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ALTERNATIVES ANALYSIS REPORT

CHAPTER: Greater Austin
COUNTRY: Panama
COMMUNITY: Sieykin (Arriba)
PROJECT: Water and Health

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Alternatives Analysis Report Part 1 – Administrative Information

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2.0 Travel History

Dates of Travel	Assessment or Implementation	Description of Trip
January 5 – 17, 2009	Assessment I	This was the first assessment/exploration trip to verify that the entire community wanted to partner with EWB Greater Austin, and to define the scope of the project with the community.
August 1 – 23, 2009	Assessment II	This was the second assessment trip to collect further data/information for implementation, discuss designs with the community, and to initiate a community-wide health education and hand washing campaign.
May 26-June 1, 2010	Pre-Implementation	This was an impromptu trip to assess the community's commitment to the project and sign work contracts.
June 26-August 19, 2010	Implementation I	This was the first implementation trip to construct the water system in the central sector of the community. Goals of this trip were to construct a 5000L water tank, a spring box, lay pipeline connecting the spring box to the tank, and the tank to all users, repair existing tank for non-potable water and continue the community-wide health education campaign.
December 30, 2010-January 13, 2011	Assessment III	The purpose of this trip was to monitor and assess the functioning of the water system installed during the first phase of implementation, to collect data/information for the design of the second phase of implementation in Sieykin Arriba, and to continue the health education campaign.

3.0 Project Discipline(s): Check the specific project discipline(s) addressed in this report. Check all that apply.

Water Supply

__x_ Source Development
__x_ Water Storage
__x_ Water Distribution
__x_ Water Treatment
____ Water Pump

Sanitation

____ Latrine
____ Gray Water System
____ Black Water System

Structures

____ Bridge
__x_ Building

Civil Works

____ Roads
____ Drainage
____ Dams

Energy

____ Fuel
____ Electricity

Agriculture

____ Irrigation Pump
____ Irrigation Line
____ Water Storage
____ Soil Improvement
____ Fish Farm
____ Crop Processing Equipment

Information Systems

____ Computer Service

4.0 Project Location

Longitude: 82°40'50.92"W
Latitude: 9°23'58.85"N

Alternatives Analysis Report Part 2 – Technical Information

1.0 INTRODUCTION

This document presents a formal analysis of the sub-system alternatives which have been considered for the EWB – Greater Austin clean water project in the Arriba sector of Sieykin, Panama. Information specific to this sector was gathered during Assessment III, though EWB – Greater Austin has also gained institutional knowledge of the community through previous assessments and the Centro sector Implementation I trip.

Analyses of alternatives for four distinct subsystems of the Arriba sector system are presented. These subsystems are 1) source, 2) distribution, 3) storage, and 4) bridging. The distribution subsystem is how the new potable water will be routed to community members' homes and includes piping and storage tank placement. The source subsystem is how potable water will be obtained. The storage subsystem is how potable water will be stored. There are two large stream crossings that the distribution subsystem piping will need to overcome. The bridging subsystem is how these crossings will be spanned. The alternatives considered in this document assume an implementation timeframe of approximately four weeks. The impact of this timeframe on construction schedule is considered for each alternative

According to information gathered from household interviews, the population of the Arriba sector is approximately 79 people. Of these 79, 47 currently have (unclean) piped water to their households. The remaining 32 retrieve their water from neighbors' faucets or directly from the nearest stream. These divisions represent two distinct user groups of the system: (1) those who will utilize the system for only potable water and (2) those who will utilize the system for all water needs. For the potable-only group, the demand is assumed to be 13.2 gal/person/day [50 L/p/d]. For the full water needs group, the demand is assumed to be 39.6 gal/person/day [150 L/p/d]. These design demand amounts are based on the recommendations of the World Health Organization (WHO) standards for "intermediate" and "optimal" water access (given as 50 L/p/d and 100+ L/p/d) (Howard and Bartram 2003).

The CIA World Fact Book (2011) states the national average growth rate of Panama's population is 1.435%. To be conservative, we use a 2% growth rate. For this growth rate and a 15-year design time, the total design population is 107, with 64 in the potable-only group and 43 in the full water needs group. [1] For the demands presented above for each group, the total design demand is 2542 gal/day. Based on the assumptions and estimates presented above, EWB has determined that a storage tank of capacity 528 gallons is necessary to adequately provide the community with all their water needs. Further details and calculations are presented below and in the concurrent 524 document for this project.

[1] $P = P_0(1+r)^t = 79(1+0.02)^{15} \approx 107$ [Total population]
$47(1+0.02)^{15} \approx 64$ [Potable-only]
$32(1+0.02)^{15} \approx 43$ [Full demand]

Note: Analyses of alternatives for all subsystems of this project are based on the 528 gallon storage tank calculation.

2.0 PROGRAM BACKGROUND

2.1 Introduction/Background

The Panama Project was launched in spring 2008. The project began immediately following an EWB member's return from a semester abroad in Panama with the SIT Panama program. After traveling throughout the country and making contacts through SIT, the EWB member worked with a partner NGO (La Alianza para la Conservación y el Desarrollo, or the Alliance for Conservation and Development, ACD) and SIT to identify a community where an EWB project would be feasible. This decision was based on safety in the community, familiarity of SIT and ACD with the community, the community's need for a project, and the predicted involvement of community members. SIT provided the contact information of the community members that coordinate SIT's program in the Naso community of Sieyic, which is across the river from the EWB Greater Austin project community of Sieykin. Communication was immediately initiated with Sieykin via the main contact, Edwin Sanchez. The EWB Greater Austin group remained in contact with the community via Edwin for approximately one year prior to the first EWB trip to the community. During this year, Edwin arranged various community-wide meetings to discuss the community's desire to partner with EWB, as well as gathered preliminary information for the EWB group to complete the EWB-USA 501 project submission application. The EWB Greater Austin group traveled to Sieykin in January 2009 for the first needs assessment trip.

The project is located in northwestern Panama in Sieykin, a community consisting of 400 people which belongs to the indigenous group of the Naso. Among the smallest and most impoverished indigenous groups in Panama, the Naso people number only 3,300 people. Houses are made from locally harvested wood. There are no roads or vehicles in Naso communities; all transportation is carried out on foot, in motorized canoes, by bamboo raft, and by horse. The Naso people retain the last monarchy governance system in the Americas.

2.2 Community Need

The community, and most of the Naso people, lack access to many basic services, including water treatment, a reliable water distribution system, sanitation infrastructure, comprehensive health services, and electricity. This lack of access to basic services in Sieykin has resulted in numerous health and community development issues. The people of Sieykin consistently suffer from diarrhea, vomiting, fever, and other water-related illnesses due to contaminated drinking water. There are also other health issues identified in the community, the most common involving skin problems and respiratory illnesses.

Water testing from both assessment trips ascertained that community water contains the presence of E. Coli and/or coliforms, indicating that fecal contamination and harmful pathogen presence in the community's water is highly likely. Many community members do not have a water distribution system that comes to their home. For the areas that do have water distribution, the system is old and unreliable, often requiring community members to drink water from surface water streams, open to contamination from humans and animals. The existing water system is gravity fed from the source, which is a network of mountain springs. Most community members utilize some version of an open-pit latrine for sanitation services; however, these latrines are not always strategically located or kept clean.

2.3 EWB Greater Austin Assessment Trip I and II

The first assessment trip to the community was undertaken in January 2009 by five EWB Greater Austin members, one professional mentor, and 2 UT graduate nursing students. The principal goal of the first assessment trip was to become familiar with the community of Sieykin in northwestern Panama to determine if residents would like to partner with EWB Greater Austin in a project, as well to assess the needs of the community. Tasks completed on the trip included performing numerous community meetings, water testing, land surveying, community in-home interviews, a materials survey, a community health assessment, and a meeting with a local non-governmental organization (NGO) to discuss future collaboration and partnership. During this trip, the community decided that it would like to partner with EWB in a project, and identified its first project priority to be improvement of community water quality and water distribution. The EWB group gathered valuable information to begin forming preliminary design concepts to present to the community in the second assessment trip.

During spring semester 2009, the project group researched and began developing preliminary design options for the community project. The group also developed plans to initiate a health campaign in the community in order to educate community members, as it pertains to clean water, sanitation, and hygiene.

During the second assessment trip in August 2009, six EWB members and two professional mentors traveled to Panama to further assess the feasibility of this project and to collect detailed, additional information necessary for project implementation. One of the group's goals was to discuss project plans, management, and organization in detail with the community to ensure that the project is exactly what the community desires. This was done through individual household interviews and community-wide meetings. A second goal was to collect detailed additional information necessary for actual project implementation. This included identifying potential spring sources and collecting flow rate and water testing data at those sources to assess the feasibility of a closed spring system. Also, thorough survey data was collected of the potential pipe path and of every house in the sector of the community where initial implementation is planned. A third goal was to meet with governmental and non-governmental agencies in-country to gain support and assistance with the project. The final goal for this assessment trip was to launch a health and hygiene campaign in the community to teach them about waterborne illness, person to person disease transmission, and the importance of hand washing.

2.4 Implementation Phase I

Summer 2010 marked the beginning of the implementation phase of the Panama water project of EWB – Greater Austin. The primary goals of the first implementation trip were to install a potable water system, improve the community's current water system (to serve as a non-potable system), and continue with health and system maintenance education efforts. The dual potable/non-potable water system now serves the central sector of the community, where the school, health post, church, and about 30 households are located.

During the trip, for the potable water system, the EWB group and community constructed a spring box for clean water capture and a 5,000 L potable water storage tank using poured concrete construction. They also laid about 5450 ft of piping from the spring box to the potable tank and from the tank to the community center. For the non-potable system, the EWB group and community installed about 3300 ft of piping from the non-potable water source to the current water tank and from the tank to the community center. The piping was buried or encased in larger PVC pipe to protect it from UV damage. Valve and air release boxes were installed as necessary, as well as small bridges when crossing ravines or particularly uneven terrain.

EWB group members taught health education in the local primary school through role play, activity books, songs, and visual tools (including a microscope). Meetings were held with community members every week to discuss progress, work and food preparation for the upcoming week, and any project concerns. The final meetings focused more on leadership and completion of the project after the EWB group returned home.

2.5 Assessment Trip III

During the third assessment trip, the EWB team monitored and assessed the first phase of implementation, initiated the second phase of implementation, and continued the health education campaign in Sieykin. EWB-AUS' travel team spent 10 days in the community. During this time, the team split into two groups. Although there was some cross-over, half the team focused primarily on health education and community relations, while the second half focused on the technical aspects of the project.

The health education group conducted household interviews. The main purpose of these interviews was to assess the community's satisfaction with the first phase of implementation, assess how the new system was working, and discuss any changes in the health of each household. They also educated the community about the water system and EWB's continued presence in the community for the duration of the program. They also met with the water committees to discuss their roles and to guide them into becoming better functioning committees.

With the assistance of community members, the technical group located potential spring sources, tested them for water quality, and surveyed the area to provide elevation and distance information for the water distribution line. They also inspected the first phase of implementation and worked with the community to troubleshoot some problems they have had with the system.

3.0 DESCRIPTION OF COMPARISON METHODOLOGY

Alternatives for each of the four subsystems are analyzed according to a three-tiered "filter" process, depicted in Figure 1. An analysis for a particular alternative need not go through the next tier of the process if it is found deficient in an earlier tier. That is, some alternatives may be ruled out before they reach a full cost and time analysis.

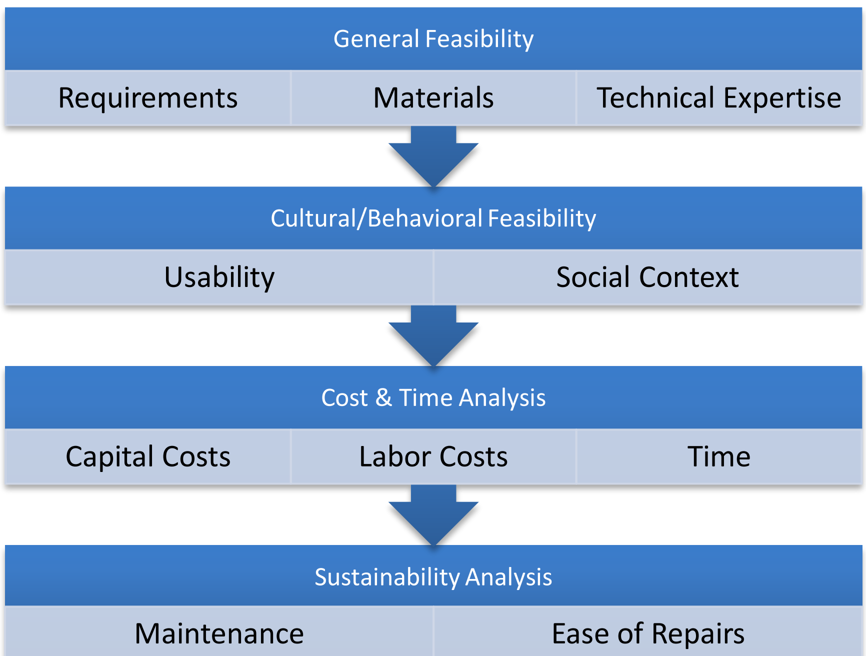

Figure 1: Analysis Filters

The first tier of analysis is the General Feasibility of the alternative. In this tier, the alternative is examined to make sure that it can meet the demand requirements, is constructible with materials available in-community or in from nearby Changuinola, and that the EWB team and/or community members possess the necessary technical expertise to implement the alternative.

The second tier of analysis the Behavioral/Cultural Feasibility of the alternative. This tier is more subjective and includes judgments of how the EWB team believes the community would react to the alternative. These judgments are based on our interactions with the community members, as well as on survey and interview responses collected during assessment trips. In general, alternatives that would require a large behavioral change on the part of the community members will not make it past this tier of the analysis process.

The third tier of analysis is the estimated Cost & Time of the alternative. In this tier, the time to construct, cost of materials, and amount of labor required are examined. Only the best alternatives for each subsystem will reach this tier of analysis as it requires significant design work to create an adequate estimate of time, cost, and labor. The details of this analysis for the corresponding alternatives can be found in the Appendix.

The fourth and final tier of analysis is the Sustainability of the alternative. In this tier, the long-term maintenance of the alternative and ease of repairs are taken into consideration.

4.0 DESCRIPTION OF ALTERNATIVES

4.1 Source Alternatives

4.1.1 Chlorination

Chlorine is a popular method of drinking water disinfection in developed countries (Gordon, Cooper, Rice, & Pacey, 1987). Disinfection by chlorine occurs when the chemical is introduced to the system as either a gas, solid or liquid form and is converted to hypochlorous acid. Hypochlorous acid is a strong disinfectant and destroys disease-causing microorganisms by interacting with enzymes within the cell that are critical to the metabolic processes of the microorganism. When water is chlorinated to the appropriate dose, a chlorine-residual is generated. This protects the system from contamination by maintaining disinfection properties throughout the entire distribution system (Droste, 1997)

4.1.2 Solar Disinfection

Solar disinfection is a good source of disinfection for inhabitants of developing regions where access to resources for water treatment are limited. The combination of heat and ultraviolet radiation from the sun kill most bacterial pathogens present in a water supply when left in a transparent container under direct sunlight. When a temperature of 45°C is reached and the container is exposed to at least seven hours of direct sunlight, bacterial pathogens are inactivated, making the water safe to drink (McGuigan, Joyce, Conroy, Gillespie, & Elmore-Meegan, 1998). Turbidity present in the water makes solar disinfection less effective because the UV rays cannot penetrate the water. It has been shown that if a temperature of 55°C is reached bacteria will be inactivated even in water with high turbidity (McGuigan, Joyce, Conroy, Gillespie, & Elmore-Meegan, 1998).

4.1.3 Ceramic Filters

Ceramic filters are a point-of-use option for filtration that can readily be used in many rural or emergency situations (Kayaga, 2007). Ideally, the filters are made locally with local materials to encourage sustainability and stimulate the local economy. The filters are created by mixing local clays with organic material and then firing them in a kiln. After firing, the filters are often coated with some form of silver to function as a disinfectant.

Ceramic filters work by trapping particles while allowing water to trickle though the small pores in the material matrix. Filters with no silver coating remove some bacteria, but in order achieve near 100% efficiency, a silver coating is required. To maintain high filter volume outputs the ceramic must be scrubbed approximately once a month to remove the build-up of solids that are trapped during the filtration process (Lantagne, 2002).

4.1.4 Hand-Dug Well

A well is a structure used to extract water from the ground by tapping into groundwater to provide a constant flow of clean water free from the contamination that affects surface water (Watt & Wood, 1977). A depth of approximately ten meters is required avoid surface contamination while still remaining within a practical sinking level (Watt & Wood, 1977). The well structure is typically a cylindrical concrete construction with layers of gravel and sand providing a natural filter between the soil and the well. Rebar and mortar are used to reinforce the structure. Water enters the well through the base, which has been sunk into the water table. The plug, a cement block covering gravel and sand, provides the last means of filtration for the entering water. A hand pump or electric pump is necessary to extract water from the well unless artesian conditions exist in the aquifer. Electric pumping could be achieved through the use of a solar powered pump at the surface of the well. Wells need to be constructed a significant distance away from any pit latrines and the wellhead needs to be covered to avoid contamination. Figure 2 shows the general construction of a hand dug well (Watt & Wood, 1977).

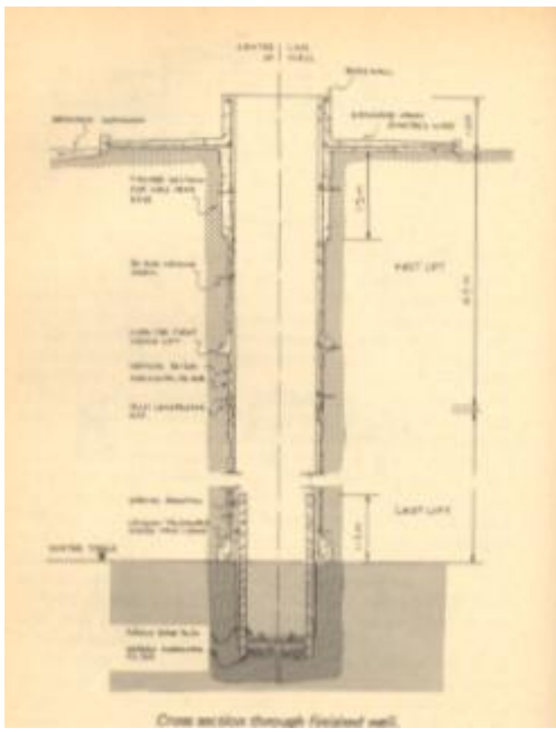

Figure 2: Hand-Dug Well Diagram (Watt & Wood, 1977)

4.1.5 Rainwater Harvesting

Rainwater harvesting is often considered a good source of clean water for areas in developing countries that receive adequate regular rainfall and where surface or groundwater is scarce. One common method of rainwater harvesting is using roof collection systems. A gutter system on each home's roof is used to funnel rainwater into household storage tanks. To avoid contamination from decaying plant or animal/bird fecal matter that may be present on the roofs, a flush system is used. In a flush system, the first or second filling of the storage tank is released and only water collected afterward is stored for use. Nevertheless, routine cleanings of the roofs, gutters, and storage vessels is often necessary to provide contaminant-free water.

The region of Bocas del Toro seems to have plenty of rainfall, and there is little variation throughout the year (see Figure 3 which shows average monthly rainfall in the area). There have, however, been studies that show that the water quality collected from roof runoff is not sufficient for potable uses (Lye, 2002). There is also the risk of further contamination in storage tanks where the water is kept (Crabtree, Ruskin, Shaw, & Rose, 1996).

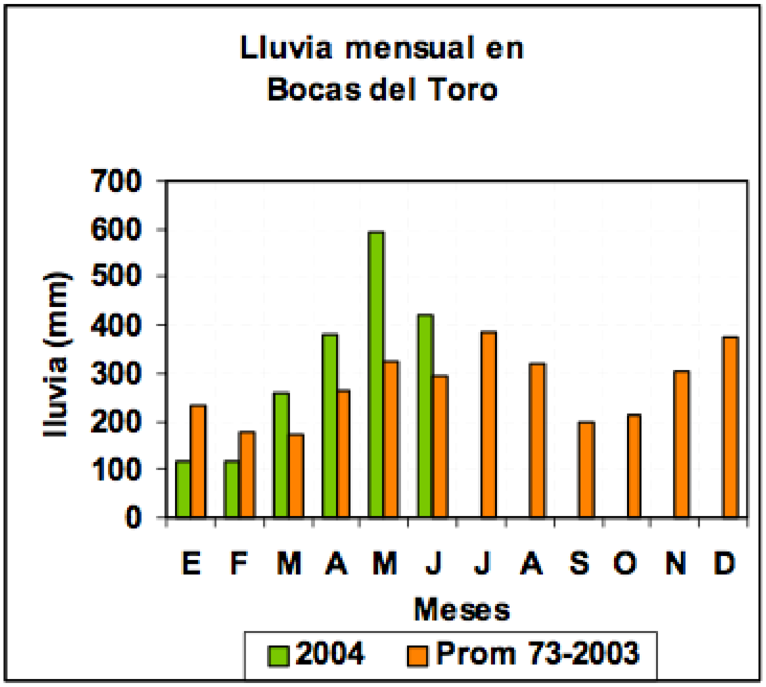

Figure 3: Monthly rainfall in Bocas del Toro (ETESA, 2005)

Orange bars represent the monthly average (in mm), and green bars represent measurements taken in the first part of the year 2004.

4.1.6 Slow Sand Filter

Slow sand filtration has a long history of being used effectively to treat water for the removal of bacteria and to prevent the spread of gastrointestinal disease (Logsdon, Kohne, Abel, & LaBonde, 2002). Use of slow sand filtration in the developed world has waned since the early 20^{th} century, with pressurized rapid filtration becoming the more popular method. There has been a recent renewed interest in slow sand filtration, particularly for use in developing countries (Logsdon, Kohne, Abel, & LaBonde, 2002). Slow sand filtration is suitable for small-scale water systems in the developing rural and semi-rural communities due to the availability of construction materials and methods in-community, relatively simple construction, and high efficiency in removing bacterial contamination (Huisman & Wood, 1974).

The principles behind slow sand filtration are relatively straightforward. A filter tank holds a layer of uniform fine-grain sand supported by a bed of coarse gravel. On top of the sand bed is a bio-layer composed of algae, bacteria, plankton and other microorganisms, collectively known as *schmutzdecke* (German: "dirt cover"). Raw influent water from a surface water source enters through the top of the filter tank. The raw water slowly (at a rate of approximately 0.33 ft/h) passes through the *schmutzdecke* and sand bed. The *schmutzdecke* mechanically strains suspended materials along with consuming nutrients and harmful microorganisms. Water and suspended material that passes through the *schmutzdecke* then travels through the sand layer where the suspended material is adsorbed onto or otherwise captured by the filter media. Clean water flows out through the coarse gravel support layer into collection pipes and is then stored in a clear well reservoir. Figure 4 shows a typical slow sand filtration system.

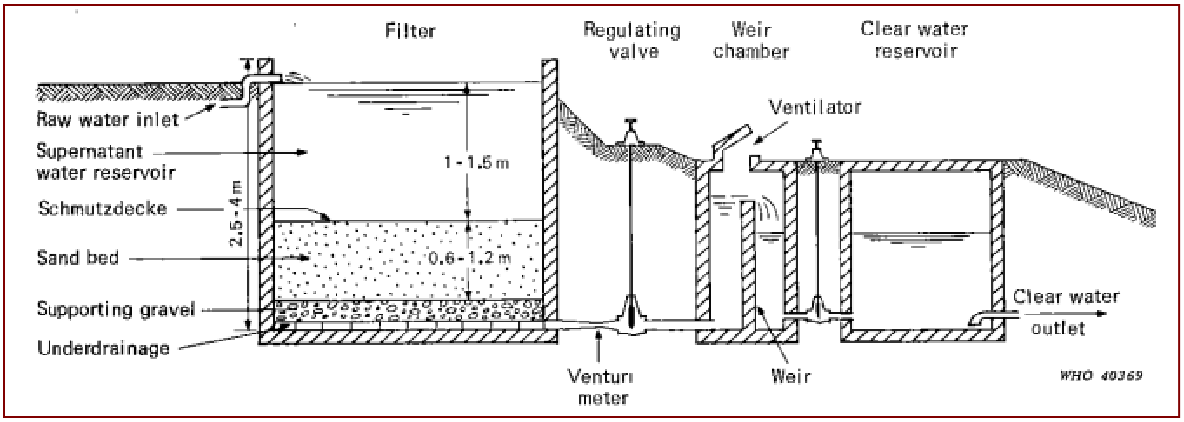

Figure 4: Slow Sand Filter Layout (Huisman & Wood, 1974, p. 18)

Slow sand filters perform quite well at microorganism removal, including coliform bacteria, giardia, and cryptosporidium, as shown in

Table 1.

Table 1: Microorganism Removal by Slow Sand Filtration (Logsdon, Kohne, Abel, & LaBonde, 2002)

Reference	Organism	Filtration rate (m/h)	Temperature (°C)	Removal percentage
Poynter and Slade (1977)	Poliovirus	0.2	16 to 18	99.997 average
Poynter and Slade (1977)	Poliovirus	0.4	16 to 18	99.865 average
Poynter and Slade (1977)	Poliovirus	0.2	5 to 8	99.68 average
Poynter and Slade (1977)	Poliovirus	0.5	5 to 8	98.25 average
Bellamy et al. (1985*b*)	Total coliform bacteria	0.12	17	97 average
Bellamy et al. (1985*b*)	Total coliform bacteria	0.12	5	87 average
Bellamy et al. (1985*a*)	*Giardia*	0.12	5 to 15	99.994 average
Bellamy et al. (1985*a*)	*Giardia*	0.4	5 to 15	99.981 average
Bellamy et al. (1985*b*)	*Giardia*	0.12	17	>99.93 to >99.99
Bellamy et al. (1985*b*)	*Giardia*	0.12	5	>99.92 to >99.99
Pyper (1985)	*Giardia*	0.08	0.5	93.7
Pyper (1985)	*Giardia*	0.08	0.5 to 0.75	99.36 to 99.91
Pyper (1985)	*Giardia*	0.08	7.5 to 21	99.98 to 99.99
Ghosh et al. (1989)	*Giardia*	0.3	4.5 to 16.5	>99.99
Ghosh et al. (1989)	*Giardia*	0.4	4.5 to 16.5	99.83 to 99.99
Ghosh et al. (1989)	*Cryptosporidium* oocysts	0.15 to 0.40	4.5 to 16.5	>99.99
Hall et al. (1994)	*Cryptosporidium* oocysts	0.2	Not stated	99.8 to 99.99
EES and TWU (1996[a])	*Cryptosporidium* oocysts	0.29	12 to 14	>99.99

4.1.7 BioSand Filters

BioSand filters have been in use in the developing world since their inception in the early 1990s by Dr. Manz at the University of Calgary (CAWST, 2009). Dr. Manz helped start the Centre for Affordable Water and Sanitation Technology (CAWST), which publishes information on the design of and aids in implementation of BioSand filters in rural communities worldwide (CAWST, 2009).

The mechanism behind producing clean water from BioSand filters is quite similar to that of slow sand filters as discussed in the previous section. A diagram of a typical BioSand filter is provided in Figure 5. The main difference between the community-scale slow sand filter and BioSand filters is that BioSand filters are generally considered point-of-use sources of clean water, meaning each family would own a private filter. Each family then is responsible for proper use and maintenance of their filter, though some guidance and aid from knowledgeable community members would be expected.

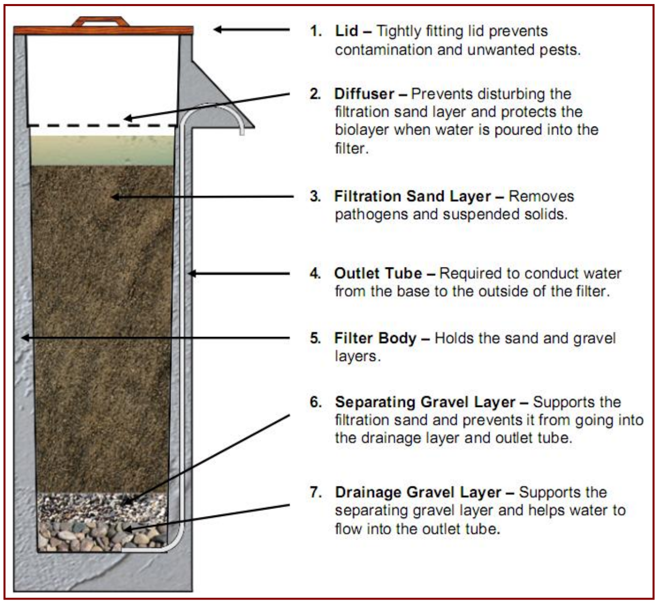

Figure 5: BioSand Filter Diagram (CAWST, 2009)

4.1.8 Source Protection

Source protection is a method of securing clean water based on the construction of a spring box to utilize the natural flow of a spring. As surface water travels through the ground, it is filtered and often results in clean, potable ground water. There are two main springs located near each other in the Arriba sector of Sieykin that could provide safe water to the community at reasonable flow rates. The springs are approximately 2000 ft from the nearest home in the community, so a large distance of pipe will be needed. However, the elevation change to the spring sources is approximately 400 ft, so there is enough pressure to bring the water to the tank site by gravity alone.

Spring boxes are a form of source protection to protect the clean spring water from surface contamination. A spring box is usually built by digging out a section of soil around the source of a spring, and then installing a brick or concrete structure around the spring. Piping runs from the box downhill to the community to carry protected water to a storage tank from which it will be distributed. A diagram of a typical spring box is provided in Figure 6.

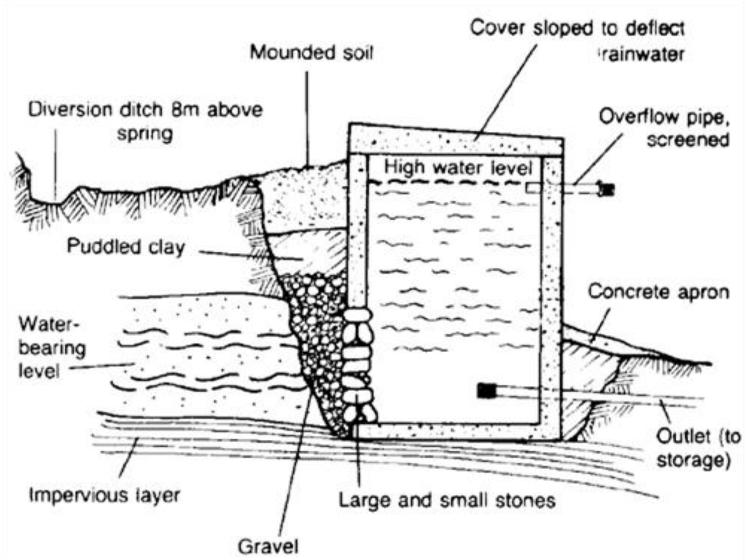

Figure 6: Spring Box Diagram (Lifewater International)

4.2 Distribution Alternatives

The topology of Sieykin Arriba creates interesting hydraulic considerations for the implementation of a potable water system in this community. The water source is a spring approximately 400 feet above the approximate geographic center of the village. Water from a spring box at this spring will be piped to a storage tank, and the elevation of this tank will define what water pressure is delivered by faucets in the village. However, the hill to the northwest of the village center has a number of homes that extend approximately 250 feet above the house of lowest elevation. Using surveying data gathered during the assessment trip, we have built a model in Pipe Flow Expert (PipeFlow, Inc.) that shows the location and elevation of each house as well as critical points throughout the survey line. One crucial decision variable in our design is location of the storage tank. Using the model we constructed, we hope to determine an optimal tank elevation for four scenarios that consider the number of people reached by the network, system wide pressure ranges, construction cost and labor and potential for future expansion.

All systems make use of Schedule 40 PVC pipe and the model results yield system pressure well within the working range of this material (at a minimum 1 inch maximum operation pressure = 270 psi (ASTM 2006)). For the alternatives analysis, the community demand was standardized as the system wide average daily demand (ADD) equally distributed throughout the 19 homes (users) in Sieykin Arriba. Community surveys and WHO recommendations were utilized to determine a total potable water demand to the system of 3170 gal/day. This potable demand incorporates additional flowrate for non-potable uses from houses which currently are not connected to the existing non-potable system. These considerations and a 10% safety factor on average daily demand result in a per-node ADD of 0.13 gallons per minute (gpm). In all cases one-inch Schedule 40 PVC is used to convey water from the spring to the storage tank, capable of conveying approximately 11 gpm, or approximately 4 times the measured capacity of the spring.

Minor losses (fittings, bends, etc.) were placed throughout the system as can be reasonably anticipated. A rudimentary sensitivity analysis was conducted by randomly placing high K-value fittings throughout the system to test the importance of minor losses on overall system operation. These tests resulted in small changes to both system flowrates and pressures and therefore ad-hoc changes in future implementation to the chosen pipeline layouts can likely be accommodated without appreciably affecting the design intent of that alternative. Clean-out and air release valves are similar throughout all alternatives and will be placed at local high and low elevations throughout the system.

Survey stations referenced throughout the document refer to surveying completed during the Assessment III trip and community elevation profiles are provided in Appendix 2.

4.2.1 Option 1

Option 1 consists of a tank at sufficient elevation to provide clean water to all residents of Sieykin Arriba relying only upon frictional losses in the pipeline and minor losses to reduce system energy from that present at the tank. One-inch Schedule 40 PVC is used to convey water from the protected spring, to the Tee at survey point AR, and northwest to the residents at higher elevations. Half-inch Schedule 40 PVC is used to convey water from the tee at survey point AR to the residents on the southwest side of the system. One-half inch PVC has been substituted along the branch from Station AR to EA to reduce system pressures in this region. However, this design results in a wide range of pressures throughout the system due to the large disparity in elevation throughout the community. This option presents a straightforward system in terms of construction and maintenance and is included for consideration as the “base” case.

4.2.2 Option 2

Option 2 varies from the base case by eliminating service to two residents (Jaun y Flores and Enrique at survey points DAJ and DAF, respectively) within the community who built their houses at relative high points in the area. This reduces the PVC pipeline material need by approximately 3000 linear feet and brings system pressures into a smaller, more appropriate range. PVC pipeline in this scenario is one-inch Schedule 40 throughout the entire community.

4.2.3 Option 3

Option 3 varies from the base case by grouping houses at elevation 700 feet and below onto a common line and utilizing a frictional diffuser to reduce system pressure at these houses to a preferred range. This allows the placement of the storage tank at sufficient elevation to provide reasonable working pressure to the houses at higher elevation (greater than 700 feet) in the northwest region of Sieykin Arriba. One-inch Schedule 40 PVC is utilized throughout the system.

4.2.4 Option 4

Option 4 varies from the base case by implementing two parallel lines from the storage tank to provide water to the high and low clusters of houses noted in Option 3. In this scenario, a break pressure tank is modeled on the line serving the houses at lower elevation to “reset” the static head at an appropriate elevation which will provide reasonable working pressure to the users at low elevation. The storage tank is placed at a sufficient elevation to provide reasonable working pressure to the houses at higher elevation. One-inch Schedule 40 PVC is utilized throughout the system.

4.3 Storage Alternatives

These are the different options for storing the clean water once obtained. Not all Source alternatives will require storage.

4.3.1 Reinforced Concrete Tank

Concrete is composed of fine aggregate (sand), coarse aggregate (gravel), water, and cement. To compensate for concrete's low tension strengths, rebar is usually added to accept tension stresses that develop within concrete members therefore preventing failure due to rupture. This composite material of steel and concrete is called reinforced concrete. Reinforced concrete is widely used in many construction applications, and can be used in water storage. A water tank made from reinforced concrete is acceptable if certain precautions are taken. First, cold joints must be sealed to prevent water from touching the rebar (causing corrosion) and escaping to the outside. Second, significant concrete compression strength is required to support the live and dead loads of water and the surroundings. Finally, additional material, like admixtures, may be used to account and/or address mix inconsistencies and variables. A sample tank diagram is shown below. Like all tanks, there is an inlet, an outlet, an overflow, and a roof access. These fenestrations must be addressed in the formwork before concrete is placed to prevent points of failure or water leakage.

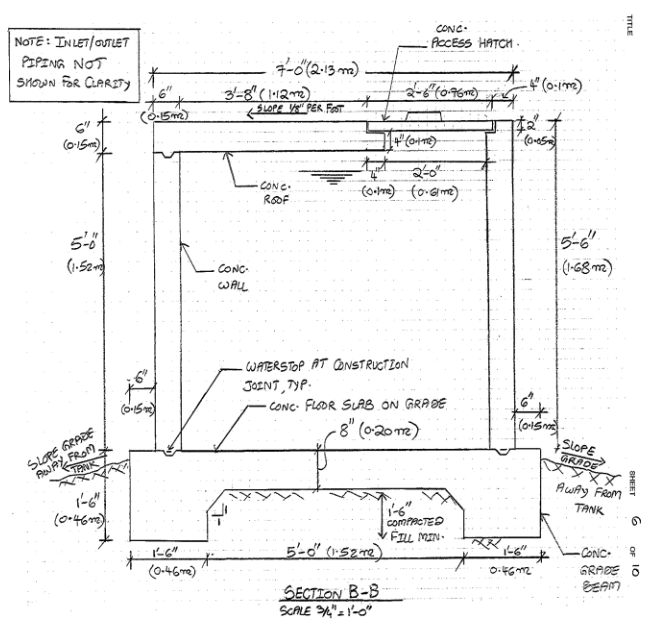

Figure 7: Typical Reinforced Concrete Tank

This is the method which was used to construct the tank on the previous implementation trip in Sieykin Centro. Advantages of this method include its strength and resilience over time if properly designed. Additionally, being one of the most common construction techniques, it is a technically well understood process with rigorous design standards and people familiar in i's construction in both the US and in developing countries. Disadvantages include the time required for construction due multiple pours each requiring seven days of setting and the large amount of Portland cement and aggregate which must be transported to the construction site.

4.3.2 Ferrocement Tank

Ferrocement is a construction technique which is commonly implemented in developing countries and in instances by individuals in developed countries. In this technique a steel reinforcement frame is also constructed but generally from wire, mesh, and sometimes steel bars. Figure 8 is an example of a typical ferrocement tank design. The concrete mix is somewhat different containing no coarse aggregate and less water. The resulting mixture of Portland cement, sand, and water is the consistency of grout. No forms are constructed but rather the concrete is plastered onto the steel form and then wet cured. Advantages of this technique include the reduced resource demand due to forms not being required in construction and generally a reduction in the required wall thickness, though a considerable amount of sand and Portland cement still needs to be transported to the site. Also there is a reduction in the time required for construction as there is only one concrete "pour." Disadvantages include that it is a less common Portland cement construction technique and therefore lacks the rigorous standards and near universal understanding of poured concrete.

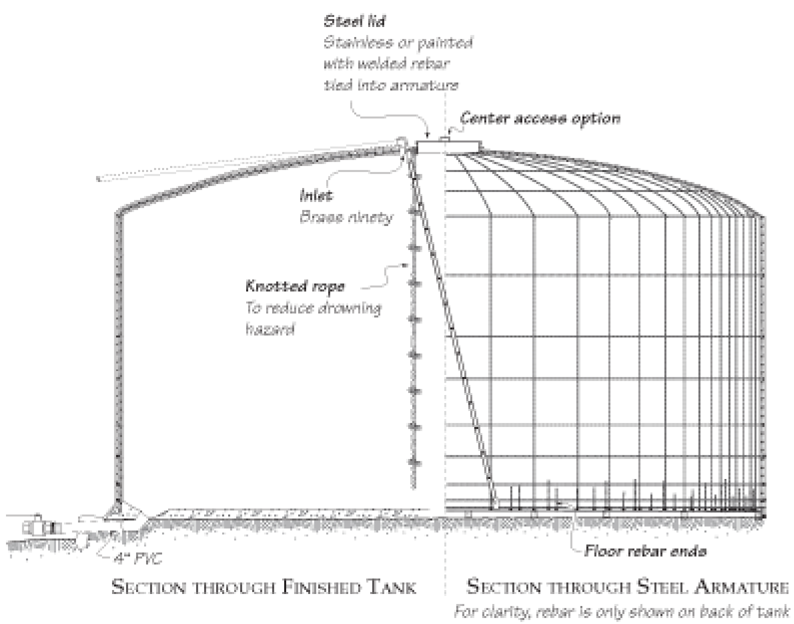

Figure 8: Typical Ferrocement Tank (Ludwig 2005)

4.3.3 Prefabricated Tanks

Prefabricated tanks are built in a factory, generally from polypropylene, and transported to the site where they are installed. Though construction of the tank is not required, site preparation, foundation construction, and a tie-down system are required. In order to meet design capacities without exceeding them significantly and to feasibly transport the tanks to the site it is likely that several smaller tanks will be installed in parallel. Advantages include significantly less labor requirements and construction times. Additionally because multiple small tanks are used this option is considered modular and lends itself better to capacity increases in the future. Disadvantages include transportation of the tanks to the community and up to the construction site, increases piping and valving requirements due to the modular nature of the system, and uncertainties in the life of the tanks before they require replacement.

4.4 Bridging Alternatives

There are two streams that will need to be crossed in our design. Both of these streams are 20-30 feet wide. We have come up with three alternatives to crossing the stream, described below.

4.4.1 GI Pipe in River Bed

The first alternative for crossing the river is a GI pipe placed in the riverbed. The GI pipe refers to galvanized iron, which is a strong material that is able to withstand more load than PFC. In a riverbed, there are both static and dynamic forces that would act on the pipe in addition to the loads induced by debris and sediment traveling within the water. In this design, the GI pipe would be placed along the bottom of the riverbed in order reduce the probability of encountering miscellaneous debris loads.

4.4.2 Buried GI Pipe in River Bed

The second alternative is burying GI pipe beneath the riverbed. This option is essentially the same as the distributed pipeline throughout the community. The water from the river would have to be diverted during construction so that a trench to bury the pipe can be dug. The pipe is then buried and backfilled according to the regular pipeline construction practices. Once the installation is complete, diverted river water would be rerouted to its natural course.

4.4.3 Suspended Bridge

The third and final alternative is building a suspended bridge crossing. This alternative consists of building reinforced concrete columns beyond both banks of the river from which the pipe will be suspended. A cable also suspends the stream crossing and is connected to the pipe such that the load of the pipe is carried by the cable. The cable is connected to the columns and is held in tension by concrete anchors that are slightly beyond the columns. The cable thereby transmits the load of the pipe into the columns thereby supporting the pipe.

5.0 ANALYSIS OF ALTERNATIVES

5.1 Source Alternatives

5.1.1 Chlorination

General Feasibility
A critical aspect in the selection of chlorine as a disinfection method is the availability of supplies. Chlorine for disinfection purposes can be transported as a gas, liquid or solid. Each of these different phases of chlorine requires a different method of introduction to the drinking water. Because of the remoteness of Sieykin, gaseous chlorine is immediately a non-viable selection due to its requirements of being stored and transported under-pressure and the advanced technological requirements for the successful introduction of the gas into the liquid.

According to information gathered on previous trips to Sieykin, liquid chlorine (in the form of bleach) is available in Changuinola but solid forms of chlorine are currently only manufactured in different region of the country. The long term dependence on the success of a supply chain is a risk to the chlorine disinfection alternative. Proper volumes of chlorine need to be stored within the community to prepare for the potential disruption of the supply chain.

The volume of liquid bleach, at 4-6% available chlorine, required to disinfect 3005 gallons of water per day is approximately six gallons per day (EPA, 2006). However, it was determined during the initial EWB visit to the region that the chlorine content of bleach in the local area was not reliable. This could lead to the potential under- or over-dosing of the water supply. In addition, research on drip chlorinators, which would be needed for a liquid chlorine disinfection system, found that these devices are difficult to maintain and hard to find in Panama.

Cultural/Behavioral Feasibility
Introducing disinfection via chlorination to a community is not void of challenges. The community members may not enjoy the taste of chlorinated water. There is evidence collected during the in-home interviews conducted by the EWB group that residents expressed their dislike of drinking chlorinated water. If the community members chose not to drink chlorinated water due to the taste and smell the system will not be able to serve its purpose.

The lack of readily available materials and the potential that the community will completely reject the water due to the taste of chlorine results in chlorination not being a viable alternative.

5.1.2 Solar Disinfection

General Feasibility
One problem with using solar disinfection in Sieykin is that a majority of the days have overcast conditions for all or part of the day. This makes it difficult to achieve the temperatures and UV exposure needed to effectively treat the water. On cloudy days it generally takes two days for the water to be properly treated (McGuigan, Joyce, Conroy, Gillespie, & Elmore-Meegan, 1998). Solar disinfection is only feasible as a point-of-use treatment method, and the effort required to treat the water makes it unlikely to be used properly by the community. It is unlikely that the high water demands of the community could be met through solar disinfection. Solar disinfection is not a viable alternative for Sieykin Arriba.

5.1.3 Ceramic Filters

General Feasibility
Depending on the materials used to construct the filters, the rate of flow is approximately 0.13 to 0.9 gal/hr [0.5 to 3.5 L/hr] (Lantagne, 2002). In communities that are accustomed to using water sparingly this is more than enough filtration and disinfection. However, the community of Sieykin has always had ample access to water and individuals consume far more water than the point-of-use ceramic filters could provide. In addition, the community does not have local knowledge for producing ceramic, nor is it known whether the soil in the region is acceptable for ceramic creation.

Ceramic filters are not a viable alternative in the community due to their limited volume output and the fact that they cannot currently be manufactured locally.

5.1.4 Hand-dug Well

General Feasibility
A well in Sieykin Arriba would have to be dug and built by hand since there is no electricity and transporting heavy machinery would not be possible. Although hand digging or drilling might be feasible, bringing a sufficient quantity of water to the surface by hand pumping would be extremely laborious. A solar pump could be used for pumping, but the inconsistent amount of sunlight due to cloud and tree cover would not provide a reliable supply.

Materials, such as concrete, sand, gravel, and rebar, for building a well are available in-community and in Changuinola. Equipment for drilling could also be purchased in Changuinola. However, determining appropriate placement of and constructing wells is outside the technical expertise of the both the community members and members of the EWB - Greater Austin team.

Unreliable pumping methods and possible construction issues lead to a hand-dug well being not a viable alternative.

5.1.5 Slow Sand Filter

General Feasibility
Construction of a slow sand filtration system is possible in Sieykin. Materials such as cement, rebar, and pipes for the concrete filter tank are available in Changuinola/ Most of the other necessary materials, such as sand and coarse aggregate for the filter tank and wood for the forms to make the tank, are available in and around the village. Sand collected during the August 2009 trip to the community and analyzed University of Texas was determined to meet the criteria for slow sand filtration media.

Slow sand systems need a large amount of land due to the amount of surface area required for the filter. There is space available in the Sieykin village, though clearing and leveling of the site would be quite labor intensive and time consuming. There is also concern, that the amount of sand required for both the concrete mix and filter media would be extremely difficult to gather and sieve to the required sizes and transport from its source along the riverbanks to the filter site uphill.

Cultural/Behavioral Feasibility

Culturally and socially, the Sieykin community appears willing to accept responsibility for a system such as a slow sand filter. The community Water Committee would be accountable for ensuring that maintenance of the filter media is performed. However, very high-quality training and specific instructions would need to be provided to direct the maintenance efforts. In the case of the central system, there would not be any reduction in current water use required, so acceptance should not be an issue.

Cost & Time Analysis

Preliminary design estimates for a slow sand filter to provide an adequate supply of water as determined by our demand analysis show that a tank with a volume of nearly 2500 gallons [9,260L] would be required. These preliminary calculations are in Appendix 4.

Based on the nearly 28 days it took to build the 1300 gallon [5000 L] storage tank for Implementation I last summer, the 2500 gallon filter tank for a slow sand filter would require more time than we can permit. In addition, we are not confident in our ability to procure sand of an acceptable quality and uniformity necessary to get a functioning sand filter working. Maintenance of slow sand filters is also challenging, and requires completely new filter sand every few years. For these reasons, this alternative is rejected without a full cost analysis required.

5.1.6 BioSand Filters

General Feasibility

Just as for the slow sand filter, materials for the construction of BioSand filters are available in Changuinola and in the community. The materials and very detailed construction steps are explained fully in the CAWST BioSand filter manual and there do not appear to be any particular technical challenges.

According to CAWST, these filters have a relatively low daily output of approximately 6.3 – 19 g/d [24-72 L/d] (CAWST, 2009). To meet the water demands of the community, multiple filters would be needed per household. For those households without a current non-potable line to their homes, water would need to be continued to be transported by hand.

Cultural/Behavioral Feasibility

There is one major issue with the feasibility of BioSand filters in Sieykin. The houses in Sieykin are wooden and built on wooden stilts. It was noted on the second EWB assessment trip that the houses are not very sturdy and therefore might not be able to support the additional weight of a large concrete filter inside, so filters would have to be placed outside on the ground. Carrying the clean water from the filters outside instead of from indoor faucets would require a substantial change in behavior by the community. There is a big concern that this change would lead to disuse of the filters.

Because of the behavioral difficulties imposed by using BioSand filters and the requirement of multiple filters per house, personal BioSand filters are not a viable alternative.

5.1.7 Rainwater Harvesting

General Feasibility
All of the houses in Sieykin have thatch roofs, a material that can harbor bacteria growth that would negatively affect the quality of roof runoff. In order for rainwater harvesting to be a viable option in the community, all of the roofs would need to be replaced, and gutters would need to be installed in all of the households. Materials for replacing the roofs and constructing gutter systems to collect rainwater are available in Changuinola. The technical details and design of rainwater collection systems could reasonably be determined by the EWB team.

Our research has indicated that additional treatment of water collected via rainwater harvesting would be necessary to meet WHO or US EPA potable water standards (Lye, 2002). Thus, point-of-use filtration via BioSand filters or the addition of chlorine would be necessary for this alternative.

Due to the additional treatment necessary for harvested rainwater, both of which have also been ruled out in this analysis, rainwater harvesting is not a viable alternative.

5.1.8 Source Protection

General Feasibility
Construction materials for a spring box are readily available in Changuinola and in the community. Based on our demand analysis the springs we located on Assessment III will provide an adequate amount of water for the potable needs of the community. As we experienced on Implementation I, the construction of the spring box itself is not a difficult task, especially given the aid of a mason versed in its construction. However, the transportation of materials, namely sand, aggregate, and cement, to the spring box location is an arduous task. Building a pipeline from the spring box down to the storage tank will also be a challenge because of the thick jungle terrain.

Cultural/Behavioral Feasibility
The community would be satisfied with spring water, because the taste of the water would is not affected by addition of chemicals. The water will be distributed from a central storage tank to the community through spigots in their homes. Because the spring sources cannot provide an adequate supply for all water needs (39.6 gal/p/d) for all of the Arriba inhabitants, some slight changes in behavior will be required. Like their Centro counterparts, the Arriba community members will need to learn for which purposes they should use potable water, and for which they should use non-potable water.

Cost & Time Analysis
The majority of the cost (nearly $700) of constructing a spring box is for contracting a mason. See Appendix 4 for a summary of calculations.

Total Estimated Cost: $1631.50

Man-Hours for Construction: 1900

Sustainability
Maintenance of a spring box is relatively simple. The box should be checked on a monthly basis for buildup debris or animals that may have entered. If it is determined to require cleaning, a simple flush and hand-removal of debris will typically suffice. A chlorine wash may also be done periodically to sanitize the box.

5.2 Distribution Alternatives

The alternatives considered exhibit a wide range of system pressures, costs, construction man-hours, and timeframes. Note that all scenarios include the incorporation of the spring-tank option, which will vary to a small degree based upon the elevation of the tank in a particular option.

Figure 9 summarizes the end user pressures throughout the system for each scenario modeled. Tabular presentation of this data along with elevations, hydraulic grade line and demand at each user node is provided in Appendix 2. Maximum and minimum pressure ranges are based upon the State of Washington's published recommendations and correspond with a minimum of 40 psi and a maximum of 80 psi (Washington State Department of Health 2009) Options 1 and 2 exhibit significant variability outside of this range, while Option 2 cannot provide water to two users (representing two families) for the designed system and flowrate considered. Options 3 and 4 achieve a more appropriate and consistent profile of pressures at the users due to the incorporation of pressure reducing strategies, frictional diffusers and break-pressure tanks, respectively. These features result in a more robust design, but add complexity to the construction, operation and maintenance of the system.

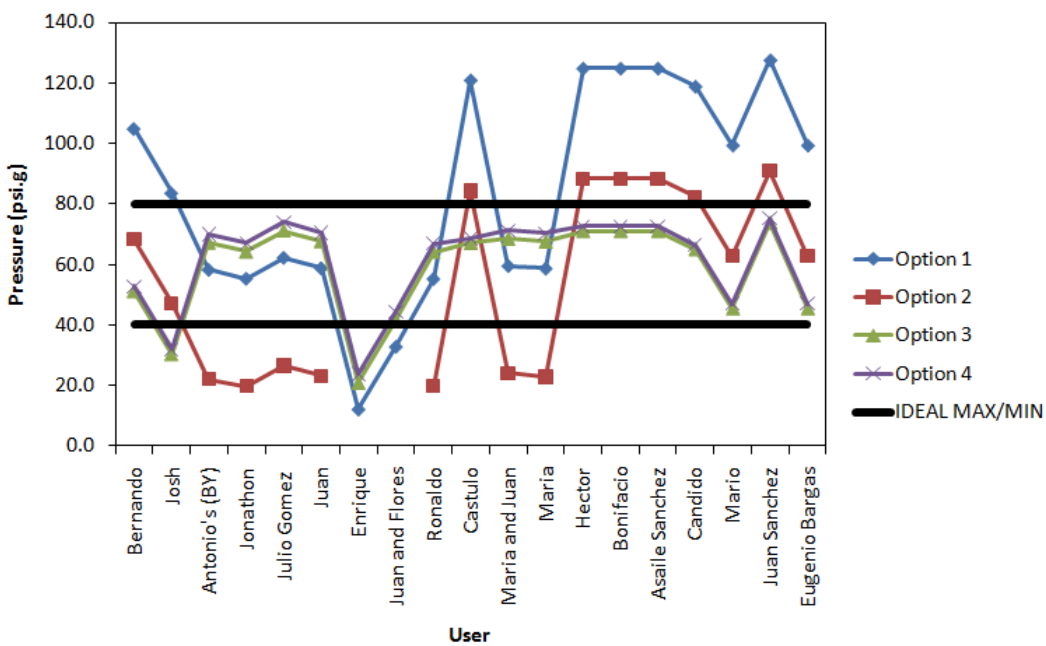

Figure 9: Summary of Pressures at User Nodes

Cost, man-hours, and timeframe for each option are summarized in Table 2. Estimates of cost are based on available pricing information from a local hardware store in Changuinola (a way point approximately three hours from the community). Estimates were made based on similar parts for those materials not priced in the available price list. Delivery costs are not included and are assumed similar for all analyses. Delivery will be accomplished utilizing community members' boats to transport equipment and material to the community. Fuel costs will be incorporated into a final budget, but are anticipated to be small compared to EWB travel costs and material costs. Manpower calculations are based from the average construction rate of pipeline on the Implementation I trip which occurred in the summer of 2010. The rate utilized in these calculations was 11 feet of constructed pipeline per worker-hour. It is anticipated that this estimate is conservative given the need for a wider trench during Implementation I to accommodate a dual potable/non-potable system. Furthermore, with the experience gained by both EWB and the community during Implementation I, it is anticipated that the pipeline portion of workflow will be reduced significantly from these estimates. The timeframe is an approximation based upon previous traveler's experience with the community and incorporates qualitative factors such as community organization, politics, work ethic and skill sets.

Table 2: Summary of costs, labor, and timeframe for distribution alternatives

	Spring-Tank	Option 1	Option 2	Option 3	Option 4
Cost	$ 413.50	$ 3,757.39	$ 3,134.91	$ 4,403.06	$ 5,071.25
Man-hours	176	1420	1152	1525	1731
Timeframe (days)	2	14	10	21	24

5.2.1 Option 1

General Feasibility

The advantages of option 1 result from the simplicity of design. The community members are familiar with the use of PVC pipe to convey water from areas of high elevation to lower elevation, and the use of storage to provide peak flow has been successfully implemented in the Centro community during Implementation I. Because of the design simplicity this option could likely be constructed in a short time frame which may allow sufficient time for testing and disinfecting the system, a planned goal for previous implementation trips but not achieved.

Cultural/Behavioral Feasibility

This disadvantages of this design arise from the wide range of pressures throughout the system. Modeled pressures range from 12 psi.g to 127 psi.g. A total of ten of the 19 user taps are outside the design range of 40-80 psi (Figure 9: Summary of Pressures at User Nodes). While the community understands the unique challenges associated with the design of gravity fed system under such topographical constraints, pressures above 80 psi may result in user dissatisfaction due to rapid flow rates, which may also contribute to system-wide shortages of stored water.

Cost & Time Analysis

Estimated Cost: $3,757
Estimated Labor: 1420 man-hours
Estimated Time: 14 days

Sustainability

Community members are well versed in the maintenance of PVC systems and have shown themselves to be capable of diagnosing and solving problems related to the pipe breakages, leaks, clogs, etc.

5.2.2 Option 2

General Feasibility

The feasibility of Option 2 mirrors that of Option 1 from a construction and maintenance standpoint, but exhibits a narrower range of pressures compared to Option 1 due to the exclusion of two houses at high elevation from the main system. Modeled pressures in this scenario range from 19 psi.g to 90 psi.g. While this narrow range is beneficial, more user taps are outside of the 40-80 psi design range than Option 1 due to the balancing of end user pressures between the houses at low elevation (on the southwest branch of the system) and those at high elevation (on the northwest branch of the system). Nevertheless, this narrow range will likely result in greater usability for those served by the line. Construction would be less expensive and more rapid due to the absence of 3000 linear feet of PVC pipeline to service the users at the highest local elevation (Enrique and Juan y Flores).

Cultural/Behavioral Feasibility

This disadvantage of this design in the exclusion of two community members. While the consequence of constructing a home at high elevation is understood by the community, the hydraulics in the area do allow options that can accommodate all users. Because EWB-Greater Austin is limited to, at most, one implementation trip per year, options that can accommodate all users and then move this sector to the observation/maintenance phase are preferred.

Cost & Time Analysis

Estimated Cost: $3,135
Estimated Labor: 1152 man-hours
Estimated Time: 11 days

Sustainability

Community members are well versed in the maintenance of PVC systems and have shown themselves to be capable of diagnosing and solving problems related to the pipe breakages, leaks, clogs, etc.

5.2.3 Option 3

General Feasibility

Option 3 introduces the use of a frictional diffuser to reduce pressure to the users at lower elevation by introducing a custom-made fitting with an extremely high K-value. This apparatus

(Figure 10) can be constructed from only PVC fittings, PVC pipe and a small diameter orifice through which water must flow (Jordan 1984).

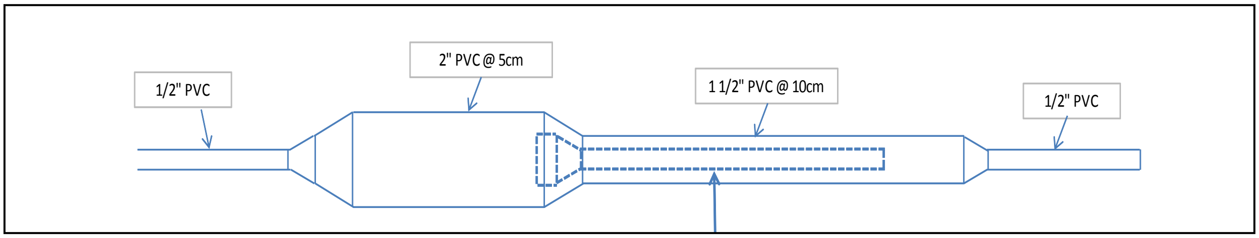

Figure 10: Frictional Diffuser

By grouping users at low elevation (<700 feet) and users at high elevation (>800 feet) greater independence between these sets of users can be achieved. Varying the number of frictional diffusers and the size of the orifice to adjusts system pressures for users at low elevations while varying the height of the storage tank adjusts system pressures for users at high elevations. This system design puts 17 out of 19 users within the 40-80 psi.g pressure range, with the outliers at relatively reasonable pressures (20 and 30 psi.g for Enrique and Josh, respectively).

Cultural/Behavioral Feasibility

This option introduces a new technology and apparatus to the community. During Assessment III however, this community repeatedly reiterated their desire to implement new technologies and to learn from EWB-Greater Austin. This sector of the community was intimately involved in the design of bridges, pipeline layout, and spring box construction during Implementation I and EWB-Greater Austin therefore does not foresee difficulties with community acceptance of this frictional diffuser design. Furthermore, in the case of failure of the frictional diffuser, Option 3 is essentially converted to Option 1 and the system would continue delivering water at higher pressure until a repair or alternative can be formulated.

Cost & Time Analysis

Estimated Cost: $4,403
Estimated Labor: 1525 man-hours
Estimated Time: 21 days

Sustainability

Community members are well versed in the maintenance of PVC systems and have shown themselves to be capable of diagnosing and solving problems related to the pipe breakages, leaks, clogs, etc. However, repair of the newly introduced frictional diffuser could pose issues since it is a new concept. We believe that the community members will avail themselves to learning about this technology and how to fix it. We will also provide a maintenance manual in Spanish and with several illustrations.

5.2.4 Option 4

General Feasibility
Option 4 is similar to option 3 in that it builds pressure independence between the users at high elevation and low elevation. In this option this is achieved by building two pipelines from the storage tank, one to provide water to houses at high elevation and one to provide water to houses at low elevation. The pipeline that serves the houses at low elevation incorporates a break-pressure tank to "reset" the static head in this line to atmospheric pressure at a desired elevation. This results in a similar profile of pressures to Option 3, but with greater pipelines requirements, an additional tank and slab, and associated labor.

Cultural/Behavioral Feasibility
While this option achieves a desirable pressure range, the break pressure tank must be designed in a manner that does not deplete the storage tank during off-peak usage. The storage is necessary to provide adequate flow to the community during the day and therefore the break-pressure tank must be sized to provide adequate storage to the lower elevation houses, or a float valve which seals the overflow when the storage tank is full. The operation of this break-pressure tank would therefore require significant education of the community as well as additional cost, maintenance and construction labor.

Cost & Time Analysis
Estimated Cost: $5,071
Estimated Labor: 1731 man-hours
Estimated Time: 24 days

Sustainability
Community members are well versed in the maintenance of PVC systems and have shown themselves to be capable of diagnosing and solving problems related to the pipe breakages, leaks, clogs, etc. The break-pressure tank might pose some problems due to its either its float-valve or due to erosion from near-constant overflowing.

5.3 Storage Alternatives

Hydrograph analysis of the estimated spring production and community withdrawals of water indicate that the minimum tank volume is 528 gallons (see 524 report).

5.3.1 Reinforced Concrete Tank

General Feasibility
The construction of a reinforced concrete tank is feasible in the area of implementation. The non-local materials like cement and rebar can be obtained from the adjacent town or from the United States with ease. The coarse and fine aggregate needed for the concrete can be obtained locally.

The community has experience with the mixing and placing of concrete though no technical or professionally trained personnel is attainable within the area. A mason might be needed to help create form and place concrete. Traveling members of EWB will possess enough information and knowledge to form, mix, place, and finish concrete.

Cultural/Behavioral Feasibility
The community members are open to a reinforced concrete tank since one was created for a different sector in the summer of 2010 by EWB. There are also many reinforced concrete tanks in the community, most probably constructed by the government.

Cost & Time Analysis
An estimated cost of a 528 gallon designed tank is outlined in Appendix 5.

However, the time required to complete excavation, forming, mixing, placing, and finishing of this tank will be around 28 days or more depending on environmental and political factors within the community and region. The length of time to complete a reinforced concrete tank of the required size rules out this alternative for storage.

5.3.2 Ferrocement Tank

General Feasibility
Constructing a ferrocement tank to store potable water is generally feasible because of the low cost, sustainability and readily acquired material resources available in the area. Typical materials required to build this type of tank include, wooden poles, galvanized wire mesh, clean sand, cement, and pipe, all of which can be easily acquired in Changuinola. Wooden poles and sand can be acquired in Sieykin directly however past trips have demonstrated that efforts to clean dirty sand have been unsuccessful due to the amount of extra time and labor required to sift and transport the sand to the project site.

One aspect of ferrocement tanks that make it an appealing alternative is the significantly low time and material costs needed to fully construct the tank. Although these provide great benefits to EWB, EWB Greater Austin lacks the technical expertise and guidance to feasibly design and construct a sustainable and reliable tank. It is anticipated that future projects will research this alternative further however presently, it has been determined by the team and the professional mentors that this type of technology cannot be realized at this time and it is not appropriate for this project.

5.3.3 Prefabricated Tanks

Inspection of a bill of material provided by Franklin's hardware store in Changuinola (see Appendix 1) indicates the availablity of 200 gallon tanks, three of which would provide 600 gallons of capacity. In further discussion of this alternative it will be assume that three 200 gallon tanks will be used in construction. Additionally this option will require the assessmennt of two sub-alternatives involving the foundation for the tanks. These include a poured concrete slab and directly placement of the tanks on a layer of gravel. These will be discussed internally within this section when needed to avoid the addition of more alternatives.

General Feasibility
The materials required for this option potentially include the PPE tanks, PVC pipe, PVC t-connections, 90^{o}-connections, PVC valves, Portland cement, aggregate, rebar, tie down cables, and lumber. All materials are all available in Changinoula at Franklin's General Store and most are used in other aspects of the project. Unique materials issues associated with this alternative

are the tanks themselves as our group has never transported anything of that scale (in terms of volume not mass) to the community. However large prefabricated tanks do exist in the community and inspection of typical shop drawings (see Figure 11) indicate that the tank available in the community will be able to fit on one of the canoes.

Technical expertise required for this alternative beyond the standard problems encountered on this project should not be great. A structural engineer will have to aid in the design of the foundation and tie-down system as will be needed with the other tank options.

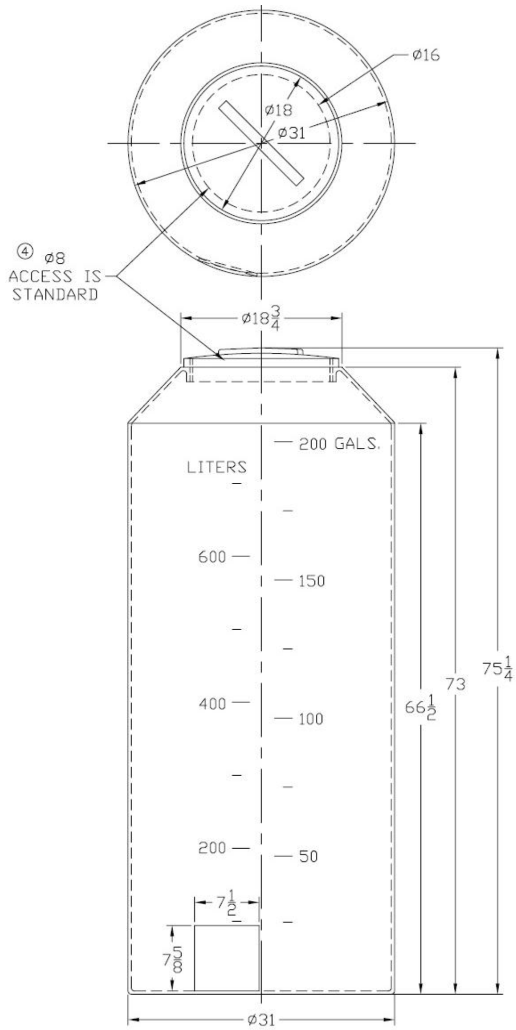

Figure 11: Example Prefabricated Tank (from ChemTain web site)

Cultural/Behavioral Feasibility

Cultural and social issues associated with the tank are not as great of issues as those involved in other aspects of the project. However there are some unique issues to address with the prefabricated tanks alternative. First of these is that damage to the tank may be more difficult for community members to repair without outside assistance as compared to the other options raising concerns about sustainability of this option; though if the water committee is able to save enough funds tank replacement may be a possibility without outside assistance. A potential advantage of this alternative is due to it's being a modular options. Future increases in population greater than those anticipated may be able to be compensated for by the addition of tanks.

Cost & Time Analysis
The total cost for materials associated with three 200 gallon tanks, the tie-down system, the piping and valves, and the materials transport to the site is $894. The two base options include steel reinforced slab and a gravel base. Additional costs of $106 will be incurred in capital and transport costs for the concrete slab option while no additional capital costs will be incurred for the gravel base option.

Time and Labor will factor heavily into selecting the preferred option for the tank. A rough estimation for the total time required to construct the prefabricated tank indicates that implementation of the prefabricated tank with the gravel base option will take less than 2 weeks including concrete curing times. The same rough estimate indicates that 4 or 5 days will require community involvement of site preparation, 3 or 4 days will involve light work, and the remaining days are for concrete curing. If the concrete base option is employed several more days requiring community involvement will be added to the schedule.

The preferred option for the base is the gravel option. This is primarily due to the difficulties associated with transporting water to the tank site, not cost and labor considerations. Preliminary calculations indicate that a foundation with a larger footprint is not necessary from a geotechnical standpoint. The stress due to a single full 200 gallon tank plus two 250 lb people divided by the base area of the tank pictured above is approximately 477 psf, which is significantly less than the conservative estimation of soil bearing capacity for the last implementation trip which was 1500 psf. Additionally the 6 to 8 inches of gravel should provide adequate drainage and erosion protection around the tanks. These assumptions will be checked by a certified geotechnical engineer in future design phases.

Sustainability
Sustainability concerns with the prefabricated tanks include the life expectancy of the tank and possibility of tank failure. Polypropylene tanks are not likely to form cracks in the first few years of service as is a concern with concrete tanks. This is due to the tanks not being partially embedded in the ground which is subject of swelling and contraction. Degradation and weakening over time is however a concern with polypropylene tanks which must be considered.

Manufacturers of polyproplyene tanks indicate that life expectancy is highly dependent on the chemical which is stored in the tank but that 15 to 20 years of service is common, especially for water. By following manufacturer recommendations to extend tank longevity we believe that our tanks will last this long. Unique advantages of prefabricated tanks which make them a more sustainable option includes their modularity which will allow for capacity expansion if community growth is greater than estimated.

5.4 Bridging Alternatives

5.4.1 GI Pipe in River Bed

General Feasibility
Laying GI pipe in the river bed presents many challenges for construction and maintenance. It would be difficult to lay pipe at the bottom of a river bed in a large stream that flows year round. Furthermore, the constant force of the flow on the pipe would place extra stresses on the pipe that would compromise the longevity of the piping. Therefore, this alternative will not be used.

5.4.2 Buried GI Pipe in River Bed

General Feasibility
Burying GI pipe in the river bed also presents many challenges for construction and maintenance. It would be very difficult to lay the pipe and dig a ditch through the river bed. It would involve diverting the flow of a large stream, which is impossible given our situation. Therefore, this alternative will not be used.

5.4.3 Suspended Bridge

General Feasibility
The suspended bridge stream crossing provides a reliable form of crossing the stream that is also feasible to construct and maintain. Therefore, we have decided to design a suspended bridge stream crossing, which is typical of most development work.

Both of these streams are 20-30 feet wide, but the distance between columns will need to be approximately 150 feet. This extra distance ensures that the columns are buried in firm ground that is located a safe distance away from the banks of the river to protect them from erosion in flooding events.

The stream crossings were designed using calculations from Jordan (1984) and Mihelcic et al. (2009). These designs are based on a typical suspension bridge that will support the loads of the pipeline. The designs factor in the weight of the pipe, the water in the pipe, the weight of the cable and the loads from wind and other external forces. A factor of safety is incorporated into the designs to ensure that the cable is sufficient to handle the loads. In order to support the loads, a 5/16" cable will be required. This cable will have a sag of 12 feet in the middle and will be in tension thereby transferring the loads of the pipeline to the columns.

6.0 DESCRIPTION OF PREFERRED ALTERNATIVE

Based on our analysis, the preferred alternatives for their respective subsystems are:

- *Source*: **Source Protection** – Spring Box
- *Distribution*: **Option 3** – Full Service with Frictional Diffuser
- *Storage*: **Prefabricated Tanks**
- *Bridging*: **Suspended Bridge**

The reasons for each of these decisions are described below. Each of the following sections also includes a summary table showing how each alternative performed according to our "filter" methodology.

6.1.1 Preferred Source Alternative

The successful construction of a spring box for the Centro sector of Sieykin during Implementation I leads us to believe that this is best source alternative. Our education team performed well when teaching the Centro inhabitants when to use potable and when to use non-potable water, so we are confident we can do the same for the Arriba sector. Furthermore, the community has prior experience with springs and has widely accepted and supported this type of project. All other alternatives would require a change in cultural and social behavior which is simply not feasible with the resources available to the project.

Table 3: Source Alternatives Analysis Summary

Source	General Feasibility	Cultural/Behavioral Feasibility	Cost & Time	Sustainability
Chlorination	Pass	Fail	-	-
Solar Disinfection	Fail	-	-	-
Ceramic Filters	Fail	-	-	-
Hand-Dug Well	Fail	-	-	-
Slow Sand Filter	Pass	Pass	Fail	-
BioSand Filters	Pass	Fail	-	-
Rainwater Harvesting	Fail	-	-	-
Source Protection	Pass	Pass	Pass	Pass

6.1.2 Preferred Distribution Alternative

Deciding upon the preferred distribution alternative was the most difficult. All four options presented meet pass all four tiers of our analysis "filters." As stated previously, because EWB – Greater Austin can only reasonably do a single implementation trip per year, Options 1 and 2, which do not serve the entire Arriba sector in a single system, are ruled out. Between Options 3 and 4, which provide potable water all Arriba sector inhabitants, Option 3 has a lower cost and is (in our opinion) more sustainable than Option 4. Thus, Option 3 with the frictional diffuser is the preferred distribution alternative.

Table 4: Distribution Alternatives Analysis Summary

Distribution	General Feasibility	Cultural/Behavioral Feasibility	Cost & Time	Sustainability
Option 1	Pass	Pass	Pass	Pass
Option 2	Pass	Pass	Pass	Pass
Option 3	Pass	Pass	Pass	Pass
Option 4	Pass	Pass	Pass	Pass

6.1.3 Preferred Storage Alternative

The preferred storage subsystem alternative is the prefabricated tank option with the gravel base. This is chosen over the other options because of the prohibitively long construction time required for construction of a poured concrete tank and the lack of experience in our group with ferrocement tanks. Additionally due to the large amount of concrete required for both the poured concrete and ferrocement options there should be a very significant savings in the time and labor associated with transporting the required aggregate, Portland cement, and water to the site. This is positive in terms of community relations as the amount of labor involved in transporting concrete materials to the tank site was a point of contention on the previous implementation. Materials for the prefabricated tank option will cost slightly more than the other options but we believe this is more than justified when considering the labor and time savings. Furthermore the prefabricated tanks are modular and capacity can be extended in the future if necessary.

Table 5: Storage Alternatives Analysis Summary

Storage	General Feasibility	Cultural/Behavioral Feasibility	Cost & Time	Sustainability
Concrete Tank	Pass	Pass	Fail	-
Ferrocement Tank	Fail	-	-	-
Prefabricated Tanks	Pass	Pass	Pass	Pass

6.1.4 Preferred Bridging Alternative

The preferred bridging alternative for this project is the construction of a cable suspension bridge over both the rivers that meander through Sieykin Arriba. This alternative provides the community with the most reliable design for transporting potable water over the rivers due to the technical expertise and reliable design criteria available to EWB. Both of the GI pipe alternatives are simply not sustainable for the community. Laying unsecured pipe in the river bed exposes the pipe to forces that are difficult to anticipate and design for because of the variability in the river stage over the year. Furthermore, redirecting the river for construction is too large scale for EWB to handle with the limited equipment available in and near the community.

Table 6: Bridging Alternatives Analysis Summary

Bridging	General Feasibility	Cultural/Behavioral Feasibility	Cost & Time	Sustainability
GI Pipe in River Bed	Fail	-	-	-
Buried GI Pipe	Fail	-	-	-
Suspended Bridge	Pass	Pass	Pass	Pass

7.0 MENTOR ASSESSMENT

The project leads and subgroup leads prepared the various sections of this alternatives analysis document. Information was gathered from previous assessment and implementation reports, first-hand experience from traveling to Sieykin, as well as from discussions during the weekly Panama Project meetings. These weekly meetings have been a forum to discuss the various possible designs for the next implementation trip.

Subgroups were formed for piping, storage tank, source, and bridging with all members of the Panama technical team contributing to the analysis.

7.1 Professional Mentor/Technical Lead Name: Tim Ager

7.2 Professional Mentor/Technical Lead Affirmation

I have been directly involved in the development of this alternatives analysis and will continue my involvement up to and throughout the implementation trip.

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9.0 APPENDICES

9.1 Appendix 1 – Price List

MATERIALES FRANKLIN, S. A.
CHANGUINOLA BOCAS DEL TORO
TEL FAX 758-7151
RUC 1033898-1-543359 DV 96

Nro. 1203
Fecha 04/03/2010
Página 1

COTIZACION

Propuesto a:
CONTADO
INGENIEROS SIN FRONTERA
Código: 0000

Enviado a:
Tlf.:

Enviar: Entrega Términos: Efectivo Vendedor: Referencia:

Código producto	Descripción del producto	Cantidad	Precio Unit. B/.___	Subtotal B/.___
T0018	TANQUE 100 GLS. CONTENEDOR DE LIQUIDOS	1,00	125,00	125,00
T0019	TANQUE 200 GLS CONTENEDOR DE LIQUIDOS	1,00	171,45	171,45
T0038	TANQUE 250 LTS MINITANK	1,00	72,43	72,43
P0018	PEGAMENTO 1/2 PVC PINTA-	1,00	3,50	3,50
P0083	PEGAMENTO 1/32 GL -1/4 PINTA	1,00	2,36	2,36
LL0048	LLAVE DE PASO C/R 1/2 PFISTER VALVULA	1,00	8,22	8,22
LL0053	LLAVE DE PASO 11/4 C/R "NIBCO" VALVULA	1,00	8,98	8,98
LL0062	LLAVE DE BOLA 11/2"S/R PVC GLOBE VALV	1,00	3,98	3,98
LL0068	LLAVE PASO 1/2 PVC LISA VALVULA	1,00	1,58	1,58
LL0046	LLAVE PASO PVC 1/2 C/ROSCA VALVULA	1,00	1,36	1,36
LL0051	LLAVE PASO 2"C/R VALVULA	1,00	26,48	26,48
LL0070	LLAVE BOLA 3/4 C/PALANK ITAL GLOBE VALV	1,00	5,36	5,36
T0122	TUB PVC 1/2 SDR 13.5 PIPA	1,00	2,02	2,02
T0293	TUB PVC 1/2 CAL 40 PIPA	1,00	4,05	4,05
T0126	TUB PVC 3/4 SDR 21 PIPA	1,00	2,20	2,20
T0128	TUB PVC 3/4 CAL 40 PIPA	1,00	4,55	4,55
T0120	TUB PVC 1 SDR 26 PIPA	1,00	3,70	3,70
T0139	TUB PVC 11/2 SDR 32.5 PIPA	1,00	6,25	6,25
T0140	TUB PVC 11/4 SDR 26 PIPA	1,00	4,58	4,58
T0124	TUB PVC 2 SDR 41 PIPA	1,00	5,21	5,21
T0158	TUB PVC 2´ CAL 40 PIPA	1,00	15,03	15,03
T0138	TUB PVC 3 X 20 CAL 40 PIPA	1,00	28,18	28,18
T0092	TUB PVC 3 X 20 DREN PIPA	1,00	11,38	11,38
T0117	TUB PVC 4 SDR 26 PIPA	1,00	32,79	32,79
T0127	TUB PVC 4 X 20 DRENAJE PIPA	1,00	11,95	11,95
T0173	TUB PVC 4´´ CAL 40 PIPA	1,00	47,40	47,40
T0080	TUB PVC 6 CAL 40 PIPA	1,00	68,95	68,95
T0146	TUB PVC 6 X 20 DRENAJE PIPA	1,00	32,54	32,54
T0043	TEFLON 3/4 X 15 M	1,00	0,50	0,50
PB82WSA1	PINT COL ACEIT BLANCO GL GALON	1,00	18,29	18,29
PB79HSA7	PINT COL LATEX MARFIL CREMA GALON	1,00	13,47	13,47
C0033	CEMENTO HOLCIM 110 lbs	1,00	9,00	9,00

MATERIALES FRANKLIN, S. A.

CHANGUINOLA BOCAS DEL TORO
TEL FAX 758-7151
RUC 1033898-1-543359 DV 96

Nro. 1203
Fecha 04/03/2010
Página 2

COTIZACION

Propuesto a:
CONTADO
INGENIEROS SIN FRONTERA

Código: 0000

Enviado a:
Tlf.:

Enviar: Entrega   Términos: Efectivo   Vendedor: Referencia:

Código producto	Descripción del producto	Cantidad	Precio Unit. B/.___	Subtotal B/.___
C0041	CEMENTO PANAMA U.G 90 LBS	1,00	9,00	9,00
		33,00	Subtotal	761,74
			Impuesto:	38,09
			TOTAL B/.___	**799,83**

ESTA COTIZACION ES VALIDA POR 15 DIAS

TENEMOS LAS REDUCCIONES PRRA TODAS LAS MEDIDAS DE PIPAS, ADEMAS
TODOS MIDEN 20 pies

9.2 Appendix 2 – Survey Points and Notes

Station	Distance (yds)	Vert. Angle (deg)	Bearing (deg)	Total Distance	Del. Elevation	Elevation (ft)	Notes	GPS
Ojo Norte						1000		
A	35	-12.5	203	35	-22.7	977.3	At intersection of creek where 2 springs meet just in front of fallen log that crosses spring (towards spring) few ft up to spring	9° 24' 12.9"N 82° 40' 6.7"W
B	18	-7	220	53	-6.6	970.7	slow slope from A-B clay mixed with rock thick jungle, on creek bank, potenially intermediate point perharps	
C	14	-14.5	197	67	-10.5	960.2	May need bridge at C-D or come down on east side of the creek. Less rock in soil	
D	19	-7	180	86	-6.9	953.2	a long steep bank, two lardge tree trunks to pass through	
E	18.5	0.5	155	104.5	0.5	953.7	sloping cliff (45 degree grade to creek) wet mud, soil	
F	18.5	-1.5	150	123	-1.5	952.3	several trees in the way mud, steep slope	
G	21	-2.5	160	144	-2.7	949.5	walking tree, fallen tree	
H	9	0	180	153	0.0	949.5	under a tree for a sight at next sta, no BS	
I	22	-3	144	175	-3.5	946.1	steep slope, mud, jungle	
J	19	-3	157	194	-3.0	943.1	steep slope, mud, jungle	
K	15	-8	182	209	-6.3	936.8	crosses the creek and begins to climb in elevation	
L	35	7	220	244	12.8	949.6	in middle of creek	
M	18	1	220	262	0.9	950.6	heading side of loma towards the toma, thick jungle	
O	25	6.5	210	287	8.5	959.0		
P	14	11	225	301	8.0	967.1	approaching high point may need ARV lower ridge to the right	
Q	9	-20	225	310	-9.2	957.8	high point at faller tree possible tank location, according to the community could serve as ARV	
R	29	-16	242	339	-24.0	933.8	steep slope, possible	
S	17.5	-2	240	356.5	-1.8	932.0		
T	15	8	230	371.5	6.3	938.3		
U	12	-2	225	383.5	-1.3	937.0		
V	19	-9	262	402.5	-8.9	928.1		
W	13	-10	292	415.5	-6.8	921.3	sighting to intermediate down point	
X	14	-19	260	429.5	-13.7	907.7		
Y	18	1.5	220	447.5	1.4	909.1	bank remains very mudy	
Z	17	4	224	464.5	3.6	912.6	meet with path	

Station	Distance (yds)	Vert. Angle (deg)	Bearing (deg)	Total Distance	Del. Elevation	Elevation (ft)	Notes	GPS
AA	22	-7.5	205	486.5	-8.6	904.0	along with path	
AB	40	-7.5	210	526.5	-15.7	888.3	along path	
AC	42	-3	220	568.5	-6.6	881.8		
AD	30	-15	200	598.5	-23.3	858.5	along path	
AE	26	-11	196	624.5	-14.9	843.6	along path down steep hill	
AF	43	-20.5	173	667.5	-45.2	798.4		
AG	21	-21	175	688.5	-22.6	775.8		
AH	18	-22.5	180	706.5	-20.7	755.2	off path following line of existing water line	
AI	20	-19	170	726.5	-19.5	735.6	along existing waterline	
AJ	16	-18	180	742.5	-14.8	720.8	along existing waterline	
AK	29	-15	172	771.5	-22.5	698.3	along existing waterline	
AL	30	-20.5	184	801.5	-31.5	666.8	along existing waterline	
AM	16	-17.5	195	817.5	-14.4	652.3		
AN	18	-19	175	835.5	-17.6	634.7		
AO	17	-17	202	852.5	-14.9	619.8	pipe begins to be strung in trees as the bridge begins	
AP	7	-21.5	218	859.5	-7.7	612.1	leading to edge	
AQ	11	-7.5	185	870.5	-4.3	607.8	last station before edge of bankk	
AR	**19**	**5**	**185**	**889.5**	**5.0**	**612.8**	no backsity or bearing, from center of.....(cant read word) Under lazy tree, directly under existing pipe. Last station of the day	X = 316556.354, Y = 1039675.17
BA	12	46	190	12	25.9	638.7	up very steep bank to island in midle of the river	
BB	19	6	267	24	6.0	644.6	follow tree to the river where mr B and josh. To the west of arriba island	
BC	29	0.5	260	43	0.8	645.4		
BD	20	-13	275	72	-13.5	631.9	To Mr. B's house	
BE	35	9	274	92	16.4	648.3	at Mr. B's topstand 10 feet above grade, outlet	
BF	50	5	305	127	13.1	661.4	uphill following existing pathline	
BG	45	7.5	320	177	17.6	679.0	along pipeline	
BH	32	3.5	287	222	5.9	684.9	along pipeline	
BI	26	4	310	254	5.4	690.3	alonge pipeline	
BJ	51	1.5	295	280	4.0	694.3	at base of Josh's house up 12 feet to sink from grade	

Station	Distance (yds)	Vert. Angle (deg)	Bearing (deg)	Total Distance	Del. Elevation	Elevation (ft)	Notes	GPS
BK	29	-2	295	331	-3.0	691.3	tee from main line for 2 houses (40 feet of brank) Tomas and Rapha	
BL	20	-1.5	300	360	-1.6	689.7	shift to right to feet	
BM	25	-10.5	285	380	-13.7	676.1	along pipeline	
BN	16	1	300	405	0.8	676.9	to west of small hill	
BO	14	-7.5	280	421	-5.5	671.4	down a hill	
BP	24	10.5	265	435	13.1	684.5	up the hill	
BQ	35	9	285	459	16.4	701.0	up the hill	
BR	35	2.5	300	494	4.6	705.5		
BS	22	6.5	280	529	7.5	713.0		
BT	36	4.5	290	551	8.5	721.5	up a hill	
BU	35	-2	28	587	-3.7	717.8		
BV	16	-14	280	622	-11.6	706.2	down the hill	
BW	21	11.5	285	638	12.6	718.8	up hill to Antonio's casa	
BX	19	25	300	659	24.1	742.9	up hill to Antonio's casa	
BY	**15**	**12.5**	**277**	**678**	**9.7**	**752.6**	up hill to Antonio's casa at Antonio's	X = 316043.336, Y = 1039675.17
CA	4	-26	178	4	-5.3	607.5	distance start from tee in island. Head starts from tee in island	
CB	14	-41	154	18	-27.6	580.0	down south bank of island from tee	
CC	48	0	162	66	0.0	580.0	across river to edge of other bank	
CD	8	47	180	74	17.6	597.5	up steep bank of south side of the river	
CE	32	-6.5	157	106	-10.9	586.7	across a pasture of gate	
CF	30	10	210	136	15.6	602.3	across a field apperas to be 1" line	
CG	24	0	207	160	0.0	602.3	out of the field	
CH	19	-5	212	179	-5.0	597.3	potential house at this station	
CO	21	-2	215	200	-2.2	595.1		
CP	12	-6	217	212	-3.8	591.4		
CQ	12	6.5	215	224	4.1	595.4	across small creek	x= 316530.154 y= 1039052.029
CR-1	19	-0.5	282		-0.5		branch to Hector's and Bnifacio .5" line at Hector	
CR-2	23	1	310		1.2		lost of rocks through this area large	
CR-3	24	4	285		5.0		less rocky, but pr	
CR-4	20	-0.5	282		-0.5		at the house of Bonifacio (5 feet away) 10 feet up	

Station	Distance (yds)	Vert. Angle (deg)	Bearing (deg)	Total Distance	Del. Elevation	Elevation (ft)	Notes	GPS
CR-4-1	17	1	280		0.9		at house of juan Sancez 10 feet up first branch of CR4-1	
CR-4-2	19	2.5	210		2.5			
CR-4-2-1	9	0	170		0.0		asaille, at the house sanchez. asaile sanchez	
CS	17	5	197	241	4.4	599.9	up hill from hectos, from CR	
CT	29	1	230	270	1.5	601.4	following pipe	
CU	20	2	223	290	2.1	603.5	following pipe	
CV	12	3.5	222	302	2.2	605.7	following pipe	
CW	21	10.5	225	323	11.5	617.2	following pipe	
CX	11	-5.5	235	334	-3.2	614.0	at high point	
CY	21	-1	225	355	-1.1	612.9	tee for Candido	X = 316450.197, Y = 1038965.732
CY-1	15	4	317		3.1		to corner of Candido... (cant read the last word)	
CZ	23	4	230	378	4.8	617.7	down to .5"	
CAA	20	8.5	215	398	8.9	626.6		
CAB	31	11	240	429	17.7	644.3		
CAC	**33**	**9.5**	**225**	**462**	**16.3**	**660.7**	at the corner of house of Mario	X = 316377.789, Y = 1038901.694
DA	16	-4	311	16	-3.3	749.3	starting from BY (Antonio's house)	
DB	15	-6.5	279	31	-5.1	744.2		
DC	14	-14	289	45	-10.2	734.0		
DD	15	-20	291	60	-15.4	718.6		
DE	24	4.5	265	84	5.6	724.3		
DF	11	14	260	95	8.0	732.2		
DG	24	5	273	119	6.3	738.5		
DH	19	9.5	248	138	9.4	747.9		
DI	24	-8.5	260	162	-10.6	737.3		
DJ	19	-9	250	181	-8.9	728.4		
DK	29	-11	273	210	-16.6	711.8	up to top of hill	
DL	25	19	270	235	24.4	736.2		
DM	19	-1	273	254	-1.0	735.2		
DN	24	12.5	280	278	15.6	750.8	tee for Maria	
DO	32	16.5	297	310	27.3	778.0		
DP	43	4.5	273	353	10.1	788.2		

Station	Distance (yds)	Vert. Angle (deg)	Bearing (deg)	Total Distance	Del. Elevation	Elevation (ft)	Notes	GPS
DQ	19	3.5	290	372	3.5	791.6		
DR	24	3	312	396	3.8	795.4		
DS	29	-5	305	425	-7.6	787.8		
DT	24	-0.5	320	449	-0.6	787.2		
DU	11	0	335	460	0.0	787.2		
DV	17	-4	315	477	-3.6	783.6		
DW	24	4	324	501	5.0	788.7		
DX	25	10	317	526	13.0	801.7		
DY	17	6.5	292	543	5.8	807.5		
DZ	21	0	286	564	0.0	807.5		x = 315587.457, y = 1039584.372
DAA-1	32	-9	347		-15.0		Tee to Johnathon and Juan Gomez	
DAA-2	48	-14	35		-34.8			
DAA-3	35	-8.5	345		-15.5		Tap for Johnathon	
DAA-4	40	-11	280		-22.9		Tap stand para Julio Gomez	
DAA-5	13	-12	300		-8.1		Tee for branch (?)	
DAA-6	7	-8.5	320		-3.1		possible bridge crossing	
DAA-7	11	27.5	320		15.2		up to hill steep slope	
DAA-8	19	5.5	302		5.5		through jungle lots of debris	
DAA-9	12	-1.5	300		-0.9		through jungle lots of debris	
DAA-10	21	-10	332		-10.9		through jungle lots of debris	
DAA-11	40	16	335		33.1		possible bridge crossing	
DAA-12	24	11.5	330		14.4		high hill, tap for Juan	9°24'7.9" N 82°40'50.4" W
DAB	30	3.5	245	594	5.5	812.9	main line continues from DAA	
DAC	32	-1	233	626	-1.7	811.3		
DAD	29	17	267	655	25.4	836.7		
DAE	20	18	256	675	18.5	855.3		
DAF	27	9	222	702	12.7	867.9	Tap for Mr. E	
DAG	70	-2	197	772	-7.3	860.6		
DAH	19	-9	190	791	-8.9	851.7		
DAI	26	-16	200	817	-21.5	830.2		
DAJ-1	9	2	312		0.9		Tee to Ojo	
DAJ-2	14	-16	310		-11.6			

Station	Distance (yds)	Vert. Angle (deg)	Bearing (deg)	Total Distance	Del. Elevation	Elevation (ft)	Notes	GPS
DAJ-3	37	-5	278		-9.7		Ojo- potentially for Juan and Flores	
DAJ	30	-9	210	847	-14.1	816.1	(two more springs in this and also Reynaldo)	X = 315434.882, Y = 1039406.53
DAK	30	-10.5	176	877	-16.4	799.7		
DAL	40	4	172.5	917	8.4	808.1		
DAM	24	-3.6	199	941	-4.5	803.5		
DAN	37	6.5	199	978	12.6	816.1		
DAO	30	-10.5	203	1008	-16.4	799.7		
DAP	45	-8.5	170	1053	-20.0	779.8		
DAQ	14	-10	140	1067	-7.3	772.5		
DAR	23	-11	148	1090	-13.2	759.3		
DAS	15	-1	126	1105	-0.8	758.5	Tap at Ronaldo	
DAT	8	-7	102	1113	-2.9	755.6	Corner of Ronaldo	
DAU	24	-16	136	1137	-19.8	735.7		
DAV	26	1	124	1163	1.4	737.1		
DAW	18	8	134	1181	7.5	744.6		
DAX	14	-18	106	1195	-13.0	731.6		
DAY	7	16.5	99	1202	6.0	737.6		
DAZ	13	19	74	1215	12.7	750.3		
DBA	23	12	96	1238	14.3	764.6		
DBB	13	9.5	105	1251	6.4	771.1		
DBC	18	6.5	131	1269	6.1	777.2		
DBD	18	1	150	1287	0.9	778.1		
DBE	9	4	125	1296	1.9	780.0		
DBF	23	-5	103	1319	-6.0	774.0		
DBG	22	-3	111	1341	-3.5	770.6		
DBH	35	-4.5	78	1376	-8.2	762.3		
DBI	20	-8	96	1396	-8.4	754.0		
DBJ	24	2	55	1420	-2.5	751.5		
DBK	24	0.5	62	1444	0.6	752.1		
DBL	14	-5.5	53	1458	-4.0	748.1		
DBM	15	2	40	1473	1.6	749.6		
DBN	14	-1	45	1487	-0.7	748.9	Tap for Maria y Juan G.	

Station	Distance (yds)	Vert. Angle (deg)	Bearing (deg)	Total Distance	Del. Elevation	Elevation (ft)	Notes	GPS
DBO	35	-3	57	1522	-5.5	743.4		
DBP	24	-10	11	1546	-12.5	730.9		
DBQ	30	-20	14	1576	-30.8	700.1		
DBR	38	-10	4	1614	-19.8	680.3		
DBS	9	-8	5	1623	-3.8	676.6		
DBT	14	7	14	1637	5.1	681.7		
DBU	18	-11.5	22	1655	-10.8	670.9		
DBV	10	-17.5	15	1665	-9.0	661.9	to bottom of creek bed, need bridge	
DBW	13	18.5	18	1678	12.4	674.3		
DBX	35	8	355	1713	14.6	688.9		
DBY	20	1.5	5	1733	1.6	690.5		
DBZ	10	9	347	1743	4.7	695.2		
DCA	11	-14	25	1754	-8.0	687.2	To valley	
DCB	12	25	9	1766	15.2	702.4		
DCC	10	3.4	15	1776	1.8	704.2		
DCD	**49**	**15**	**0**	**1825**	**38.0**	**742.2**	at the codo for Maria should match DN	
EA	38	-6	100	38	-11.9	609.6	Castulo's house (should meet up with CAC)	9°23'47.8" N 82°40'31.5"W
EB	25	-2	105	63	-2.6	597.7		
EC	17	-10	141	80	-8.9	595.1		
ED	19	-11	115	99	-10.9	586.2	creek crossing	
EE	16	18.5	134	115	15.2	575.4		
EF	29	6.5	175	144	9.8	590.6		
EG	32	15	155	176	24.8	600.4	have S curved from C's	
EH	31	-11	180	207	-17.7	625.3	house, can cut straight through	
EI	40	0.5	185	247	1.0	607.5	to pt EI	
EJ	19	11	155	266	10.9	608.6	very marshy from EI-EJ	
EK	17	-6	173	283	-5.3	619.5		
EL	8	-23	166	291	-9.4	614.1	bottom of creek bed	
EM	19	7.5	124	310	7.4	604.7		
EN	12	-9	57	322	-5.6	612.2		
EO	19	1.5	91	341	1.5	606.6	creek bed EO and EP	

Station	Distance (yds)	Vert. Angle (deg)	Bearing (deg)	Total Distance	Del. Elevation	Elevation (ft)	Notes	GPS
EP	17	1.5	63	358	1.3	608.1		
EQ	8	4	178	366	1.7	609.4	at the jardin de botanica	
ER	16	7	105	382	5.8	611.1		
ES	16	-6	125	398	-5.0	616.9		
ET	19	2	112	417	2.0	611.9		
EU	21	1	110	438	1.1	613.9		
EV	10	-7	102	448	-3.7	615.0		
EW	8	1	90	456	0.4	611.3		
EX	29	3	111	485	4.6	611.7	cacoa	
EY	20	0	106	505	0.0	616.3		
EZ	7	-17	110	512	-6.1	616.3	ditch bottom	
EAA	13	9.5	110	525	6.4	610.2		
EAB	3	-15	104	528	-2.3	616.6	creek crossing	
EAC	13	6.5	120	541	4.4	614.3		
EAD	15	-2	104	556	-1.6	618.7	creeky bog	
EAE	4	2	142	560	0.4	617.1		
EAF	11	14.5	95	571	8.3	617.5		
EAG	34	20	90	605	34.9	625.8	casa de Mario Sanchez	
EAH	**13**	**2.5**	**30**	**618**	**1.7**	**660.7**	*matches CAC (should)	

Legend		
STA	A-AR	(Ojo Norte- Island of Arriba)
STA	BA-BY	(Island Arriba @ "Y" to Antonio's)
STA	CA - CAC	(Island Arriba @ "Y" to South Cluster (Hector,etc.))
STA	DA - DCD	(Island Arriba-Antonio's to Enriques. Only front sights in this stretch
STA	EA - EAH	(Island Arriba-Antonio's to Enriques. Castulo to Mario Sanchez

Notes:
Survey data acquired from Januray 8-10th, 2011 in Sieykin Arriba

Backsights have been deleted from station ranges A-AR, BA-BY, and CA-CAC to enhance readability. Backsights were taken for each station to verify data acquired. Maximum error was 1 yard, 0.5 degrees, 5 degrees for distance, vertical angle, and horizontal angle respectively.

Gray sections refer to branches surveyed

9.3 Appendix 3 – Distribution Alternative Calculations

Material	Description	Unit	Units Needed (Designed)	Safety Factor	Total Needed	Length	Unit Price	Total Price	Comments
POTABLE MATERIALS LIST - Tank to Users - One line - Frictional Diffuser									
1" PVC (ANSI) Sch. 40	Potable water main	20 ft Sections	706	1.2	847	16946	4	$3,389.28	
1" PVC Butterfly Valve	Shut-off/Throttling Valve	-	1	1	1		6.48	$6.48	
1" PVCBall Valve	Build Air Release Valves	-	4	1.25	5		10	$50.00	Check valves before purchase
1" PVCBall Valve	Build Cleanout Valves	-	6	1.25	8		10	$75.00	Check valves before purchase
1" PVCBall Valve	Sectional Shut-off	-	4	1.25	5		10	$50.00	Check valves before purchase
1" PVC Tee	Tee for splitting 1" pipe	-	16	1.1	18		0.58	$10.21	
1" PVC 90-deg Elbow	1" 90-deg direction change	-	24	1.1	26		0.42	$10.87	10 per 3000 feet
1" PVC 45-deg bend	1" 45-deg direction change	-	24	1.1	26		0.45	$11.65	10 per 3000 feet
1"-0.5" PVC Reducer	Reduce pipe from 1" to 0.5"	-	16	1.2	19		0.15	$2.88	
0.5" PVC (ANSI) Sch. 40	Non-potable water service pipe	20 ft Sections	23	1.5	35	702	4.05	$142.16	
0.5" Ball Valve	System isolation @ each branch	-	15	1.1	17		5.99	$98.84	
0.5" PVC Tee	Tee for splitting 0.5" pipe	-	1	3	3		0.2	$0.60	
0.5" PVC 90-deg Elbow	0.5" 90-deg direction change	-	5	1.5	8		0.15	$1.13	Lesser of 5 or 5 per 3000 feet
0.5" PVC 45-deg bend	0.5" 45-deg direction change	-	5	1.5	8		0.2	$1.50	Lesser of 5 or 5 per 3000 feet
0.5" Faucet	End user valve	-	19	1.1	21		5.99	$125.19	
0.5" Non-thread to thread adapter	Connect faucet to pipe	-	19	1.1	21		0.5	$10.45	
Joint Compound	Pipe Glue	-	2	1	2		5.8	$11.60	
1"-2" Expansion	Frictional Diffuser	-	2	1	2		1	$2.00	
2" PVC (ANSI) Sch. 40	Frictional Diffuser	20 ft Sections	1	1	1	20	15.03	$15.03	
1.5" PVC (ANSI) Sch. 40	Frictional Diffuser	20 ft Sections	1	1	1	20	6.25	$6.25	
1" PVC Endcap	Frictional Diffuser	-	2	1	2		0.75	$1.50	
0.5" PVC (ANSI) Sch. 40	Frictional Diffuser	20 ft Sections	1	1	1	20	4.05	$4.05	
1"-1/2" Reducer	Frictional Diffuser	-	2	1	2		0.15	$0.30	
1.5"-1" Reducer	Frictional Diffuser	-	2	1	2		0.55	$1.10	
Transportation	Boat Trip	-	10	1.5	15		25	$375.00	
							COST SUBTOTAL	$4,403.06	
							MANPOWER SUBTOTAL	1525	hours
							ANTICIPATED TIMEFRAME	21	days

9.4 Appendix 4 – Source Alternative Calculations

Slow Sand Filter

	Hydraulic Loading Rate (m/h)	0.1		ACSE, SSF, pg. 128
	Filter Area (m2)	4.03		
	Area for each side of tank (m2)	2.01		Doing two sides so one can be shut down and cleaned while other is operational
	Sand Depth (m)	0.8		ASCE, SSF, pg. 128
	Underdrain Depth (m)	0.3		WHO, SSF, pg 58
	Water Depth (m)	1		ASCE, SSF
	Freeboard (m)	0.2		ASCE, SSF
	Wall thickness (m)	0.15		
	Base thickness (m)	0.15		
	Total Height (m)	2.45		
	Total Area (m2)	5.65		
	Storage Volume (m3)	9.26		HUGE TANK
	Vconcrete (m3)	4.58		
	Vsand (m3)	3.22	19159	lbs Just for filter bed, not concrete mix
	Vgravel (m3)	1.21	7185	lbs Just for filter bed, not concrete mix
Concrete Mix	Vsand (m3)	1.53	9126	lbs For Concrete
	Vgravel (m3)	1.80	10708	lbs For Concrete
	Vcement (m3)	0.42	2943	lbs For Concrete
Total	**Vcement (m3)**	0.42	2943	lbs
	Vsand (m3)	4.75	28285	lbs
	Vgravel (m3)	3.01	17894	lbs

BioSand Point-of-Use

	Filter Output (L/d)	50		24-72 L/d as per HWST Fact Sheet http://www.cawst.org/assets/File/HWTS_Fact_Sheet_Conc
	Num filers needed	201		Pretty much 1/person
	Vcement per filter (m3)	0.012		BioSand Filter Design Manual http://desertification.files.wordpress.com/2010/04/biosand-fi
	Vsand per filter (m3)	0.024		(same)
	Vgravel per filter (m3)	0.024		(same)
Total	**Vcement (m3)**	2.41	1545.120779	lbs
	Vsand (m3)	4.81		
	Vgravel (m3)	4.81		
Cost	**Cement**	$ 154.51		

Greater Austin
Sieykin (Arriba), Panama
Water and Health

Spring Box - Arriba

Cover Slab for Intake Rock Filter		
Length	5.00	m
Width	3.00	m
Thickness	0.20	m
Rebar Spacing	0.25	m
Cement Ratio	0.17	
Sand Ratio	0.33	
Gravel Ratio	0.50	
Floor Slab in Collection Box		
Length	0.00	m
Width	0.00	m
Thickness	0.00	m
Rebar Spacing	0.25	m
Cement Ratio	0.17	
Sand Ratio	0.33	
Gravel Ratio	0.50	
Walls of the Collection Box		
Height	0.25	m
Width	0.30	m
Thickness	0.08	m
Rebar Spacing in Wall	0.15	m
# of Concrete Walls	3.50	
Rebar Spacing in Screen	0.05	
# of Screened Walls	1.00	
Cement Ratio	0.17	
Sand Ratio	0.33	
Gravel Ratio	0.50	
Achoring Lip for Collection Box		
Width	0.50	m
Length	0.50	m
Thickness	0.10	m
Rebar Spacing	0.20	m
Cement Ratio	0.17	
Sand Ratio	0.33	
Gravel Ratio	0.50	

Piping Spring to Tank	$ 413.50
Cement and rebar	$ 307.10
PVC Pipe (1/2")	$ 0.48
Wire screen for seive	$ 10.00
Mason	$ 700.00
Transporting materials	$ 200.00
Total Cost	$ 1,631.08

Rebar Calculations

Cover Slab		
Rebar Needed	128.00	m
Rebar (30 feet)	14.00	Pieces
Floor Slab in Collection Box		
Rebar Needed	0.00	m
Rebar (30 feet)	0.00	Pieces
Walls of the Collection Box		
Rebar Needed	7.35	m
Rebar (30 feet)	0.80	Pieces
Door Lid		
Rebar Needed	3.50	m
Rebar (30 feet)	0.38	Pieces
Total Rebar		
Rebar Needed	15.19	Pieces
Waste %	10.00	%
Total to Purchase (3/8")	**16.70**	**Pieces**

Volume Calculations

Cover Slab		
Cement Volume	0.75	m^3
Sand Volume	1.50	m^3
Gravel Volume	2.25	m^3
Concrete Volume	**3.00**	**m^3**
Floor Slab in Collection Box		
Cement Volume	0.00	m^3
Sand Volume	0.00	m^3
Gravel Volume	0.00	m^3
Concrete Volume	**0.00**	**m^3**
Walls of the Collection Box		
Cement Volume	0.00	m^3
Sand Volume	0.01	m^3
Gravel Volume	0.01	m^3
Fill Concrete Volume	**0.02**	**m^3**
Lip		
Cement Volume	0.01	m^3
Sand Volume	0.01	m^3
Gravel Volume	0.02	m^3
Concrete Volume	**0.03**	**m^3**
Cement Needed		
Cement Needed	0.76	m^3
Waste %	10.00	%
Cement Required (40kg)	**25.22**	**Bags**
Sand Needed		
Sand Needed	1.52	m^3
Waste %	10.00	%
Sand Required	**1.67**	m^3
Gravel Needed		
Gravel Needed	2.28	m^3
Waste %	10.00	%
Gravel Required	**2.51**	m^3

Cost	$ 307.10
Total weight (kg)	1386.29

Spring Box Construction Labor Estimate:

Column1	People	Hours per da	Days	Total Hour:
Mason	1	8	20	160
Transporting	20	8	5	800
Trenching	25	8	4	800
Pipe Laying	4	8	4	128
				1888

9.5 Appendix 5 – Storage Alternative Calculations

2000 L Reinforced Concrete Tank

MATERIALS			
Material	**Quantity**	**Cost per unit**	**Total Cost**
Cement (50 kg)	22	$9.00	$198.00
PVC Pipe	1	$4.05	$4.05
Water Stop	18	$2.08	$37.44
#3 Rebar (540')	27	$5.16	$139.32
#4 Rebar (140')	7	$9.15	$64.05
Valves	3	$1.58	$4.74
Sika (Sika Colombia S.A.)			
Plastocrete®DM (Option 1 - 7kg needed)			
4.5 kg bottles	2	$31.32	$62.64
Sikafluid (Option 2 - 7kg needed)			
1 Kg bottles	7	$4.15	$29.05
5.5 kg bottles	1	$22.87	$22.87
Coarse Aggregate (7078 lbs)	42 ft3		
Fine Aggregate (6032 lbs)	36 ft3		
Materials Cost			$510.24
PERSONNEL			
	Days	**Cost per Day**	**Total Cost**
Mason	3	$35.00	$105.00
Personnel Cost			$105.00
TOTAL			$615.24