken at each residence's tap. Three trials were conducted for each tap, where the filling of a 5-gallon bucket at maximum flow rate was timed. The spatial coordinates of each tap were recorded using a hand-held Garmin GPS.

Figure 16: ACC leveling the Auto-Level

For obtaining point elevations, the auto-level (Figure 16) was first carefully leveled in the horizontal plane. Next, the auto-level was oriented due north where azimuth is clockwise from 0°. Four measurements were taken for each shot: the azimuth angle and the height from the ground of the upper, center, and lower stadia. When measuring elevation along the water lines in Calabazal, the azimuth angle was ignored, since spatial coordinates were obtained via GPS. By multiplying the difference between the upper and lower stadia by the stadia constant of 100 (for this device), the distance from the station to the point of measurement is calculated.

Figure 17: Depiction of soil consistency.

A test pit approximately 3 feet deep and about 1 foot in diameter was dug at the Quebrada Miña water storage tank. The soil at the bottom of the test pit was then analyzed by its composition and found to be sandy clay (Figure 17).

The flow rate of the existing spring was measured near the Calabazal spring box by Dr. David Watkins. By partially damming the source, Professor Watkins was able to channel the flow into one location. This concentrated flow could then be measured to get a flow rate of the spring. The process was similar to obtaining flow rates in Quebrada Miña. Professor Watkins concluded the flow rate of the eye of the migrated spring to be slightly greater than 10 gallons per minute (40 liters per minute).

Figure 18: ACC Surveying with Brunton Compass

The auto-level was used for measuring elevations starting at the spring box and following a transect line toward the storage tank and the school. Parts of the water lines were surveyed using a Brunton surveyor's compass (Figure 18). The compass measurements were taken along a transect line to the spring starting at a residence near the school. The investigator used the compass to sight the top of a bamboo rod cut to eye level and obtain the angle of elevation between two points. The lateral distance between the two points was measured with surveying tape. The change in elevation between the two points can be calculated from the trigonometric relationship between the angle of elevation and the lateral distance between the two points.

Upon locating any potential new springs, photographs of the spring and its geologic context were taken with care to provide a visual scale in each image. A sketch was also drawn to emphasize the geometry of the flowing water. Strike and dip were also measured, using the Brunton surveyor's compass, on bedrock surfaces in order to determine the orientation of the layers through which the groundwater was escaping, and in case any associated geological knowledge was needed to assess the groundwater spring.

Figure 19: Alternate Spring in Calabazal

4.1 Field Data Summary

The data obtained during personal interviews and flow rate measurements in Quebrada Miña are presented here. The topographic survey data from the Calabazal and Quebrada Miña water storage tanks are contained in Appendix B. The topographic survey data from the Calabazal water line are contained in Appendix B.

4.2 Personal Interviews

From the personal interviews that were conducted in Quebrada Miña, it was immediately apparent that the community as a whole was very happy with their water system. Every household within the community has a tap to the water system. None of the residents interviewed reported any bad taste or the presence of any visible contamination in the water supply. The community's overall satisfaction with their water catchment and distribution system was at least in part a result of the fact that it was so new. As a result of its novelty and the community's satisfaction, however, the initial questions about water satisfaction seemed too broad to community members and—as was previously mentioned—were revised.

The only problems or concerns the community reported about their water system were that the pressure was sometimes too high and that the water appeared cloudy. This was a result of numerous air bubbles being trapped in the water due to high velocity, and turbulent flow leaving the tap. The residents of Quebrada Miña thought that it was similar to soapy water, and were concerned about their water quality. The Water Committee and the current Peace Corps volunteer, however, have been working to convince the residents that they do not need to worry.

Few improvements to the water system were suggested by the community. Most of these were planned, personal enhancements of the respondent's household tap, such as building a bathtub or installing curtains for privacy. One resident, who was familiar with the concept of chlorination, as it was described to the community by a visiting MINSA official, said that he thought chlorination should be included in their water system. Another resident, however, indicated that he felt it was unnecessary.

From the answers to questions about pit latrines, it is clear that the most common concern about them in the community of Quebrada Miña is accessibility. Many residents in the community share a pit latrine with another household, commonly one in their extended family. Others, who do not have access to any pit latrine, recognized that they should have a latrine and expressed either a desire for one or a plan to install one in the near future. One household that had recently installed a pit latrine essentially lost their ability to use it during a landslide when the concrete slab became dislodged, threatening to fall into the pit. Another household that has a pit latrine was apparently waiting until they could get a zinc roof before using it. Yet another household had recently installed their own pit latrine without any encouragement or direction from the Peace Corps volunteer. From those that indicated a preference, three families favored the pit latrine design, and one family indicated they favored a composting latrine design. Though many families lacked pit latrines, not all of them were interviewed about their latrine preference or future plans, as the investigators did not want to embarrass a family by pressing the issue.

4.3 Flow Rate Measurements

Flow rates were measured at almost all faucets in Quebrada Miña. No controls on use at faucets other than the one being measured were employed. Flow rates were measured during the day from approximately 10:00 AM to 4:00 PM. The average flow rate measured in Quebrada Miña was 7.4 gal/min (0.016 ft^3/sec). The maximum flow rate measured was 9.5 gal/min (0.021 ft^3/sec), and the minimum was 3.4 gal/min (0.007 ft^3/sec). The lowest flow rate was measured at household numbers 17, 18, and 19, where the supply was provided by a damaged and leaking water line. Further flow rate measurements can be seen in Appendix C.

5.0 Project Development

From the personal interviews, ACC decided that there were two main needs in the communities, improved sanitation and water treatment. Both communities possess an adequate design for pit latrines that met their cultural and social expectations; however there is no system for water treatment in either community. The government agency, MINSA, encourages water treatment and those villagers aware of a water treatment have expressed interest in it. The need for treatment and desire for the system led ACC to design a water filtration system. In addition, ACC is providing an educational program within the operations and maintenance manual to help the community realize this is something that would improve their health. The age of the Calabazal water catchment and distribution system was also assessed and considered.

Julie Herrick indicated the system suffered from a low flow rate and sometimes complete lack of flow from the spring box during the dry season. The migrated spring directly contributes to the excessively low flows. ACC decided the best way to solve this problem was to construct a new spring box uphill from the existing one, to capture the migrated source. ACC also located another groundwater spring, which could be captured in the future if the community continues to expand. Julie Herrick indicated the new spring was flowing at a rate similar to that of the currently utilized spring before it was developed. In the future, this additional source could potentially double the amount of water the community receives.

5.1 Project Scope

Before much was known about the community, the team decided it would focus its efforts on either the enhancement of the existing water supply system. Since Calabazal and Quebrada Miña consider themselves to be two different communities and they each have their own water committee, the wants and needs of each were considered separately. Based on the answers from interviews that were conducted, ACC decided to incorporate chlorination in the existing system. The community spends time every year trying to manually remove the sediments that settle out of the water in the tank in order to address this problem; ACC decided it would be suitable to design a filtration system. After observing the current state of the Calabazal water system, the team also came to the conclusion that recommendations should be made for the rehabilitation of any pertinent or broken pipes. The last piece to be included within the project scope came from the observation of Peace Corps Volunteer, Julie Herrick, who had noticed that the spring had migrated, creating further contamination within the system in Calabazal. It was decided that a new spring box design would be created for catchment of water from the migrated spring source.

5.2 Considerations

Utilizing the understood constraints, ACC began researching potential solutions to treat the water. The options considered were sedimentation, drum filtration, modified media drum filtration, roughing filtration, slow sand filtration, biofiltration and rapid sand filtration. Sedimentation, which is the current situation, is the manual removal of sediment from the tank. A drum filter is a cylindrical-shaped container, which filters out sediments as they pass through a layer of sand. In a modified media drum filter, water passes through media such as carpentry nails. Sediments are removed in a roughing filter, which is rectangular in shape, by moving through a first chamber with a larger media all the way to a third chamber containing a finer media. Slow sand filtration is the removal of sediments through the formation of a biological layer which is suitable for the removal of particles from the influent water. A biofilter is composed of living materials, for instance plants, to degrade suspended solids. Finally, the option of rapid sand filtration was considered and is the recommended filter type. A rapid sand filter is a vertical system which requires water to flow through several layers of media and a porous material.

A decision matrix, which can be viewed in Table 1, was constructed to better analyze potential solutions. It weighted the potential options against the criteria. The criteria used for evaluation of the options were maintenance, constructability, costs, availability of materials, effectiveness of the design, hazards introduced, ease of use, implementation and cleaning, durability and social acceptance. Since most community members do not have a regular income, it was decided that the most important criteria were the operational costs and availability of materials as this would also help to cut costs. The next most important criteria were the maintenance, which ACC wanted to ensure would come at a minimal cost and would not be

Table 1: Decision Matrix

EVALUATION CRITERIA	WEIGHT	Slow Sand		Roughing		Drum		Modified Media Drum		Biofilter		Sedimentation	
Maintenance	**8**	2	**16**	3	**24**	3	**24**	2	**16**	4	**32**	1	**8**
Constructability									**0**				
Time to Build	**3**	4	**12**	4	**12**	5	**15**	5	**15**	1	**3**	4	**12**
Expertise Required	**7**	4	**28**	4	**28**	4	**28**	4	**28**	1	**7**	4	**28**
Costs									**0**				
Fixed Costs (Materials)	**7**	4	**28**	4	**28**	5	**35**	2	**14**	1	**7**	5	**35**
Operational Costs	**9**	3	**27**	5	**45**	5	**45**	2	**18**	4	**36**	5	**45**
Availability of Materials	**9**	4	**36**	4	**36**	4	**36**	2	**18**	2	**18**	4	**36**
Effectiveness									**0**				
Reduction of Bacteria	**4**	5	**20**	4	**16**	3	**12**	5	**20**	5	**20**	3	**12**
Reduction of Viruses	**4**	0	**0**	0	**0**	0	**0**	5	**20**	4	**16**	0	**0**
Reduction of Protozoans/Parasites	**5**	5	**25**	4	**20**	3	**15**	4	**20**	5	**25**	3	**15**
Reduction of Turbidity	**5**	5	**25**	4	**20**	4	**20**	4	**20**	5	**25**	4	**20**
Flow Rate Treated	**6**	2	**12**	4	**24**	4	**24**	3	**18**	3	**18**	3	**18**
Hazards Introduced	**6**	2	**12**	4	**24**	3	**18**	2	**12**	3	**18**	5	**30**
Ease									**0**				
Ease of Use	**7**	5	**35**	5	**35**	5	**35**	5	**35**	5	**35**	5	**35**
Ease of Implementation	**5**	3	**15**	3	**15**	4	**20**	4	**20**	1	**5**	5	**25**
Ease of Cleaning	**7**	4	**28**	4	**28**	3	**21**	2	**14**	5	**35**	2	**14**
Durability									**0**				
Life Expectancy	**6**	4	**24**	4	**24**	3	**18**	3	**18**	5	**30**	4	**24**
Number of Components	**5**	4	**20**	3	**15**	4	**20**	4	**20**	5	**25**	4	**20**
Social Acceptance	**8**	2	**16**	4	**32**	3	**24**	3	**24**	3	**24**	4	**32**
	[1-10]	[1-5]	**379**		**426**		**410**		**350**		**379**		**409**

required often and social acceptance, because ACC wanted the community to want to implement the design. Each option was also given a weight from one to five based on how well it met the expectations of the different criteria. The totals were calculated and it was found that a roughing filter was the best option. However, with advice given after the initial decision was made, it was decided that a better option would be the rapid sand filter. This option will be discussed in further detail in *Section 6.0, Recommended Solution*.

5.3 Sedimentation

Sedimentation was considered before any of the other options. Currently both communities are utilizing this method without classifying it as such. With the current system, water flows from each spring box down to a storage tank where the water then flows to the system taps. In Calabazal's older system, more sedimentation occurs in comparison to the new system in Quebrada Miña. Annually, the residents of Calabazal have had to shovel out the sediment collected within the storage tank. Thus, sedimentation is a practice already implemented. For this reason, sedimentation was rejected as a solution for both communities. The use of sedimentation as a filter would likely be socially unacceptable as it does not improve upon the current system by much.

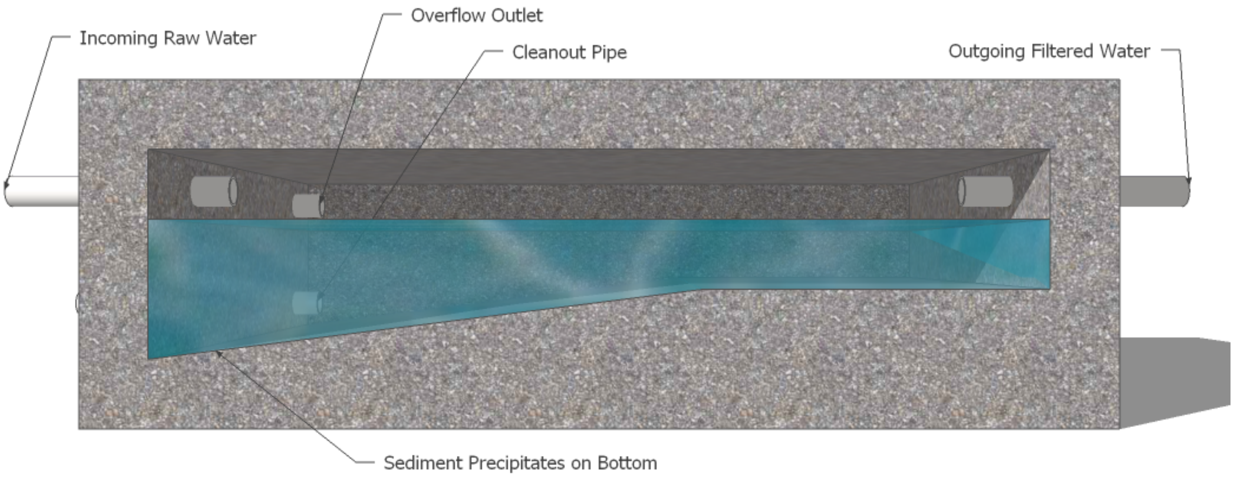

Figure 20: Example of a Sedimentation Filter

5.4 Drum Filtration

A drum filter is a water filtration system usually made from a container such as an oil drum, or similar cylindrical-shaped object. Sand is used as the filtration media. This media filters out most harmful bacteria and protozoa as water flows through it. The drum filter is very effective, with a removal rate upwards of 95% of bacteria and protozoa. It is only minimally effective at removing viruses, however (Sobsey, 2009). It is simply constructed by filling a drum two-thirds full with sand and making the appropriate pipe connections. The pipe connections need to allow for both regular flow and reverse flow so as to enable backwashing and cleaning the filter. Backwashing expands the volume of the filtration media, suspending the individual filtration particles (in this case sand grains) in the water. The lighter contaminants, now freed from the pore space of the media, are then carried away by the flowing water. This is done approximately once a month (depending on turbidity of the water) to maintain appropriate flow rates and to ensure pathogen filtration can be achieved. Failing to backwash would lead to slower flow rates and potential failure of the filtration system.

Additional media can be added to a drum filter to improve the removal of viruses. This "modified" medium is usually metal and can be as simple as carpentry nails. These materials filter viruses (among other pathogens of similar size) from raw water by electrostatic attraction. Modified media improve virus removal to 90% effectiveness but need to be replaced often to ensure efficacy (Sobsey, 2009). This modified medium would need to be occasionally removed from the filter and replaced. This is done to eliminate the risk of rust residue in the system. Modified media, while helpful, greatly increases the maintenance of the drum filter.

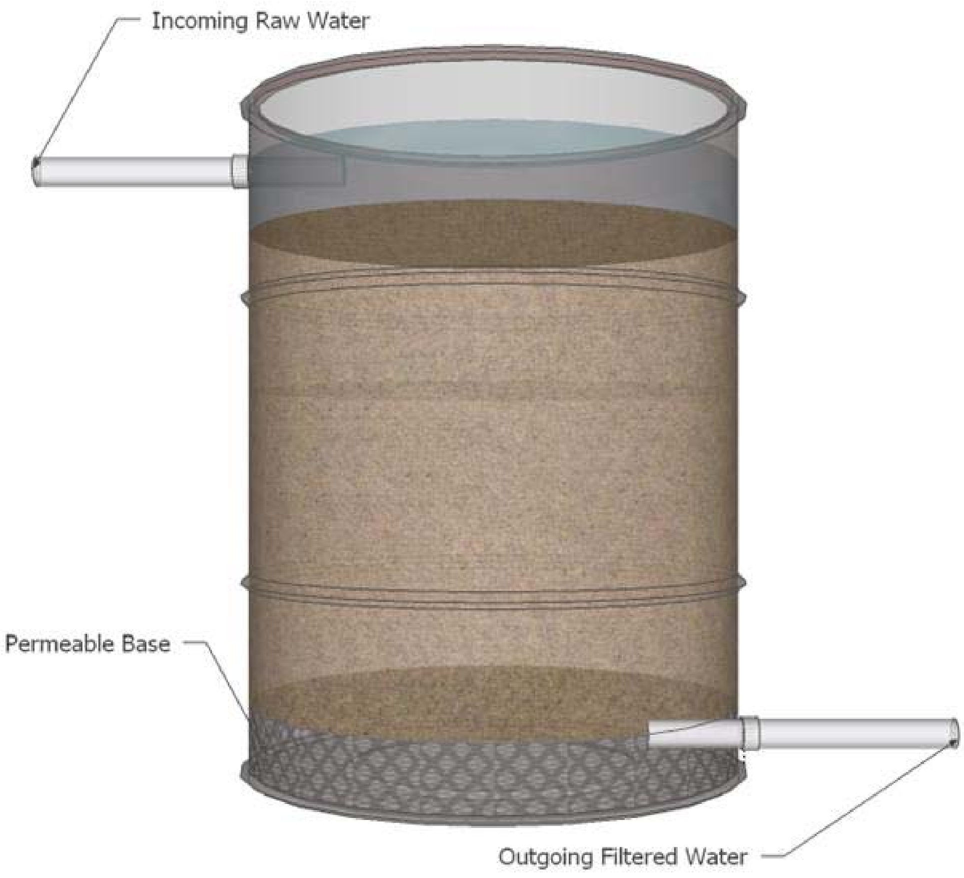

Figure 21: Example of a Drum Filter

5.5 Roughing Filtration

Roughing filtration consists of a three-chamber system encased in a concrete or ferrocement structure. The system utilizes multiple sizes of media and allows water to flow from coarser to finer media. One of the greatest benefits of using granular media and concrete/ferrocement to construct the entire system is the availability of these materials locally. Using local materials significantly helps to cut costs, which has been ranked as one of the most important factors in choosing what filtration system to build. Another benefit of the roughing filter is the ease of maintenance. All that is required on a regular basis for maintenance is backwashing, which involves reversing the flow to unclog material that has been filtered out of the water. This also helps reduce the cost of the system since backwashing is a free process and it increases the longevity of the system by keeping the media in better condition and reducing the need for replacement. Any other upkeep would address overall wear of the system, such as the structure's integrity and the eventual need to replace the used media. Overall the system is fairly simple which leaves a minimal need for engineering expertise. Maintaining the system allows the system to run optimally in order to remove as much as 90-99% of indicator bacteria (Sobsey, 2002).

Despite all of this, the roughing filter was not the best option as it is a large system which requires three times as much concrete and area to construct as the best option. All of this would increase the amount of time needed for construction and the cost of materials.

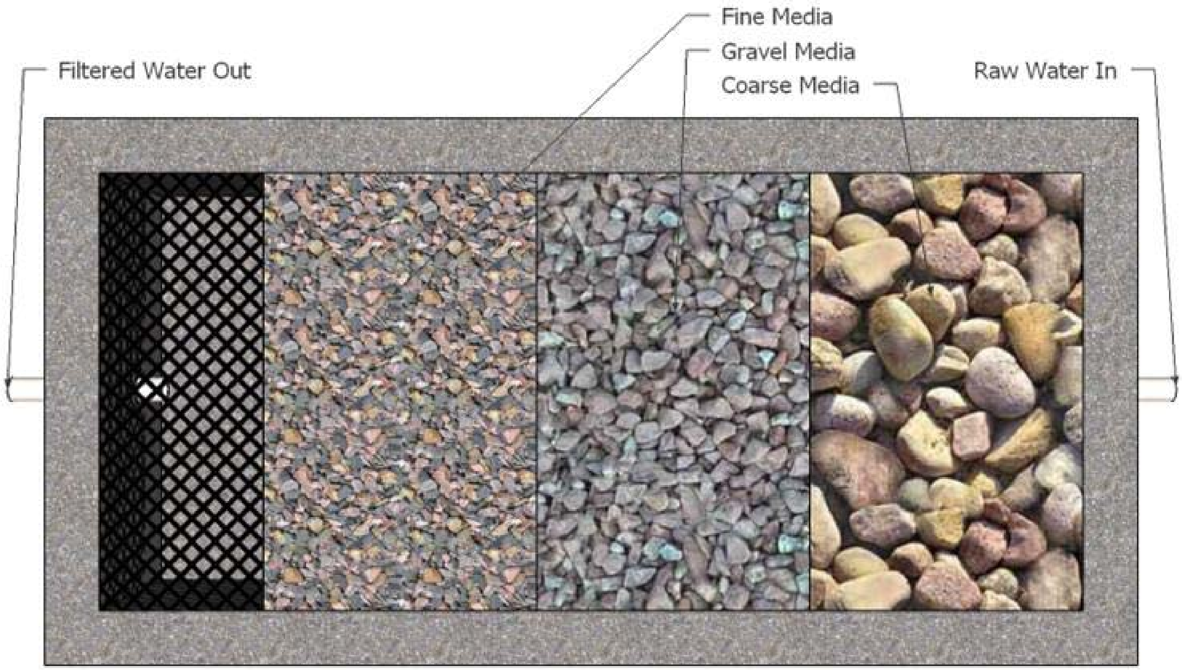

Figure 22: Example of a Roughing Filter

5.6 Slow Sand Filtration

Another method of filtration considered was slow sand filtration. The way a slow sand filter works is by creating a biological layer known as the schmutzdecke which is used to treat raw water. Water is slowly added over the top of a tank of fine sand until the schmutzdecke forms naturally. After 2-3 days, the schmutzdecke is ready to treat water. Once established, the filter removes 90-99% of bacteria and particulates in the water (Huismans, 1974). The problem with a sand filter is that the top few inches of schmutzdecke must be scraped away and replaced every few months. The fresh replaced sand is an additional cost beyond construction, which is one reason it is not feasible for Quebrada Miña and Calabazal. Another disadvantage of slow sand filtration is the typically low flow rates, between 0.1 and 0.4 cubic meters per hour. In order to treat the volume of water coming into either system, the slow sand filter would have to be significantly larger than other available filtration methods. A slow sand filter would have to be at least ten times as large as the chosen design to achieve the necessary flow rate. Lastly, slow sand filtration requires some level of skill to operate. The Ngäbe technician has to be familiar with the system in order to properly assess when the schmutzdecke has formed, when to replace the schmutzdecke, and how to handle algal blooms which may form and reduce the effectiveness of the system.

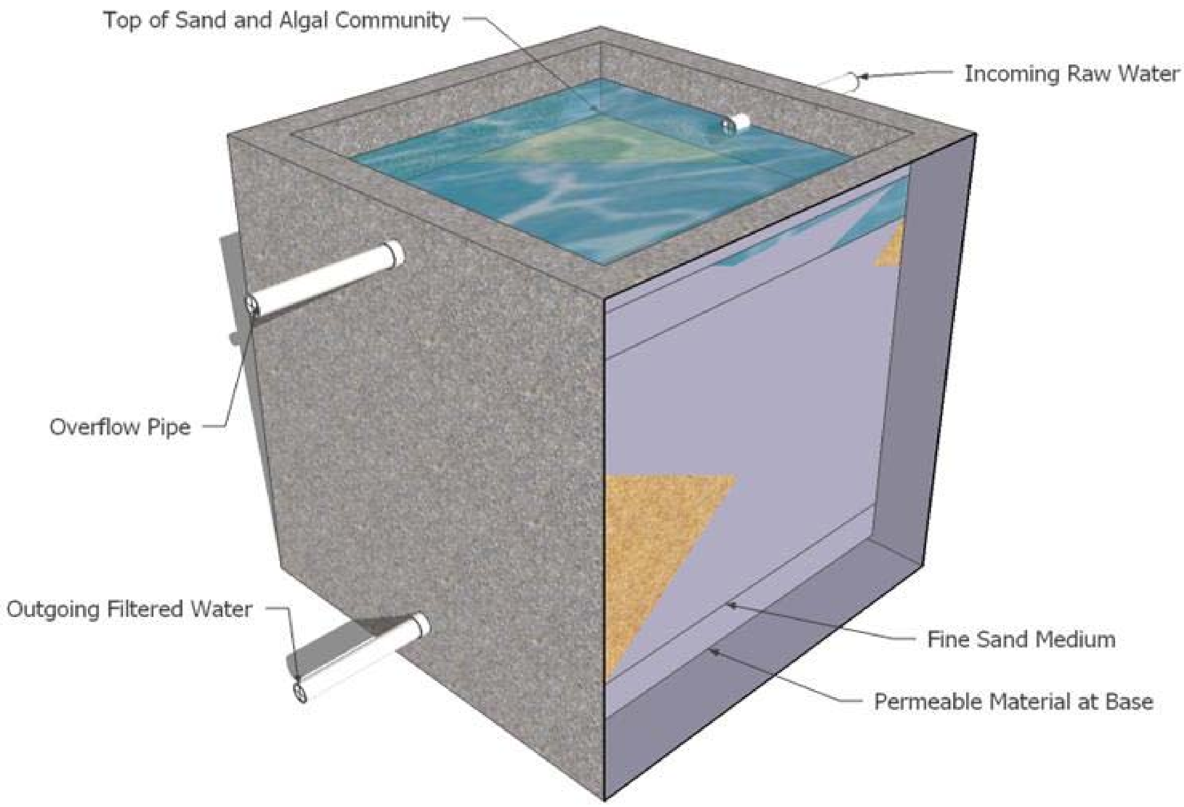

Figure 23: Example of a Slow Sand Filter

5.7 Biofiltration

The concept of biofiltration is rooted in the decomposition of biogenic material through natural processes. From this perspective, even the slow sand filter, which contains an intentional algae community helpful in removing pathogens, is a type of biofilter. The specific type of biofilter considered by ACC is generally constructed on a much larger scale. It consists of a bed of medium-grained (0.5-15 mm) volcanic rock sown with marsh plants and bounded by coarse gravel material. As water flows through and across this bed, it seeps into the subsurface and is treated by aerobic bacteria that aid in the decomposition of organic matter. The subsoil is kept sufficiently oxygenated by the plants' roots, which deliver oxygen from the atmosphere, thus supporting a large community of helpful bacteria. After appropriate residence time, the water can be siphoned through the gravel filtration margin and brought to the community.

The chief advantage of this biological filter is apparent over the long term: the system has a very long life expectancy; it requires no operational costs and almost no maintenance. The system requires no energy input and for obvious reasons can be implemented easily in rural areas. An additional benefit of the filter is that it produces vegetable dry mass (about 50 to 70 tons of hay per hectare year). However, the system has an enormous start-up cost and requires a large amount of arable land (5 square meters per community member). The system also demands that the input spring water be free of suspended solids and as such would require a pre-filtration stage.

6.0 Recommended Solution

ACC had begun to design a horizontal roughing filter, until it learned of a rapid flow sand filter. Clearly, this was the best choice because the smaller filter is cost effective, as it is one-third the size of the roughing filter and has the same rates of removal. Rapid sand filtration is a form of pretreatment that removes particulate from water, making pathogen removal easier. The new rapid sand filter would still require chlorination in order to fully remove any harmful pathogens from the water. From this need and evaluation of the current system, the idea of batch chlorination was born (Dr. David Hand, personal communication).

6.1 Rapid Sand Filtration

After a thorough analysis, the rapid sand filtration system was determined to be the most cost effective and efficient for the community and their available materials. Rapid sand filtration is the process of physically removing particulate matter from water by passing it through a column of coarse-grained sand (1-2 mm), under the force of gravity. In the chosen design, water will travel from the source into the top of the filter. The water will percolate through the media, as sediment becomes trapped in the sand. Cleaner water is then discharged from the base of the filter where it will travel to the existing storage tank.

Maintenance involves backwashing. Once the filter becomes clogged, the flow will be reversed from the top of the filter into the base through a series of PVC pipes. The diverted flow will force upwards through the media and suspend the sand in the flow stream. A throttling ball valve will be included prevent too much pressure from washing out the media. The backwashed water will spill into the overflow channel where it is wasted, along with the lighter than sand particulates that were trapped in the filter.

After the water runs clear from the filter, flow is returned to normal, entering from the top of the filter. The initial effluent from the box will have to be wasted, since the filter is washed with raw water. Once clean water is again passing though the filter, it can again be sent to the storage tank.

7.0 Design Components

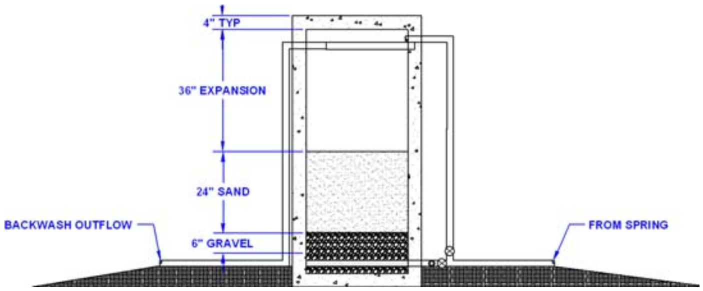

Figure 24: Rapid Sand Filter Side View

ACC's rapid sand filter design will be an 80-inch tall concrete structure that is 38 inches in both width and length. The structure consists of a 6 inch permeable material at the base to keep the filter media from flowing out into the storage tank. This material is than followed by 6 inches of gravel that has a similar purpose as the permeable base below. There is than a 24 inch layer of sand that is responsible for filtering out the pathogens in the system. This sand layer will have a pore size of 0.155mm that will produce a design flow rate of 10gpm. Above the sand is a 12 inch area for sand expansion and an additional 20 inches until the cleanout troughs. These troughs are responsible for the system cleaning during the backwash stage.

To promote better understanding of the system components and how to maintain them, ACC compiled an operations and maintenance manual (O&M manual) (Appendix D). It explicitly describes how to clean the filter, operate the chlorination system, and repair any potential breaks in the system. Supplementary optional system additions are discussed within the manual. All aspects of the design are thoroughly explained for a comprehensive understanding of the system.

7.1 Chlorination System

Chlorination is quickly becoming known for treating water in the region. ACC is anticipating that the communities will desire to implement this. Chlorination can be used in a few different ways. The most common method of use is "shock" chlorination, which is an infrequent treatment; essentially "shocks" a well or a storage tank to reduce any bacterial growth. This involves administering a large amount of chlorine to kill all forms of life inside the tank. Another method is continuous discharge chlorination which requires automation to consistently emit a very small dosage to the system. The last viable option is batch chlorination, which treats a large quantity of water for consumption as it is needed. Variations of these treatment methods are also available.

After weighing the pros and cons of each method, ACC has decided to pursue the batch chlorination option. ACC plans to adapt the existing cleanout valves to measure the volume in the storage tanks with a piezometer attachment. The piezometer will have graduations on it that will correspond to a container with proportional graduations. Details of this upgrade can be found in the Table 3 and 4 (below). When the tank needs chlorinated, the piezometer will be read and the smaller graduated container is filled with common household bleach (1-10% chlorine) to the same level as the piezometer. The chlorine is then added to the tank via a cap installed next to the filter so it can mix inside the tank. After adequate contact time (30 minutes) has been reached, the tank is reopened to the system where it will provide clean water to the community.

Table 2: EPA recommended Chlorination dosages (EPA, 2006)

Available Chlorine	Drops per Quart/Gallon of Clear Water	Drops per Liter of Clear Water
1%	10 per Quart - 40 per Gallon	10 per Liter
4-6%	2 per Quart - 8 per Gallon (1/8 teaspoon)	2 per Liter
7-10%	1 per Quart - 4 per Gallon	1 per Liter

Table 3: Calabazal Sample Dosage Sheet

Allow 30 minutes of contact time		Piezometer Mark Drops Needed									
Chlorine Percent	Drops/Gallon	1	2	3	4	5	6	7	8	9	10
1%	40	24,000	48,000	72,000	96,000	120,000	144,000	168,000	192,000	216,000	240,000
4-6%	8	4,800	9,600	14,400	19,200	24,000	28,800	33,600	38,400	43,200	48,000
7-10%	4	2,400	4,800	7,200	9,600	12,000	14,400	16,800	19,200	21,600	24,000
Tank Size	4600	Gal									
1.71322E-05	drops/Gallon	Piezometer Mark Gallons Needed									
		1	2	3	4	5	6	7	8	9	10
		0.411	0.822	1.234	1.645	2.056	2.467	2.878	3.289	3.701	4.112
		0.082	0.164	0.247	0.329	0.411	0.493	0.576	0.658	0.740	0.822
		0.041	0.082	0.123	0.164	0.206	0.247	0.288	0.329	0.370	0.411

Table 4: Quebrada Miña Sample Dosage Sheet

Allow 30 minutes of contact time		Piezometer Mark Drops Needed									
Chlorine Percent	Drops/Gallon	1	2	3	4	5	6	7	8	9	10
1%	40	12,000	24,000	36,000	48,000	60,000	72,000	84,000	96,000	108,000	120,000
4-6%	8	2,400	4,800	7,200	9,600	12,000	14,400	16,800	19,200	21,600	24,000
7-10%	4	1,200	2,400	3,600	4,800	6,000	7,200	8,400	9,600	10,800	12,000
Tank Size	3000	Gal									
1.71322E-05	drops/gallon	Piezometer Mark Gallons Needed									
		1	2	3	4	5	6	7	8	9	10
		0.206	0.411	0.617	0.822	1.028	1.234	1.439	1.645	1.850	2.056
		0.041	0.082	0.123	0.164	0.206	0.247	0.288	0.329	0.370	0.411
		0.021	0.041	0.062	0.082	0.103	0.123	0.144	0.164	0.185	0.206

7.2 Pipe System Rehabilitation

Pipe replacement for existing pipelines is also suggested for Calabazal Ideally, the community would update the entire system, and so specifications are suggested for sizing of pipes throughout the system. ACC, however, realizes that specific sizes may be unrealistic given that the available materials might vary tremendously. Thus, a range of sizes will be suggested for each line. If available, SDR 21 CL 200 pipe should be used for construction.

Table 5: Available pipe sizes

Type of Pipe	Outside Diameter, OD	Inner Diameter (in)	Wall Diameter (in)	PSI
1/2"	.840 (~7/8", 21.336mm)	0.716	0.062	200
3/4"	1.050 (~1", 26.670mm)	0.93	0.06	200
1"	1.315 (~1-5/16", 33.401mm)	1.189	0.063	200
1-1/4"	1.660 (~1-5/8", 42.164mm)	1.502	0.079	200
1-1/2"	1.900 (~1-7/8", 48.260mm)	1.72	0.09	200
2"	2.375 (~2-3/8", 60.325mm)	2.149	0.113	200
2-1/2"	2.875 (~2-7/8", 73.025mm)	2.601	0.137	200
3"	3.500 (3-1/2", 88.900mm)	3.166	0.167	200
4"	4.500 (4-1/2", 114.300mm)	4.072	0.214	200
5"	5.563 (~5-1/2", 141.300mm)	--	--	--
6"	6.625 (~6-5/8", 168.275mm)	5.993	0.316	200
8"	8.625 (~8-5/8", 219.075mm)	7.74	0.41	200
10"	10.750 (10-3/4", 273.050mm)	9.65	0.511	200
12"	12.750 (12-3/4", 323.850mm)	11.45	0.606	200

7.3 Spring box

The final component recommended for addition to the system is capture of additional spring flow for Calabazal's aging system. ACC has designed an appropriate spring box to capture the migrated spring in Calabazal, and an additional option is to add a second spring to the system to increase flow rates. ACC will make a recommendation about how much work and materials will need to be supplied if this is an option the community chooses to undertake.

Additionally, guidelines for best management practices around the spring box are outlined to reduce risk of contaminants entering the system. Contamination sources such as animals, farming, and foot traffic are discussed (Appendix D).

8.0 Construction

Construction guidelines will be given, including necessary materials and their costs. Julie Herrick generously provided a list of materials and their costs that were utilized in the construction of the Quebrada Miña water system (Appendix E). ACC will utilize this to estimate costs for the rapid sand filtration and to aid in composing a task schedule for construction. Additionally, within the operations and maintenance manual and cost estimate there will be instructions explaining how much of specific supplies are necessary for the construction (Appendix D).

The first step of the project will be to gain funding for the project. Peace Corps Volunteer, Kevin, will submit the project for funding and hopefully obtain it in a short period of time, but it is hard to determine the amount of time that it will take for a project to receive funding. As soon as funding is ensured, the tools and materials can be ordered for the project. It will take about a month for materials and tools to be delivered to the community as some of the items are not locally accessible. Once this is received, construction may begin, following the schedule described in more detail on the Gantt chart in Appendix G. The maximum total time for construction will be about seven and a half months, with an additional year for acquiring funding. In Table 6, the construction schedule is summarized.

Table 6: Construction Task List

Task	Duration (Maximum Time to Complete)
Acquire funding	1 year
Acquisition of materials and tools	1 month
Construction of spring box	2 months
Construction of rapid sand filter	3 months
Rehabilitation of any pertinent or broken pipes	1 ½ months
Total time needed for construction of project	7 ½ months (plus a year to receive funding)

9.0 Cost Estimate

The total cost of the project was estimated based on the materials and tools that will be needed for construction. Costs for each the tools, transportation and supplies for the pipe rehabilitation, chlorination, the spring box and the rapid sand filter are shown in the table below. All of the construction can be done by community members, as they are well-versed in work with concrete and other materials that will be used for the project; therefore there is no cost added for labor.

Table 7: General Cost Estimate

Component	Cost
Spring Box	$300
Rapid Sand Filter (2)	$800
Pipe Rehabilitation	$100
Tools	$600
Transportation	$200
Chlorination	$100
Total	$2100

After the estimate total was calculated, a fifteen percent contingency was added to the total to yield a total of about $2400.

10.0 Final Recommendations

For the communities of Calabazal and Quebrada Miña, ACC would like to recommend the addition of a rapid sand filtration system with supplementary components of chlorination and an additional spring box, if desired. The added spring box—with its open side—will capture water from the migrated spring, preventing surface waters or debris from entering the line by virtue of the pre-filtration gravel media it contains.

The rapid sand filter will achieve flow rates of 10 gal/min and will insure that any turbidity introduced by surface waters or other processes will not fill the storage tank or reach the faucets of community members. The process of backwashing the filter is simple and effect at maintaining the life of the filter and insuring its efficacy by removing clogged particles.

Both communities significantly lack any form of treatment which results in a variety of health issues apparent in the residents. The option to chlorinate their water will give the residents of these communities a chance to improve their water quality and, consequently, their health conditions. In addition, the system in Calabazal is in major disrepair and will benefit greatly from our proposed maintenance plan.

The proposed design was weighted against a variety of options and found to be the most cost-efficient and effective for the area. With the total cost at a mere $2400, the design has a high chance of being implemented by the Peace Corps with discretionary funding. As community members are already knowledgeable in working with reinforced concrete, the entire design can be completed with the help of volunteer labor and will require about 7½ months.

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Index of Appendices

Appendix A: Community Interview Results and Household Data

Appendix A

Household: 3

1) "It's good; it's new." He is happy the water system is in place.
2) No problems reported.
3) Resident wishes to build a bath with a rooftop around his tap.
4) He wants to change the location of his pit latrine because it is too close to the road and already full from regular use. He wants a composting latrine.

Household: 2

1) Sometimes the water pressure is very high, other times it is very low. When it's high, the water appears white, and the family thinks they are similar to soap bubbles.
2) MINSA talked to this family about chlorination; the family thinks it is necessary.
3) The family wouldn't change anything about their water system.
4) The family currently uses the same latrine as Household 1. They want their own latrine so they don't have to walk so far, sometimes getting wet in the rain.
5) Resident would like a concrete slab for appearances' sake.

Household: 4

1) "It's good."
2) Resident is also concerned about the whitening of the water (due to trapped air bubbles).
3) The whitening 'creeps them out' as Peace Corps volunteer Julie Herrick, who was translating, put it.

An extended family member indicated at this point in the questioning that he was curious about why the investigators were asking questions about the water supply if they had no plans to change anything about it—to work on a project similar to the Peace Corps volunteer. This man was the Secretary of the Water Committee, and his concern was the reason the questions were revised to be more specific. His testimony is included in his own household's interview.

4) This family uses the same latrine as household 4 (the next household interviewed after the Secretary's testimony).
5) They would like their own latrine, as household 4 is far from them.

Household: 5 (Water Committee President)

1) The water is always clean.
2) The water has no bad taste.
3) Salvador has no changes in mind for the water system.
4) and 5) should be considered the same as residents of household 6,7 answers as they share the latrine; residents of household 6,7 and of household 5 emphasized that at this point because the investigators had just asked the same questions of resident of household 6,7.

At this household the tap is damaged because the children have been playing with it. The damage causes the tap to leak a small amount of water when the valve is fully closed.

Household: 6,7 (Water Committee Secretary)

1) Resident is happy with "the [water] velocity, the [water] pressure" and its quality. He said it is "crystalina" clear. He knows that when it flows white ("flowing like milk") that it is safe to drink and explains to community members, "It's only white."
2) He is concerned about the water supply during the dry season.
3) Resident thinks chlorination is not needed.

4) This family uses the same latrine as their households 4 and 5, except the immediate families of Households 1 and 2 who share another latrine (which is full).

Household: 8

1) The color is clear; there is no trash.
2) The taste is fine.
3) The family has no suggestions of what to change. The father likes that the children do not have to go to the stream to get water anymore—now they are no longer late for school. He also thinks it is good that the children can reach the tap.
4) This family uses the same latrine as household 4 since theirs is filled up; the father says they don't mind the walk.
5) The family plans to build a new latrine of pit construction.

Household: 9

1) There is no trash "yet" in the water; the family member interviewed specified "yet" indicating an awareness that the water quality may change.
2) There is no bad taste.
3) The family has no suggestions.
4) and 5) the family does not have a latrine but the head of the household has an idea of where to build one in the future.

Appendix A

Household: 10

1) The water is clean and there is no trash.

2) The water tastes fine.

3) There are no suggestions.

4) The family does not have a latrine.

5) The family would prefer a pit latrine to a composting latrine.

Household: 12

1) and 2) The water is flowing clean; there is no trash, no bad smell, no bad color, and no leaves.

3) The family already added rocks for foot stability around the tap.

4) and 5) The family had a pit latrine but a landslide widened the pit and now the concrete slab is in danger of falling into the pit.

Household: 13

1) The water is clean; there is no trash.

2) There is no bad taste.

3) The family is happy with the way the water is delivered now; before the system was installed they had to go downhill to a stream and carry the water back up.

4) The family has no pit latrine.

Appendix A

Household: 14

1) The family has seen no trash or dirt.
2) They say the water "tastes like water."
3) They have already installed curtains for privacy when showering.
4) The family has no pit latrine.

Household: 15,16

This family was gifted a house of concrete construction by the government. As a result, they have had a concrete basin attached to the outside of their house. When the water system was installed, their tap was modified to eject water into the basin.

1) The water is good and clean.
2) There is no bad taste.
3) The family is happy with their concrete basin.
4) The family has a pit latrine but is waiting for zinc (ceiling) before putting up walls around it and using it.

Household: 17, 18, 19

1) The water is clean and they've seen no trash.
2) No bad taste or smell.
3) She would like a new tap because hers leaks.

****Note** Not all households were surveyed due to lack of time.**

Appendix A

Quebrada Miña Data						
#	GPS Coordinates (n° n.n N n° n.n W)	Number of People	Elevation	Number of Taps	Number of Latrines	Notes
1	8° 16.836N 81°48.818 W	6	143 m	1	1	A sister has a pluma but no water in the summer they collect in a river during the summer
2	8° 16.836N 81°48.765 W	11	137 m	1	0	
3	8° 16.831N 81°48.755 W	4	141 m	1	1	
4	8° 16.841N 81°48.728 W	6	147 m	1	0	
5	8° 16.834N 81°48.742 W	4	141 m	1	1	They take water from the river, there's a a pit latrine somewhere nearby, she wants a latrine
6,7	8° 16.809N 81°48.715 W	17	128 m	1	1	
8	8° 16.827N 81°48.700 W	6	143 m	1	0	
9	8° 16.877N 81°48.661 W	5	159 m	1	1	Has a waterline
10	8° 16.989N 81°48.569 W	8	167 m	1	0	
11	8° 16.970N 81°48.540 W	10	173 m	1	1	
12	8° 16.979N 81°48.502 W	2	186 m	1	0*	Water is from two places: the nearby river in the winter and the ojo(start of spring) are considered for primary source in summer *=share gilberts latrine
13	8° 16.949N 81°48.546 W	6	179 m	1	0	Takes water from below but is optimistic about water because he doesn't have money
14	8° 16.926N 81°48.571 W	5	170 m	1	0	
15,16	8° 16.861N 81°48.539 W	4	128 m	1	0	Water from river
#	GPS Coordinates (n° n.n N n° n.n W)	Number of People	Elevation	Number of Taps	Number of Latrines	Notes

Appendix A

#	GPS Coordinates (n° n.n N n° n.n W)	Number of People	Elevation	Number of Taps	Number of Latrines	Notes
17, 18, 19	8° 16.837N 81°48.567 W	6,5,2	176 m	1	0	No latrines, water close duringn winter in a nearby pozo but they have to walk up higher in winter
20	8° 16.953N 81°49.009 W	4	103 m	1	0	Pit latrine with no cover, has a wooden slab water goes dry in the summer. Has deep well that needs a top. Good water.
Calabazal Data						
21	8° 16.938N 81°48.999 W	2	103 m	1	1	Brand new latrine--a pit with wood slab and roof will also try keeping and a cover on it. Water goes dry in the summer
22	8° 16.889N 81°49.018 W	8	127 m	0	1	Water comes from stream(west) or head of spring (south)
23	8° 16.882N 81°49.029 W	9	120 m	0*	1	Water is from stream/spring *some time shares
24	8° 16.915N 81°49.058 W	13	109 m	1	1	Has a tap but uses a hand dug pit in summer latrine is a good distance from Quebrada Miña, another tap
25	8° 16.906N 81°49.031 W	12	102 m	1	1	A hand dug pit is used in the summer; latrine is close to the house.
26	8° 16.911N 81°49.046 W	3	102 m	1	1	Broken Tap, bad latrine
27	8° 16.931N 81°49.033 W	8	95 m	0	0	
28	8° 16.932N 81°49.041 W	4	99 m	1	0	Vaccant house w/ tap
29	8° 16.922N 81°49.041 W	11	103 m	1	0	Good tap here
30	8° 16.898N 81°49.069 W	5	58 m	1	0	Broken tap
31	8° 16.902N 81°49.081 W	8	71 m	1	0	Tap is broken
32	8° 16.873N 81°49.085 W	4	67 m	0	0	Possible tap isn't needed since there is a permanent spring in Quebrada Miña behind the house

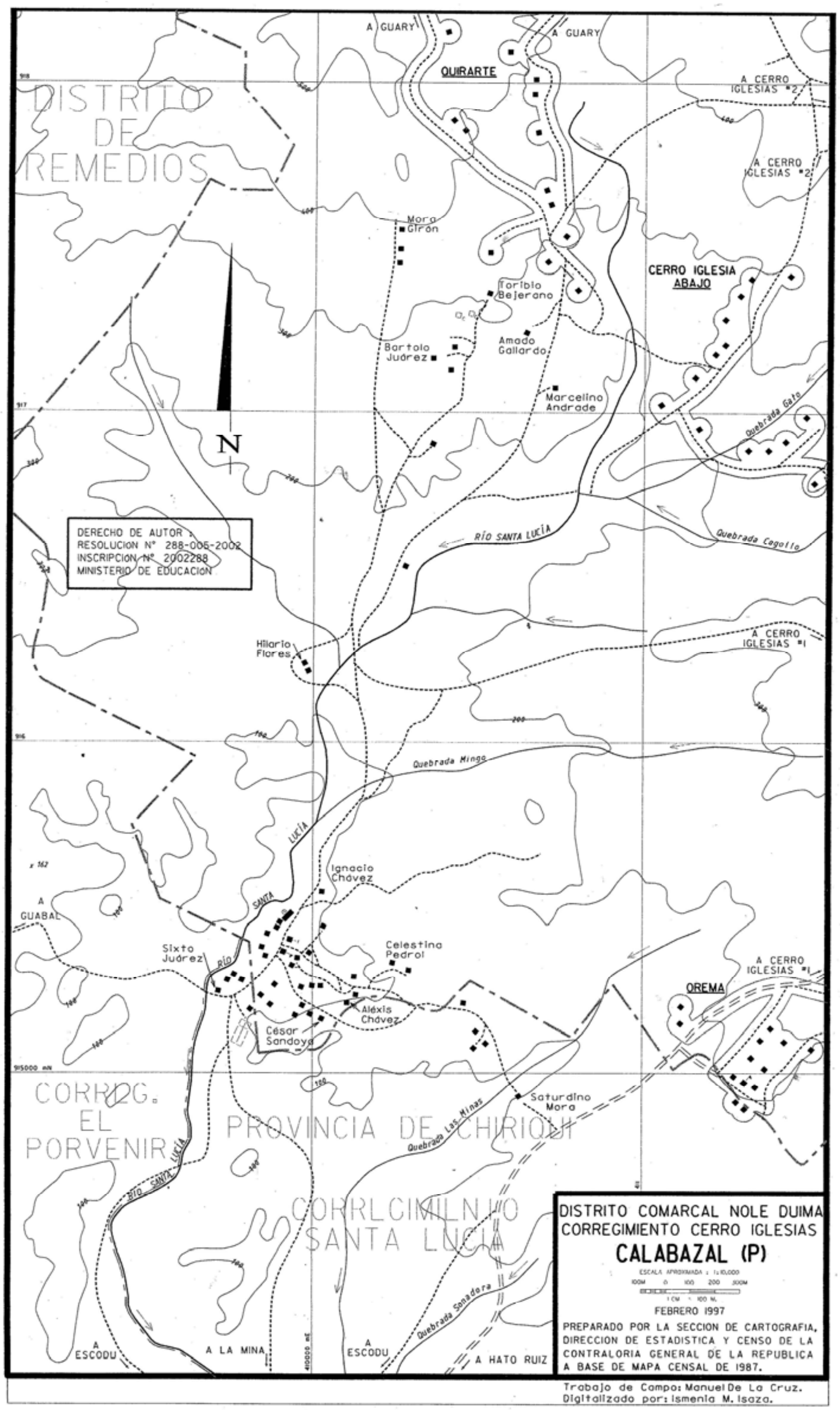
Appendix A

33	8° 16.882N 81°49.135 W	12	90 m	0	2	The road to Escodu passes here and the family runs a small store. Have interest in "private" water supply to sell water to travelers. Take water from hand dug wells.
34,35,36	8° 16.929N 81°49.135 W	3,3,5	143 m	1	1	One latrine and one tap for the three houses in the summer they need to walk to the hand dug pits
37	8° 16.935N 81°49.139 W	15	95 m	1	1	Tap has a broken top, no tap, in the summer they walk to the hand dug pit for water
38	8° 16.974N 81°49.136 W	7	85 m	0	0	House closest to the river might share latrines and tap- share composting latrine with orlando chavez
39	8° 16.968N 81°49.126 W	8	85 m	0	1	latrine is only two rocks to sit on, drains down to river
40	8° 16.976N 81°49.118 W	8	89 m	1	1	
41	8° 16.964N 81°49.108 W	7	92 m	0	1	
42	8° 16.948N 81°49.083 W	3	90 m	1	0	Tap leaks, no service now, plot in mind already, gets water from hand dug pit near store but isn't enough
43	8° 16.939N 81°49.083 W	4	91 m	0	1	shared a tap with neighbors
44,45	8° 16.944N 81°49.081 W	3,7	92 m	1	0	shares pluma/tap also, summer they suse hand dug pits no latrine for area
46	8° 17.006N 81°49.073 W	6	93 m	1	1	2 stopped up taps here. Might be two houses one tap works has a small amount of water in summer so they use hand dug pits
47	8° 16.998N 81°49.073 W	6	97 m	1	1	Broken tap top, metal tap attached to PVC with leaks
48	8° 17.046N 81°49.119 W	6	97 m	0	0	Well nearby with water year round
49,50,51	8° 17.034N 81°49.125 W	5	95 m	0	0	
52	near clinic			0	0	
53	near clinic			0	0	
54	8° 17.044N 81°49.026 W	7	99 m	1	0	Water all year round b/c they are just before tank
#	GPS Coordinates (n° n.n N n° n.n W)	Number of People	Elevation	Number of Taps	Number of Latrines	Notes

55	8° 17.208N 81°48.902W	12	112 m	1	1	
56	8° 17.007N 81°49.024 W	12	122 m	0	0	House on hill above water tank-no line but have semi regular water (tough in summer) older latrine-planning to dig new one
57	8° 16.997N 81°49.009 W	9	121 m	0	1	Latrine shared-take water directly from tank
58	8° 16.967N 81°49.012 W	7	110 m	1	0	
59	8° 16.952N 81°48.848 W	3	163 m	0	0	Spring nearby with two strong flows
60	8° 16.963N 81°48.876 W	6	150 m	0	0	Share spring
61	8° 16.942N 81°48.909 W	7	134 m	0	0	
62	N/A	4				

Appendix E

This map shows the distribution of houses within the community of Calabazal.
Each black square represents a home.



Appendix B: Surveying Data

Appendix B

Quebrada Miña Storage Tank		
HI	104.39	
Azimuth	Height (ft)	Distance (ft)
342	103.47	30
355	103.28	23
12	104.2	18
42	104.14	12
76	103.1	13
88	103.25	16
112	101.04	23
130	96.13	49
139	96.94	36
154	96.78	22
185	96.35	23
199	96.38	15
204	96.29	18
199	94.71	33
190	94.95	34
208	94.61	32
175	96.17	28
190	95.97	22
250	91.29	30
233	90.59	35
272	94.69	25
301	98.77	29
344	103.95	30
123	98.96	37

	Calabazal Storage Tank		
	HI	104.8	
	Azimuth	Height (ft)	Distance (ft)
	268	98.28	17
	208	103.68	11
	222	101.2	30
	232	99.31	33
	237	98.04	33
	250	96.84	30
FS	233	101.6	14
	HI	107.06	
BS	16	101.6	8
	194	101.15	8
	199	100.1	21
	227	96.38	22
	47	97.86	24

Appendix B

BRUNTON COMPASS						
START	END	GPS ID	ANGLE	DISTANCE (ft)	NOTES	ELEVATION DIFFERENCE (ft)
1	2	72	6	101	Elieser´s	11
2	3	71	5	92	Road towards school	8
3	4	70	-1	92	Towards school	-2
4	5	69	9	100	Top of hill	16
5	6	68	1	100	Base of hill	2
6	7	64	0	100	Soccer field	0
7	8	65	2	100	Closer to school	3
8	9*	66	2	83	At school	3
6	9	67	5	100	Soccer field to path	9
9	10	63	4	100	Start of path	7
10	11	62	5	100	By telephone tower	9
11	12	60	2	100	Next to fence	3
11	Tank	61	21	90	Tank (SW Corner)	35
12	13	59	4	60	Across stream	4
13	14	58	0	100	Along path	0
14	15	57	4	94	By cutoff to farm	7
15	16	56	5	100	On fence	9
16	17	55	5	100	Along path	9
17	18	54	3	100	Along path	5
18	19	53	5	100	By entrance to farm	9
19	20	52	1	100	Just after farm	2
20	21	51	2	100	Along path	3
21	22	50	5	82	By gate	7
22	23	49	4	100	Just after fence	7
23	24	48	3	95	At Y in road	5
24	25	47	6	100	Just after Y	11
25	26	46	4	100	Before fence	6
26	27	45	4	48	Fence	3

Appendix B

AUTO LEVEL									
START	END	GPS ID	DISTANCE (ft)	NOTES	ELEVATION DIFFERENCE (ft)				
						HI	MID	LOW	SHOT DISTANCE FROM INSTRUMENT
27		44		FS		10.34	**10.05**	9.75	59
	28	43	79	BS	9.03	1.12	**1.02**	0.92	20
28		42		FS		14.87	**14.64**	14.39	48
	29	41	73	BS	14.06	0.7	**0.58**	0.45	25
29		40		FS		10.96	**10.68**	10.39	57
	30	39	139	BS	-10.22	0.86	**0.46**	0.04	82
30		38		FS		14.83	**14.4**	14.01	82
	31	37	112	BS	13.4	1.15	**1**	0.85	30
31		36		FS		18.2	**17.95**	17.66	54
	32	35	90	BS	-11.77	6.36	**6.18**	6	36
32		34		FS		12.45	**12.2**	11.95	50
	33	33	110	BS	6.05	6.45	**6.15**	5.85	60
33		32		FS		6.6	**6.35**	6.15	45
	34	31	72	BS	-0.56	5.93	**5.79**	5.66	27
34		30		FS		10.55	**10.23**	10.1	45
	35	29	73	Spring Box	9.33	1.04	**0.9**	0.76	28
			DISTANCE (ft)		ELEVATION DIFFERENCE (ft)	SLOPE (ft/ft)			
	Spring Box to Storage Tank		2037		82	0.0400			
	Spring Box to School		2527		144	0.0570			
	Storage Tank to School		490		63	0.1276			
	Spring Box to Elieser´s		3294		185	0.0562			
	Storage Tank to Elieser´s		1257		104	0.0824			

Appendix C: Quebrada Miña Flow Rate Data

						FLOW RATE	
RESIDENCE	**t1**	**t2**	**t3**	**MEAN t**	**STD DEV t**	**(gal/min)**	**(ft^3/s)**
1	38.85	37.72	37.31	**37.96**	0.80	7.90	0.018
2	40.65	38.78	31.62	**37.02**	4.77	8.10	0.018
3	43.85	42.06	36.72	**40.88**	3.71	7.34	0.016
4	38.06	37.41	38.53	**38.00**	0.56	7.89	0.018
5	34.65	30.63	29.25	**31.51**	2.81	9.52	0.021
6,7	37.09	37.09	36.97	**37.05**	0.07	8.10	0.018
8	37.41	36.53	38.19	**37.38**	0.83	8.03	0.018
9	32.75	31.35	32.19	**32.10**	0.70	9.35	0.021
10	46.03	46.62	46.84	**46.50**	0.42	6.45	0.014
11	50.50	46.06	46.78	**47.78**	2.38	6.28	0.014
12	78.06	77.28	77.66	**77.67**	0.39	3.86	0.009
13	49.84	50.25	51.27	**50.45**	0.74	5.95	0.013
14	40.85	40.59	39.94	**40.46**	0.47	7.41	0.017
15	33.53	33.16	33.37	**33.35**	0.19	8.99	0.020
16	32.31	33.16	32.31	**32.59**	0.49	9.20	0.021
17,18,19	78.25	84.31	106.42	**89.66**	14.83	3.35	0.007
bucket capacity	5	gallons			**Avg**	7.36	0.016
					Max	9.52	0.021
					Min	3.35	0.007

Operations and Maintenance Manual

Appendix D: Operations and Maintenance Manual

ACC
12/11/2009

Appendix D

System Maintenance

Filter

The rapid sand filter will provide a much needed reduction in bacterial lode in the water system. It is important to upkeep the system to ensure appropriate removal. Cleaning care is outlined below in the backwashing section.

Additionally, over time additional media will need to be added to the filter to account for the inevitable miniscule loss of some media (sand) through backwashing. This will be a seldom necessary occurrence but vital for system maintenance. All materials available (including media used in sand filter) are listed under the materials section of this document.

Backwashing

To reduce build up in the system, it needs to be flushed to ensure the usability of the media. To do this the necessary valves (depicted below) need to be turned “off” to allow for flow to circulate back through the system and flush out any build up. All build up will flow out via the flow-out pipe.

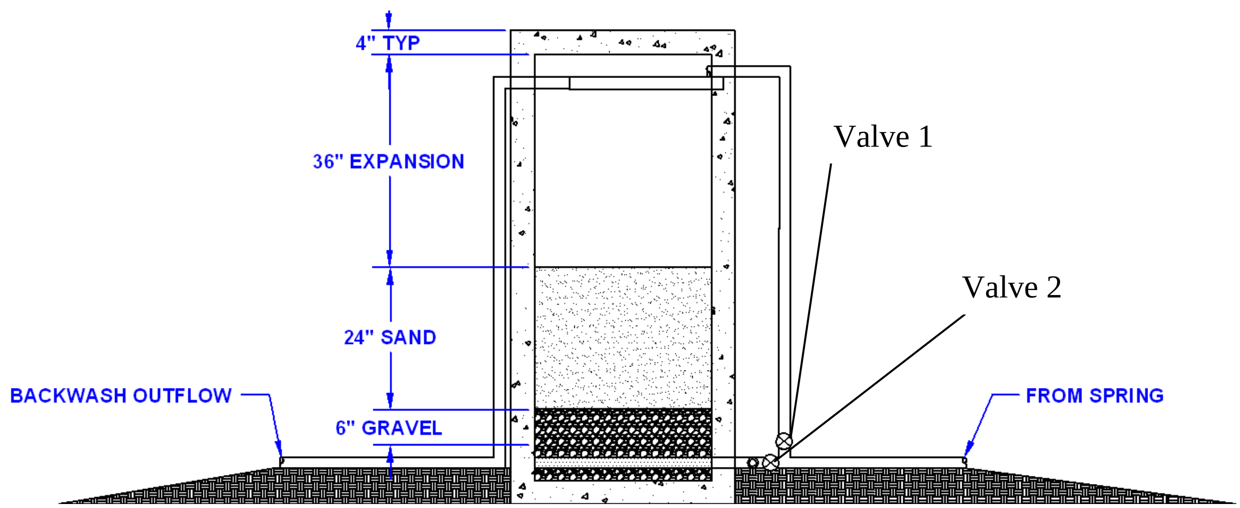


Figure 25: Location of Valves

Chlorination

In order for the filtration to eliminate bacteria and viruses effectively chlorination is an optimal choice to implement. The rapid sand filtration system will effectively remove sediment from the system which should remove a large portion of the bacteria thriving off of the sediment. Following the guidelines in tables 1 and 2 the system should be chlorinated. As shown in figure 1, the piezometer is used to determine the amount of chlorination necessary. A container with similar marks as the piezometer will be provided to the communities to measure out the appropriate amount of chlorine. A responsible party will be assigned the task of chlorinating the system. Initially they will review the level of water within the piezometer. Once the reading is taken the same measurement will be used to measure out the chlorine in the provided container. Both reading levels should be the same in the piezometer and in the provided container.

Appendix D

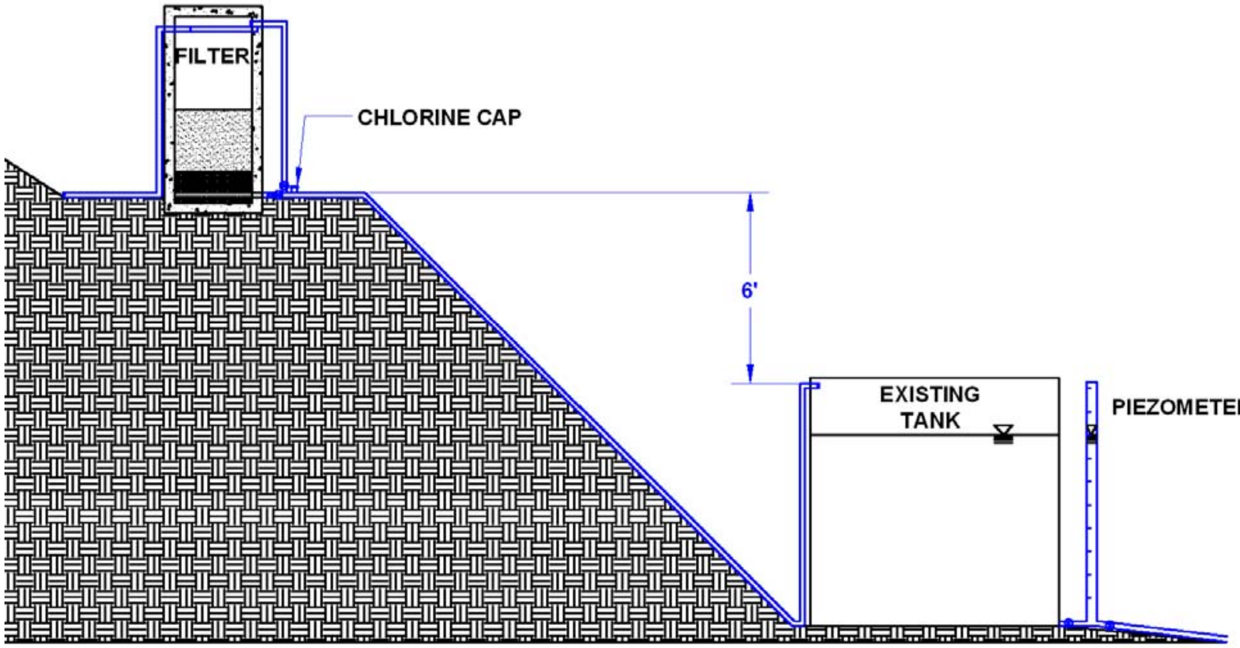


Figure 26: Location of Chlorine cap and piezometer

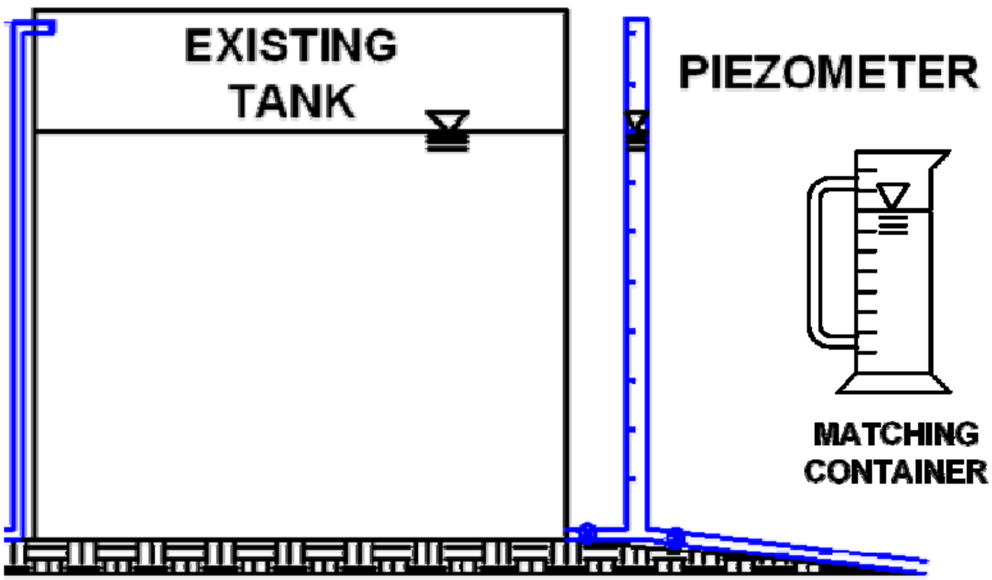


Figure 27: Depiction of Provided Container

Appendix D

Table 8: Chlorination Information

Available Chlorine	Drops per Quart/Gallon of Clear Water	Drops per Liter of Clear Water
1%	10 per Quart - 40 per Gallon	10 per Liter
4-6%	2 per Quart - 8 per Gallon (1/8 teaspoon)	2 per Liter
7-10%	1 per Quart - 4 per Gallon	1 per Liter

Table 9: Calabazal Chlorination Measurements

Bleach Table - Calabazal											
Allow 30 minutes of contact time		Piezometer Mark Drops Needed									
Chlorine Percent	Drops/ Gallon	1	2	3	4	5	6	7	8	9	10
1%	40	24,000	48,000	72,000	96,000	120,000	144,000	168,000	192,000	216,000	240,000
4-6%	8	4,800	9,600	14,400	19,200	24,000	28,800	33,600	38,400	43,200	48,000
7-10%	4	2,400	4,800	7,200	9,600	12,000	14,400	16,800	19,200	21,600	24,000
Tank Size	4600	Gal									
1.71322 E-05	Gallons/ Drop	Piezometer Mark Gallons Needed									
		1	2	3	4	5	6	7	8	9	10
		0.411	0.822	1.234	1.645	2.056	2.467	2.878	3.289	3.701	4.112
		0.082	0.164	0.247	0.329	0.411	0.493	0.576	0.658	0.740	0.822
		0.041	0.082	0.123	0.164	0.206	0.247	0.288	0.329	0.370	0.411

Table 10: Quebrada Miña Sample Dosage Sheet

Allow 30 minutes of contact time		Piezometer Mark Drops Needed									
Chlorine Percent	Drops/ Gallon	1	2	3	4	5	6	7	8	9	10
1%	40	12,000	24,000	36,000	48,000	60,000	72,000	84,000	96,000	108,000	120,000
4-6%	8	2,400	4,800	7,200	9,600	12,000	14,400	16,800	19,200	21,600	24,000
7-10%	4	1,200	2,400	3,600	4,800	6,000	7,200	8,400	9,600	10,800	12,000
Tank Size	3000	Gal									
1.71322E -05	Gallons/ Drop	Piezometer Mark Gallons Needed									
		1	2	3	4	5	6	7	8	9	10
		0.206	0.411	0.617	0.822	1.028	1.234	1.439	1.645	1.850	2.056
		0.041	0.082	0.123	0.164	0.206	0.247	0.288	0.329	0.370	0.411
		0.021	0.041	0.062	0.082	0.103	0.123	0.144	0.164	0.185	0.206

Appendix D

Tank
With the addition of the chlorination system and rapid sand filter, no major maintenance should be necessary for the water storage tank. Through time from weathering additional upkeep may be necessary to reduce the risk of leaks in the tank.

Additionally, care needs to be taken around the piezometer. The usability of the chlorination system depends upon this piece of equipment. If the piezometer is found broken in any way it should be fixed immediately. Chlorination should not be attempted without the piezometer.

Spring box
The spring box is a vital improvement to the Calabazal system. An increase of flow rate will result from the addition of the newer spring. Guidelines are provided below in the spring etiquette section to ensure the cleanliness of the water and the safety of the individuals coming in contact with it.

Spring Etiquette
There are several guidelines that should be made common practice in the community to ensure that their water source continually provides the highest quality water possible. Although groundwater sources are generally clean, having been filtered by the subsurface, there is still the possibility of secondary contamination at the effluent (point on the surface where ground water flows from) and the presence of pathogens. The treatment of the community's spring water is accomplished through the rapid sand filter and chlorination; however, there are simple and easy ways to prevent introducing any new contaminants into the spring water.

First, as a rule, no animals should be allowed near the spring. In both communities the springs are fairly remote and not located near human traffic. However, as much as possible, domesticated animals and livestock should be prevented from grazing, browsing, urinating, or defecating near the spring. The behavior of wild animals is obviously harder to restrict; if wild animals are in fact a concern, the community should consider fencing off the spring. The appropriate area to fence in should be about 9 meters square around the spring box.

People, too, should be careful around the springs. Foot traffic on the rocks above the springs can introduce dirt and other contaminants that may have traveled underfoot from far away. This dirt and possible contaminants can be easily captured by the spring with surface runoff. It is best to build and maintain a diversion ditch to prevent surface runoff from being collected at the spring. In Calabazal this may not be practical due to the surface cover around the spring. Children should be properly instructed to stay away from the spring, not to play with the valves or pipes, and not to remove the lid of the spring box.

Farming activities above (upstream or up-slope of) the springs should be prohibited. This ensures not only that no fertilizer or other agricultural chemicals are captured as runoff but also helps prevent erosion and captured sediment. Additionally, swimming, bathing and the washing of clothes near or above the spring should be discouraged.

Proper maintenance of the spring box and the surrounding area also protect the source water. The up-slope wall of the spring box and the impermeable layer outside of it should be checked regularly to be sure that they are not cracked or being worn down by erosion. The spring box lid should be checked to be sure of a good seal. The area surrounding the spring box should be cleared of brush and debris (trees should be left alone).

Guidelines for cleaning the spring box are as follows and should be performed at least once a year. First, completely drain the spring box by opening the clean-out valve. Once drained, use a shovel or hand trowel to remove sediment. This may require the temporary displacement of some or all of the gravel in the spring box. Any gravel that is returned to the spring box should first be rinsed in source water. Next, all walls of the spring box should be washed with a chlorine solution. Shock treatment or the suspension of chlorine for 24 hours may follow; however, these steps may not be necessary because both communities have a storage tank where these steps are performed. Finally, be sure to check any pipe fittings or screens to see if they need to be cleaned.

Water Line Assessment and Rehabilitation

Prior to initiating the new updates to the system the overall waterlines should be assessed and repaired if necessary. All broken PVC pipe should be replaced to remove any leaks and loss of water in the system. Additionally, taps should be evaluated to ensure appropriate flows are coming from them. Any broken ones should be replaced at this time.

An option to add an additional spring to the current system for Calabazal is suggested by ACC to increase flow rates. This will aid overall, however, it will be significant during the observed dry season. Costs for this addition are included in the overall cost estimate within the final report. Below depicts where the new water line connection would be placed. This will not be necessary in Quebrada Miña due to the fact that their current water system incorporates two spring sources.

Furthermore, any homes in obscure locations relative to the waterline will need to be assessed on an individual basis. For example in Calabazal, the family residing just before the water storage tank will need to relocate their tap to ensure they receive treated water.

Materials

The materials necessary for construction need to be obtained prior to the start of the project. This includes any and all equipment pieces that might need to be gathered. Below are the list of available materials and their unit costs (All materials included were used in the construction of the Quebrada Miña system and should be available for future projects). Following the cost estimate within the final report the materials should be obtained and utilized. Pipe sizing should also be taken into consideration. Table 11 shows other options in case availability is an issue.

Appendix D

Table 11: Pipes Options

Type of Pipe	Outside Diameter, OD	Inner Diameter (in)	Wall Diameter (in)	PSI
1/2"	.840 (~7/8", 21.336mm)	0.716	0.062	200
3/4"	1.050 (~1", 26.670mm)	0.93	0.06	200
1"	1.315 (~1-5/16", 33.401mm)	1.189	0.063	200
1-1/4"	1.660 (~1-5/8", 42.164mm)	1.502	0.079	200
1-1/2"	1.900 (~1-7/8", 48.260mm)	1.72	0.09	200
2"	2.375 (~2-3/8", 60.325mm)	2.149	0.113	200
2-1/2"	2.875 (~2-7/8", 73.025mm)	2.601	0.137	200
3"	3.500 (3-1/2", 88.900mm)	3.166	0.167	200
4"	4.500 (4-1/2", 114.300mm)	4.072	0.214	200
5"	5.563 (~5-1/2", 141.300mm)	--	--	--
6"	6.625 (~6-5/8", 168.275mm)	5.993	0.316	200
8"	8.625 (~8-5/8", 219.075mm)	7.74	0.41	200
10"	10.750 (10-3/4", 273.050mm)	9.65	0.511	200
12"	12.750 (12-3/4", 323.850mm)	11.45	0.606	200

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Item	Unit Price
PVC reductions	0.85
screw driver	1.75
screws	0.15
PVC smooth covers 1/2"	0.19
Globe valve 1"	6.49
Globe valve 1/2"	2.29
Globe valve 1/2" (plastic)	1.59
Globe valve _" (household)	1.19
wire #14lb	1.35
wire #14lb	1
wire #12lb	1.35
PVC smooth cover 3"	1.7
PVC 90 elbows 1/4"	0.57
PVC tees 2"	1.79
PVC tees 3/4"	0.39
PVC reductions 2"x1"	0.89
PVC reductions 3/4"x1"	0.09
PVC reductions 3/4"x1"	0.09
PVC smooth cover 1 1/4"	0.39
PVC reduction 2"x1 1/4"	0.89
Rubber washers	2.29
Cable wrap (m201)	4.58
Chisel 3/4	5.49
mallet	8.49
cable 5/32	0.4
drill bit 1"	9.95
drill bit 3/8"	3.95
cable wrap 3/4"	1.5
cable clamps 1/4"	0.35
nail sleeves 1/2"x 4"	4.95
PVC glue (small)	1.79
PVC glue (large)	3.99
PVC glue (extra large)	6.2
Nails 3 1/2"	1.1
Stencils 3"	5.85
PVC smooth adapter 1"	0.16
PVC smooth elbow 1"	0.2
White cement 5kg	3.99
Tap washers	0.39
PVC adaptor 1" (gray)	0.19
screws (g)	0.9
metal taps	4.59
PVC smooth adapter 1/2"	0.09
PVC female adapter 1/2"	0.19
PVC smooth elbow 1/2"	0.19
Teflon tape 3/4"	0.29
plastic taps	2.99
PVC smooth tees 2"	1.75
PVC smooth tees 1 1/2"	0.95
PVC smooth adapter 1 1/2"	0.45
PVC male adapter 2"	0.65
PVC smooth adapter 3/4"	0.15
PVC smooth tees 3/4"	0.35
PVC smooth adapter 1"	0.25
PVC smooth tees 1"	0.4
PVC smooth elbows 3/4"	0.38
Teflon tape 1"	1.55
Nails 2 1/2"	0.9
Metal gate valve 2"	33.75
Wire #16	1
White cement	3
PVC threaded cap 2"	1
PVC adaptor 2"	1
PVC tee 2"	1.75
PVC tee 3/4"	0.35
PVC elbow 3/4"	0.8
PVC cap 1/2"	0.25
PVC adapter 1/2"	0.25
black paint	7.49
Clear Polyvinyl	3.99
Masking tape	9.99
Stencil's 2"	3.59
Paintbrush 3"	2.09
ruler set	14.99

Appendix D

paint thinner	3.49
plastic bin	11.99
PVC smooth adapter 3/4"	0.15
PVC male adapter 1 1/2"	0.46
PVC smooth adapter 1/2"	0.13
PVC reductions 3/4"x 1/2"	0.1
PVC smooth elbow 1"	0.4
PVC smooth cap 1 1/2"	0.35
PVC smooth reductino 1"x3/4"	0.3
PVC adapter 3/4"	0.15
PVC elbow 1"	0.65
PVC reduction 1"x 3/4"	0.8
Teflon (roll)	1.75
PVC glue (large)	5.95
Sacks of sand	0.8
metal clamps	1.75
compound bolts	1.75
PVC elbow 1 1/2"	1.25
PVC adapter 1 1/2"	0.65
PVC caps 1"	0.5
PVC tubes 1 1/2" SDR16	6.75
PVC valves	3.5
PVC elbows with tees 3/4"	0.35
PVC adapters 1 1/4"	0.65
PVC adapters 3/4"	0.45
PVC elbows 45 degrees	0.85
PVC valve 1 1/2"	4.95
PVC cap 4"	3
PVC adapter 4"	2.25
PVC tube 2"	8.95
String	
plastic bags	1.25
metal valves 2"	32.95
metal valves 1 1/2"	25.95
metal valves 1"	19.95
PVC adapter 2"	0.8
PVC elbow 1 1/2"	0.75

PVC tees 2"	1.5
chisel 1"	5.5
PVC tees 1"	0.55
PVC elbows 1/2"	0.25
PVC tees 1 1/2"	1
PVC tees combinations 3/4"	5.2
PVC tee 1"	0.45
PVC reductions 3/4"x 1/2"	0.35
Teflon tape	0.75
PVC 50x38	1.25
PVC tubes 3/4" SDR26	5.95
PVC tubes 1" SDR26	6.95
PVC tubes 1/2" SDR13.5	2.5
PVC elbows 1"	0.6
PVC adapters 1"	0.5
PVC reduction 1 1/4"x1"	0.6
Spade	3
Plastic taps 3/4"	3.25
PVC adapter 3/4"	0.35
PVC "J" 2"	1.75
metal valves 3/4"	6.95
PVC glue (small)	2
chisel 1"	3.95
PVC adapter 2"	0.75
PVC reductions 2"x3/4"	0.85
PVC reductions 1 1/2"x3/4"	0.45
PVC reductions 1"x3/4"	0.4
PVC tee 1 1/4"	1.1
PVC elbows 3/4"	0.3
PVC tubes 3/4" SDR26	5.95
PVC tubes 2" SDR26	7.95
PVC tubes 1 1/2" SDR26	6.95
rebar 3/8"	5
Sacks of cement	8.75
Sacks of sand	0.85
Bottles of Sika	8.93
Sacks of cement	9
Cement blocks of 6"	0.55

Appendix D

Meter of sand	25
Meter of gravel	27
rebar 1/2" 30 ft	9.5
rebar 3/8" 30 ft	6
Wood: 1x12x10'	6.5
Wood: 2x4x10'	4.5
wire	1.25
Nails 2 1/2" (wood nails(	1.95
Nails 3 1/2"	1.15
Nails 3"	1.15
Nails 2"	1.15
Nails 2 1/2"	1.15
White cement	0.2
metal screen	2.55
Sand paper	1.35
Paintbrush 4"	1.45
PVC tee 3"	3.75
PVC reduction 3x1"	3.25
PVC tube 3"	3
PVC tube 2" (drainage)	1
PVC adapter 2" 3	3
PVC threaded cap 2"	1
PVC smooth cap 2"	1
PVC tubes 2" SDR26	8.95
PVC tubes 1 1/4" SDR26	7.95
PVC tubes 3/4" SDR26	5.95
PVC elbows 2"	0.85
PVC elbows 1"	0.5
PVC elbows 1 1/4"	0.95
PVC reduction 1 1/4"x3/4"	0.65
PVC reduction 1 1/4"x1"	0.65
PVC "J" 1 1/4"	1
PVC elbow 3/4"	0.35
metal valve 1"	11.95
PVC male adapter 1"	0.5
PVC cap 3/4"	0.25
PVC elbow 1 1/4"	0.55
tarp	29

Paint brush	3.25
plastic bags	0.95
Sacks of sand	0.8
PVC tubes 1" SDR26	3.95
PVC tubes 3/4" SDR26	2.75
Cable 1/8"	
PVC tee and elbow combination	
Cable clamps 3/16"	0.3
Garden hose 25'	5.8
Pliers	1.9
Zip ties	0.2
plastic bags	5.95
metal valves 1 1/2"	10.35
PVC adapters 1 1/2"	0.65
PVC elbows 3/4"	0.35
cable cutters	10.5
metal valve 2"	32.95
PVC adapters 2"	0.85
PVC threaded adapters 2"	0.85
PVC adapters 2"	0.75
PVC caps 1 1/2"	0.65
PVC caps 3/4"	0.45
PVC threaded caps 3/4"	0.35
PVC elbows 3/4"	0.35
PVC adapters 3/4"	0.35
PVC tees 3/4"	0.35
metal valve 3/4"	6.95
PVC threaded adapter 3/4"	0.3
Metal valve combination	20.8
PVC glue	3.25
Plastic bins	4.39
Zipper	0.78
Paint brushes	1.35
Stencils 1"	5.95

Appendix E: Available Materials List Provided by Peace Corps Volunteer Used in the Construction of the Quebrada Miña System

Item	Quantity	Unit Price ($)	Cumulative Price ($)
PVC reductions	4	0.85	3.4
screw driver	1	1.75	1.75
screws	10	0.15	1.5
PVC smooth covers 1/2"	10	0.19	1.9
Globe valve 1"	4	6.49	25.96
Globe valve 1/2"	3	2.29	6.87
Globe valve 1/2" (plastic)	2	1.59	3.18
Globe valve _" (household)	42	1.19	49.98
wire #14lb	2 lb	1.35	2.7
wire #14lb	1lb	1	1
wire #12lb	6lb	1.35	8.1
PVC smooth cover 3"	2	1.7	3.4
PVC 90 elbows 1/4"	4	0.57	2.28
PVC tees 2"	11	1.79	19.69
PVC tees 3/4"	7	0.39	2.73
PVC reductions 2"x1"	2	0.89	1.78
PVC reductions 3/4"x1"	16	0.09	1.44
PVC reductions 3/4"x1"	6	0.09	0.54
PVC smooth cover 1 1/4"	1	0.39	0.39
PVC reduction 2"x1 1/4"	1	0.89	0.89
Rubber washers	1	2.29	2.29
Cable wrap (m201)	1	4.58	4.58
Chisel 3/4	1	5.49	5.49
mallet	1	8.49	8.49
cable 5/32	276 ft	0.4	110.4
drill bit 1"	1	9.95	9.95
drill bit 3/8"	1	3.95	3.95
cable wrap 3/4"	6	1.5	9
cable clamps 1/4"	19	0.35	6.65
nail sleeves 1/2"x 4"	1	4.95	4.95
PVC glue (small)	1	1.79	1.79
PVC glue (large)	1	3.99	3.99
PVC glue (extra large)	1	6.2	6.2
Nails 3 1/2"	1	1.1	1.1
Stencils 3"	1	5.85	5.85
PVC smooth adapter 1"	4	0.16	0.64

Appendix E

PVC smooth elbow 1"	4	0.2	0.8
White cement 5kg	1	3.99	3.99
Tap washers	2	0.39	0.78
PVC adaptor 1" (gray)	6	0.19	1.14
screws (g)	1	0.9	0.9
metal taps	18	4.59	82.62
PVC smooth adapter 1/2"	20	0.09	1.8
PVC female adapter 1/2"	20	0.19	3.8
PVC smooth elbow 1/2"	20	0.19	3.8
Teflon tape 3/4"	1	0.29	0.29
plastic taps	20	2.99	59.8
PVC smooth tees 2"	2	1.75	3.5
PVC smooth tees 1 1/2"	2	0.95	1.9
PVC smooth adapter 1 1/2"	2	0.45	0.9
PVC male adapter 2"	2	0.65	1.3
PVC smooth adapter 3/4"	2	0.15	0.3
PVC smooth tees 3/4"	2	0.35	0.7
PVC smooth adapter 1"	1	0.25	0.25
PVC smooth tees 1"	1	0.4	0.4
PVC smooth elbows 3/4"	2	0.38	0.76
Teflon tape 1"	1	1.55	1.55
Nails 2 1/2"	2	0.9	1.8
Metal gate valve 2"	1	33.75	33.75
Wire #16	1lb	1	1
White cement	10lb	3	3
PVC threaded cap 2"	1	1	1
PVC adaptor 2"	1	1	1
PVC tee 2"	1	1.75	1.75
PVC tee 3/4"	1	0.35	0.35
PVC elbow 3/4"	2	0.8	1.6
PVC cap 1/2"	1	0.25	0.25
PVC adapter 1/2"	1	0.25	0.25
black paint	1	7.49	7.49
Clear Polyvinyl	1	3.99	3.99
Masking tape	1	9.99	9.99
Stencil's 2"	1	3.59	3.59
Paintbrush 3"	1	2.09	2.09
ruler set	1	14.99	14.99
paint thinner	1	3.49	3.49
plastic bin	1	11.99	11.99
PVC smooth adapter 3/4"	6	0.15	0.9

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PVC male adapter 1 1/2"	2	0.46	0.92
PVC smooth adapter 1/2"	5	0.13	0.65
PVC reductions 3/4"x 1/2"	11	0.1	1.1
PVC smooth elbow 1"	4	0.4	1.6
PVC smooth cap 1 1/2"	1	0.35	0.35
PVC smooth reductino 1"x3/4"	1	0.3	0.3
PVC adapter 3/4"	1	0.15	0.15
PVC elbow 1"	1	0.65	0.65
PVC reduction 1"x 3/4"	2	0.8	1.6
Teflon (roll)	1	1.75	1.75
PVC glue (large)	2	5.95	11.9
Sacks of sand	15	0.8	12
metal clamps	4	1.75	7
compound bolts	8	1.75	14
PVC elbow 1 1/2"	1	1.25	1.25
PVC adapter 1 1/2"	2	0.65	1.3
PVC caps 1"	2	0.5	1
PVC tubes 1 1/2" SDR16	2	6.75	13.5
PVC valves	4	3.5	14
PVC elbows with tees 3/4"	11	0.35	3.85
PVC adapters 1 1/4"	2	0.65	1.3
PVC adapters 3/4"	1	0.45	0.45
PVC elbows 45 degrees	1	0.85	0.85
PVC valve 1 1/2"	1	4.95	4.95
PVC cap 4"	6	3	18
PVC adapter 4"	6	2.25	13.5
PVC tube 2"	1	8.95	8.95
String	20 yards		4
plastic bags	1	1.25	1.25
metal valves 2"	1	32.95	32.95
metal valves 1 1/2"	1	25.95	25.95
metal valves 1"	2	19.95	39.9
PVC adapter 2"	2	0.8	1.6
PVC elbow 1 1/2"	12	0.75	9
PVC tees 2"	4	1.5	6
chisel 1"	1	5.5	5.5
PVC tees 1"	10	0.55	5.5
PVC elbows 1/2"	44	0.25	11
PVC tees 1 1/2"	2	1	2
PVC tees combinations 3/4"	1	5.2	5.2
PVC tee 1"	3	0.45	1.35

Appendix E

PVC reductions 3/4"x 1/2"	3	0.35	1.05
Teflon tape	1	0.75	0.75
PVC 50x38	1	1.25	1.25
PVC tubes 3/4" SDR26	86	5.95	511.7
PVC tubes 1" SDR26	112	6.95	778.4
PVC tubes 1/2" SDR13.5	59	2.5	147.5
PVC elbows 1"	4	0.6	2.4
PVC adapters 1"	4	0.5	2
PVC reduction 1 1/4"x1"	1	0.6	0.6
Spade	1	3	3
Plastic taps 3/4"	13	3.25	42.25
PVC adapter 3/4"	13	0.35	4.55
PVC "J" 2"	1	1.75	1.75
metal valves 3/4"	2	6.95	13.9
PVC glue (small)	2	2	4
chisel 1"	1	3.95	3.95
PVC adapter 2"	3	0.75	2.25
PVC reductions 2"x3/4"	4	0.85	3.4
PVC reductions 1 1/2"x3/4"	5	0.45	2.25
PVC reductions 1"x3/4"	2	0.4	0.8
PVC tee 1 1/4"	2	1.1	2.2
PVC elbows 3/4"	4	0.3	1.2
PVC tubes 3/4" SDR26	20	5.95	119
PVC tubes 2" SDR26	30	7.95	238.5
PVC tubes 1 1/2" SDR26	100	6.95	695
rebar 3/8"	30ft	5	5
Sacks of cement	2	8.75	17.5
Sacks of sand	12	0.85	10.2
Bottles of Sika	6	8.93	53.58
Sacks of cement	45	9	405
Cement blocks of 6"	200	0.55	110
Meter of sand	8	25	200
Meter of gravel	5	27	135
rebar 1/2" 30 ft	18	9.5	171
rebar 3/8" 30 ft	4	6	24
Wood: 1x12x10'	10	6.5	65
Wood: 2x4x10'	8	4.5	36
wire	5	1.25	6.25
Nails 2 1/2" (wood nails(	2	1.95	3.9
Nails 3 1/2"	2	1.15	2.3
Nails 3"	2	1.15	2.3

Appendix E

Nails 2"	2	1.15	2.3
Nails 2 1/2"	1	1.15	1.15
White cement	10	0.2	2
metal screen	1	2.55	2.55
Sand paper	4	1.35	5.4
Paintbrush 4"	1	1.45	1.45
PVC tee 3"	1	3.75	3.75
PVC reduction 3x1"	2	3.25	6.5
PVC tube 3"	1	3	3
PVC tube 2" (drainage)	1	1	1
PVC adapter 2" 3	1	3	
PVC threaded cap 2"	3	1	3
PVC smooth cap 2"	2	1	2
PVC tubes 2" SDR26	2	8.95	17.9
PVC tubes 1 1/4" SDR26	1	7.95	7.95
PVC tubes 3/4" SDR26	1	5.95	5.95
PVC elbows 2"	3	0.85	2.55
PVC elbows 1"	2	0.5	1
PVC elbows 1 1/4"	2	0.95	1.9
PVC reduction 1 1/4"x3/4"	2	0.65	1.3
PVC reduction 1 1/4"x1"	4	0.65	2.6
PVC "J" 1 1/4"	1	1	1
PVC elbow 3/4"	3	0.35	1.05
metal valve 1"	1	11.95	11.95
PVC male adapter 1"	2	0.5	1
PVC cap 3/4"	8	0.25	2
PVC elbow 1 1/4"	6	0.55	3.3
tarp	1	29	29
Paint brush	1	3.25	3.25
plastic bags	4	0.95	3.8
Sacks of sand	20	0.8	16
PVC tubes 1" SDR26	20	3.95	79
PVC tubes 3/4" SDR26	12	2.75	33
Cable 1/8"	300 ft		204.75
PVC tee and elbow combination			25.9
Cable clamps 3/16"	10	0.3	3
Garden hose 25'	1	5.8	5.8
Pliers	1	1.9	1.9
Zip ties	6	0.2	1.2
plastic bags	1	5.95	5.95
metal valves 1 1/2"	1	10.35	10.35

Appendix E

PVC adapters 1 1/2"	2	0.65	1.3
PVC elbows 3/4"	4	0.35	1.4
cable cutters	1	10.5	10.5
metal valve 2"	1	32.95	32.95
PVC adapters 2"	2	0.85	1.7
PVC threaded adapters 2"	2	0.85	1.7
PVC adapters 2"	4	0.75	3
PVC caps 1 1/2"	1	0.65	0.65
PVC caps 3/4"	1	0.45	0.45
PVC threaded caps 3/4"	2	0.35	0.7
PVC elbows 3/4"	4	0.35	1.4
PVC adapters 3/4"	2	0.35	0.7
PVC tees 3/4"	2	0.35	0.7
metal valve 3/4"	2	6.95	13.9
PVC threaded adapter 3/4"	4	0.3	1.2
Metal valve combination	1	20.8	20.8
PVC glue	1	3.25	3.25
Plastic bins	2	4.39	8.78
Zipper	1	0.78	0.78
Paint brushes	1	1.35	1.35
Stencils 1"	1	5.95	5.95

Appendix F: Cost Estimate

Appendix F

Cost Estimate				
Cost for spring box		Unit Price	# of units	Total Price
Labor				
	Peace Corps Volunteer	$0.00	480	$0.00
	Laborers (per worker per hour)	$1.00	480	$480.00
Supplies				
	Sack of Cement (100lb)	$10.35	8	$82.80
	Sack of Sand (3.75 gal)	$0.98	29	$28.42
	Water (Liters)	$0.00	200	$0.00
	Sack of Gravel (3.75 gal)	$1.15	44	$50.60
	Rebar (30 ft)	$5.75	1	$5.75
	Screening	$2.93	1	$2.93
	Wood boards	$7.48	8	$59.84
	Globe Valves	$4.60	12	$55.20
	PVC glue	$4.59	1	$4.59
	PVC joints			
	Lubricant (quart)	$11.50	2	$23.00
	Nails	$2.30	3	$6.90
	Screws	$2.30	1	$2.30
	PVC Pipe	$9.14	2	$18.28
Tools				
	Shovels	$28.75	5	$143.75
	Measuring tape	$5.75	2	$11.50
	Mallet	$9.76	2	$19.52
	Saw	$17.25	2	$34.50
	Buckets	$9.20	5	$46.00
	Carpenter's square	$23.00	2	$46.00
	Mixing bin	$13.79	2	$27.58
	Crowbar	$17.25	2	$34.50
	Pliers	$2.19	2	$4.38
	Pipe wrench	$28.75	2	$57.50
	Wheelbarrow	$69.00	2	$138.00
	Adjustable wrench	$17.25	2	$34.50
	Screwdriver	$2.01	2	$4.02
	Trowel	$11.50	2	$23.00
Transportation**		$230.00	2	$460.00
Total				$1,425.36
Cost of filter				
Labor				
	Peace Corps Volunteer	$0.00	160	$0.00
	Laborers (per worker per hour)	$1.00	160	$160.00
Supplies				
	Sack of Cement (100lb)	$10.35	11	$113.85
	Sack of Sand (3.75 gal)	$0.98	54	$52.92
	Water (Liters)	$0.00	280	$0.00
	Sack of Gravel (3.75 gal)	$1.15	51	$58.65
	Rebar (30 ft)	$5.75	1	$5.75
	Screening	$2.93	1	$2.93
	Wood boards	$7.48	8	$59.84
	Globe Valves	$4.60	12	$55.20
	PVC glue	$4.59	1	$4.59
	PVC joints			
	Lubricant (quart)	$11.50	2	$23.00
	Nails	$2.30	3	$6.90
	Screws	$2.30	1	$2.30
	PVC Pipe	$9.14	3	$27.42
			Total	$413.35
Cost of Pipe Rehab		Unit Price	# of units	Total Price
Labor				
	Peace Corps Volunteer	N/A	N/A	N/A
	Laborers (per worker per hour)	$1.00	200	$200.00
Supplies				
	PVC Pipe	$9.14	4	$36.56
	Metal Faucet	$5.28	2	$10.56
	Faucet Washers	$0.45	2	$0.90
	Globe Valves	$4.00	6	$24.00
	PVC joints			
	PVC glue	$4.59	1	$4.59
			Total	$48.02
			TOTAL:	$1,900.00

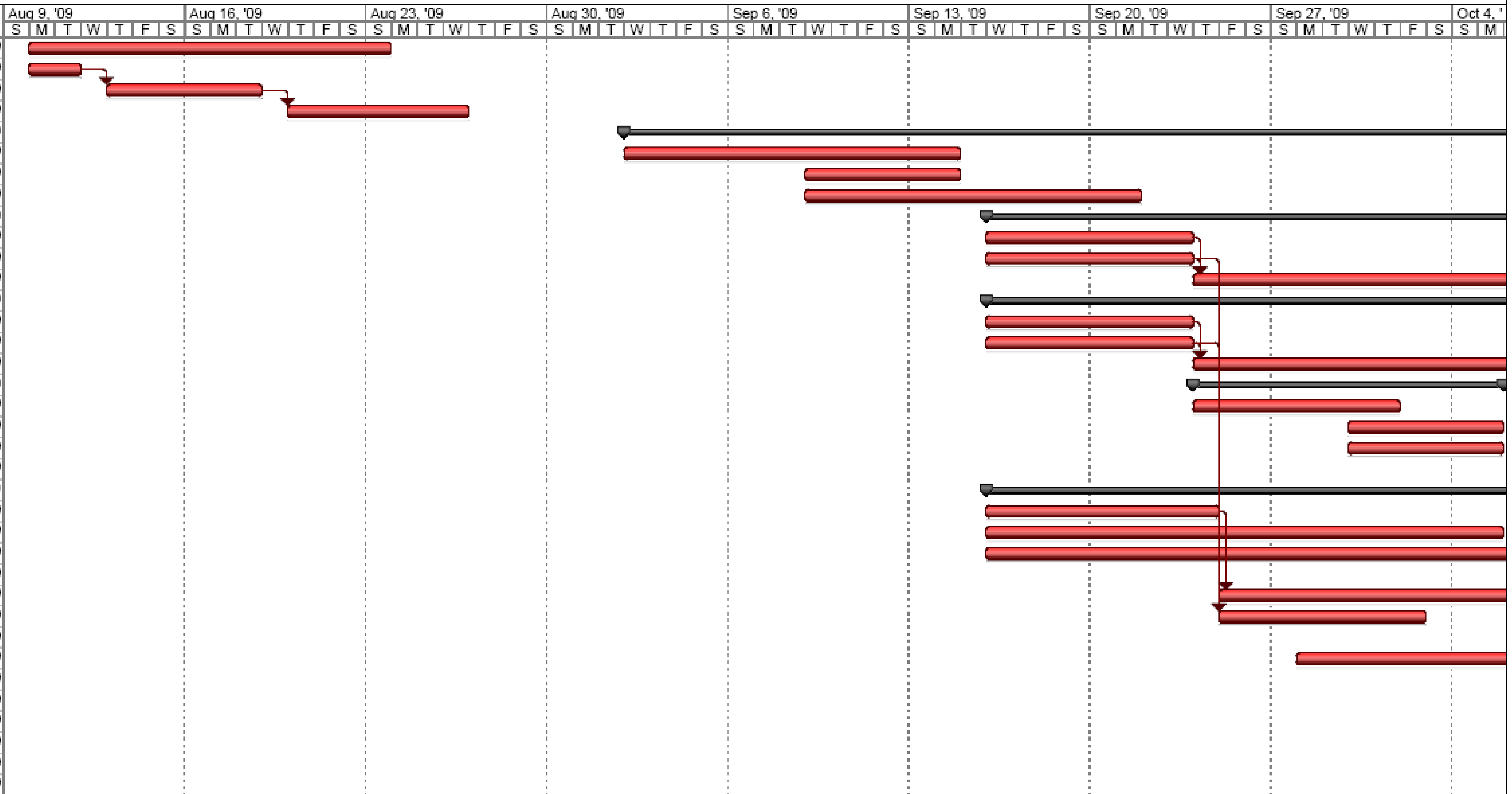
Note: Factor in an extra 15% to all costs to cover changes in costs

Appendix G: ACC Timeline Gantt Chart

Agua Contigo Consultados

Work Breakdown Schedule

ID	Task Name	Duration	Start	Finish
1	Panama	12 days	Mon 8/10/09	Sun 8/23/09
2	Pre-site Planning	2 days	Mon 8/10/09	Tue 8/11/09
3	Field Data Collection	4 days	Thu 8/13/09	Tue 8/18/09
4	Data Compilation	7 days	Thu 8/20/09	Wed 8/26/09
5	**Research and Development**	**27 days**	**Wed 9/2/09**	**Thu 10/8/09**
6	Team Logo and Mission Stateme	9 days	Wed 9/2/09	Mon 9/14/09
7	Progress Report	4 days	Wed 9/9/09	Mon 9/14/09
8	Work Breakdown Schedule	9 days	Wed 9/9/09	Mon 9/21/09
9	**Filtration System**	**17 days**	**Wed 9/16/09**	**Thu 10/8/09**
10	Identifying Options	6 days	Wed 9/16/09	Wed 9/23/09
11	Decision Matrix	6 days	Wed 9/16/09	Wed 9/23/09
12	CAD Drawing	11 days	Thu 9/24/09	Thu 10/8/09
13	**Water Treatment**	**17 days**	**Wed 9/16/09**	**Thu 10/8/09**
14	Identifying Options	6 days	Wed 9/16/09	Wed 9/23/09
15	Decision Matrix	6 days	Wed 9/16/09	Wed 9/23/09
16	CAD Drawing	11 days	Thu 9/24/09	Thu 10/8/09
17	**Water System Rehabilitation**	**8 days**	**Thu 9/24/09**	**Mon 10/5/09**
18	Spring Box Design	6 days	Thu 9/24/09	Thu 10/1/09
19	Tank Maintenance	4 days	Wed 9/30/09	Mon 10/5/09
20	New Spring and Piping Evalu	4 days	Wed 9/30/09	Mon 10/5/09
21	D80 Conference	1 day	Sat 10/17/09	Sat 10/17/09
22	**Design Completion**	**64 days**	**Wed 9/16/09**	**Fri 12/11/09**
23	Status Report	7 days	Wed 9/16/09	Thu 9/24/09
24	Design Scheme Memo	14 days	Wed 9/16/09	Mon 10/5/09
25	Interm Project Presentation	17 days	Wed 9/16/09	Thu 10/8/09
26	Revising/Preparing for D80	6 days	Fri 10/9/09	Fri 10/16/09
27	Status Report	15 days	Fri 9/25/09	Thu 10/15/09
28	Flow Calculations	6 days	Fri 9/25/09	Fri 10/2/09
29	Education on New Components	12 days	Mon 10/19/09	Tue 11/3/09
30	AutoCAD System Concepts	8 days	Mon 9/28/09	Wed 10/7/09
31	Cost Estimate & Schedule	12 days	Mon 10/19/09	Tue 11/3/09
32	Status Report	11 days	Fri 10/16/09	Thu 10/29/09
33	Status Report	10 days	Fri 10/30/09	Thu 11/12/09
34	Final Report Draft	9 days	Wed 11/4/09	Mon 11/16/09
35	Poster Draft	9 days	Wed 11/4/09	Mon 11/16/09
36	Final Deliverables	19 days	Tue 11/17/09	Fri 12/11/09



Project: ISD
Date: Sun 11/15/09

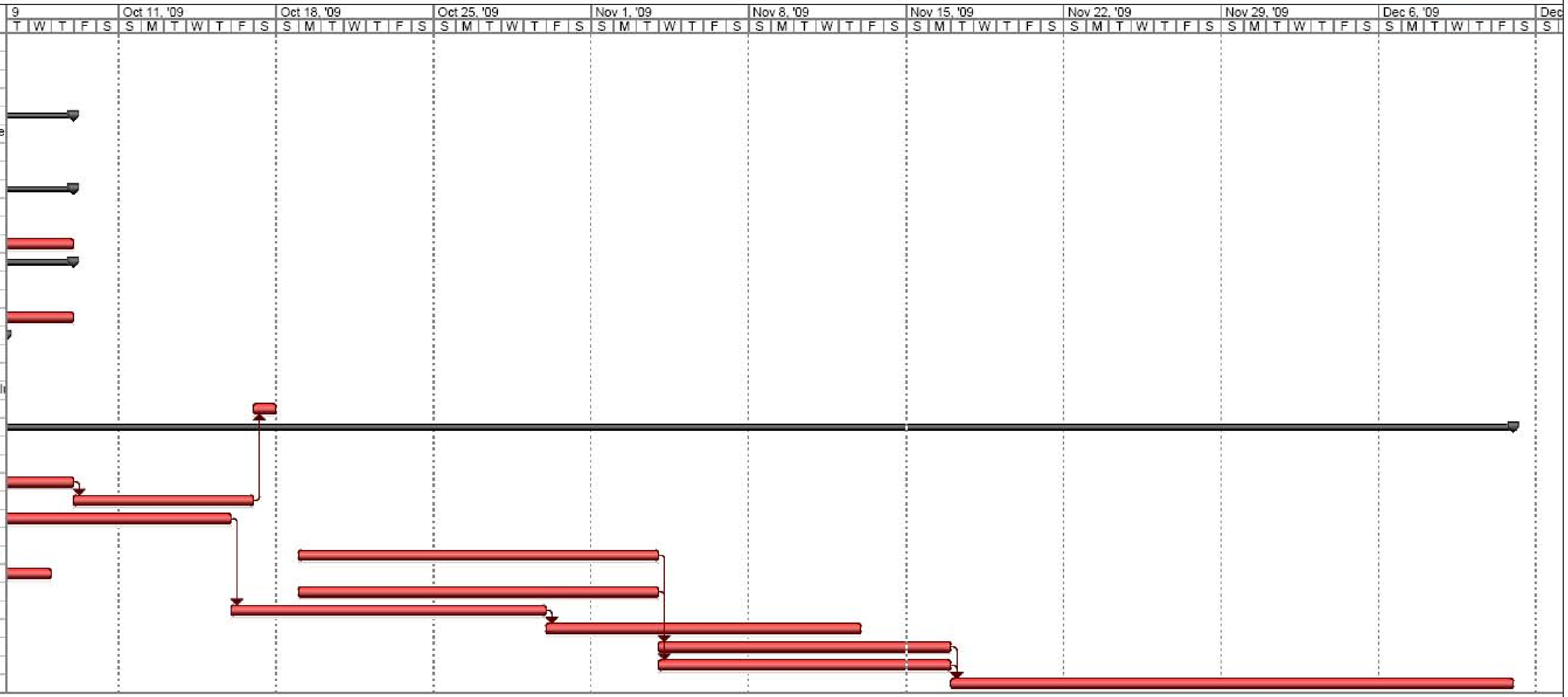
Task — Split — Progress — Milestone — Summary — Project Summary — External Tasks — External Milestone — Deadline

Page 1

Agua Contigo Consultados

Work Breakdown Schedule

ID	Task Name
1	Panama
2	Pre-site Planning
3	Field Data Collection
4	Data Compilation
5	**Research and Development**
6	Team Logo and Mission Stateme
7	Progress Report
8	Work Breakdown Schedule
9	**Filtration System**
10	Identifying Options
11	Decision Matrix
12	CAD Drawing
13	**Water Treatment**
14	Identifying Options
15	Decision Matrix
16	CAD Drawing
17	**Water System Rehabilitation**
18	Spring Box Design
19	Tank Maintenance
20	New Spring and Piping Eval
21	D80 Conference
22	**Design Completion**
23	Status Report
24	Design Scheme Memo
25	Interm Project Presentation
26	Revising/Preparing for D80
27	Status Report
28	Flow Calculations
29	Education on New Components
30	AutoCAD System Concepts
31	Cost Estimate & Schedule
32	Status Report
33	Status Report
34	Final Report Draft
35	Poster Draft
36	Final Deliverables



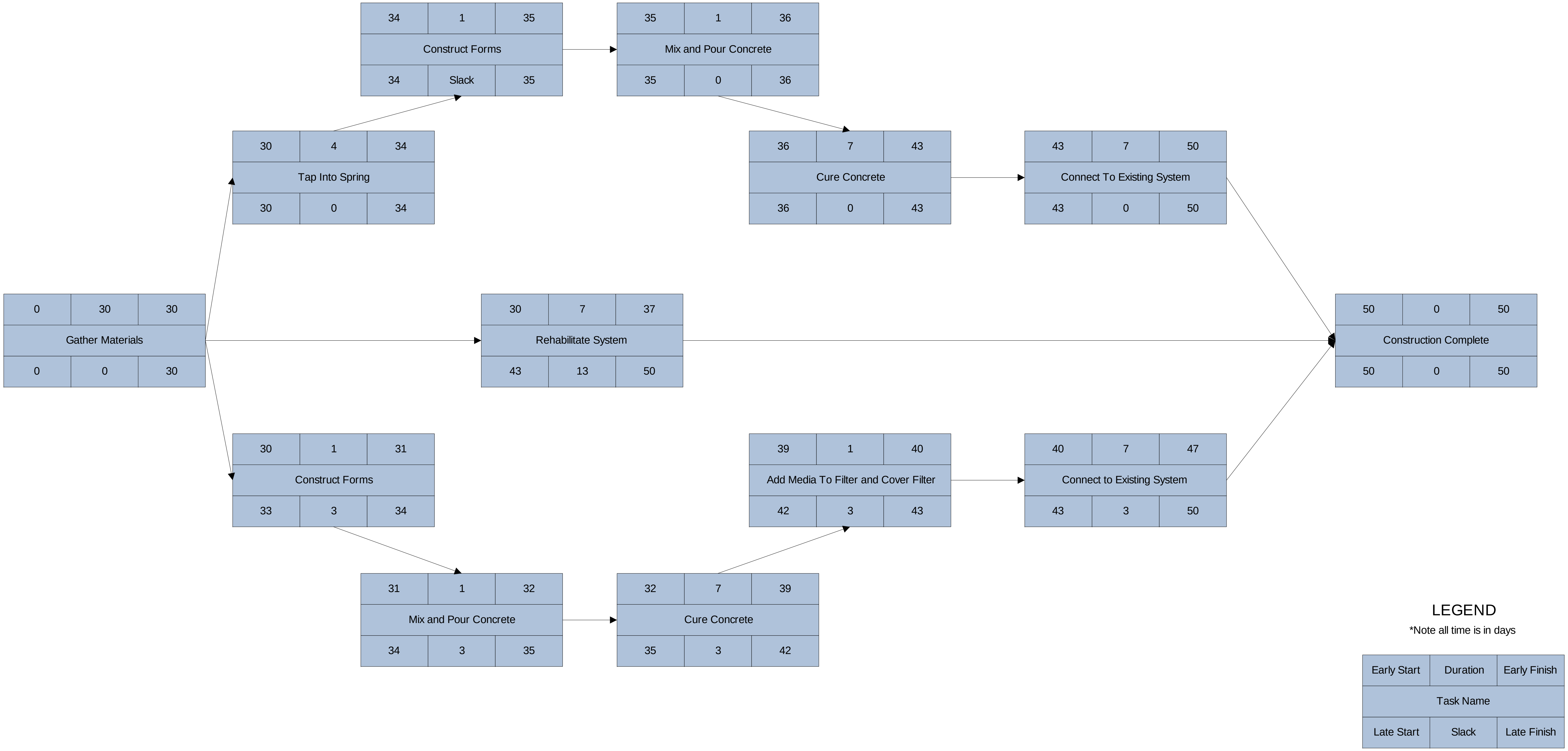
Project: ISD
Date: Sun 11/15/09

Task		Progress		Summary		External Tasks		Deadline	
Split		Milestone		Project Summary		External Milestone			

Page 2

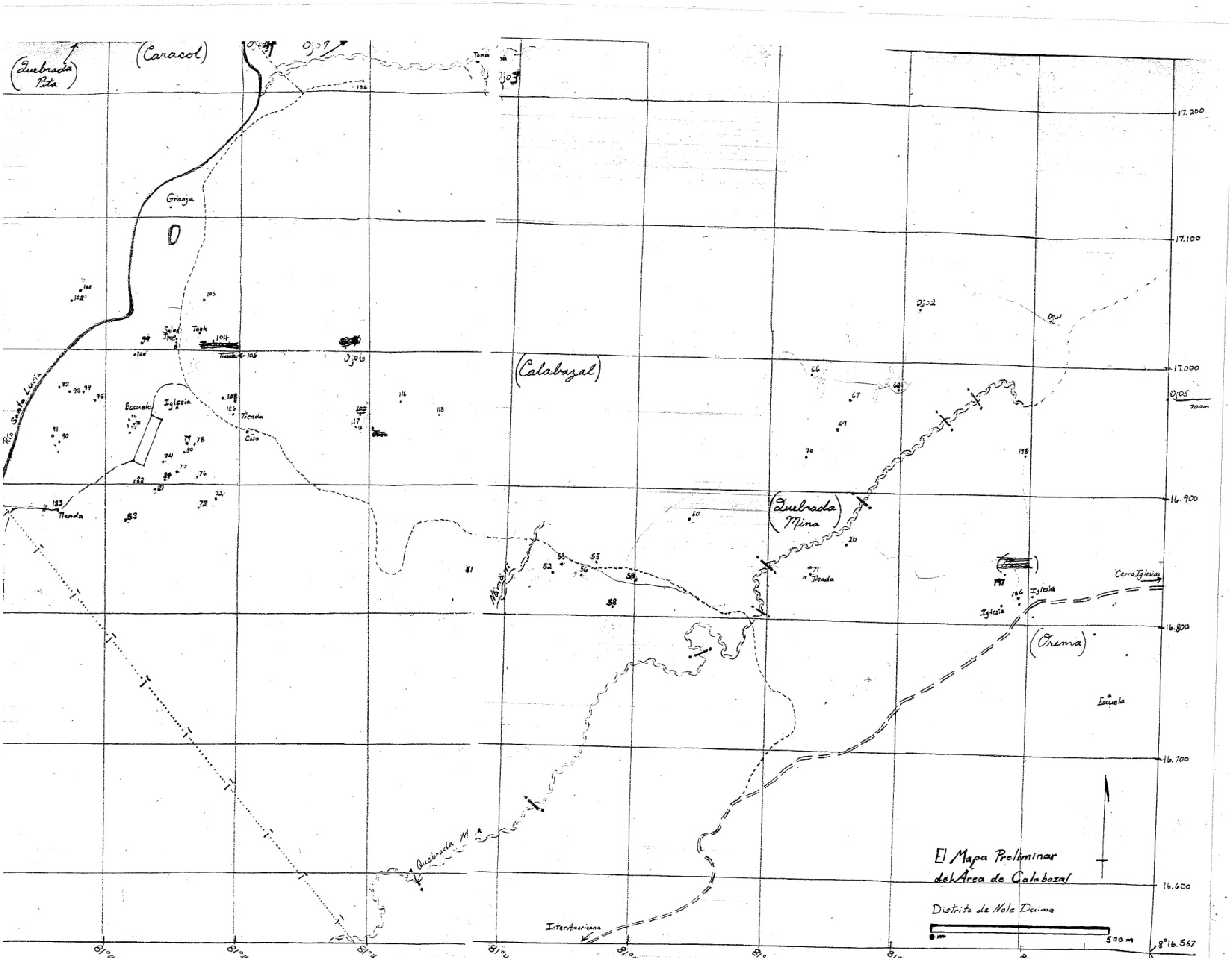
Appendix H: Project Construction Schedule

Appendix H


34 1 35
Construct Forms
34 Slack 35
35 1 36
Mix and Pour Concrete
35 0 36
30 4 34
Tap Into Spring
30 0 34
36 7 43
Cure Concrete
36 0 43
43 7 50
Connect To Existing System
43 0 50
0 30 30
Gather Materials
0 0 30
30 7 37
Rehabilitate System
43 13 50
50 0 50
Construction Complete
50 0 50
30 1 31
Construct Forms
33 3 34
39 1 40
Add Media To Filter and Cover Filter
42 3 43
40 7 47
Connect to Existing System
43 3 50
31 1 32
Mix and Pour Concrete
34 3 35
32 7 39
Cure Concrete
35 3 42
LEGEND
*Note all time is in days
Early Start Duration Early Finish
Task Name
Late Start Slack Late Finish

Appendix I: Calabazal System Map

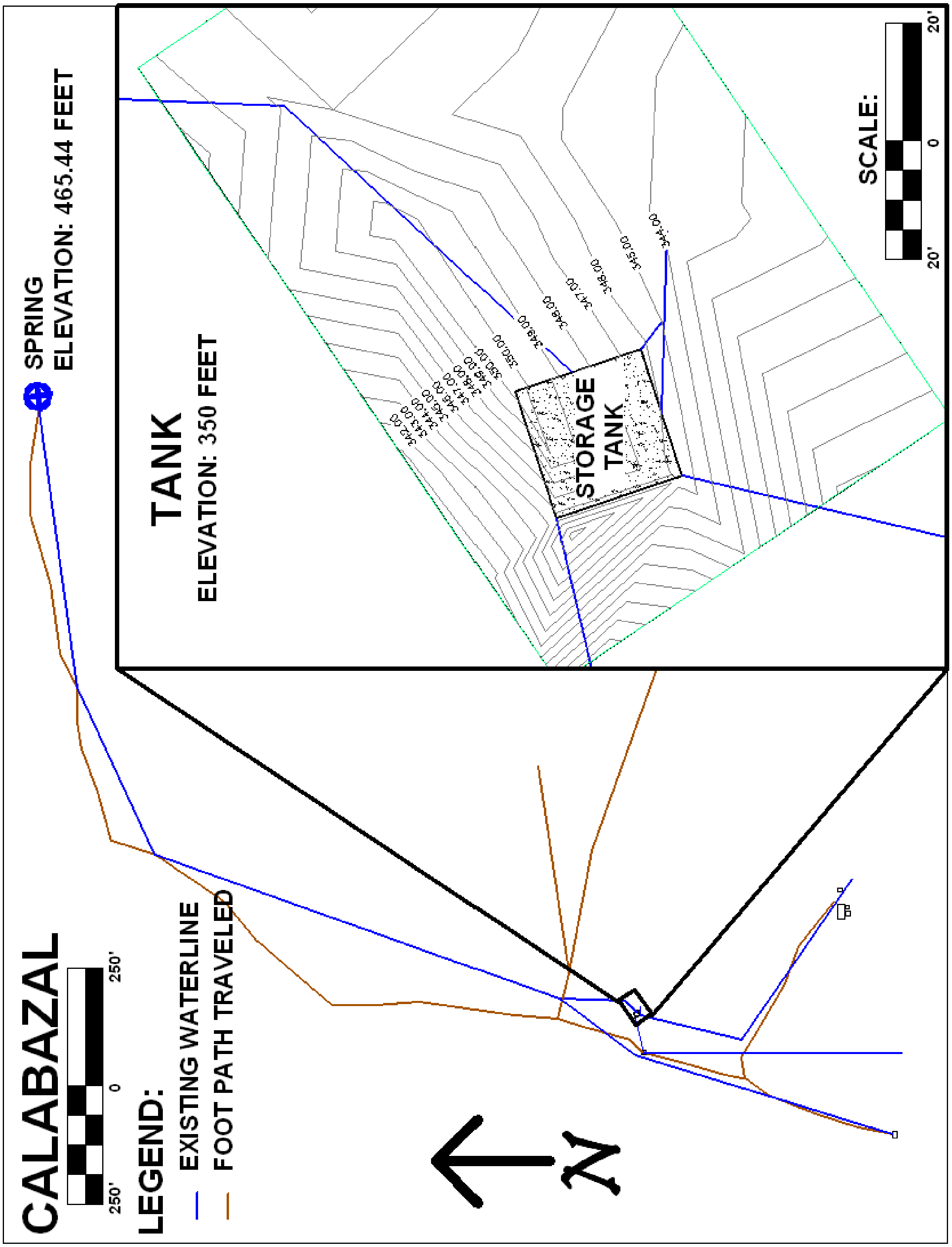
Appendix I

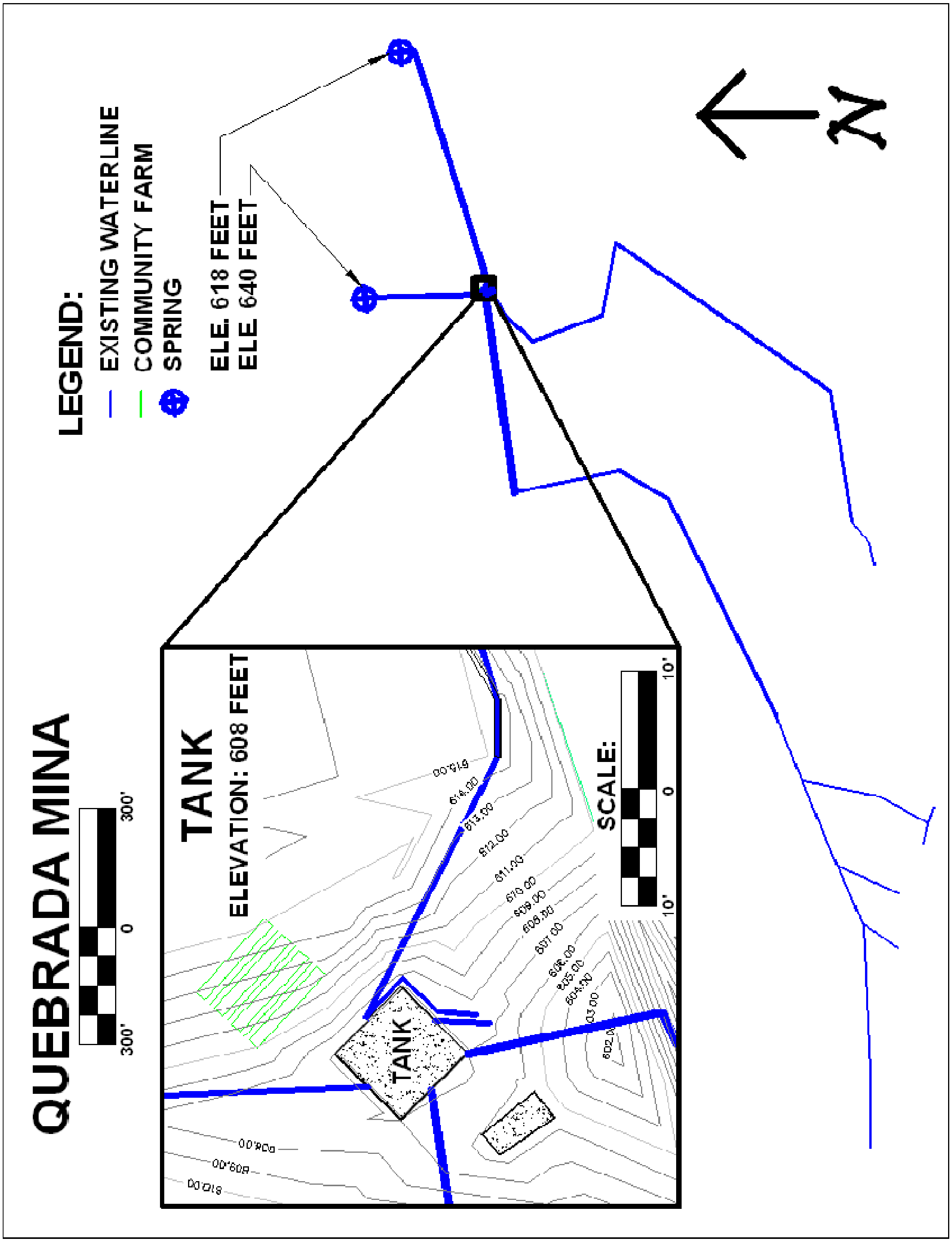


Quebrada Pita
Caracol
Granja
Calabazal
Río Santa Lucía
Escuela
Iglesia
Tienda
Casa
Quebrada Mina
Tienda
Iglesia
Cerro Iglesias
Orema
Escuela
Quebrada M
InterAmericana
El Mapa Preliminar del Área de Calabazal
Distrito de Nole Duima
500 m
17.200
17.100
17.000
16.900
16.800
16.700
16.600
8°16.567

Appendix J: Field Data AutoCAD

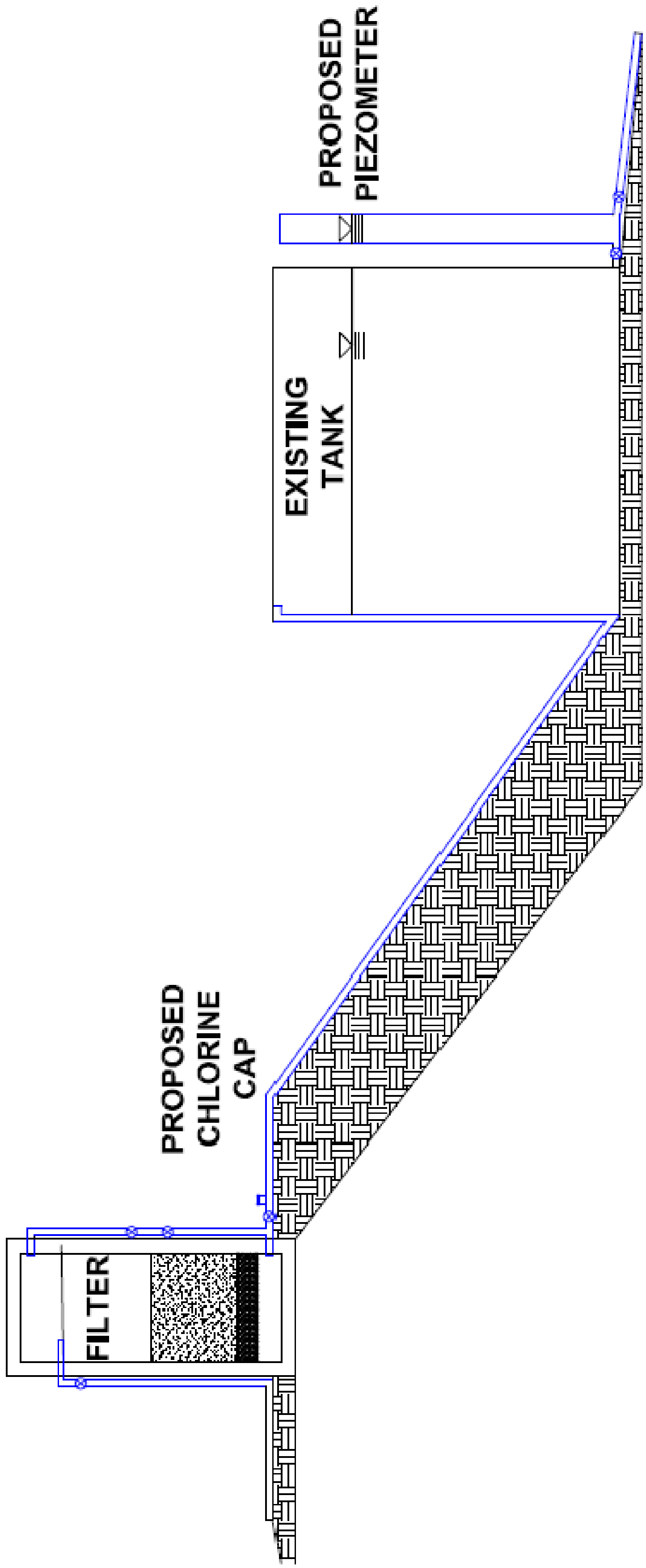
Appendix J


CALABAZAL
250'
0
250'
LEGEND:
EXISTING WATERLINE
FOOT PATH TRAVELED
N
SPRING
ELEVATION: 465.44 FEET
TANK
ELEVATION: 350 FEET
STORAGE
TANK
SCALE:
20'
0
20'


QUEBRADA MINA
300'
0
300'
LEGEND:
EXISTING WATERLINE
COMMUNITY FARM
SPRING
ELE. 618 FEET
ELE. 640 FEET
TANK
ELEVATION: 608 FEET
SCALE:
10'
0
10'
TANK
N

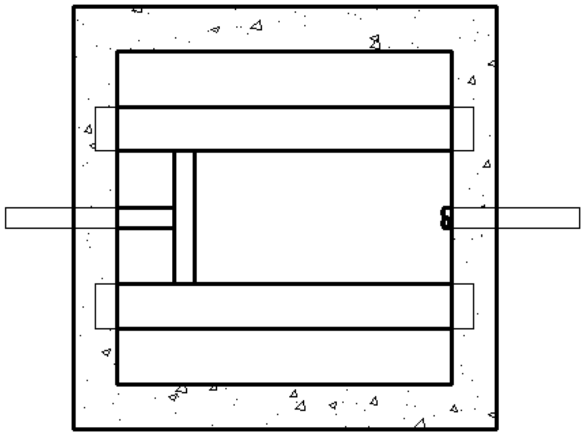
Appendix K: Slow Sand Filter Concept Layout

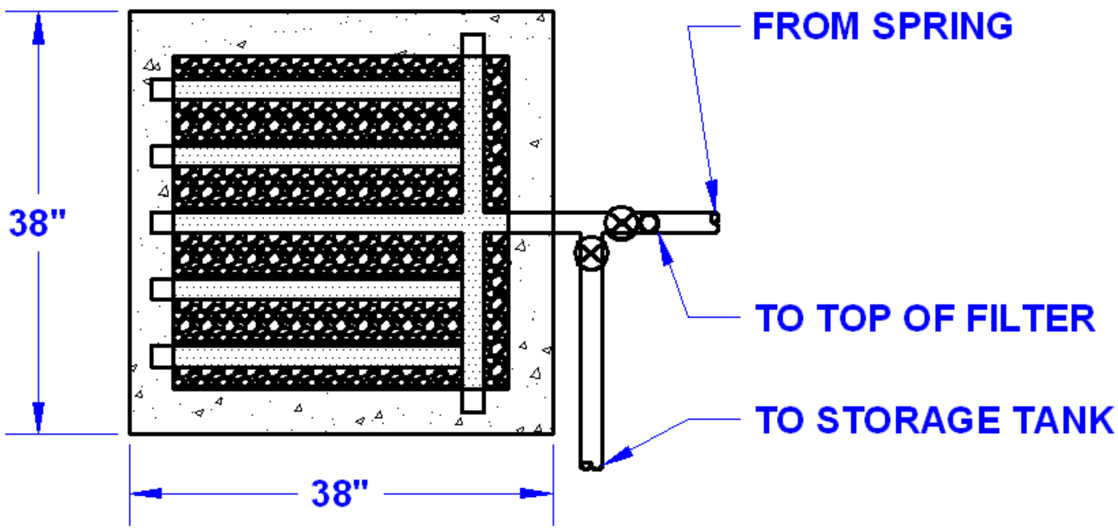
Appendix K


PROPOSED
PIEZOMETER
EXISTING
TANK
PROPOSED
CHLORINE
CAP
FILTER

Appendix L: Rapid Sand Filter Front and Side Cross Sections

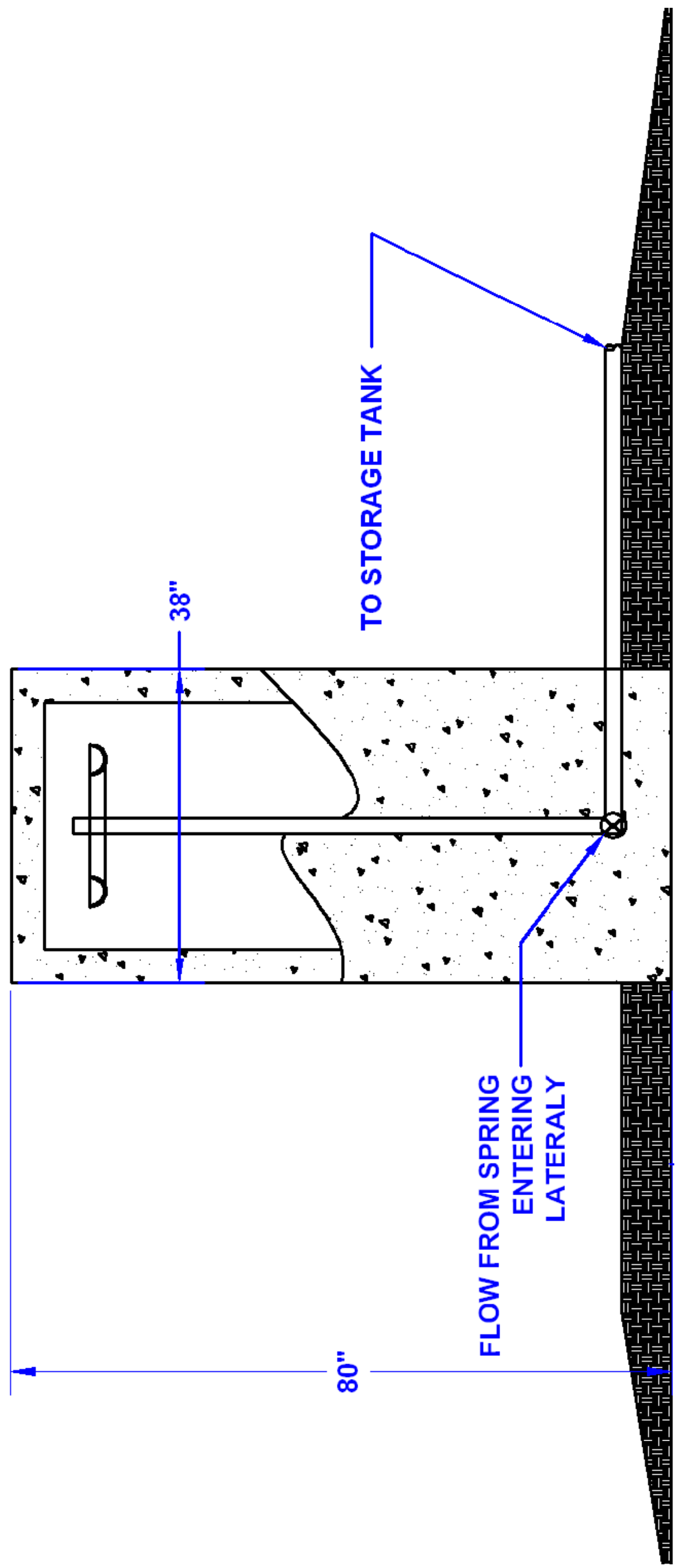
Appendix L





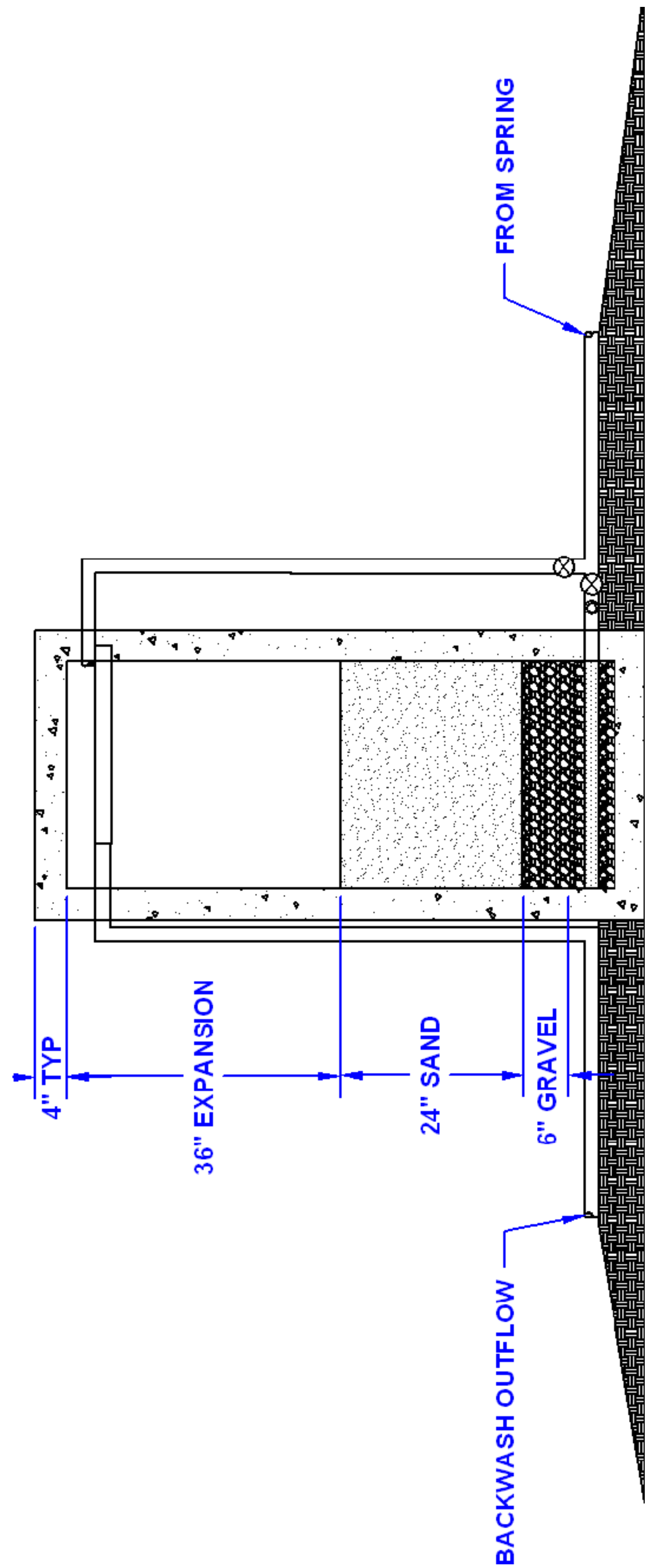
Top View

Appendix L



Side View

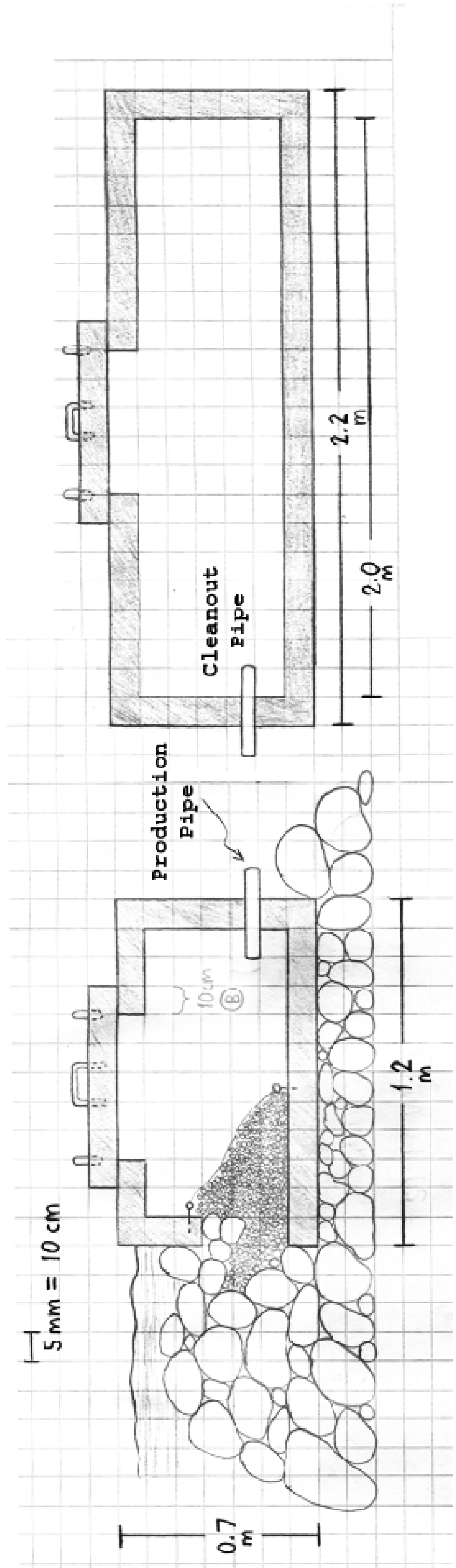
Appendix L



Front View

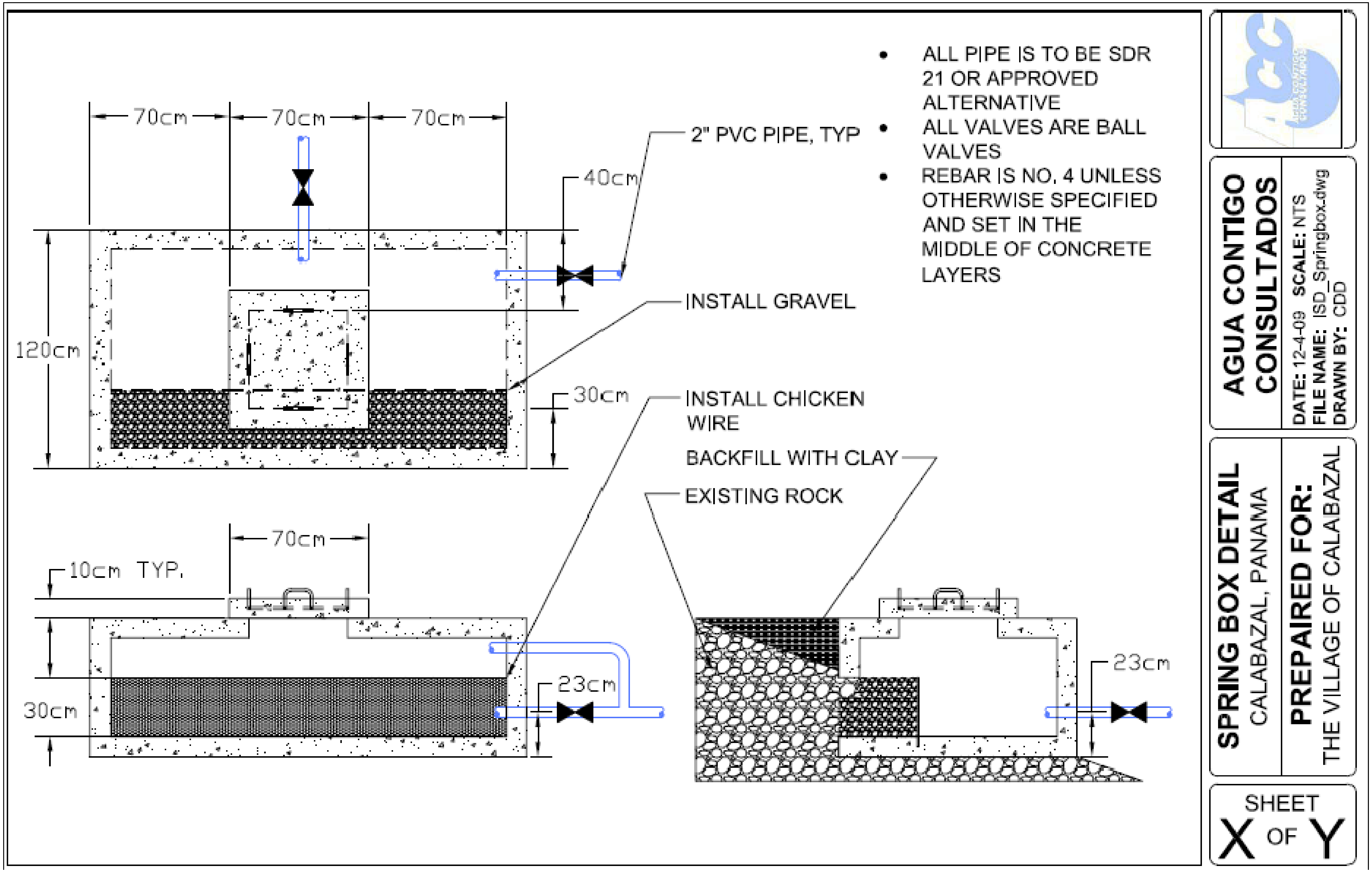
Appendix M: Spring Box Design

Appendix M



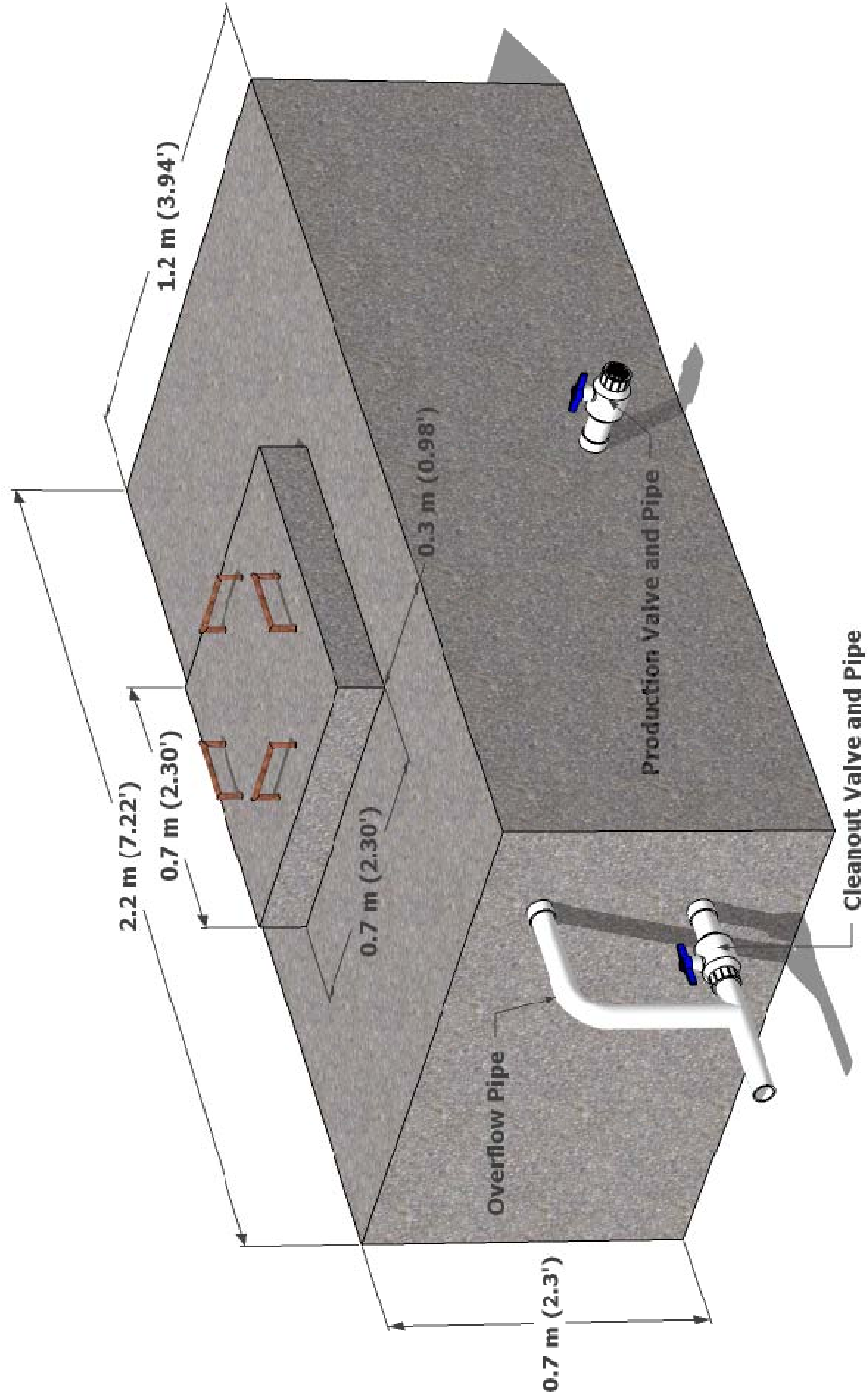
Cleanout Pipe
Production Pipe
2.2 m
2.0 m
1.2 m
0.7 m
5 mm = 10 cm
10 cm
B

Appendix M



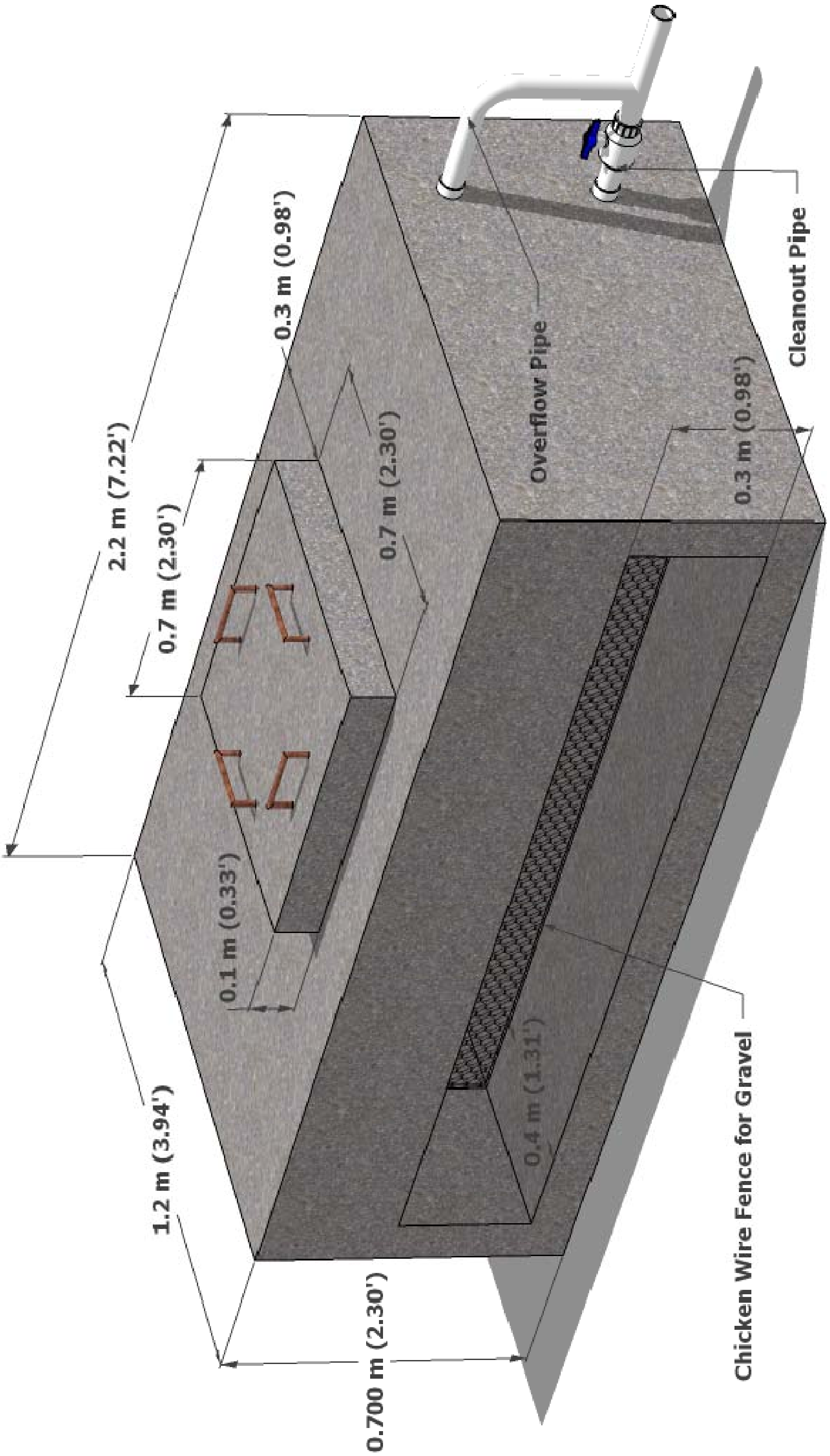
ALL PIPE IS TO BE SDR 21 OR APPROVED ALTERNATIVE
ALL VALVES ARE BALL VALVES
REBAR IS NO. 4 UNLESS OTHERWISE SPECIFIED AND SET IN THE MIDDLE OF CONCRETE LAYERS
70cm
70cm
70cm
2" PVC PIPE, TYP
40cm
120cm
INSTALL GRAVEL
30cm
INSTALL CHICKEN WIRE
BACKFILL WITH CLAY
EXISTING ROCK
70cm
10cm TYP.
30cm
23cm
23cm
AGUA CONTIGO CONSULTADOS
DATE: 12-4-09 SCALE: NTS
FILE NAME: ISD_Springbox.dwg
DRAWN BY: CDD
SPRING BOX DETAIL
CALABAZAL, PANAMA
PREPAIRED FOR:
THE VILLAGE OF CALABAZAL
SHEET
X OF Y

Appendix M



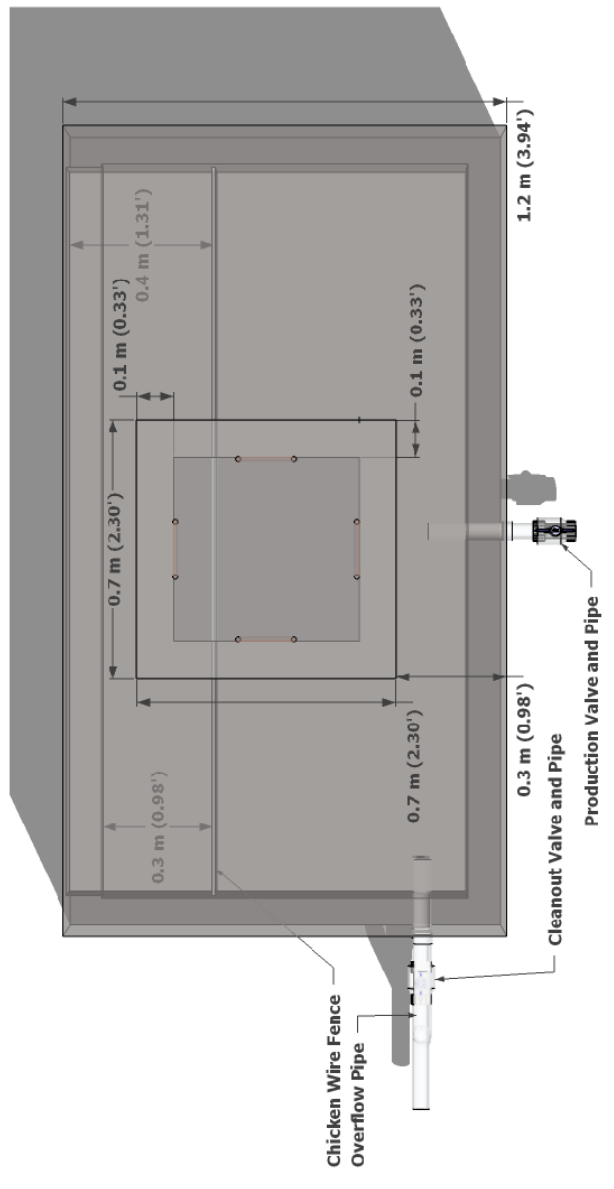
Front View

Appendix M



2.2 m (7.22')
0.3 m (0.98')
0.7 m (2.30')
0.7 m (2.30')
Overflow Pipe
Cleanout Pipe
0.3 m (0.98')
0.1 m (0.33')
1.2 m (3.94')
0.4 m (1.31')
Chicken Wire Fence for Gravel
0.700 m (2.30')

Appendix M



Top View