CHICHICA AQUEDUCT SYSTEM

CHICHICA, PANAMA

- **International Senior Design 2011**

CHICHICA AQUEDUCT SYSTEM
Chichica, Panama

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1.0 Executive Summary

For two weeks in August of 2011, TMC Engineering Consultants traveled to the Comarca District of Panama as part of the International Senior Design Program of Michigan Technological University. Their purpose was to design realistic solutions to expand the village of Chichica's access to clean water. The process for doing so was guided by the company's mission statement detailed below.

"TMC Engineering Consultants bridges the gap between interdisciplinary engineering design and water system technologies to serve the needs of industry, government and community clients. The rapid growth for the demand of clean water continues, which challenges existing technologies and available resources. TMC approaches water systems from the objective of delivering a quality water solution to our clients after the identification and assessment of several alternative solutions to ensure that all of the clients' needs and priorities are feasibly met with the best technology available. With a combined focus of ethical responsibility and cross-cultural understanding, TMC strives to be a leader in the efforts to expand access of clean water."

The iDesign program allows undergraduate students to participate in service learning while providing a multicultural context. The overall experience provides intensive and innovative real-world project experience that calls on the engineering, communication, leadership, and organizational skills of all members involved. TMC is comprised on three civil engineers and one chemical engineer, allowing for the diversity need to fully explore the water system issues at hand. Additionally, two advisors guided the team in their research, design, and professional documentation and presentation of their findings.

TMC worked in the village of Chichica, Panama to collect the data necessary to find a solution to the village's current water system issue. One of the aqueduct systems consisting of an intake structure, pipeline, storage tank and chlorinator had never properly functioned. Many sections of pipeline were found to have burst. It was the team's goal to figure out why the system never worked, how it could be fixed, as well as determining the quality of the water.

The survey data of the pipeline was used to determine the pressures and flow rates experienced by the pipeline. From this data, it was concluded that the maximum pressure of the pipe was never surpassed, yet through further research, it was found that the addition of air relief valves would help to decrease the chance that unexpected air pockets would lead to additional pressure. Recommendations also include replacing a third or the pipe line and adding a water arrestor to the pipeline after the storage tank that will further help to reduce the pressure caused by water hammer.

Modifications to the present intake structure include the construction of a settling basin as well as increasing the height of the outlet pipe. These actions will help to solve their current problems with sedimentation. Additionally, a higher entrance into the intake that is perpendicular to the water flow will further reduce the amount of sediment entering the intake and reduce the amount of maintenance needed.

Lastly, TMC recommended the purchase of a chlorine testing kit to monitor the required number of chlorine tablets in order to keep the residual chlorine concentrations at World Health Organization Drinking Standards. This will require the village to monitor these levels.

TMC has designed the necessary modifications to the pipeline and intake structure in order to accomplish the goal of providing Chichica with realistic means of increasing the amount of water supplied to their community. The research, recommendations and instructions will be submitted to the appropriate Peace Corps Volunteer members that will then oversee the implementation of the project.

2.0 Background

2.1 Project Background

The project site is set on the western Pacific side of Panama in the small mountain village of Chichica. This village is primarily inhabited by the Ngöbe people and lies in part of the province known as Comarca Ngobe-Bugle. (Figure 1) The International Senior Design group spent eight days during the summer of 2011 living in Chichica doing field surveys and interviewing villagers. The TMC Engineering Consultants senior design group consisted of David Kilpela, Megan Smaby, Pengcheng Zhou, and Samantha Kohls, all of whom were finishing their last undergraduate year at Michigan Technological University.

Figure 1. Location of Chichica, Panama

2.2 Need for water

Currently the village of Chichica has three sources of water that are connected to two storage tanks (Figure 2). Two of the sources are functioning and provide Chichica with 10,000 gallons of water daily. Those sources only provide approximately 4.4 gallons (16.7 liters) per person daily, which is below the World Health Organization (Reed, 2005) standard for minimum water requirements. A third source was added along with a 20,000 gallon tank in 2009 but was never functional. This third source has the potential of adding more than 100,000 gal in the wet seasons and 30,000 gallons in the dry seasons. This would provide a range of 17 to 48 gallons (64-177 Liters) per person daily, depending on the season.

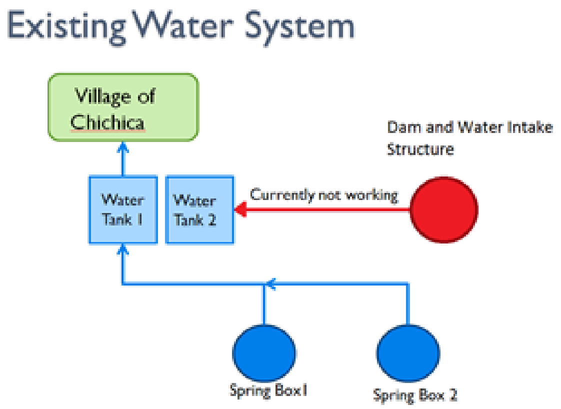


Figure 2. Existing water system in Chichica. The intake structure and pipeline noted in red is currently nonfunctional.

The local water committee speculated that every ten years, the population of Chichica has been growing by about 20% but a 35% increase is projected in the upcoming decade. The current estimate of the village population stands around 2300 people. There is also a school located in Chichica that has about 250 students, many of whom travel from nearby communities. The water committee estimated that in the next five years, the school's population would grow to 500 children. (Jessica, Personal Interview)

In the year 1990, the 2 working spring boxes supported about 65 taps plus the small high school. In 2000, there was an estimated total of 100 taps and in 2010, the numbers of taps increased to about 200 because of new housing. Currently all of the taps receive water for approximately 1-2 hours each morning. However, the taps at the end of the line start receiving water 10 to 15 minutes later than those at the beginning of the line. Additionally there are new taps added in the community that do not receive water because of the shortage. The people at these taps carry their water from nearby open sources. Because of the shortage, community members store as much water as they can in open containers and use it for all of their needs.

2.3 Funding

From a meeting with the water committee we know that currently the committee has $4,000 in their account but would like to keep $1,000 for maintenance purposes. The remaining $3000 can be spent on fixing the nonfunctioning pipeline. The committee can also charge $5 extra a year on top of the 50 cents that each family pays per month to raise more money. About 90% of the Chichica villagers currently pay this fee. Additionally, Jessica, the local Peace Corps worker, can apply for a Water Surf and Appropriate Project grant to receive an extra $1,000.

2.4 Local Resources

The main cultural resources were the assigned Peace Corps Volunteers, Jessica Rudder and Chris Kingsley. Jessica is a business major that specializes in teaching and encouraging smart and tactful ways to begin private businesses in the area. She is the main contact in the community and understands the local culture. Chris Kingsley is a Peace Corps Volunteer from a nearby village who specializes in aqueduct systems and accompanied the team during the assessment in Chichica. He acted as a translator for all of the technical questions in the field. He was also able to provide advice and insight on local water systems through his past encounters with aqueduct systems in other villages. Throughout the project both Jessica and Chris have been in contact with the team and have helped collect further data and material costs. They have also critiqued different design options.

The local water committee in Chichica consists of four main members that oversee the current aqueduct system. They are in charge of maintenance of the aqueduct system and collecting water fees. They took turns being guides for the design team each day during the assessment trip, and cleared surveying sightlines and offered their knowledge of the system. Their authority over the water system appears to be respected by the community, as they are able to collect 90% of the water fees and keep their current system running well. Their knowledge of the aqueduct and dedication to their positions greatly helped in collecting the needed data.

3.0 Project Scope

The purpose of TMC's senior design project was to provide clean and dependable drinking water to the village of Chichica. The primary focus of the project is to address the problems associated with the existing water intake structure, pipeline and storage tank system. The two-year-old system cost over $100,000 to install but never functioned. The goal of the project was to determine the cause of the system's failure and provide the community with solutions to modify the existing system in order to provide them with more water.

3.1 Intake structure

The intake structure consists of a dam on a small creek and a modified spring box. It is remotely located approximately three miles from the village and requires hiking from the main road a third of mile up a steep valley. The intake box is located directly behind the dam and has 2" intake pipes that are placed parallel to the flow of the river as seen in Figure 3. During the wet season, when there is increased flow and sediment in the water, the intake box and the area directly behind the dam fill up with sediment. The area behind the dam is normally filled with large stones. Within a few days of heavy flow the intake box becomes filled with sediment and the large stones need to be moved to clean out the sediment. This is a labor intensive job and requires frequent checking.

Figure 3. Current intake structure attached to the dam.

3.2 Pipeline layout

The pipeline is approximately three miles long and is made of 4” SDR 26 and Schedule 40 PVC pipe. As seen in Figure 4 the pipeline drops down into a large valley before heading up to the storage tank located in Chichica. The pipeline goes over multiple small hills and spans several creeks. At the creek crossings, the pipeline is suspended by a cable. At these points the pipes are exposed without any protection from ultraviolet radiation. The pipeline is buried except for a section in the middle of the pipeline. This section has multiple breaks and is located in farmland that is frequently burned to kill vegetation. Because of this, much of this section is scorched. Only two air relief valves were found on the pipeline.

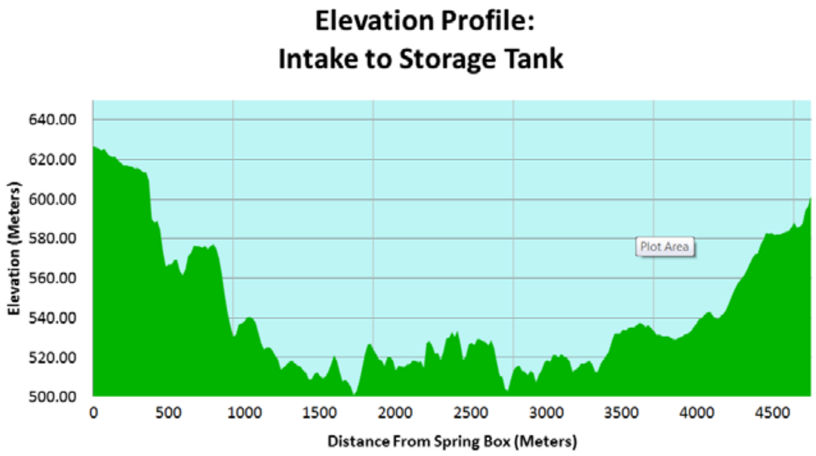


Figure 4. Pipeline elevation profile from the river intake (left) to the storage tank (right).

3.3 Comparison of Systems

The most significant difference between this system and the other two working systems is the source of water. The other two systems have spring boxes located directly above natural springs. This ensures that no extra sediment or contamination enters the system. The nonfunctioning system collects water from an open stream that carries significant amounts of sediment during the wet season. The pipelines of the other two systems are made of 2” schedule 40 PVC and have much higher pressures. The amount of water coming from this system currently serves the entire community of Chichica with approximately 10,000 gallons per day and has a flow rate of 26 gallons per minute. This source is only used for six hours during the day before being diverted to a nearby community. It only has the capacity of providing 1250 people with adequate amounts of water for drinking, cooking and washing (Reed, 2005). There are currently about 2000 using this system and about 300 more waiting for access to the system. The nonfunctioning system has a potential flow rate of 21-82gallons per minute depending on the season. Although the system has a much larger degree of fluctuation than the spring box systems, it would more than double their water supply during the dry season and provide more than enough water for everyone during the wet season. During the dry season, these systems would together provide enough water for up to 5,400 people. More details of the systems can be found in section 5.2.

4.0 Field Methods for Data Collection

While in Chichica, many field methods for data collection were used. These include abney level and GPS surveys, weir flow measurements, and water quality testing. They are described in this section.

4.1 Abney Level Survey

Because no accurate maps existed of the area, the original surveys for the system were not available and it was necessary to do a survey of the pipeline. With the issues concerning time limitations, terrain roughness, and poor sight visibility, an abney level was chosen as the tool for surveying. Since the size of the abney level, as shown in Figure 5, is easily manageable, it was easy to use even in extremely rough terrain. To complete the survey, two equal height sticks were used. The first was to rest the level on, and the second was a target to focus on (Figure 6). The measured grades of the terrain between the sticks from each direction (a front sight and back sight), as well as the distance between the sticks and compass bearing, were all recorded. From this data, a map was created showing both the lateral coordinates of the line as well as its relative elevation. The abney level survey raw data is shown in Appendix A.

http://www.cstberger.us/us/en/

Figure 5. Abney Level

Figure 6. Field Survey using Abney Level

4.2 GPS Points

Along with using the abney level, a GPS was used to partially confirm the data created in the abney level survey. This was not used as the primary source for information, as its accuracy was unknown. On the second day of surveying, the entirety of the pipeline was hiked with a GPS, recording elevation and coordinate data. Also, elevation readings were taken throughout the day at a common location so that elevation errors due to changes in the barometric pressure could be eliminated. This data was used to confirm the accuracy of our original survey. The GPS was also used to map out the location of the line leading from second spring box to the water tanks. This data map can be seen in figure 7.

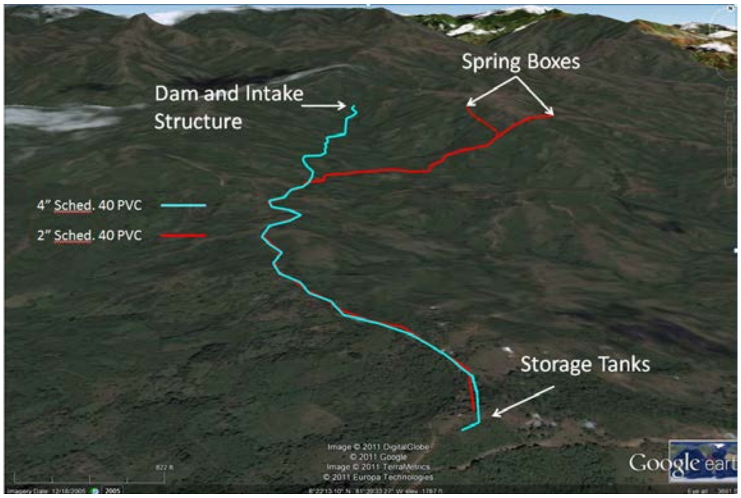


Figure 7. GPS data showing the pipeline paths and locations of the water intakes. (Google Earth)

4.3 Flow Measurements

To measure the flow rate in the river, all of the cleanout valves on the dam were plugged and a 60˚ triangular weir was placed across the spillway. By measuring the height of the water surface from the bottom of the weir the flowrate was calculated as seen in Figure 8. Chris Kingsley, the aqueduct specialist, had done some flow measurements during the dry season at the same location. (Kingsley, 2011) This provided us with an estimate of the annual river flow fluctuations. River flow calculations can be found in Appendix B.

Figure 8. Weir on Spillway of Dam

4.4 Water Quality Testing

To determine the water quality of the sources feeding the Chichica water system, a 3M Petrifilm test kit was used. To perform the test, one milliliter of sample water was collected using a pipette. Then the sample water was placed on the Petrifilm paper. Next, a protective plastic sheet was placed on the paper. The air bubbles were forced out by tapping a circular plastic spreader on the protective plastic sheet. The sample was then sandwiched between two pieces of cardboard and bundled with rubber bands. The sample was incubated next to the skin on a person's body for 24 hours (3M Food Safety, 2008).

Eight 3M Petrifilm tests were taken from the Chichica water supply. Three samples were taken upstream of the broken spring box, two samples were taken at the functioning spring box, two samples were taken from the Peace Corps volunteers' tap water, and one sample was taken from the Peace Corps volunteer's water bucket. Samples were taken upstream of the broken spring box to determine the quality of water in the stream and compare it to the quality of water from the other spring boxes. The samples taken at the functioning spring box were obtained to test the spring water going into the existing system. Water samples from the Peace Corps tap water were taken so the source water can be compared with the distributed chlorinated water samples. The sample taken in the Peace Corps water tank was taken to estimate what amounts of contamination occur during water storage. Figure 9 shows an example of a completed 3M Petrifilm test. This particular sample was taken from behind the broken spring box. The blue dots indicated E. coli, while the red dots indicated coliforms.

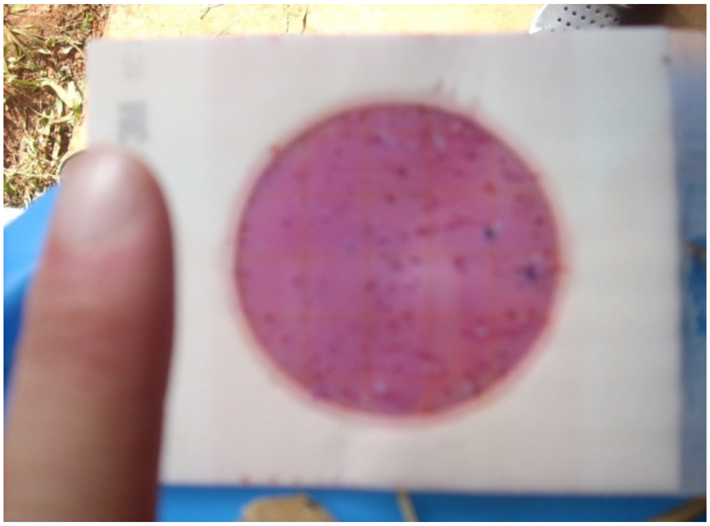


Figure 9. Completed 3M Petrifilm test

5.0 Project Development

5.1 Intake Structure Considerations

Three options for preliminary design of the intake structure are shown in figures 10, 11, and 12 (Jordan 1980). Figure 10 addresses the sedimentation problem by adjusting the water intake direction into the sedimentation tank to be perpendicular to the flow of water. This will allow less sediment to enter the sedimentation tank, or to build up behind the inflow pipe. The design allows water to flow into the sedimentation tank and then exit through the valve box via the outlet pipeline. Two alternative designs were also further researched. The second alternative shown in figure 11 incorporates several points of filtration through the use of large stones and two sedimentation tank chambers. The complexity of this design would most likely cause problems in construction and maintenance. This design may be prone to sediment clogging the intake section of the dam. The third alternative shown in figure 12 utilizes a different sedimentation tank design to provide more retention time. The baffles, or wing walls, in this design increase the path the water must travel and therefore increase the retention time. This allows more of the suspended particles to settle out of the water. A chart comparing the features of the current structure and the three alternatives is shown in Appendix C.

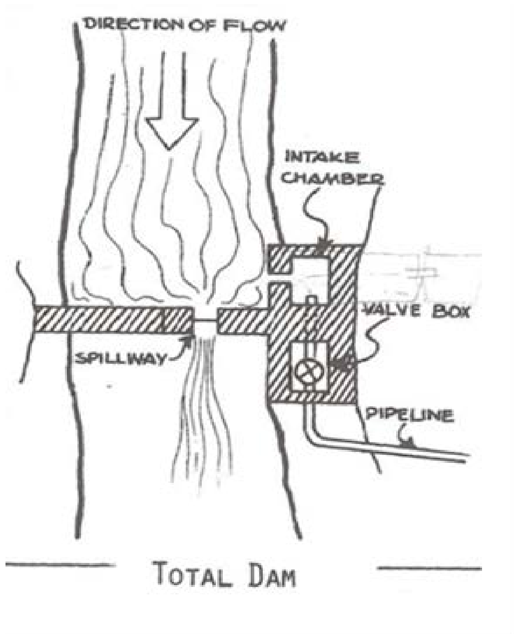


Figure 10. Dam and sedimentation tank that avoids sediment build-up (Jordan)

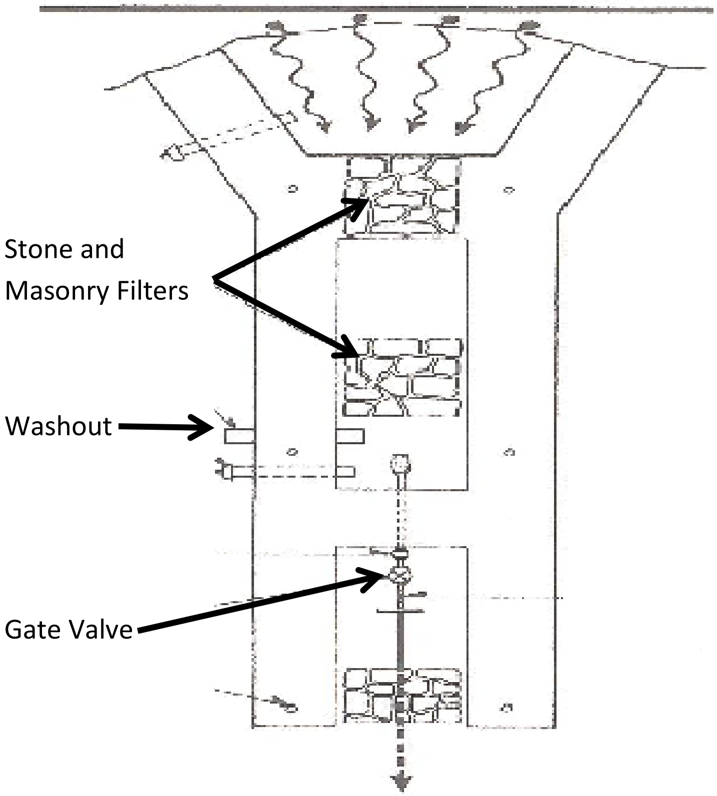


Figure 11. Design utilizes large stones for filtration. (Jordan, 1980)

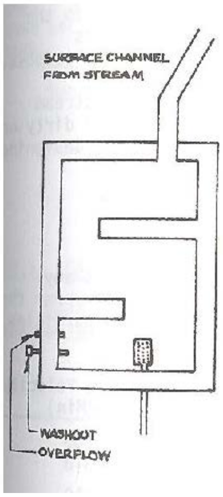
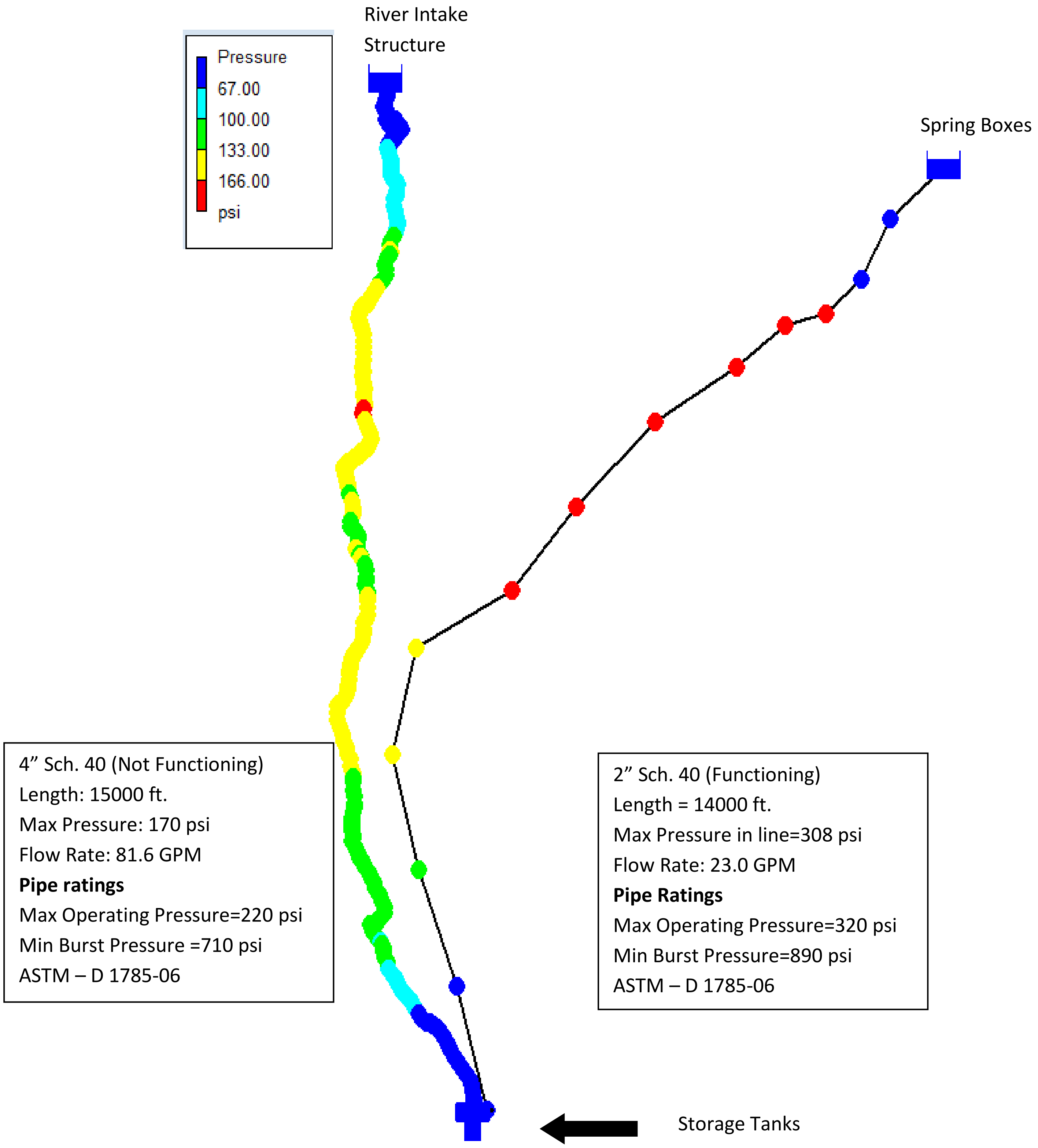


Figure 12. Sedimentation Tank with baffle (Jordan, 1980)

5.2 EPANET Simulation

Using the abney level survey data as well as GPS data, an EPANET model was created to simulate the pressures and flow rates in the current system. The elevations for each point surveyed were manually entered into EPANET along with the characteristics of the pipeline. The assumptions used in the model are shown in Appendix D. The pressures and flows were calculated with EPANET. A schematic of the system may be found in Figure 13 on the following page. The simulation shows that there is a 1.5 mile section of the pipeline, denoted in yellow, where the most pressure is exerted on the pipe. ASTM Standard D 1785-06 states that the maximum operating pressure for Schedule 40 PVC is 220 psi, and based on the pressures calculated by EPANET, there is no point along the pipeline where this maximum pressure is surpassed for Schedule 40 pipe. (ASTM, 2006) The pipes in Chichica are made to COPANOT (Comisión Panameña de Normas Industriales y Técnicas) Standards, part of the International Standards Organization (ISO). COPANIT standards are equivalent to ASTM standards for Schedule 40 PVC. The highest pressure predicted is 173 psi at node 92, which is about 1.0 mile down the pipeline. The theoretical flow through the pipeline was calculated to be 95.2 gpm. This flow rate was reduced to 80.6 gpm once the sand filters were simulated directly prior to entering the tank. At this flow rate, the storage tank would fill in approximately 3.5 hours

Another issue that arose was the analysis of why the pipes burst in the first place. Since we have now determined that, according to the EPANET simulation, the maximum pressure in the pipeline was not exceeded, alternate causes were examined. It has been hypothesized, based on the fact that the line claimed to be working for the first 20 minutes, the initial surge of the water flowing through the pipes may have caused the pipes to burst. It is also possible that air pockets in the pipeline stopped the flow completely and caused the dynamic pressure to be converted to static pressure. Another potential reason for the bursting pipes is poor quality pipes or improper installation. In the field study, many pipes had small patches placed on them to fix cracks or holes. These homemade patches or homemade couplings could also have been causes for the pipes to fail.



4” Sch. 40 (Not Functioning)
Length: 15000 ft.
Max Pressure: 170 psi
Flow Rate: 81.6 GPM
Pipe ratings
Max Operating Pressure=220 psi
Min Burst Pressure =710 psi
ASTM – D 1785-06

2” Sch. 40 (Functioning)
Length = 14000 ft.
Max Pressure in line=308 psi
Flow Rate: 23.0 GPM
Pipe Ratings
Max Operating Pressure=320 psi
Min Burst Pressure=890 psi
ASTM – D 1785-06

Figure13. EPANET simulation showing the two pipelines feeding the Chichica water system. The node colors correspond to different pressures as seen in the upper left key.

5.3 Chlorinator

The village of Chichica currently has an in-line chlorinator connected to their gravity-fed potable water system. The current operating system consisting of two spring boxes and one 10,000 gallon tank utilizes the present chlorinator by adding chlorine tablets supplied by the government free of charge. It is unclear as to how often the chlorine tablets are changed and what condition they are in at the time the refill takes place. Essentially, the chlorinator delivers a controlled dosage of chlorine that is sufficient to inactivate most disease-causing organisms. As show in Figures 14 and 15, the flow of water is directed to the center of the chlorinator, allowing a portion of the flow to encounter the chlorine tablets. This drawing does not represent the exact chlorinator found in Chichica, but the function is the same. If the flow of water is increased, the water travels upward in the chlorinator stand pipe and comes in contact with a greater amount of surface area of the tablets. This ensures that no matter the flow rate, the concentration of incoming chlorine will, for the most part, remain constant.

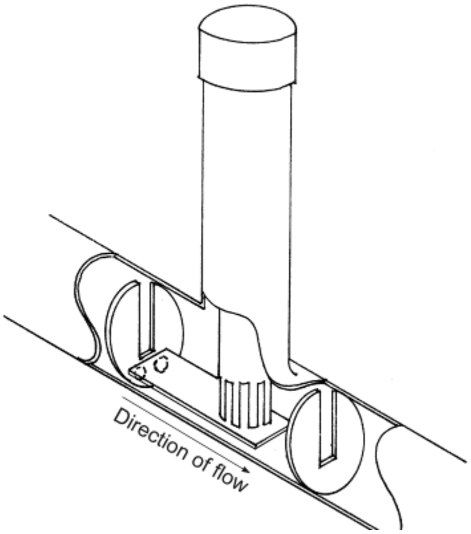


Figure 14. Drawing of Chlorinator Cutaway View

Figure 15. Chlorinator connected in parallel on the 2" waterline in Panama.

5.4 Chlorinator Recommendations

The residual chlorine concentration present in the tank and distribution system is a function of organic matter found in the water. Since the water in the tank was not tested, it is recommending that a chlorination test kit be purchased and the testing be performed. Based on this test, the water committee will know how many chlorine tablets are necessary and how often they need to be changed to keep the residual chlorine level at World Health Organization drinking water standards of 0.2 to 1.0 mg chlorine/L water (Guidelines 2011). The basic calculations for various amounts of tablets may be found in Appendix E and are provided simply as a reference. These calculations do not take into account the amount of organic matter found in the water, so the actual concentrations will be lower. The summary of the calculations may be found below in Table 1. A similar ecosystem was researched to estimate residual amounts of chlorine. Chichica's water system was compared with an experiment done on the Savannah River because both systems are found in warmer climates and both are rivers. In that system, a chlorine concentration of 1 mg/L drops to 0.45 mg/L in thirty minutes, and to near zero within 24 hours. An initial concentration of 3 mg/L drops to 1 mg/L within thirty minutes and to 0.25 mg/L in 24 hours. The greatest concentration tested was 5 mg/L which dropped to 1.75 mg/L in thirty minutes and to 0.15 mg/L in 24 hours. (Wilde, 1989) Thus, we recommend an initial concentration of .5 mg/L so that the residual amounts stay within WHO standards. (Guidelines, 2011)

Table 1. Results for initial chlorine concentrations in a 20,000 gallon tank for varying tablet amounts.

Number of Tablets	**Weight of Tables (mg)**	**Total Volume (L/15 days)**	**Chlorine Concentration (mg/L)**
1	64,210	1,136,000	0.057
5	321,400	1,136,000	0.283
10	642,800	1,136,000	0.556

Based on the chlorine concentration expected in the tank for a given number of tablets over a period of time, the village may add additional tablets of chlorine to the system until the ideal concentration is achieved. Instructions for the village are provided in the Operations and Maintenance Manual found in Appendix F.

6.0 Recommendations

6.1 Pipeline Rehabilitation

A section of approximately 7550 feet of pipeline will need to be replaced with 4" schedule 40 PVC pipe. These sections are located in the highest pressure areas in the middle of the pipeline. Because these sections of pipe have not been buried, they have been extensively damaged by UV exposure and agricultural field burns. These sections are noted in Appendix G. Trenches will be dug prior to laying the new pipe. The new pipe will be laid using the same alignment as the previous pipeline and should be buried with at least 36" of cover (Jordan, 1980). In the two suspended valley crossings that will be replaced, the original cable spanning the gorge along with the concrete footings will be reused. The pipe will be tied every 24 inches using 1 mm rebar tie wire on one foot centers. The exposed pipe will be painted to reduce UV exposure. A cleanout vale should be added to the pipeline. The location and maintenance procedure is outlined in Appendix F. Detailed drawings of the cleanout valve are located in Appendix H.

6.2 Air Relief Valves

Air pockets stuck in high points can be problematic to pipelines by reducing or even blocking flow. Air pockets increase pressure in the pipeline as the dynamic pressure in the pipeline is converted to hydrostatic pressure. Because the pipeline contains multiple high points, air relief valves are needed to release any air that becomes trapped, similar to those that have been placed on the other lines feeding the village. These valves are homemade and maintained by the water committee as seen in figure 16. Similar valves will be constructed and placed along pipeline. Reinforced concrete boxes will be constructed to be placed over the valves and protect them. Drawings of the air relief valves and the protective boxes can be seen in Appendix H. An estimated eighteen air relief valves are needed to adequately relieve the system of air pockets. These valves will be placed along the main peaks in the water system. These locations are mapped out in Appendix I.

Figure16. Homemade air relief valve used on the working waterline.

6.3 Water Hammer Arrestor

Water hammer is caused by closing a valve on the system too quickly. This can cause pressure waves to travel through the pipeline. In a system of this size, water hammer can cause a surge of up to 220 psi if the valve leading to the storage tank were to be closed quickly. This pressure surge would be added to the dynamic pressure and could cause damage to the system, especially in the high pressure areas. To counter this potential problem, a water hammer arrestor valve will be added directly behind the valve leading to the storage tank. The arrestor consists of a 4” PVC standpipe 24 inches tall. This can be seen in figure 17. Details of the arrestor valve can be seen in Appendix H. Calculations for sizing the arrestor and calculating pressure surges can be found in Appendix J. The arrestor has two valves on the line that allow the standpipe to be drained. More details of this procedure are found in the maintenance manual in Appendix F.

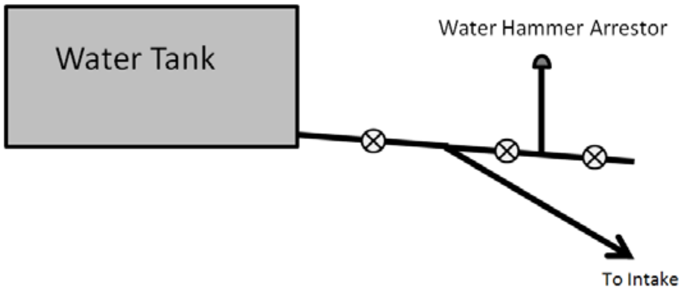


Figure 17. Water hammer arrestor located directly behind the storage tank.

6.4 Final Intake Structure Design

It is recommended that a new intake structure be constructed and the old intake structure removed. The constraints for the intake structure are: (1) no more than fifty percent of the river can be diverted during the dry season, and (2) the intake should filter out sediment in the water during high flows. The existing dam will be used, and all the existing pipes through the dam will be closed. The new structure will be placed on the west river bank. This structure consists of an intake entry perpendicular to the flow of the river. The amount of water entering the intake structure will be regulated by the spillway. The intake spillway will be built to the exact elevation and width as the spillway on the dam. This will prevent too much water from being diverted from the river during the dry season. The intake structure itself is 16' long, 8.5' wide, and 6' tall. All of the walls will be 6" thick and reinforced by rebar. It has three evenly spaced wing walls inside it to slow the water down as seen in Figure 18. The retention time of the water is designed to be 30 minutes so that all of the large and some of the small particles will settle out. The sand filters at the end of the pipeline will filter out the rest of the particles before the water is distributed to the community. See calculations in Appendix K.

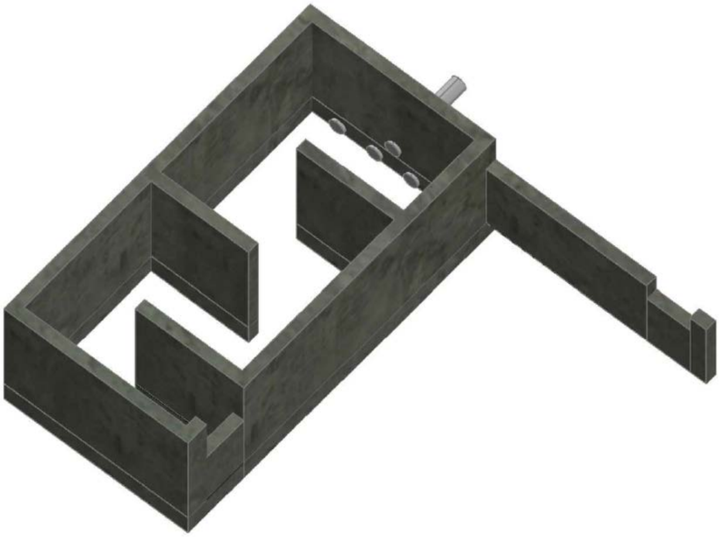


Figure 18. A 3D model of new intake structure. (Note: A concrete floor 4" thick will be built for the intake structure)

The new design addresses the sedimentation issue by adjusting the direction of intake gate perpendicular to the flow of water. The new intake pipe is designed to be placed 1.5 ft. above the bottom floor instead of placing it right on the bottom. This design ensures the function of the intake and requires less frequent maintenance, since it offers more space for settled sediment.

The three baffle walls also are incorporated into the new design. The winged walls increase the length of flow path, allowing a longer travel time settling out more particulate. In addition three cleanout pipes are located near the bottom of the intake structure. These pipes can be opened up to help clean out built up sediment. Detailed drawings of the intake and rebar details can be found in Appendix H. Rebar calculations can be found in Appendix L.

6.5 Chlorination

It is recommended that the village of Chichica continue using their current chlorination system once the second tank is connected to the first. It is also recommended that they purchase and utilize a chlorination testing kit over a period of 90 days to determine the effect of the number of tablets on the chlorine concentration within the tank. The instructions for the adjusting the chlorine levels can be found in Appendix M.

6.6 Sand Filtration

Two sand filters are located in the small outbuilding next to the storage tank. These filters are currently disconnected from the system and are not in use. These filters can be used to effectively trap fine sediment not filtered out by the sedimentation tank. If the filters were connected to the system, it is estimated that the flow rate would be reduced from 90 gpm to 81 gpm. These calculations were based on broad assumptions because little was known of the aggregate inside. Because of this actual flow rates may vary. Procedures for periodic flushing of the filters can be found in Appendix F.

7.0 Construction Schedule

The construction schedule found in Appendix N shows the estimation of the time required to complete the project to be approximately 35 days. The pipeline labor estimates are based on the length of time required to place the original pipeline. This data was obtained from speaking with Lucas, the head of the village water committee. During the pipeline replacement, air relief valves will be placed along the pipeline in the proper locations. The pipeline replacement will be followed by the intake structure construction. The final stage of the implementation includes period of chlorine monitoring which is not included in the project duration. During this monitoring period, adjustments to the chlorine content will be made if chlorine levels do not meet expected values.

8.0 Final Cost Estimate

The cost estimate includes the required materials and services to construct the additional intake structure components, replace 7550 ft. of pipeline, and conduct further water quality tests. Also included in the estimate is a 15% contingency cost to include any unexpected expenses. The significant costs of materials were found by Peace Corps volunteers in the Comarca, Jessica Rudder and Chris Kingsley (Rudder, Kingsley). Other minor costs were researched online, and an average price was used. Table 2 below shows the major cost breakdown. Details of each component's individual costs may be found in Appendix O.

Table 2. Overall Material and Service Cost Estimate for Chichica, Panama

Component	Cost
Intake Structure	$1,060
Water Quality	$40
Pipeline	$3,070
Labor- estimated at $1,300, but will be donated	$0
Total Cost	$4,170
Total Cost + 15% contingency for unexpected costs	$4,800

Labor is assumed to be donated by community members. If labor were contracted out, there are two methods of payment that were outlined by Lucas, the head of the water committee. The average wage per day for the city of Chichica is twelve dollars. This method was used for the labor pricing of the intake structure. A more specific estimate involves charging $1 to bury each 20’ tube and $2 to excavate the area for each tube.

The largest costs for the intake structure include the costs of cement, rebar and boards. For the pipeline replacements, 170 units of 4” schedule 40 pipes in 20 ft. sections will be purchased along with socket T sections, small hollow balls, caps, screens and cables used to construct the air relief valves.

9.0 Summary of Final Recommendations

Currently, several problems exist with the latest aqueduct system in Chichica, Panama. Several upgrades are needed to address the problems. First, a significant section of the pipeline will be replaced and buried to fix the areas that have breaks, fire damage, and UV damage. Air relief valves will also be added along the pipeline as well as a cleanout valve to wash out any sediment. A water hammer arrestor valve will be constructed near the storage tank to help minimize surge pressures.

Secondly, a new intake structure will be built on the river. This tank has a settling basin and a higher outlet pipe. This will reduce the amount of sediment entering the pipeline. The high entrance and intake perpendicular to the water flow will reduce the amount of sediment entering the intake and reduce the amount of maintenance needed.

Lastly, a chlorine monitoring system will be implemented to ensure that the correct levels of chlorine are being added to the water entering the storage tank. During the initial assessment, water samples showed large amounts of bacteria and e-coli in the water. It will be important that the water committee follow the recommended testing procedures to ensure that adequate chlorine levels are maintained in the water system.

10.0 Acknowledgments

TMC would like to thank the individuals who have helped us in our project. Your assistance was crucial in helping us attain our goals, and we have learned a lot from you. A special thank you goes out to these individuals: you.

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Chris Kingsley

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

Other Resources
Brian Barkdoll, P.E., D.WRE.
Martin Auer, Ph.D.

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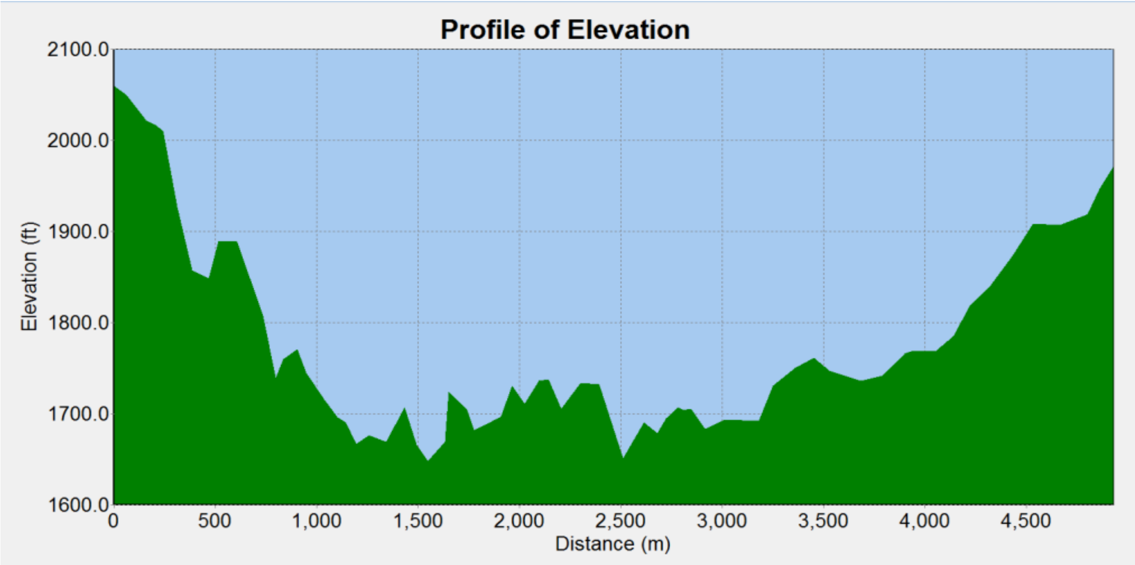
Appendix A:



Abney Level Survey Results

Notes	Point	Measured Distance (Meters)	Front Site (Percent Grade)	Compass Bearing (Degrees)	Elevation Relative to Start (Meters)	Cumulative Dist. (Meters)
"Spring Box 1"	1	17	-7	200	-1.04	0.00
	2	11.94	-4	140	-1.48	11.93
Exits Stream Goes Underground	3	21.7	-7.5	168	-1.92	33.59
	4	10.41	11	171	-3.34	43.94
	5	12.84	-18	201	-2.25	56.61
Pipe crosses small stream	6	17.4	-10	209	-4.32	73.95
Exposed Pipe next to river	7	12.83	-6.5	198	-5.83	86.76
	8	15.9	1.5	142	-6.53	102.66
	9	13.6	-17	150	-6.40	116.11
goes to right, open path (sunlight)	10	13.4	-8.5	182	-8.35	129.47
	11	15.95	-10	185	-9.40	145.36
	12	7.55	1.5	158	-10.79	152.91
Pipe suspended above gully	13	14.34	-4.5	148	-10.69	167.24
	14	12.22	-2	80	-11.22	179.46
	15	18.3	-5	51	-11.51	197.74
	16	5.05	5	62	-12.31	202.79
wraps around mt. to right open grass	17	12.45	-8	150	-12.09	215.21
	18	25.61	-5.5	139	-12.96	240.78
	19	11.74	0.5	157	-14.25	252.52

Notes	Point	Measured Distance (Meters)	Front Site (Percent Grade)	Compass Bearing (Degrees)	Elevation Relative to Start (Meters)	Cumulative Dist. (Meters)
	20	14.57	-34	234	-14.22	266.44
	21	30.3	-78.5	216	-18.54	289.94
	22	16.7	-14.5	242	-37.66	306.51
	23	10.64	11	214	-39.80	317.10
	24	12.5	-43	216	-38.78	328.71
Crosses River (flowing to left) Not part of vertical profileabout 3 m. below pipe	25	16.5	-82	194	-43.42	341.16
	26	12.3	-75	167	-54.24	350.89
	27	5	21	145	-61.77	355.80
	28	20.7	0	17.2	-60.84	376.50
	29	8.8	31	15.9	-60.93	384.97
	30	23.3	1	168	-58.54	408.27
	31	15	-43.5	180	-58.34	422.16
	32	15.4	-16	189	-63.99	437.41
at broken pipe (picture)	33	14	23.5	184	-66.13	451.14
	34	14.5	57	149	-63.37	463.85
	35	17.7	9	130	-56.39	481.50
	36	14.6	30	150	-55.08	495.59
	37	27.7	-1	184	-51.24	523.29
	38	17.2	0	192	-51.48	540.49
	39	17.3	-5	208	-51.56	557.77
	40	27.2	4	180	-52.39	584.94
	41	17.75	-11	174	-51.32	602.61
	42	30.2	6.5	164	-53.02	632.77
	43	17	6	169	-51.38	649.74
	44	13.6	-19	173	-50.49	663.15
	45	17	-34	192	-52.79	679.41
	46	19.3	-49	194	-57.76	697.00
	47	16.6	-77	216	-65.69	710.04
	48	19.6	-53	209	-75.96	727.54
	49	13.3	-61	198	-84.79	739.00
	50	15.9	-39	187	-91.54	753.97
suspended w/ thick cables-	51	9.18	6.5	189	-96.91	763.13
	52	10.5	60	150	-96.41	772.20
	53	11.7	6	216	-91.12	783.89
pipe is burnt and bent	54	17	6	212	-90.51	800.87
	55	30	9	203	-89.69	830.78
	56	18.58	1.5	170	-87.47	849.36
	57	21.69	-5	184	-87.14	871.03
grassland/pasture	58	19.4	-11.5	208	-88.14	890.33

Notes	Point	Measured Distance (Meters)	Front Site (Percent Grade)	Compass Bearing (Degrees)	Elevation Relative to Start (Meters)	Cumulative Dist. (Meters)
	59	10.95	-55.5	220	-90.08	900.01
	60	13.5	-44.5	218	-95.20	912.49
lots of underbrush, about 10 ft. small trees (3m)	61	37.1	-10.5	214	-100.34	949.43
	62	15.5	8	214	-103.81	964.89
	63	20.8	0	213	-102.73	985.69
	64	21	-7.5	219	-102.73	1006.64
	65	6	-52	214	-104.15	1012.04
pipe broken straight down	66	13.8	-16	245	-106.78	1025.70
	67	7.7	-84	234	-108.73	1031.47
	68	8.5	12	220	-113.83	1039.92
	69	7.6	24.5	208	-112.95	1047.35
	70	12.65	11.5	194	-111.35	1059.93
	71	7.85	10	208	-110.06	1067.75
	72	15	-10	191	-109.37	1082.70
	73	16.07	-7	170	-110.68	1098.73
	74	14.05	-5	162	-111.73	1112.77
angle to the left- entering cornfeild	75	9.35	-24	163	-112.34	1121.91
	76	9.3	-13.5	160	-114.29	1131.15
	77	20	-19.5	158	-115.40	1150.85
	78	30.6	1	180	-118.83	1181.45
	79	27.05	11	176	-118.70	1208.38
piece off to the side 1.5 m lon	80	20.7	6	174	-116.10	1229.05
	81	30.7	-7.5	190	-115.11	1259.68
	82	30.7	-3	183	-117.18	1290.37
	83	17.5	5	174	-118.12	1307.85
partially burnt	84	14.35	22	187	-117.36	1321.94
	85	30.7	14	168	-114.62	1352.43
	86	24.3	21	170	-111.01	1376.32
lightly burnt section	87	17.3	-19	199	-106.58	1393.38
	88	30.7	-20	194	-109.44	1423.59
	89	12	-50	167	-114.90	1434.49
	90	27.1	4	174	-119.93	1461.57
	91	12.3	-12	180	-119.04	1473.81
	92	15.7	-17	209	-120.33	1489.32
down to stream	93	18.4	-25.5	191	-122.71	1507.27
	94	12.3	19	148	-126.77	1519.40
cow attack	95	17.3	33	164	-124.74	1535.98
corn field (burnt pipes)	96	30.7	25	156	-119.79	1565.95
burnt pipes	97	30.7	27.5	158	-113.15	1595.82

Notes	Point	Measured Distance (Meters)	Front Site (Percent Grade)	Compass Bearing (Degrees)	Elevation Relative to Start (Meters)	Cumulative Dist. (Meters)
exiting corn field	98	21.8	25	170	-106.05	1617.10
	99	7.2	9	192	-101.33	1624.28
pipe suspended above ground	100	18.21	-19	200	-100.77	1642.24
Exposed Pipe next to river	101	13.2	-20	212	-103.77	1655.25
	102	12.5	-25	233	-106.01	1667.45
	103	16.4	-5	241	-108.71	1683.84
	104	7.1	-45	241	-109.36	1690.41
Gully pipe suspended 5' up	105	14.7	35	213	-112.04	1704.45
This is where the pipe usually breaks	106	10.5	4	238	-107.68	1714.94
pipes exposed from here til otherwise noted	107	11	-20	249	-107.34	1725.76
	108	11	-54	237	-109.35	1735.54
	109	15.5	19	224	-114.38	1750.84
	110	11.4	-4	251	-111.89	1762.23
pipe suspended above river by 6'	111	20.5	-1	236	-112.29	1782.73
	112	13.15	12	176	-112.56	1795.82
corn field	113	9.15	2.5	170	-111.30	1804.97
	114	17.3	12	170	-111.12	1822.18
burnt pipes	115	13.4	-2	166	-109.35	1835.57
	116	10.65	-6.5	180	-109.58	1846.21
patched and burnt sections	117	14.7	3	162	-110.16	1860.90
	118	8.6	-45	168	-109.84	1868.86
break in pipe, patched	119	32	47.5	168	-113.10	1898.18
break in two places	120	15.8	6	150	-100.27	1913.96
another break	121	17.2	-16	161	-99.45	1930.98
	122	27.1	-17	168	-101.91	1957.78
burnt pipes	123	13.15	4.5	182	-105.92	1970.92
	124	10	-44	202	-105.40	1980.21
	125	15	33.5	192	-109.11	1994.57
	126	19.9	39	188	-104.75	2013.35
pipe is still exposed and is patched	127	22.2	2.5	182	-98.19	2035.55
	128	26.6	12.5	132	-97.81	2061.99
	129	19.2	-14	142	-94.91	2081.04
	130	11.75	30	167	-97.29	2092.40
	131	30.7	-24	195	-94.28	2122.43
	132	15.15	-67	194	-100.66	2135.06
crosses stream flowing left	133	10.3	21	140	-109.02	2145.19
	134	15.8	44	141	-107.14	2159.84

Notes	Point	Measured Distance (Meters)	Front Site (Percent Grade)	Compass Bearing (Degrees)	Elevation Relative to Start (Meters)	Cumulative Dist. (Meters)
	135	8	13.5	220	-101.22	2167.79
	136	9.35	-16	144	-100.30	2177.05
	137	30.7	12	150	-101.60	2207.58
	138	24.7	-0.5	166	-98.46	2232.28
	139	30.7	-3.5	185	-98.57	2262.97
	140	17.1	-2.5	184	-99.51	2280.07
	141	14.9	-15.5	192	-99.88	2294.84
	142	29.8	11	164	-101.79	2324.51
crosses road into community of Cerro Cruz	143	16.1	-28.5	173	-98.93	2340.12
	144	18	-47	174	-102.86	2356.61
	145	30.6	-25	179	-110.08	2386.47
	146	28.7	-3.5	183	-116.77	2415.16
Pipe cut across road	147	19	-37.5	208	-117.64	2433.14
crosses creek low point approx 2 ft below center	148	13.75	-5	220	-123.79	2446.87
on road again. Tubes buried	149	30.5	21.5	184	-124.42	2476.86
	150	18.8	29	178	-118.86	2495.06
	151	30.5	6.5	193	-114.15	2525.51
Air release valve	152	9.9	8	202	-112.42	2535.39
	153	21	-14.5	210	-111.73	2556.21
	154	11.4	-3.5	214	-114.47	2567.60
	155	12.4	-18	226	-114.85	2579.85
pipe break	158	9	30	217	-116.79	2588.54
	159	9.7	-11	223	-114.46	2598.20
crosses small creek	160	10.2	-58	200	-115.41	2607.11
begin tunnel parallel to road	161	10.2	46	195	-120.37	2616.51
	162	12.9	20.5	190	-116.43	2629.20
	163	8.1	57	177	-114.11	2636.30
	164	13.8	8.5	186	-110.21	2650.07
	165	10.7	-9	203	-109.19	2660.73
	166	15	27	175	-110.03	2675.33
	167	19.6	0	185	-106.59	2694.93
	168	24.5	-4	199	-106.63	2719.42
	169	17.1	9	187	-107.54	2736.46
	170	19.8	-6	187	-106.16	2756.23
	171	13.4	-6	209	-107.20	2769.61
	172	21.5	-10	214	-107.93	2791.03
	173	21	-28.5	231	-109.80	2811.40
	174	8.2	13.5	230	-114.93	2819.54
	175	30.6	4	184	-113.94	2850.12

Notes	Point	Measured Distance (Meters)	Front Site (Percent Grade)	Compass Bearing (Degrees)	Elevation Relative to Start (Meters)	Cumulative Dist. (Meters)
hits main road (highway)	176	30.5	8.5	177	-112.94	2880.55
	177	30.1	-0.5	153	-110.82	2910.65
	178	30.4	3	158	-110.95	2941.04
off road runs under existing line	179	30.6	3	168	-110.22	2971.63
	180	30.3	-5.5	158	-109.48	3001.89
	181	29.7	-15	167	-111.00	3031.34
crosses creek	182	16.8	0.5	145	-114.88	3048.14
	183	30.2	14	176	-114.88	3078.10
	184	17.5	15.5	170	-111.13	3095.45
	185	15	15	156	-108.81	3110.32
	186	19.2	14	174	-106.85	3129.38
	187	17.9	33	179	-104.51	3146.56
behind community of Piedra Grande	188	30.1	15	183	-99.50	3176.41
	189	28.4	0.5	173	-95.64	3204.81
crosses road	190	30.4	0.5	172	-95.58	3235.21
	191	17.8	12	192	-95.51	3252.91
	192	18.6	-3	187	-93.58	3271.50
	193	20.6	8	195	-94.10	3292.06
	194	8.7	3	201	-92.76	3300.75
automatic air valve at end point (118-11 crispin 300psi)	195	17.5	0.5	186	-92.51	3318.25
	196	14.3	8	180	-92.43	3332.51
	197	7.6	19	174	-91.37	3340.01
	198	10.9	-8	160	-90.12	3350.88
	199	10.6	-16	160	-90.93	3361.38
	200	13.8	7	185	-92.38	3375.15
	201	14.2	-11	188	-91.51	3389.29
	202	29.9	-5.5	154	-92.87	3419.15
	203	30.3	-7.5	155	-94.37	3449.38
	204	16.2	1.5	150	-96.35	3465.58
	205	17.4	-4	150	-96.21	3482.97
	206	23.9	-1	150	-96.89	3506.87
	207	30.5	1	149	-96.99	3537.37
	208	30.7	-4	146	-96.79	3568.05
	209	19.8	-4	151	-97.87	3587.84
	210	19.6	0	155	-98.56	3607.44
	211	21.9	5	158	-98.60	3629.32
	212	11.2	5	150	-97.69	3640.51
	213	26.3	5.5	156	-97.20	3666.78

Notes	Point	Measured Distance (Meters)	Front Site (Percent Grade)	Compass Bearing (Degrees)	Elevation Relative to Start (Meters)	Cumulative Dist. (Meters)
	214	18.3	3.5	140	-96.06	3685.08
	215	14.45	6.5	161	-95.62	3699.51
	216	22.9	11	189	-94.86	3722.31
	217	29.6	7	226	-92.77	3751.86
	218	24.8	11.5	215	-91.02	3776.54
	219	30.7	2.5	256	-88.59	3807.23
	220	30.6	6.5	147	-87.92	3837.79
	221	30.6	4.5	150	-86.25	3868.37
	222	26.8	2	145	-85.12	3895.16
	223	10	-22.5	144	-84.71	3904.97
	224	16.9	-9	149	-86.66	3921.82
	225	16.4	-3	172	-87.95	3938.22
	226	19.7	11	165	-88.34	3957.83
	227	20.8	5	160	-86.46	3978.60
	228	30.1	9	160	-85.46	4008.59
	229	30.2	12.5	141	-82.90	4038.60
	230	14.5	28.5	152	-79.48	4052.65
	231	30.6	12	147	-75.88	4083.09
	232	30.6	10	148	-72.75	4113.57
	233	30.6	7	140	-70.08	4144.11
	234	30.5	6	133	-68.21	4174.57
first houses of Chichica	235	30.6	10	153	-66.62	4205.06
	236	28.9	12.5	142	-64.02	4233.80
	237	22.8	15	135	-60.93	4256.40
	238	28.6	9	132	-57.96	4284.91
	239	9.8	4	101	-55.71	4294.71
	240	21	25	125	-55.35	4315.23
	241	22.85	13	126	-50.89	4337.93
	242	17.9	22	126	-48.31	4355.49
	243	30.6	-2	142	-44.82	4386.08
	244	30.6	1	148	-45.28	4416.68
	245	30.5	-4.5	158	-44.88	4447.16
	246	30.6	1	149	-46.01	4477.76
	247	30.6	-0.5	143	-45.68	4508.36
	248	30.6	3	139	-45.75	4538.94
	249	30.6	2.5	143	-44.88	4569.54
	250	9.5	3	145	-44.21	4579.03
	251	17.7	11.5	151	-43.92	4596.65
	252	18.8	15.5	166	-42.19	4615.27
	253	30.5	-10	166	-39.61	4645.66
	254	30.6	2.5	164	-42.20	4676.25

Notes	Point	Measured Distance (Meters)	Front Site (Percent Grade)	Compass Bearing (Degrees)	Elevation Relative to Start (Meters)	Cumulative Dist. (Meters)
	255	9.3	17	185	-41.60	4685.45
	256	20.1	38	204	-40.23	4704.43
	257	30.5	9.5	179	-33.60	4734.84
	258	30.3	19.5	180	-31.27	4764.69
	259	13.3	12	214	-26.08	4777.92
width of chlorination building=2.35 m compas reading 214 at back of building: pipe reduced from 75 mm to 50 mm	**Total**	**4875.47**			**-24.69**	

Total Pipeline Length=4875 Meters (15994 ft)

Total Level Distance= 4794 Meters (15728 ft)

Total Elevation Difference Between Spring Box and and Water Tank: -24.69 Meters (81ft)

Appendix B

Source Potential Volume Calculations

At the dam site, we placed a 60 degree triangular weir accross the spillway and plugged the pipes running underneath the dam. The maximum height the water reached in the spillway was .24 meters. This set of calculations shows an estimate of the wet season flow in the river.

Convert 60 degrees to radians

$$\theta := \frac{(60\cdot\pi)}{180} = 1.047$$

$$g = 9.807\frac{m}{s^2}$$

$$H_1 := .24m$$

$$P_1 := .05m$$

$$C_d := .607165 - .00087446\cdot 60 + .0000061039334\cdot\left(60^2\right) = 0.577$$

$$Q_{wet} := C_d\cdot\frac{8}{15}\cdot\sqrt{2\cdot g}\cdot\tan\left(\frac{\theta}{2}\right)\cdot H_1^{\left(\frac{5}{2}\right)}$$

$$Q_{wet} = 0.022\frac{m^3}{s} \qquad Q_{wet} = 0.784\cdot\frac{ft^3}{s}$$

Ralph A. *Wurbs* and Wesley P. *James*, *Water Resources* Engineering, Prentice Hall, New York, 2002.

A dry season flow was obtained by a Chris Kingsley a local Peace Corp Volunteer. During the dry season he channeled the water from the spillway into a five gallon bucket and timed how long it took to fill it. The did multiple tests and obtained an average of about 7 seconds needed to fill the 5 gallons.

$$Vol := 5\cdot 0.13368ft^3 = 0.668\cdot ft^3$$

$$Time := 7sec$$

$$Q_{dry} := \frac{Vol}{Time}$$

$$Q_{dry} = 0.095\cdot\frac{ft^3}{sec} \qquad Q_{dry} = 42.857\cdot\frac{gal}{min}$$

Feasable Intake

$Q_{inwet} \leq .5 \cdot Q_{wet}$

From EPANET Potential Q.in=95.16 gal per minute

$$Q_{in.pot} := 95.16 \frac{gal}{min} = 0.212 \cdot \frac{ft^3}{sec}$$

.

$$\frac{Q_{wet}}{2} = 0.392 \cdot \frac{ft^3}{sec}$$

$$\frac{Q_{wet}}{2} > Q_{in.pot}$$

During the wet season, the intake structure can run at full potential without reducing the streamflow too much.

$Q_{dry} \leq .5Q_{dry}$

$$\frac{Q_{dry}}{2} = 21.428 \cdot \frac{gal}{min}$$

$$Q_{in.pot} > \frac{Q_{dry}}{2}$$

During the dry season, the potential water from the water intake will be reduced to .048 ft^3/sec
This is an 78% reduction in water potential

$$tank := 20000gal = 2.674 \times 10^3 \cdot ft^3$$

$$tankfill_{dry} := \frac{tank}{\frac{Q_{dry}}{2}} = 933.337 \cdot min$$

$$tankfill_{wet} := \frac{tank}{Q_{in.pot}} = 210.172 \cdot min$$

From these calculations, it is apperant that the intake structure will need to restrict water from entering the intake to prevent more than 50% of the water from being diverted from the river. Because of this, there will be 78% less water available than in the dry season.

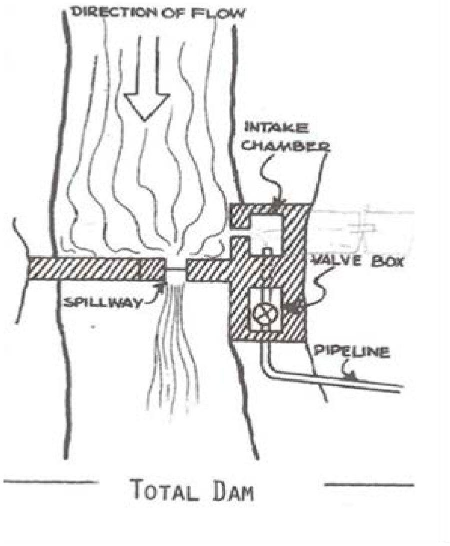
Appendix C

Water Intake Design Alternative Analysis

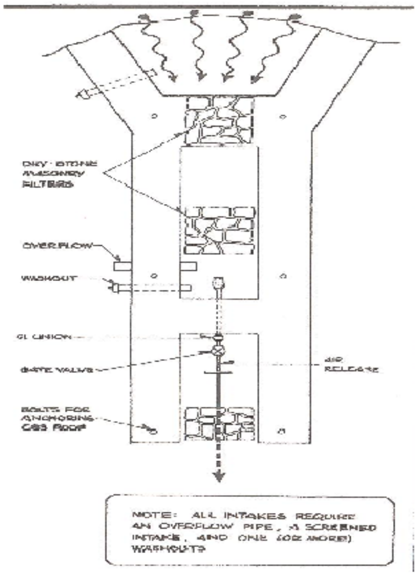
Design Options:

Option A. Current Design

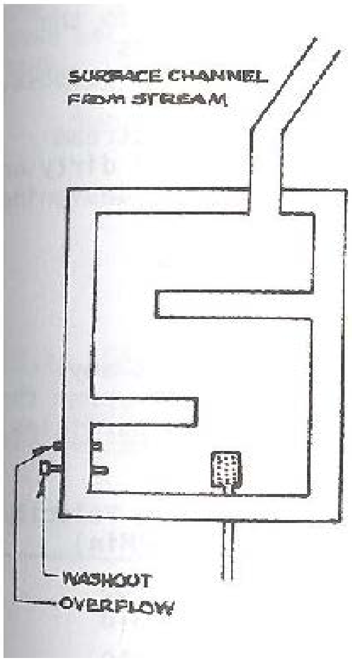
Option B: Perpendicular Intake



Option C: Rock Filters



Optipon D: Sedimentation Tank



	A	B	C	D
Sedimentation	Intake pipe frequently clogs.	Water flows perpendicular to intake, therefore less sediment buildup.	Sediment will probably get clogged behind filter.	Sediment filtered out behind walls so pipes have less sediment in them.
Constructability	Already constructed.	Could possibly use part of existing dam. Need to construct sedimentation tank.	Difficult. Lots of concrete structure and stone filters.	Not much harder than sedimentation tank. (Just 2 extra walls).
Maitenance	Requres it after every rain. (At least 1X per day) Impractical	Clean out dam and sedimentation tank. Not as frequent as current system.	Cleaning out 1st filter may require same amount of maitenamce as current structure.	Washout valves needed behind each wall.
Cost	None	Concrete, rebar	Lots of concrete, b/c big structure, rebar, stone	Could be less than normal sedimentation tank, b/c the tank wouldn't need to be as large to filter out same amount of material.

Appendix D

EPANET Assumptions

	Inner Diameter	Friction Factor
4" PVC	2.067 in	150
2" PVC	4.026 in	150

3 Gate Valves (each valve equivilant to 15 ft of pipe) (Appendix 17, Shammas)
Intake resivour elevation = 2060 ft
This is equal to water elevation at the intake

Tank Elevation =1971 ft
Tank initially set as nearly empty (water level at .1ft)

Source

Shammas, N. K., & Wang, L. K. (2011). *Water supply and wastewater removal* . (3rd ed.). John Wiley & Sons, Inc.

Appendix E

Chlorination Calculations - Sodium Hypochlorite (NaOCl)

Assumptions

1. Tank will be filled up to 20,000 gallons each day
2. Flow rate is within design specifications
3. WHO Standard: Chorine is present in most drinking-water at concentrations of 0.2-1 mg/L
4. Tablets dissolve at a constant rate

Calculations were done for 10, 5, and 1 tablets to see how chlorine concentrations related to WHO standards:

10 Tablets

$\rho := 1.11 \quad \frac{g}{cm^3}$

$r := 1.5$ radius of tablet in inches

$w := .5$ width of tablet in inches

$V_{10} := 579.12$ volume of 10 tablets in centimeters cubed

Calculate Weight of Tablets in miligrams used in 15 days

$W_{10} := V_{10} \cdot \rho \cdot 1000$

$W_{10} = 6.428 \times 10^5$

Calculate Number of Liters for 20,000 gallon tank in 15 days

$T := 15$

$TankV := 75708.24$

$TotalV := T \cdot TankV$

$TotalV = 1.136 \times 10^6$

Calculate Concentration of Chlorine in 20,000 gallon tank each day

$C := \frac{W_{10}}{TotalV}$

$C = 0.566$ mg Chlorine per L water

Appendix F

Water System General Maintenance

Sand Filters: The sand filters should be inspected prior to reconnection. It was assumed that they are filled with course sand with particles ranging from .5mm to 2mm. Because the system never functioned, these filters should be clean and ready to use. The filters should be reconnected as they had been in their previous configuration with the inlet at the top of the filter and the outlet near the bottom. During the course of a year, they may need to be cleaned periodically as fine particles start to clog the filters. This will probably occur during the wet season, when the water carries more sediment. The flow going into the tank should be monitored on a regular basis to determine that the filters are not clogged. As a starting point, this should be done on a weekly basis. After seeing how fast they clog up, the frequency of the check can be adjusted as needed. When the flow rate slows down to less than 60% of the original flowrate or there is noticeable turbidity in the water, the sand filter should be backwashed to clean out the sediment. This is done by shutting the valve before the sand filters so no water from the river is flowing through the filter. Next, there are valves located at the tops of the sand filters that can be opened up. This will let the water from the tank flow back through the filters and push any sediment clogged in the filters out. If the filters seem to be clogging up too quickly, courser sand can be placed into the filters. This however will allow more fine particles to enter the tank. This could increase the amount of chlorine needed so further chlorine monitoring would be needed after doing this. The same chlorine monitoring process as found in Appendix M would apply.

Water Hammer Arrestor: The water hammer arrestor is designed to dampen any pressure surges that occur when the water flowing through the pipe is suddenly stopped. The water hammer arrestor we recommend building uses a large pocket of air in the stand pipe to absorb the shock. Because there is no barrier between the air and the water in the standpipe, the air can slowly be dissolved in the water. This means that before the water is shut off to the tank, the standpipe should be drained to ensure that there is enough air to absorb the pressure surge. This is simply done by closing the valve before the standpipe and opening the valve on the outlet side and draining the water. After this, the outside valve will be closed and the inside valve opened. This simply ensures that the standpipe is full of air. There are manufactured valves that require no maintenance but are very expensive to buy ($400-$1200). For this reason, we felt that this solution was more feasible.

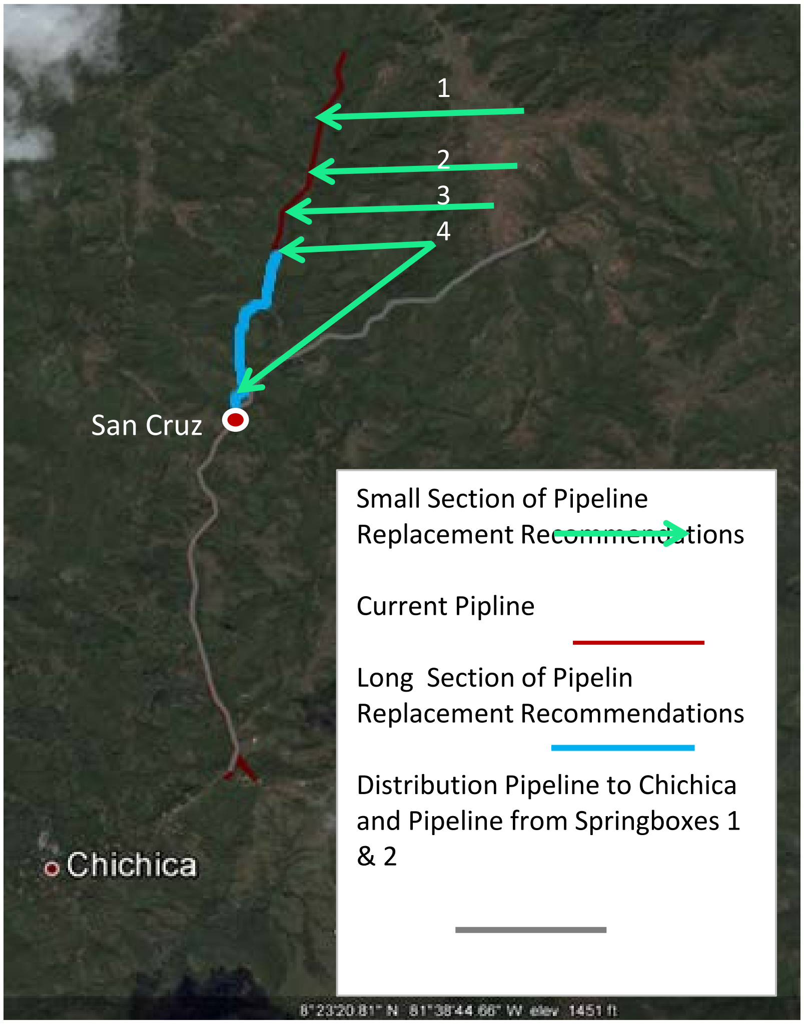
WARNING: A water hammer arrestor does not fully eliminate pressure surges associated with closing a valve. Although the water hammer arrestor reduces the surges, slowly shutting off the valves (over a period of 30-60 seconds) will help reduce any possible damage done to the pipeline.

Cleanout Valve: A cleanout valve will be placed on the pipeline approximately 1500 feet from the intake. This is located approximately 300 feet past a stream crossing near the first break in the pipeline. The cleanout valve should be placed just beyond the lowest point in that section. If sediment builds up in the system, this is where it will likely clog. Therefore, the cleanout valve can easily be opened to flush out any built up sediment if the flowrate starts to slow. Detailed drawings of the cleanout valve can be seen in Appendix H.

Appendix G

Pipeline Replacement

				Distance From Dam	
Section	**Location**	**Length**	**Material**	**(m)**	**ft**
1	Small Break approximatley 100 meters after small river crossing.	Less than 5 ft	5ft PVC Pipe Two couplings	480	1574.80315
2	Small burnt section approx 20 m. after a small suspended stream crossing	About 60 ft.	3 full pipe segments two couplings	847	2778.8714
3	Small break	5 ft	5 ft. PVC Pipe Two couplings	1042	3418.63518
4	Main Replacement Start: at the section with 4 elbows End: Approx 200 meters from the community of Cerro Cruz	3060	155 full pipe segments	1246-2139	4087.92652

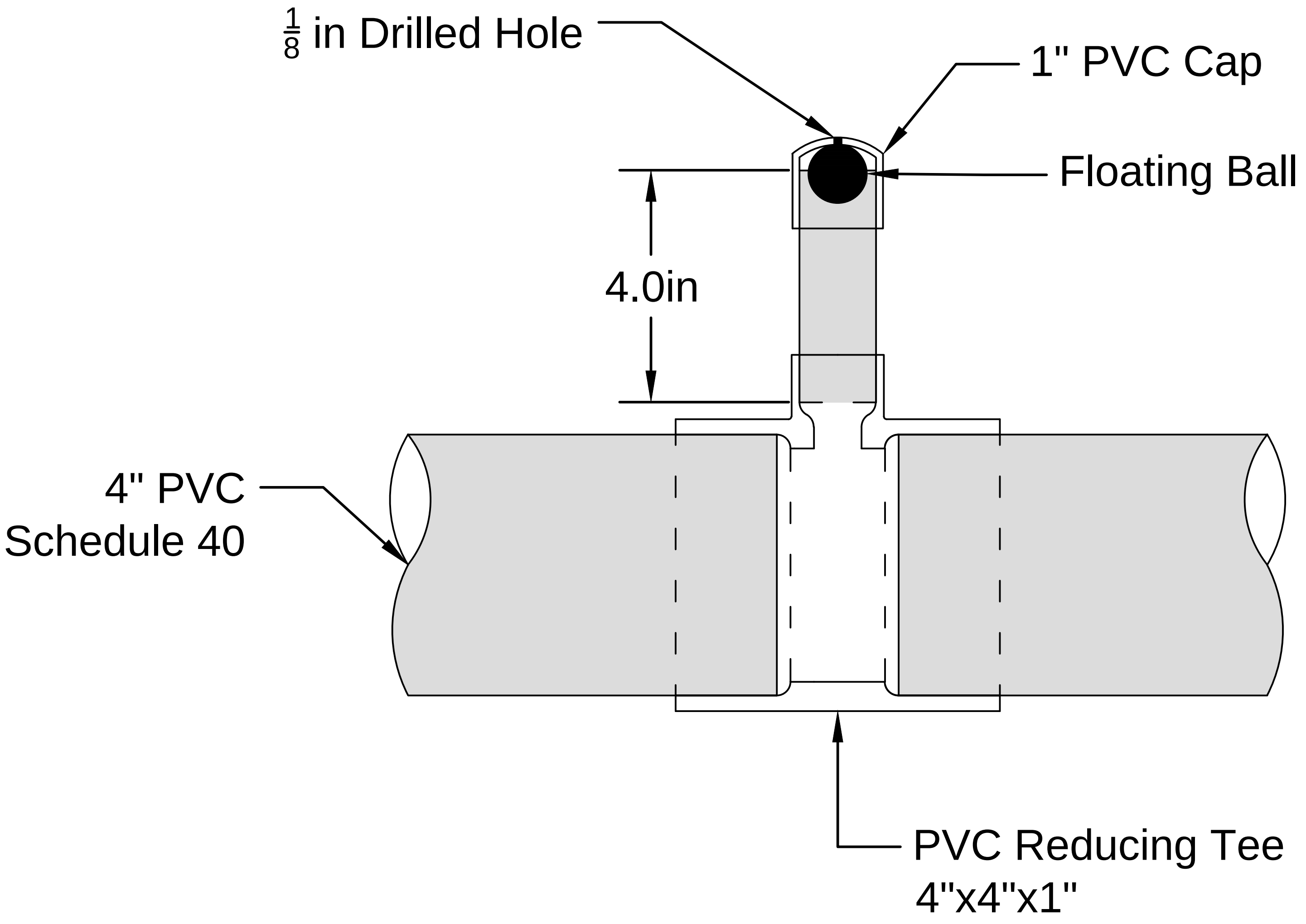


Appendix H

Detailed Drawings

Table

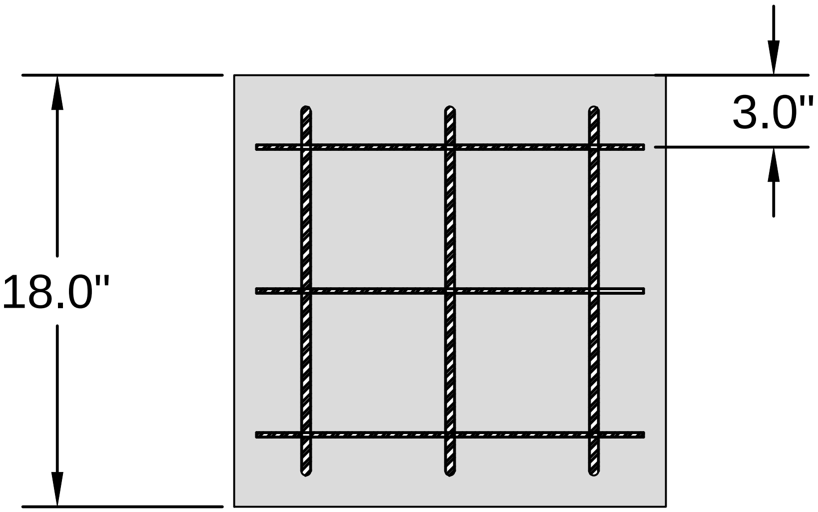
1. Air Relief Valve
2. Air Relief Reinforced Concrete Box
3. Water Hammer Arrestor
4. Clean Out Valve
5. Intake Structure Overview
6. Intake Structure Side View
7. Intake Structure Front View
8. Intake Structure Rebar Details Top View
9. Intake Structure Rebar Details Side View
10. Intake Structure Rebar Details Front View



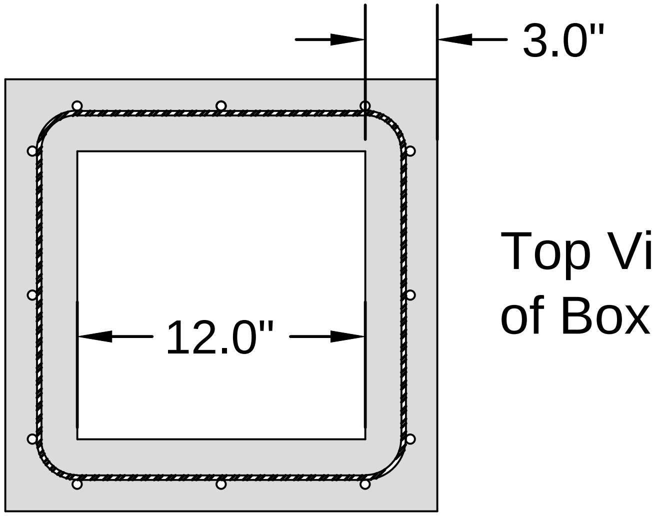
Air Relief
Valve

Drawing 1

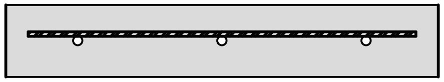
Drawn By: David Kilpela



Top View
of Cover

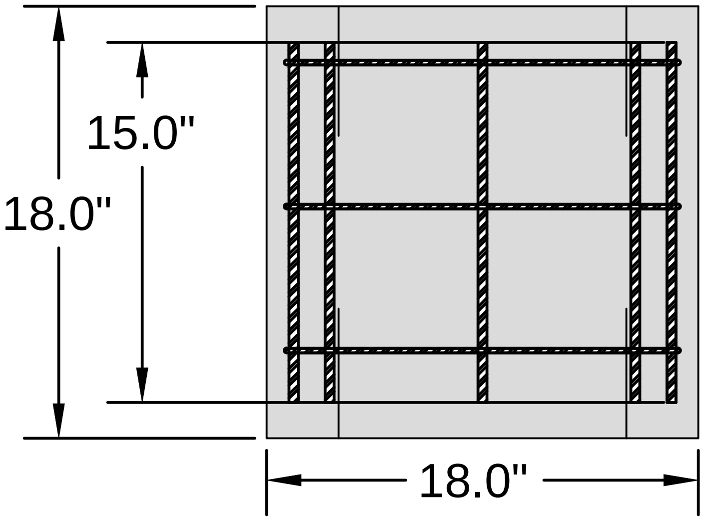


Top View
of Box



Cover

6" x 6" welded wire mesh will be used to reinforce the protective boxes. The mesh should be placed near the center of the walls and cover. A cover handle can be added by inserting a short length of #3 rebar into the cover during construction.

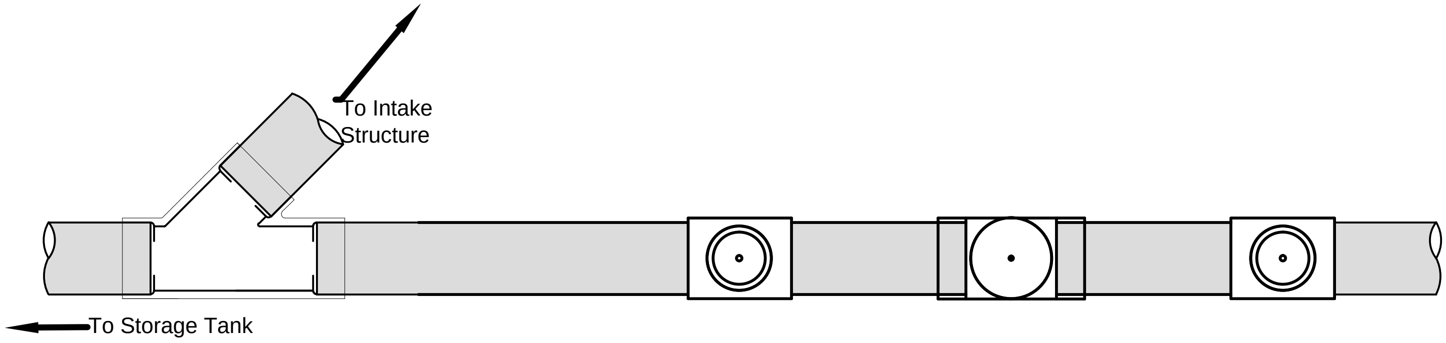


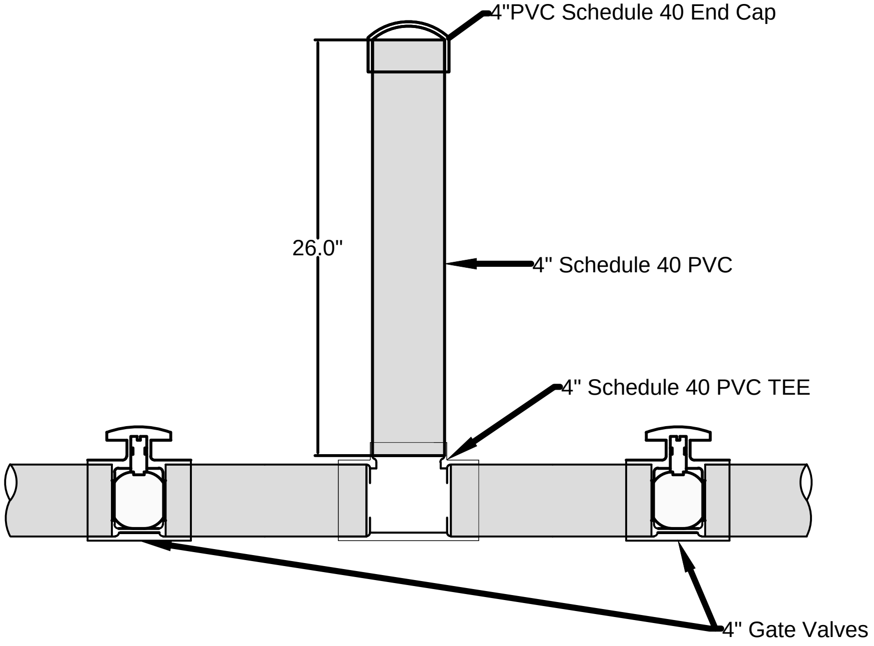
Side
View

Air Relief Valve Protective Boxes

Drawing 2

Drawn By: David Kilpela

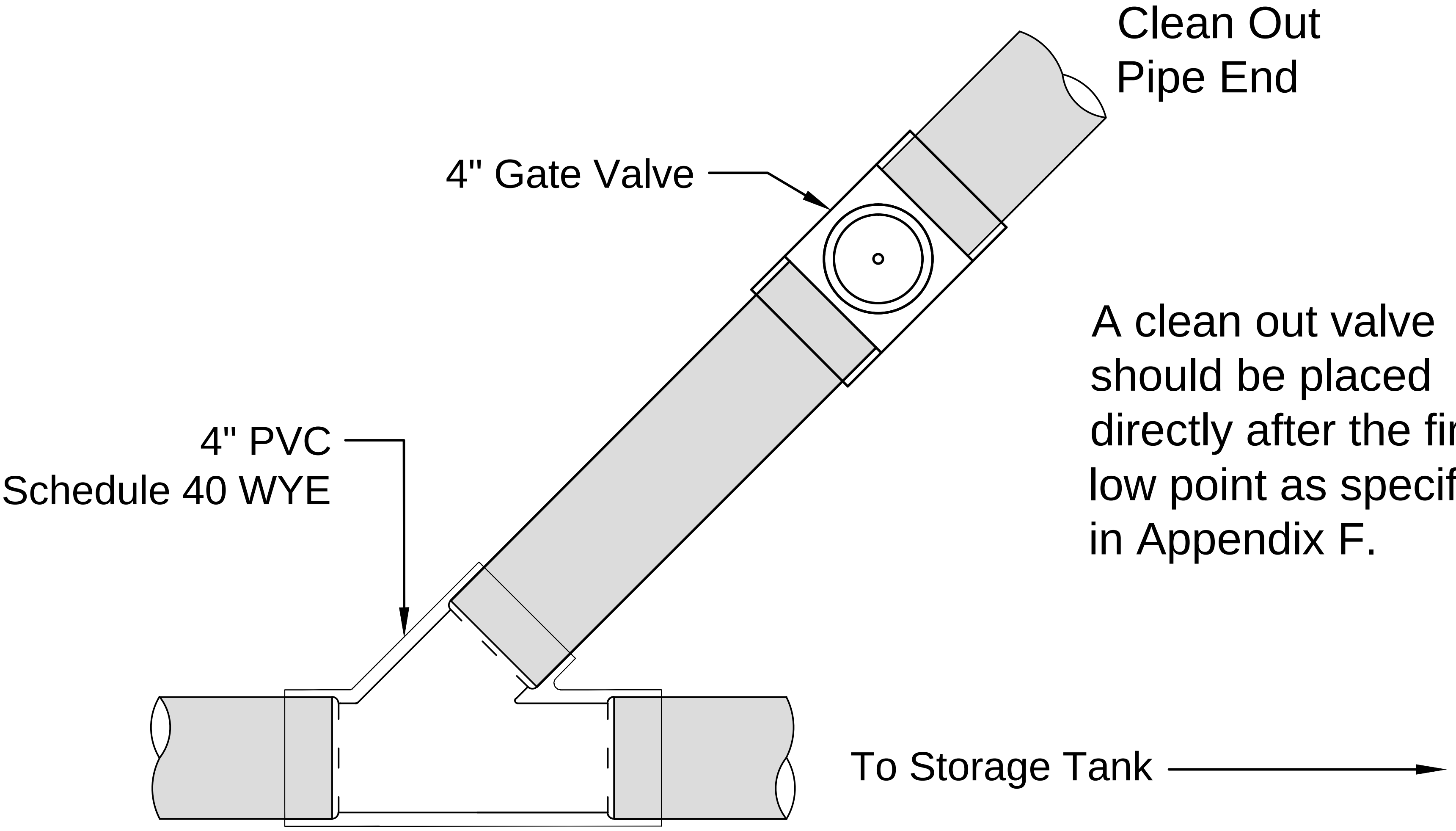




Water Hammer Arrestor Valve

Drawing 3

Drawn By: David Kilpela

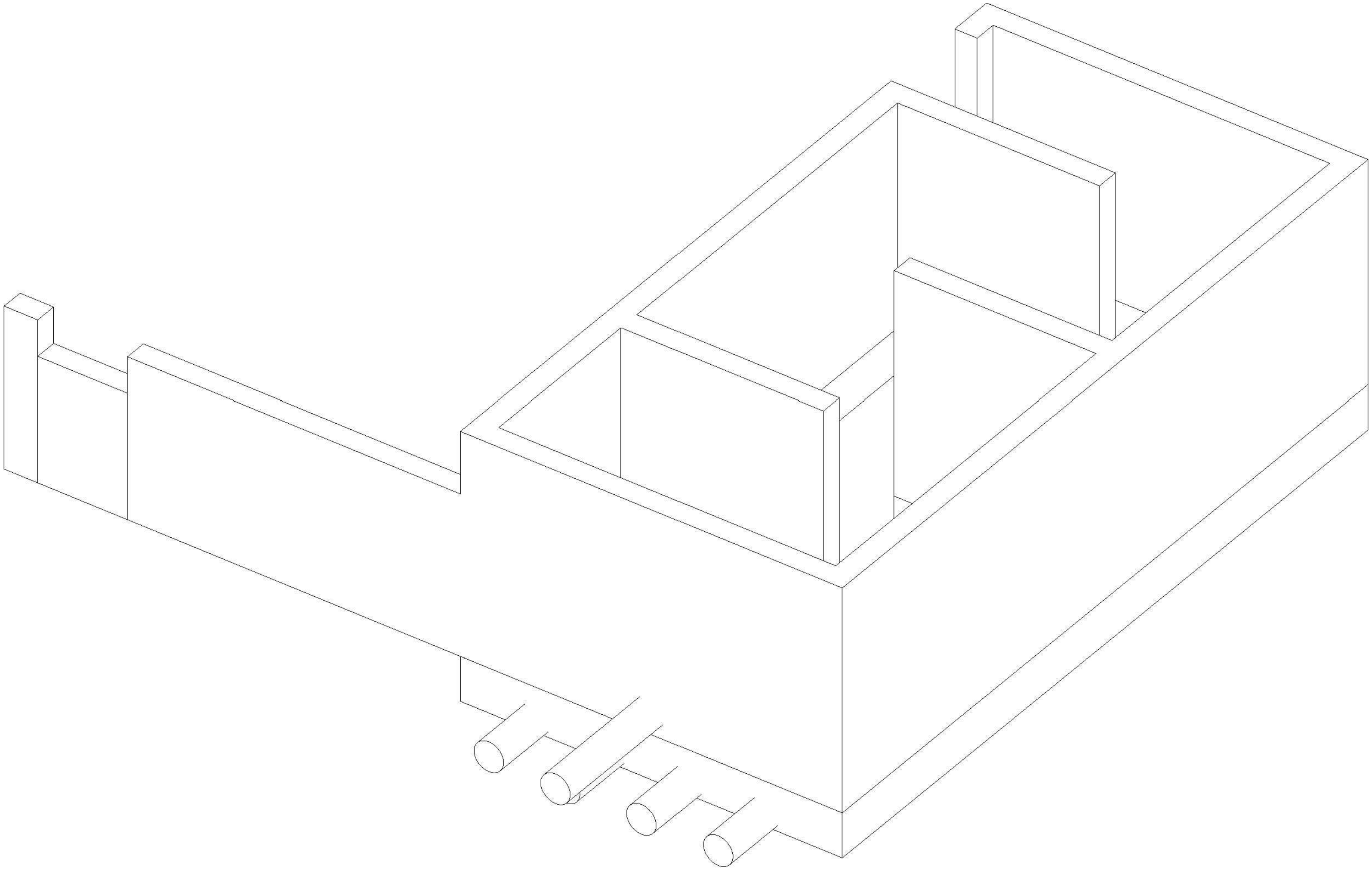


A clean out valve should be placed directly after the first low point as specified in Appendix F.

Clean Out Valve

Drawing 4

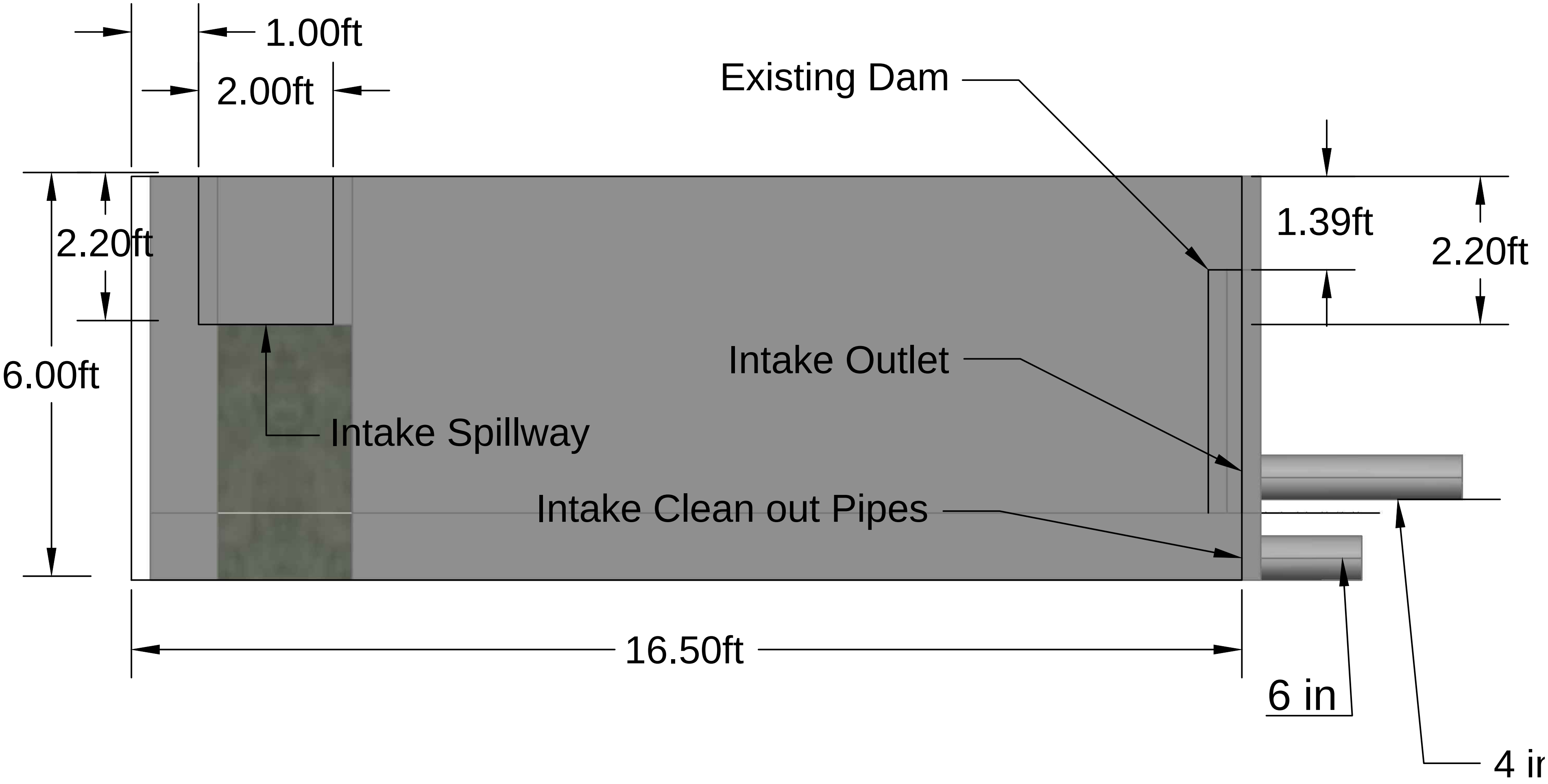
Drawn By: David Kilpela



Intake Structure Overview

Drawing 5

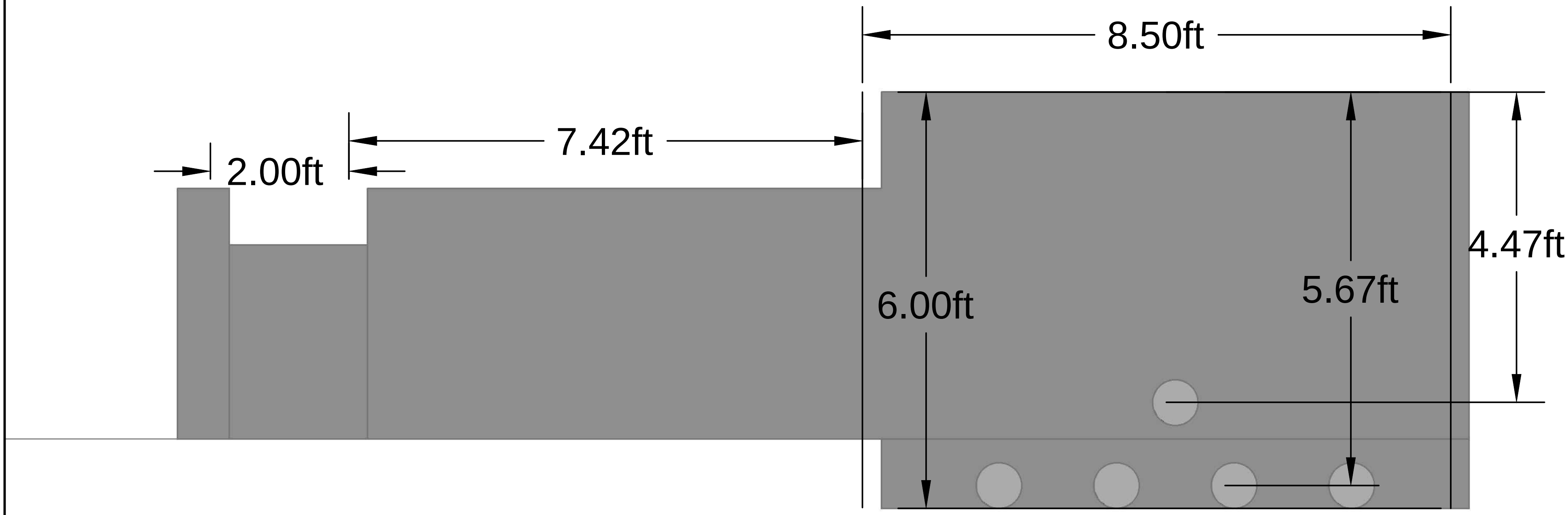
Drawn By: Pencheng Zhou



Side View of Intake Structure and Dam

Drawing 6

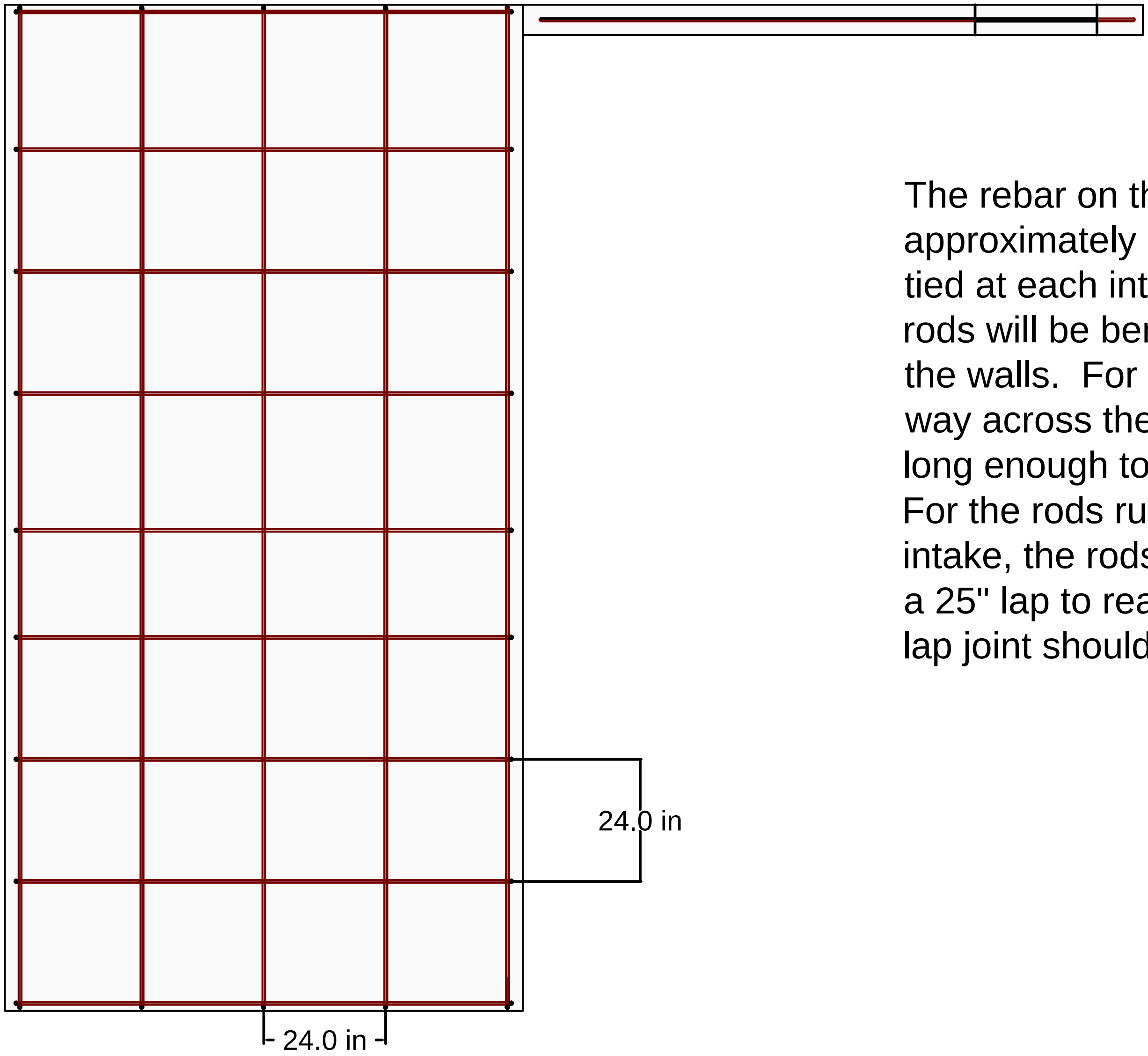
Drawn By: Pencheng Zhou



Front View of Intake Structure and Dam

Drawing 7

Drawn By: Pencheng Zhou

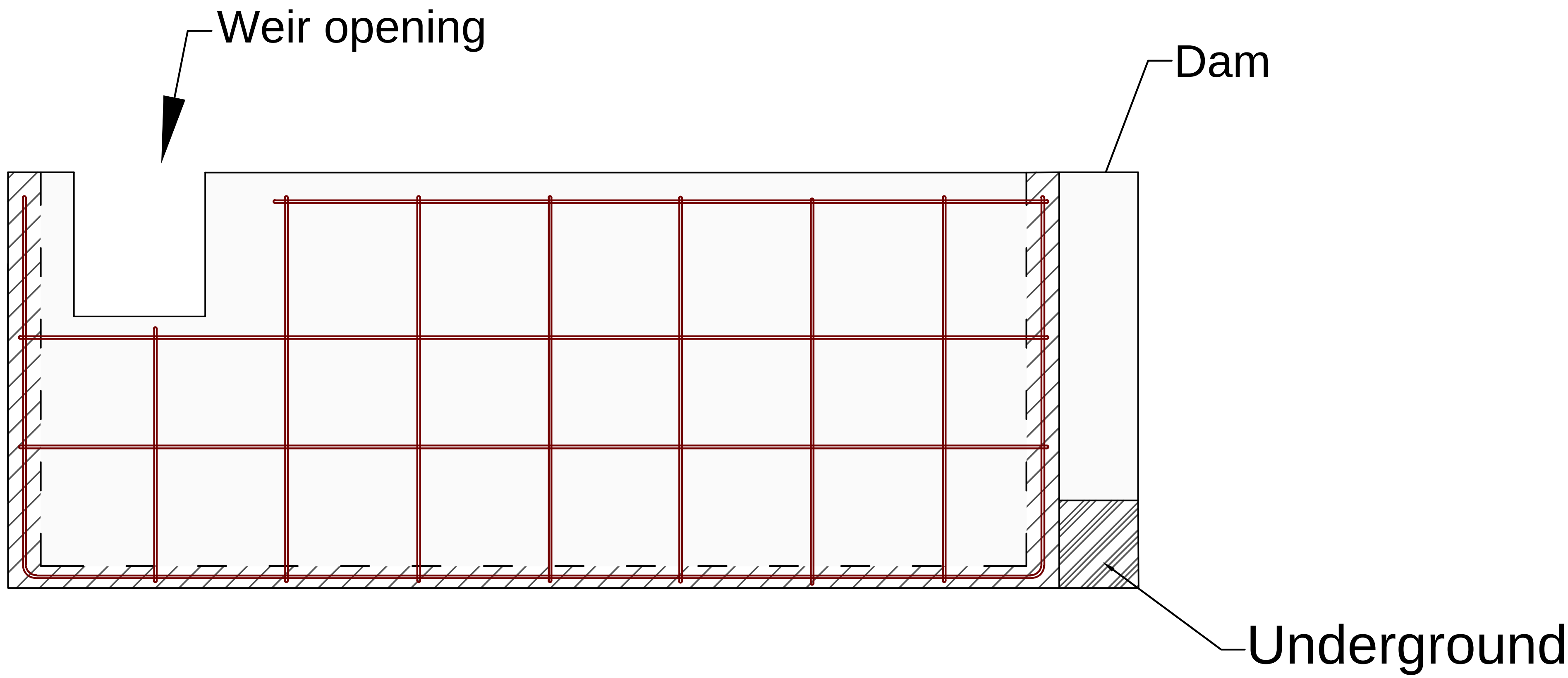


The rebar on the floor will be laid on approximately 24" centers. They should be tied at each intersection with tie wire. The rods will be bent to stick up vertically into the walls. For the rods running the short way across the intake single rods will be long enough to reach the top of the wall. For the rods running the long way of the intake, the rods will need to be spliced with a 25" lap to reach the tops of the wall. Each lap joint should be tied together with

Intake Structure Rebar Detail Top View

Drawing 8

Drawn By: David Kilpela



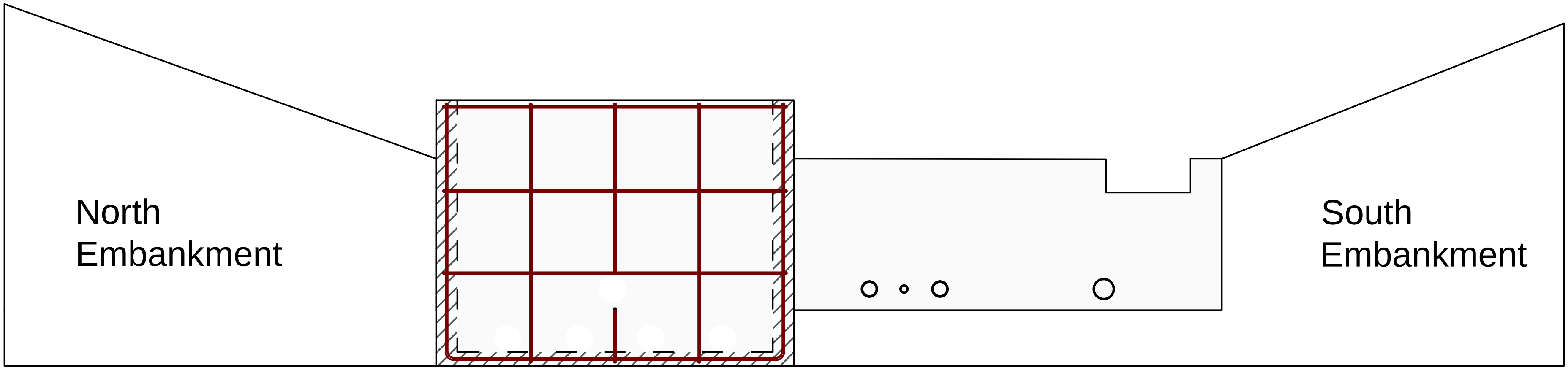
As in the floor the rebar for the walls will consist of # 4 bars placed on a 24" grid. Each connection should be tied with tie wire.

Intake Structure Rebar
Detail Side View

Drawing 9

Drawn By: Pencheng Zhou

As in the floor and side walls #4 rebar will be placed on 24" centers.



Intake Structure Rebar Detail Front View

Drawing 10

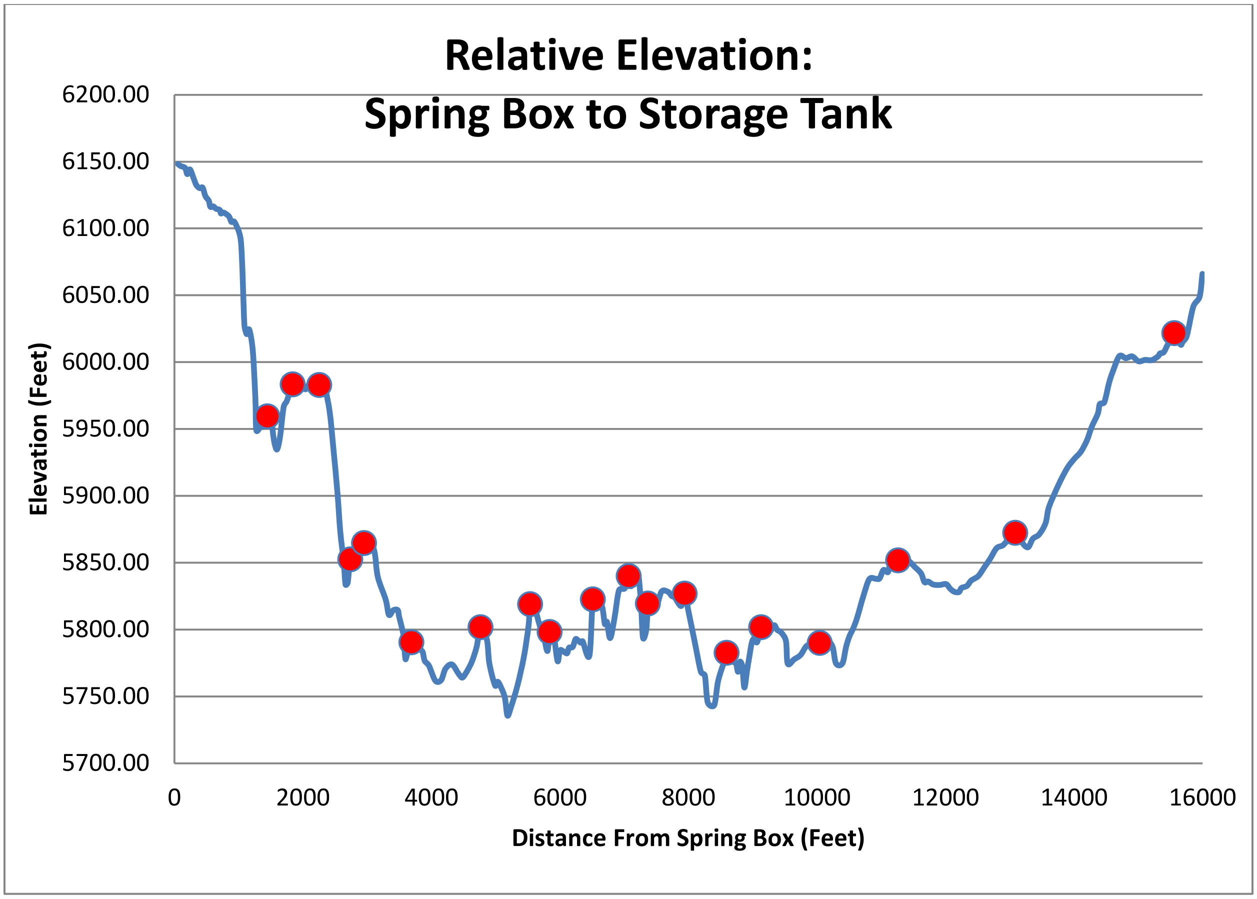
Drawn By: Pencheng Zhou

APPENDIX I

Distance from Intake Structure for the Recommended Construction of 18 Air Relief Valves

The air relief valves are located at all the high points in the system. By using notes on the Appendix A, it may be easier to locate the valve locations.

Air Relief Valve Number	Valve Location (distance from intake structure (m))	Valve Location (ft)
1	425	1394
2	540	1771
3	620	2034
4	801	2627
5	866	2840
6	1078	3536
7	1410	4625
8	1641	5382
9	1684	5524
10	1931	6334
11	2098	6881
12	2152	7059
13	2357	7731
14	2552	8371
15	2736	8974
16	2958	9702
17	3335	10939
18	4663	15295


Relative Elevation:
Spring Box to Storage Tank
6200.00
6150.00
6100.00
6050.00
6000.00
5950.00
5900.00
5850.00
5800.00
5750.00
5700.00
Elevation (Feet)
0
2000
4000
6000
8000
10000
12000
14000
16000
Distance From Spring Box (Feet)

Appendix J

WATER ARRESTOR SIZING

L = pipe length (ft)
V = change in velocity (gpm)
D = I.D. of pipe (in)
F = Flow pressure (psig)
Y = Function of M/F graph
M = maximum allowable pressure (psig)

$L_1 := 4875$

$L_2 := \frac{L_1}{3.281}$

$L_2 = 1.486 \times 10^3$

$V_1 := 0$

$V_2 := 90$

$\Delta V := V_2 - V_1$

$D := 4.026$

$F := 10.6$

$M := 220$ psi

$YChart := \frac{M + 14.7}{F + 14.7}$ Chart found on Sioux Chief Manufacturing Sizing Guide

$YChart = 9.277$

$Y := 144.21$

$$C := \frac{1.5 \cdot L_2 \cdot \Delta V^2}{D^2 \cdot (F + 14.7) \cdot Y}$$

$C = 305.268$ inches squared

The water hammer arrestor will need to have a total volume of 305 in^2

Appendix K

Intake Structure Sizing Calculations

Background Information	
Assumed dentention time(min)	30
Max flow(rainny season) (L/s)	6.003
Min flow(dry season)(L/s)	1.359

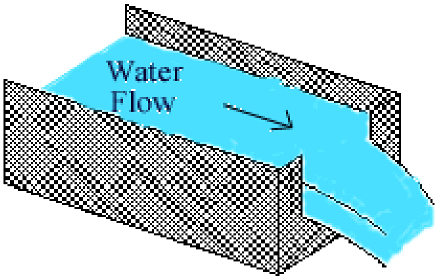
Dimension of Main structure			
Min Volume (m^3)	5.40	190.77	ft^3
Width(m)	1.162	3.81	ft
Length(m)	4.649	15.25	ft

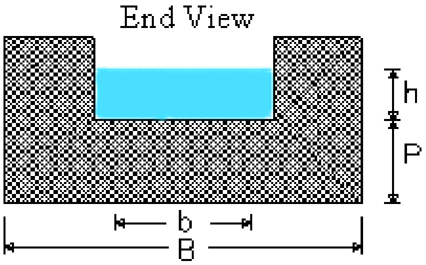
Minimum $Volume = 0.5Q * T$ $Assume\ just\ 50\%\ flows$ into the water intake and 50% flows through the spillway during rainy season

Tank specification
Length/Width ratio at least 4.0
Water depth between 0.75-1 m
Assume water depth is 1m, L/W is 4

$$Minimum\ Volume = length \times width \times depth = 4W \times W \times 1m$$

Assume just 50% flows into the water intake and 50% flows through the spillway during rainy season





http://www.lmnoeng.com/Weirs/RectangularWeir.htm

Q=$K_R\sqrt{2g}L_wH^{3/2}$ $K_R = 0.40 + 0.05\frac{h}{P}$=0.4+0.05× $\frac{h}{0.8}$ L_w=b-0.2h=3.5h-0.2h=3.3h

Assume P= 0.8 m b/h= 3.5

Appendix L

Concrete Reinforcement Calculations

Slab Calculations

Using guidelines from
Handbook of Gravity Fed Water Systems
Thomas Jordan.

Slab thickness = 4 inches

$\text{thickness} := 4\text{in} \qquad \text{length}_1 := 16\text{ft} \qquad \text{width} := 8.5\text{ft} \qquad \text{Area}_{no4} := .2\text{in}^2 \qquad \text{Area}_{no3} := .11\text{in}^2$

$$\text{Area}_{steel} > .00225\text{Area}_{concrete}$$

$$\text{Area}_{concrete} := \text{thickness}\cdot\text{width} = 408\cdot\text{in}^2$$

$$\text{Min}_{steel} := \text{Area}_{concrete}\cdot.00225 = 0.918\cdot\text{in}^2$$

$$\text{No}_{rods} := \frac{\text{Min}_{steel}}{\text{Area}_{no4}} = 4.59$$

Slab Reinforcement

5 no. 4 rods are required for the slab running longitudinally

The rods are to be equally spaced roughly 24 inches apart with 3inches clear space on each end

The same size and spacing applies to the rebar running perpendicularly
See Appendix H for detailed drawings.

Wall and Wing Wall Reinforcement

Walls designed according to California Building Code for
Non-Structural Design Criteria
http://sanbruno.ca.gov/comdev_images/California_Building_Code.pdf

#4 Rebar will be used on the walls. The vertical bars will be spliced with the rebar sticking out of the slab. The horizontal bars will wrap around the structure and will be spaced 24 inches apart.

Rebar in Walls of the intake structure will tie into the rebar from the floor with a 25" lap.
See Appendix H for detailed drawings.

APPENDIX M

Chlorinator Instructions

General Considerations for Community

- Training Workshop – A member of the community or selected Peace Corp Volunteer should lead a workshop on maintenance procedures and residual monitoring of the chlorinator to relay the following information. At least two community members should be familiar with the functions and maintenance of the design.
- Monetary Fund – The community should maintain a monetary fund for the chlorinator that is available to finance repairs. After speaking with the Water Committee of Chichica, a system for monetary collections is in place. It is important that this system stay consistent be taken seriously by the community.

Technical Criteria

- Flow Rate Capacity – Most chlorinators of this size are capable of treating a gravity-fed water system having a flow between 2 and 45 gallons per minute. Since the hypothetical incoming flow rate is 80 gallons per minute and we do not know the specifications of this specific chlorinator, the chlorine levels will have to be monitored for the first month of use. This may require that the chlorine tablets be replaced more frequently to ensure adequate chlorine levels.
- Testing Kit – Residual Chlorine Test Strips should be purchased by the community. This is how the correct chlorine dosage is determined.
- Responsibility – The Water Committee should be held responsible to make sure that there is a sufficient amount of chlorine tablets. The factors that will influence the number of tablets necessary include: type of tablet, water temperature, chlorine demand of the water, size of the system and the amount of water used.

Testing Instructions for Chlorine Testing Strips

1. After the rest of the system has been corrected, the chlorinator should be connected to the system. The maximum number of tablets that can fit should be inserted into the stem.
2. Once the tank has been filled for the first time, proceed with the following steps immediately.
3. Check chlorinator to make sure there are still tablets present. If they have already completely dissolved, a new chlorinator will have to be purchased to accommodate the flow rate. Until chlorinator is replaced, add chlorine bleach as directed on the bottle. Make sure to add bleach while the tank is filling the next time to ensure it is mixed.
4. If tablets are still intact after the tank has been filled the first time, test the water by dipping a stick in to the water and apply to the paper. Based on the color, determine the

concentration of chlorine. This is your initial concentration. It will decrease in concentration as time passes but it may be important to know if future modifications are made.

5. Wait just before the water is released to the village and test water with strips. This concentration should be between 0.02 ppm and 1 ppm. It should not exceed 4 ppm. If it does exceed the maximum concentration, remove one tablet at a time, checking the concentration before the water is released to the village each time.
6. If concentration is continually below 0.02 ppm of chlorine, follow step 3 until a capable chlorinator can be purchased.
7. Chlorine concentration should be checked for the first 90 days after the system is in working order. The results may be recorded in the Chlorine Testing Table found on the following pages. Adjust number of tablets until chlorine is within drinking water standards of 0.02-1 ppm.
8. After the data collection during the 90 days has been completed, check concentration of the tank once a week along with visually confirming that the tablets have not been completely dissolved.

Chlorine Testing Results of Water Tank 2 in Chichica, Panama

Dia	La Fecha	Color	La Cantidad de Cloro	El Numero de Tabletas de Cloro
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
21				
22				
23				
24				
25				
26				
27				
28				
29				
30				
31				
32				

Chlorine Testing Results of Water Tank 2 in Chichica, Panama

33				
Dia	La Fecha	Color	La Cantidad de Cloro	El Numero de Tabletas de Cloro
34				
35				
36				
37				
38				
39				
40				
41				
42				
43				
44				
45				
46				
47				
48				
49				
50				
51				
52				
53				
54				
55				
56				
57				
58				
59				
60				
61				
62				
63				
64				

Chlorine Testing Results of Water Tank 2 in Chichica, Panama

65				
Dia	La Fecha	Color	La Cantidad de Cloro	El Numero de Tabletas de Cloro
66				
67				
68				
69				
70				
71				
72				
73				
74				
75				
76				
77				
78				
79				
80				
81				
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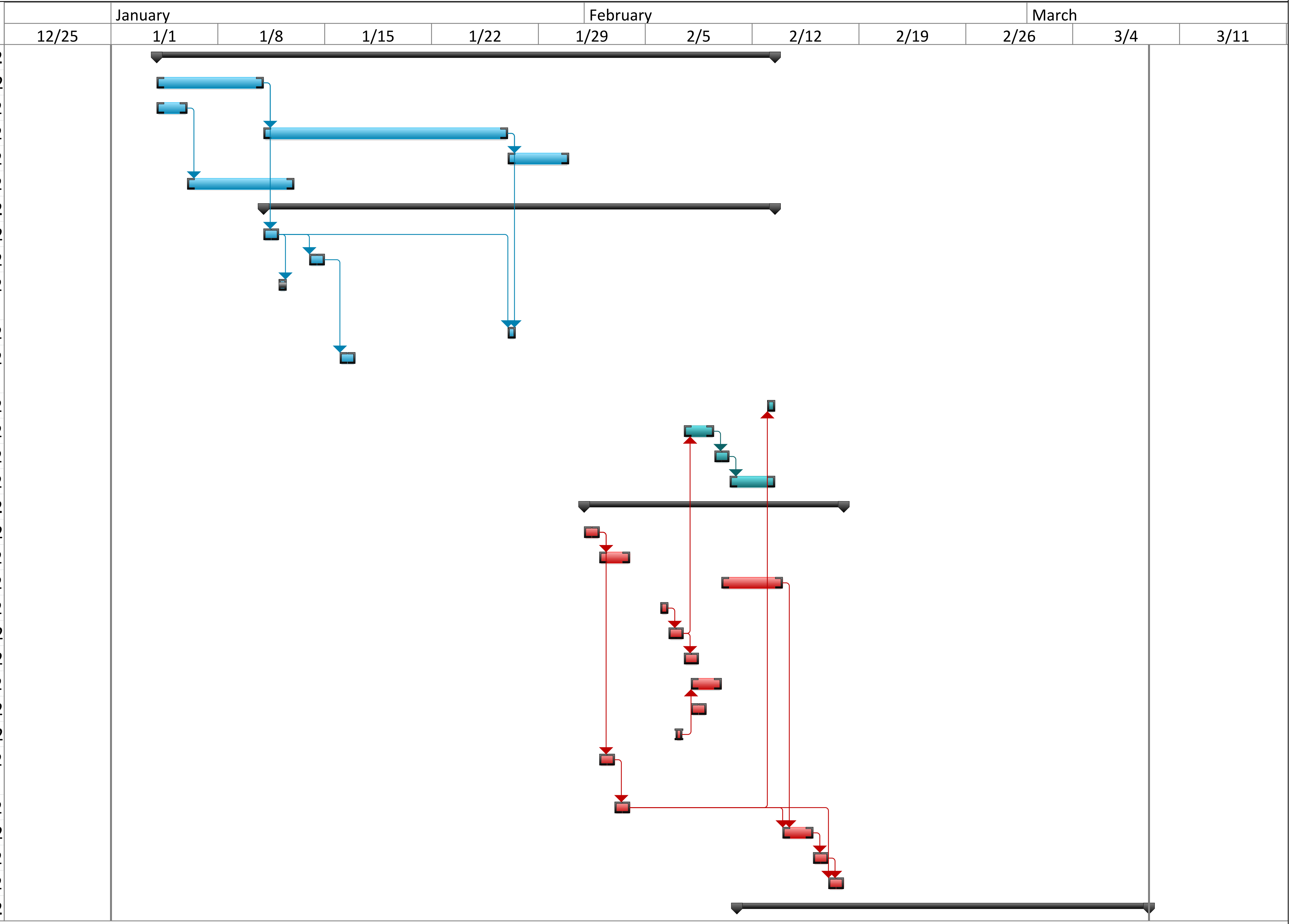
86				
87				
88				
89				
90				

iDesign Chichica Aqueduct
Project Schedule

ID	Task Name	Duration	Start	Finish
1	**Pipeline Replacement**	**28.5 days**	**Wed 1/4/12**	**Mon 2/13/12**
2	Pipe Delivery	5 days	Wed 1/4/12	Tue 1/10/12
3	Identify Damaged Sections	2 days	Wed 1/4/12	Thu 1/5/12
4	Pipe Layout	12 days	Wed 1/11/12	Thu 1/26/12
5	Cement Pipe Joints	2 days	Fri 1/27/12	Mon 1/30/12
6	Dig Ditches	5 days	Fri 1/6/12	Thu 1/12/12
7	**Valves**	**23.5 days**	**Wed 1/11/12**	**Mon 2/13/12**
8	Buy PVC Materials	1 day	Wed 1/11/12	Wed 1/11/12
9	Build Air Release Valves	1 day	Sat 1/14/12	Sat 1/14/12
10	Build and Install Water Hammer Arrestor	0.5 days	Thu 1/12/12	Thu 1/12/12
11	Install Clean Out valve	0.5 days	Fri 1/27/12	Fri 1/27/12
12	Install Air Valves and Clean Out on Pipeline	1 day	Mon 1/16/12	Mon 1/16/12
13	Build Forms for Valve Boxes	0.5 days	Mon 2/13/12	Mon 2/13/12
14	Place concrete in forms	2 days	Tue 2/7/12	Thu 2/9/12
15	Concrete cure	1 day	Thu 2/9/12	Fri 2/10/12
16	Transport and install boxes at valv	1 day	Fri 2/10/12	Mon 2/13/12
17	**Intake Structure**	**13 days**	**Wed 2/1/12**	**Fri 2/17/12**
18	Build Earth Dam and trench river	1 day	Wed 2/1/12	Wed 2/1/12
19	Excavate and form Foundation	2 days	Thu 2/2/12	Fri 2/3/12
20	Seive gravel and sand from river bed	2 days	Fri 2/10/12	Mon 2/13/12
21	Place and tie rebar	0.5 days	Mon 2/6/12	Mon 2/6/12
22	Place Concrete for floor	1 day	Mon 2/6/12	Tue 2/7/12
23	Concrete cure	1 day	Tue 2/7/12	Wed 2/8/12
24	Form exterior and wingwalls	2 days	Wed 2/8/12	Thu 2/9/12
25	Place and tie rebar	1 day	Wed 2/8/12	Wed 2/8/12
26	Place PVC pipes	0.25 days	Tue 2/7/12	Tue 2/7/12
27	Deliver cement and lumber to top of valley	1 day	Thu 2/2/12	Thu 2/2/12
28	Carry cement and lumber to site	1 day	Fri 2/3/12	Fri 2/3/12
29	Mix and place concrete	2 days	Tue 2/14/12	Wed 2/15/12
30	Concrete Cure	1 day	Thu 2/16/12	Thu 2/16/12
31	Strip forms	1 day	Fri 2/17/12	Fri 2/17/12
32	**Chlorine Monitering**	**19 days**	**Sat 2/11/12**	**Thu 3/8/12**



Project: Project_Schedule.mpp
Date: Wed 12/7/11

Task	▬	Project Summary	▬	Inactive Milestone	◇	Manual Summary Rollup	▬	Deadline	⬇
Split	┄	External Tasks	▬	Inactive Summary	▭	Manual Summary	▬	Progress	▬
Milestone	◆	External Milestone	◆	Manual Task	▬	Start-only	[		
Summary	▬	Inactive Task	▭	Duration-only	▬	Finish-only	]		

TMC Engineering Consultants
iDesign 2011

DRAFT
11/7/2011

Appendix N

Chichica Aqueduct Project
Work Breakdown Structure

Activities

1.0 Pipeline Replacement

- 1.1 Pipe Delivery
  - 1.1.1 45 sections of Schedule 40 PVC pipe will be ordered from David and shipped to Tole'
  - 1.1.2 Pipes will be transported by local chiva drivers to the midpoint of the pipeline (where the pipe crosses the road)
- 1.2 Identify damaged sections
  - 1.2.1 Using the topographical maps as well as the elevation surveys with noted landmarks, the sections in need of replacement will be marked out.
- 1.3 Pipe Layout
  - 1.3.1 Manual labor will be required to transport the pipes from the road to the sections being replaced
- 1.4 Trenches will be dug for the pipes along the sections of replacement
  - 1.4.1 At least 36" of soil cover is recommended to protect against fire damage and livestock hooves. If this is done, the pipelines expected lifetime is greatly increased. (Jordan. Pg. 84)
    - 1.4.1.1 No sharp rocks should be placed directly around the pipeline when backfilling.
- 1.5 Assemble pipeline
  - 1.5.1 Pipes will be cemented at joints and purchased couplings will be used in places were pipes are spliced together.

2.0 Valve Construction

- 2.1.1 Valve materials will be purchased from David when the pipes are ordered
- 2.1.2 Air Release Valves will be assembled according to the specified drawings
- 2.1.3 Water hammer arrestor valve will be constructed according to the specified drawings.
  - 2.1.3.1 The valve will be placed directly behind the shutoff valve as specified in the drawings
- 2.1.4 Air relief valves will be placed along the high points in the pipeline as specified in Appendix I.
- 2.1.5 A clean out valve will be installed at the point noted in Appendix F according to the specified drawings.

3.0 Intake Structure Construction

- 3.1 Build Earth Dam
  - 3.1.1 The exact height of the spillway will be marked by filling the dam until water flows over the spillway. The water level will be marked out precisely on two stakes placed near the future site of the intake on the water intake structure.
  - 3.1.2 A trench and earth dam will be created to divert the dry season flow to the pipes underneath the dam
- 3.2 Prepare materials
  - 3.2.1 Order cement from Tole’ and have it delivered to the top of the valley
  - 3.2.2 Concrete bags will be manually hauled down the valley to the intake structure site
    - 3.2.2.1 Bags will need to have adequate protection from moisture during temporary storage
- 3.3 Construct sieves out of 2”x4” lumber.
  - 3.3.1 Build 3’x4’ box and attach appropriate size screen on bottom by nailing overlapping edges to the frame.
- 3.4 Sieve sand and aggregate for concrete using screen sieves.
  - 3.4.1 Approximately 4.5 yds of sand will be needed as well as 6.5 yds of course aggregate.
    - 3.4.1.1 The sand should range between 25 mm to 6.3 mm.
    - 3.4.1.2 The course aggregate should be between ¾” and 1” ideally. http://www.lifewater.ca/Appendix_J.htm
- 3.5 Excavate Intake Structure Site
- 3.6 Form the perimeter of the floor
  - 3.6.1 Place rebar for floor
  - 3.6.2 Place Concrete for structure floor
    - 3.6.2.1 All concrete will use a standard 1-2-3 mix design
      - 3.6.2.1.1 1 part cement, 2 parts sand, 3 parts course aggregate by volume
  - 3.6.3 Let concrete cure for 24 hrs
  - 3.6.4 Remove form boards
- 3.7 Form the walls and wing walls of the intake structure
  - 3.7.1 Place and secure rebar and PVC outlet pipes using tie wire
    - 3.7.1.1 Rebar laps require a 25” splice as noted in the drawings
- 3.8 Mix and place concrete for the walls
  - 3.8.1 Allow concrete to cure for 24 hrs
  - 3.8.2 Remove form work

4.0 Chlorination Monitoring

- 4.1 Purchase chlorine test kit

            - 4.1.1 Can be obtained from multiple U.S. sources for around $15
- 4.2 Check chlorine once a day for 90 days (chlorine tablet cycle) near the tank and at the farthest point in water system
- 4.3 Determine if chlorine levels stay within expected limits
- 4.4 Retest if any changes are made

Note: specific Instructions found in Appendix M.

Appendix O

Detailed Final Cost Estimate

Component	**Cost**
Intake Structure	$1,061
Water Quality	$40
Pipeline	$3,187
Labor- estimated at $1,313, but will be donated	$0
Total Cost	$4,287
Total Cost + 15% contingency for unexpected costs	$4,930.51

Cost for intake structure			
	Quantity	Unit Price ($)	Cost
Cement (42.5 kg bag)	75 bags	$8 / bag	$600
Cement Transportation Truck cost	1 day	$55 / day	$55
Rebar 3/8"(#3) (30ft)	6 rods	$5.30 / rod	$32
Rebar 1/2"(#4) (30ft rods)	6 rods	$10 / rod	$60
Sand	4.667 yd^3	$0 (river)	$0
Aggregate	6.5 yd^3	0 (river)	$0
Board (per foot)	700 board feet	$0.30 / board ft	$210
Rod	8 rods	$10 / rod	$80
Hitch Pin	4 pins	$6.00 / pin	$24
Total Cost for Intake Structure			$1,061

Cost for Water Quality Improvement			
	Quantity	Unit Price ($)	Cost
Chlorine tablets	determined by test kit	$0 (MINSA)	$0
Chlorine test kit	1	$40 / kit	$40
Total Cost for Water Quality Improvement			$40

Appendix O continued: Detailed Cost Estimate

Cost for Pipeline			
	Quantity	Unit Price ($)	Cost
Replacement Pipes (schedule 40)	170 units	$16.08 / pipe	$2,734
Pipe Transportation from Tole' to Chichica	1 day	$44 / day	$44
Joint Fittings / coupling	10	$1 / coupling	$10
Socket T	18 sockets	$9 / socket	$162
Cap	$18 caps	$4 / cap	$72
Screen	2 screens	$5 / screen	$10
Cable	140 ft	$0.25 per foot	$35
4' by 8' welded wire mesh	2 pannels	$15 / pannel	$30
Gate Valves	3	$30 / valve	$90
Total Cost for Pipeline			$3,187

Cost for Labor - donated because it is a 'social project'				
	Total amout of work	Labour hour needed	unit cost	Cost
Laying Schedule #40 4" Pipe 4" schedule 40	3400 feet of pipe	170 pipe sections	$3 / pipe section	$510
Building concrete forms for intake structure	5 people / day	2 day	$12 / man/ day	$60
Pour concrete for intake structure	7 people / day	2 day	$12 / man/ day	$84
Pour concrete for concrete cap	3 people / day	1	$12 / man/ day	$36
Total Cost for Labor				$690