Implementation – Pre-Trip Plan

Executive Summary	
Community:	Village of Gasiza, Cyanika Sector
Country:	Rwanda
Chapter:	University of Colorado Boulder
Submittal Date:	February 2, 2020
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REIC and other mentors:	Cole Bedford (REIC, Civil Engineer), Kara Lentz (Travel Mentor), Lydie Uwantege, Travis Grieman.
Scope of Work for the project (50 words) [1]	Design and implement a rainwater catchment system with 6,000L capacity in the village of Gasiza, within the Cyanika Sector of Rwanda. Our team has an ongoing project in the Cyanika region with a promise to design and build 12 rainwater catchment systems. This will be the sixth system implemented.
Scope of Work for the trip (100 words) [2]	This will be the sixth implementation trip for the rainwater catchment project in the Cyanka region.
Proposed Next Step (100 words) [3]	After this trip, the team will focus on monitoring and evaluation of all of our previous systems, as well as assess the seventh site for a new rainwater catchment system.
Describe Recent Contact with Community, NGO, and in country partners. (100 words) [4]	Our team is currently working with two NGOs that work in the Cyanika region and have connections to some of the same community members. These two NGOs are called Village Makeover and Developpement Rural Durable. Both of these NGOs work closely with local leaders of the community, with whom we are in frequent contact by email and phone. We also meet with the Community Vision Board, a collection of the chiefs of the villages we work in when in-country to determine the best ways to enhance our projects and better meet the community's needs.
Describe the Chapters current fundraising goals and milestones. (100 words) [5]	The program has already secured enough funding for this implementation trip. Additional fundraising will be required to fund the next monitoring, evaluation, and assessment trip. /v
☒ [6]	**IS THE PROGRAM STILL ON TRACK TO MEET THE EWB PROJECT EXPECTATIONS?**

Privacy: EWB-USA may release this report in its entirety to other EWB-USA chapters or interested parties.

Project Timeline

Major Milestone	Previous Date [3]	Current Date [3]	Description
Program Adoption Date	4/2014	--	The start of our partnership with the Cyanika Sector of Rwanda.
Previous Project in Program Date Constructed [2]	Munini: 2014 Gasebeya: 2014 Nyarutosho: 2016 Ntarama: 2016 Kibaya: 2018	--	We plan to build 12 rainwater catchment systems in villages in Cyanika, Rwanda. Five of them have already been completed in the summers of the years listed to the left.
Project Approval Date	Munini: 2014 Gasebeya: 2014 Nyarutosho: 2016 Ntarama: 2016 Kibaya: 2018	--	Project approval for each water-catchment system was obtained before implementation at each site. This occurred the same year that implementation took place.
Completed Assessment Trip	Munini: 2013 Gasebeya: 2013 Nyarutosho: 2015 Kibaya: 2017 Gasiza: 2019	--	Assessment trips were completed the summer before implementation on each of the five sites already completed. The Gasiza site is the new site we plan to implement next summer.
Planned Assessment Trip	--	Summer 2020	Our next assessment trip will likely take place at the same time as our next implementation trip.
Planned Implementation Trip	--	Gasiza: Summer 2020	We plan to implement two new rainwater catchment systems in the villages of Gasiza this summer, in 2020.
Planned M&E Trip	--	Summer 2021	Monitoring and evaluation of previous sites and new sites will take place next year.

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1.0 Project Description

Engineers without Borders CU Rwanda works with communities in Cyanika, Rwanda to create rainwater catchment systems. So far, EWB CU Rwanda has implemented five water catchment systems in the communities of Munini, Nyarutosho, Gasebeya, Ntarama, and, as of last year, Kibaya. We have agreed with the community to implement twelve systems total. This summer we will be implementing another system to work towards that goal. After assessing potential sites, our team has decided to implement a new rainwater catchment system in the village of Gasiza next summer. Gasiza is still in the Cyanika sector, but it is more isolated from the other villages we have previously implemented in.

Photo 1: A previous system implemented at the village of Kibaya in 2018.

1.1 Project Background and History

Our team has been working with Village Makeover, a locally operated NGO, since 2013, and we have an agreement with both them and the Community Vision Board of community leaders to implement 12 rainwater catchment systems. As part of the agreement, our team is to teach the community about proper operation and maintenance for five years after installation of a system. After the five year period is over, point full responsibility is transferred to the community in close-out.

So far, we have implemented five rainwater catchment systems in the communities of Munini, Nyarutosho, Gasebeya, Ntarama, and Kibaya. The first three systems implemented: Munini, Nyarutosho, and Gasebeya, were ready for close-out this past summer 2019, and full responsibility is now transferred to the community. These systems are in good condition, and they are well-liked by community members. The landowners in charge of these systems report being content and appreciative, and the systems are functioning as planned. While conducting monitoring and evaluation of previous sites, our team also assessed sites for implementation of a sixth rainwater catchment system and decided to implement in the village of Gasiza this coming Summer 2020.

One significant change since the last report is that three new potential sites for implementation were assessed this summer, and we are planning to continue the project by implementing one new system this year. We have also decided to focus simply on building one system in Gasiza, versus the plans discussed in the last report to possibly build an additional retrofit system in the village of Kavunda.

1.2 Project Context

In the villages of the Cyanika sector, water is a scarce and valuable resource. The two main sources of water for the community are currently government taps, which provide clean water but are dispersed and few in number, and a lake about a two hour walk away from some of the nearest villages. Most community members walk for a few hours per day to one of these water sources, and then in the case of the government taps, pay a high fee of about 100 Rwandan Francs ($0.11 USD) per jerrycan. We are considering rainwater catchment because it is feasible for the community's needs, the population, and the topography and climate of the region. Rainwater catchment systems are easy to disperse over a large land area to make water more available to a spread-out, rural population. Wells are not feasible in the area due to the rocky, volcanic terrain. Rwanda has both rainy and dry seasons, making water catchment a feasible option, as water can still be available in the dry season if it is properly stored.

1.3 Project Goals and Objective

The primary goal of this project is to provide accessible water sources to rural villages in Cyanika, Rwanda where there is no easy, reliable access to clean drinking water. Rainwater catchment systems are the primary focus, as they are a feasible option for the climate, community expectations, and natural resources of the region. More convenient water access is the primary goal, rather than water quality. This year, EWB Rwanda wants to add another rainwater catchment system in a large community that is currently walking upwards of 4-5 hours per day to collect water from a distant lake.

1.4 Scope of Work:

This will be the sixth implementation trip for the rainwater catchment project in the Cyanka region.

Our work focuses on the design of rainwater catchment systems in the Cyanika sector of the Northern Province of Rwanda. This type of project addresses the issue of water access by providing closer, more accessible water sources in the nearby area.

1.5 Summary of Alternatives Analysis

The preferred alternative is to build a gabled-roof structure with corrugated metal sheeting for roofing. This roofing was chosen because this best captures the rainfall of the 8-by-11.2 meter roof blueprint, and the corrugations maximize water collection during intense, unpredictable storms.

The decision for roof material fit the numbers provided by the matrix, but the roof style decision did not. Upon review, the team came to see that the matrix evaluation of the roof style had not been appropriate. Although it evaluated the single lean-to to be our best option, the team later learned that the previous assumptions about leveling the site were false – we received information that the community would completely level our site for us before arrival. With this consideration, the team realized that a single gable would be more appropriate for our site since it alleviates the problems with having gutters on only one side, and would simplify trusses in a way that would save material and build-time. In addition, this gable is much easier for the community to build and maintain because this is the roof style they build their homes and buildings with.

For the columns to support the roof, the team has chosen to build masonry columns reinforced with a core of concrete and four lengths of rebar running through the middle. This was chosen based directly on community feedback and in-country engineers asking us to use this style, as metal would be incredibly hard for the community to repair should anything go wrong: they are familiar with arranging and repairing masonry, which has extreme positive implications for the long-term health of our system. This community input is what caused our team to decide against the matrix decision.

Finally, for the tanks, the team has calculated that four tanks should be far more than enough to hold the maximum water in the system in a given year. Since this system will have far more demand than any we've built in the past, we felt this slightly lower ratio of tank-volume-to-roof-size was appropriate. For the foundations to hold these tanks, the team will use concrete footers with volcanic rock forms, which is the traditional method in the region. The community is adept at this method and we have used it in most of our previous systems including our most recent one. The footers are necessary because we found it necessary to have the tap at a level that people can put a jerry can underneath it so they don't have to heave the full jerry can from lower than ground level.

1.6 Project Team

The REIC is Cole Bedford, a practicing Civil Engineer in water resources who travelled with the team during our Summer 2019 assessment, monitoring, and evaluation trip. Other mentors include Travis Greiman, a past travel mentor who helps with technical advice, Lydie Uwantege, a Civil Engineer working from Kigali, Carlo Salvinelli, another past travel mentor and engineering in developing communities professor, and Evan Thomas and Laura MacDonald with the Mortenson Center for Global Engineering at the University of Colorado Boulder. The Faculty advisor for EWB CU Boulder is Karl Linden, a professor in Civil, Environmental, and Architectural Engineering at CU Boulder. The travel mentor is Kara Lentz, a Civil Engineer currently working as a Senior Program Manager in Aviation at HNTB. Students traveling include Carrie Bishop (Chemical and Biological Engineering), Sean Connelly (Mechanical Engineering), Annamarie Guth (Environmental Engineering), and Jack Harris (Environmental Engineering).

1.7 Community Partners

In Cyanika, there is a Community Vision Board, consisting of elected officials from the district who can read and write that represent the community. They make key decisions about the implementation of future rainwater catchment systems and which villages should receive them next. Village Makeover, a locally operated NGO, is our primary contact and we communicate to the Community Vision Board through them. Village Makeover is our in-country resource, and they help coordinate the team's trips and provide any resources that are needed (ie. translators, contacts, contractors, etc.). Hasan Iranzi and Jacques Ngirabahizi are Volunteer Village's Rwanda contacts who facilitate communication between the team and the Cyanika Community Vision Board.

This year, we have also begun working with another NGO, Developpement Rural Durable (DRD), which has an office in Rwanda and does a lot of other agricultural projects in the Cyanika sector. Jean D'Amore, the founder of DRD, is in good communication with both our team and the Community Vision Board. He has a voice in their meetings, but the Community Vision Board still has ultimate decision making authority.

1.8 Reference Projects (Conducted by EWB-USA)

1. Rainwater Catchment in Mkutani, Tanzania

In Mkutani, Tanzania, two rainwater catchment systems with prefabricated tanks were built. The prefabricated tanks were preferred when compared to their alternatives, an isolated ferrocement tank with a powered pump and an underground tank with a filter and hand pump, because they weren't required to construct underground tanks or pumps. These were also considered challenges because they were more complicated and expensive to build.

2. Mariscal Castilla Rainwater Harvesting

Mariscal Castilla is near the Amazon River, which rises around 15 feet at various times throughout the year. This was a possible challenge for the team because, if the river had risen while they were there, the construction of the project would have been hindered. However, the general iiver level rise during the year is known so they were able to avoid that challenge.

3. Kubweye Community Water Project

In Kubweye, there's a risk of contracting various diseases from insects and water, which can be prevented by only allowing the team members to drink from bottled water and ensure their food is fully cooked. They will be working next to a river so in order to avoid skin damage, heat exhaustion, and risk of injury through rough terrain, the team will be required to stay constantly hydrated, stay in groups, and wear protective clothing.

Taking all these challenges and alternatives into account, we will ensure our team is well aware of the terrain and any possible infections/diseases they could incur. They will also research the terrain and what systems would be best implemented in the community for prime functionality and longevity.

2.0 Design

2.1 Description of Existing Infrastructure

In the village of Gasiza where our team plans to implement a new rainwater catchment system, people are walking for a few hours per day to either a government tap stand or to the nearest source of surface water, Lake Burera. Water from the government tap stant is 100 rwf per jerrycan (20L) and is sometimes unavailable during certain times of year. This project is proposed to add a cheaper, more reliable water source so that people in Cyanika have more time and financial freedom.

2.2 Description of Proposed Facilities

The proposed facility is a free-standing rainwater catchment system (see photo 2). This system consists of a simple gable-style roof with gutter drainage, supported by nine columns. The water from the gutters runs through PVC piping into four ten-thousand liter tanks. The dimensions of the structure were determined by the size of the land plot donated to the project, the size of the storage tanks, and the necessary surface area in order to optimize the amount of water caught by the system. Community members are expected to collect water from the systems using jerry cans and boil, or otherwise treat it, before consumption. The system is located on a plot of land behind the home of the chief of Gasiza village, which is located close to the main dirt road that runs through the village. It is easily-accessible to community members without being overly exposed.

Photo 2: Model of proposed facility.

2.3 Basis of Design:

2.3.1 List of Standards and Codes

The building codes used in this project are detailed in the Appendix. They include general design requirements, loads and forces, wind loads, foundations, roofing structures, concrete, and columns. See the Appendix..

2.3.2 Design Methodology

Solidworks was used to create the design models. Equations for calculations were obtained by referencing projects done in past years as well as by consulting with project mentors in civil engineering.

2.4 Calculations

Please see Appendix E for full calculation details and processes.

2.4.1 Water Demand

In Gasiza, community members have to walk between 5 and 10 kilometers, about two hours each way, for their drinking water. Much of this water comes from lakes and rivers, making it more likely someone becomes sick. Especially during the dry season, most of the community is forced to rely on government tap stands, enduring long hikes and wait times. Surveying other rainwater catchment systems, it appears most are able to supply about 0.09 liters of water per person per day. This initially appears to significantly under-serve the population; however, community surveys indicate a large portion of people find other sources for their water, especially when rainwater is scarce. The village of Gasiza is home to approximately 2000 people, yet likely no more than 500 will be using the system monthly. With this in mind, demand for water will be around 10,000 liters per month. Demand will also likely increase during the rainy season when water is more available and decrease as water becomes more scarce.

2.4.2 Water Supply

Musanze, Rwanda has an average rainfall of 4.3 inches per month. The rainiest month (April) has an average of 7.1 inches of rainfall. The driest month (July) had an average of 0.8 inches of rainfall. Musanze is about 23 kilometers from our build site, so the rainfall can be approximated to match that of Gasiza. With a total roof area of 89.6 square meters, this means the system would bring in an average of 9,800 liters of water per month. During the rainiest month, this would lead to a total intake of about 16,000 liters, and during the driest month, would have an intake of about 1800 liters. This lines up well with our projected usage, with more jerrycans taken during the rainy season than in the dry season.

https://en.climate-data.org/africa/rwanda/majyaruguru/musanze-3390/

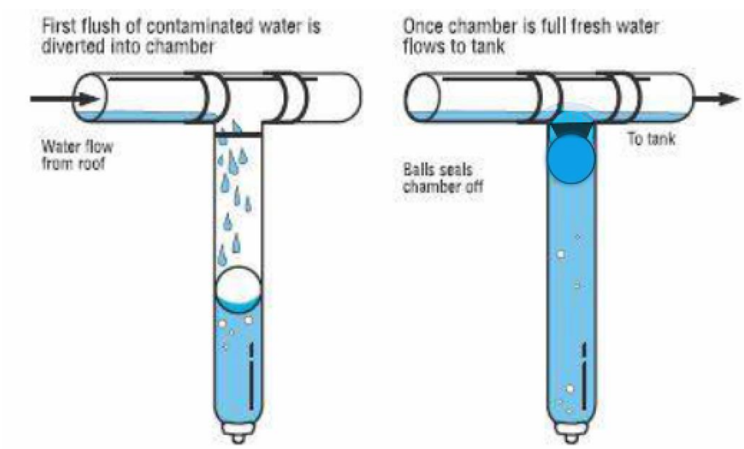
2.4.3 First Flush Sizing

The leaf catcher is the first line of defense for debris in the system. The leaf catcher is constructed as an open top cube from locally sourced wood. The open side of the cube sits underneath the end of the roof gutter, with a hole on the bottom face of the cube connecting it to a pipe leading to the first flush system. A piece of mesh is placed on the inside bottom face of the cube to catch debris from the gutter while allowing water to pool inside the cube. In this way water is not lost as the small collection of debris on the inside face slows the filtration of water. The mesh will be cleaned following every rain storm.

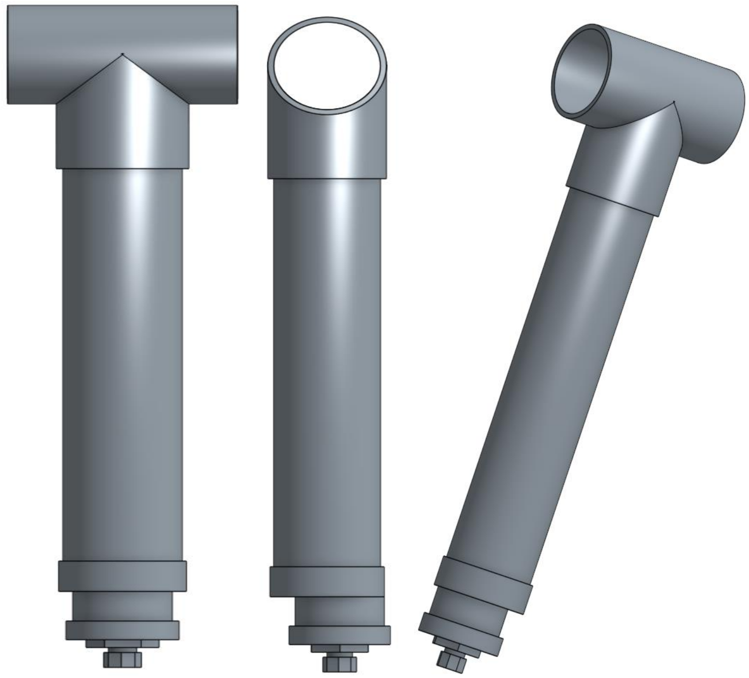
The first flush system is a downward facing, vertical component that consists of a closed tube, a ball, and a removable cap. Water will flow from the leaf catcher to the first flush system where the first water stream will flow down into the tube. A small ball at the bottom of the pipe, which floats in water, will rise as runoff is collected in the vertical closed tube. To keep the ball from rising completely to the top of the first flush system, we attach a funnel-shaped piece (a float valve) at the intersection between the first flush and the main pipe. The ball has a diameter of approximately 3 inches, so the float valve will have a small enough diameter to keep the ball from rising and restricting water flow. Once the water level fills the tube, the ball will seal the opening with the help of a tapered connection inside the PVC elbow, allowing the water to flow past the first flush system into the tanks, see figure below. The bottom of the sealed tube consists of a removable cap, which will be removed following the rain storm, allowing the debris to fall from the system, resetting the first flush system.

The combination of these two components is effective in removing any debris that was collected in the gutters and on the roof between rain storms. The leaf catcher collects larger debris, while the first flush system collects dirt and other particles. The 4” PVC piping used in each first flush will be 9.3 ft long. (See first flush sizing calculations can be found in the appendix).

In the repair and maintenance training for the systems, the community has been instructed to empty and clean the first flush and leaf catcher systems after every rainstorm. This works to prevent the build-up of sediment. The community member who opens the taps and collects tariffs each day will be responsible for checking the first flush system and leaf catchers. The Community Vision Board ensures that this instruction is followed.



The flush is a filtration system designed to prevent dirt and debris from entering the water storage tank. The first volume of water from the roof will be collected in this channel. The channel will continue filling until the ball reaches the top, see the figure below.



2.4.4 Soils Investigation

The land of the site at Gasiza was chosen by the Community Vision Board of Cyanika, Chief Ignace of Gasiza, and the local community. When evaluated in July 2019, the land was covered in large loose rock, and sloped at about a six degree angle downhill. This is not ideal for construction, so it is important to work with the community to remove all large rock, and level the site. The soil and land quality is an important factor to consider, especially when building in agricultural areas, and in areas of heavy rainfall. Caution when manipulating soil on site before construction is important to ensure a safe, reliable foundation for many years. A soil too compact can prohibit vegetation growth and drainage. Proper drainage is necessary on site so that excess water falling around the roof is not damaging the structure. An aerated and tilled soil is ideal so that proper aeration is possible in the soil, and drainage can pass through the topsoil level. High organic matter levels in the soil will allow water to infiltrate and be absorbed more easily. Perhaps composted material from the community can improve the soil quality to ensure proper drainage around the roof structure to minimize flooding. This will be managed throughout and after construction, as workers will be walking all around and moving materials on the land throughout the project. Proper communication and planning for this potential hazard will be managed by EWB Rwanda and the community of Gasiza.

2.4.5 Water Quality

Current state of water quality in the community:

The community of Gasiza is predominantly using surface water from Lake Burera. It is most-likely highly contaminated with bacteria and is used frequently by community members to wash clothing and provide water for livestock. Community members who are not walking to Lake Burera are walking to a distant government tap stand, which pumps disinfected water from a water treatment plant in the nearby city of Musanze and is likely cleaner than the lake water source. However, community members are often collecting water in jerry-cans that are not cleaned very often and have great potential to be contaminating the water supply even if the source is relatively clean.

Expected water quality and potential pollutant sources:

The water quality will likely be similar to the water quality of the systems our team has implemented in the Cyanika community previously. In Summer 2019, qualitative water quality tests were performed using *Watersafe Rapid Bacteria Test*, a field test showing the presence of E.coli, Pseudomonas aeruginosa, Shigella Enterobacter, and other coliform bacteria. Some tests were difficult to conclude upon, but all showed at least the threshold level that indicates a potential health hazard. These tests were performed at most of the previously-implemented rainwater catchment systems in the Cyanika region, including Nyarutosho, Gasebeya, Ntarama, and Kibaya. Recently, total coliform tests were completed for each tank at each previously-implemented system, through the help of DRD, our NGO, using a lab at the local university INES. These test results show moderate contamination around 30-200 cfu/100mL, plus an outlier of over 27,000 cfu/mL at one poorly-cleaned tank. More tests will be conducted within the next few months to investigate the real health risks of this contamination, but all community members are currently being encouraged to boil their water before use.

Possible pollutants in the area include leaves, blown grass, or particulate matter from the air. The site is not directly next to any large trees, but it is next to a small plot of cropland. The metal sheeting used for the roof could also bring the potential of dissolved iron and lead contamination, so the team will be sure to buy roofing material treated and coated to prevent this. Another potential for pollution is from the jerry cans used to collect water, as they may not be cleaned between collection from a surface water source and collection from the rainwater catchment system.

Plans for water quality monitoring and evaluation:

This year's EWB CU Rwanda team plans to improve the water quality monitoring and evaluation process. Previous teams had brought qualitative water quality tests with them to test each tank during travel, but this year's team plans to establish a partnership with students and faculty at the local university INES to improve water quality testing procedures. With collaboration from students who live near Cyanika, water samples may be taken more frequently, and with the resources of the INES lab, bacterial levels can be more precisely quantified. The team hopes to collect water quality test results about four times per year as long as the project is under our control.

Water treatment methodology:

Water is treated by individual community members before use. Community members are encouraged to treat their water as they would treat water from previous sources such as lakes or government tap stands, either by boiling or using the chemical treatment distributed by the Rwandan government. The system itself employs a leaf catcher to ward away large particulate matter, as well as a first flush system. The first flush system aims to direct dirty water from the beginning of the storm away from the tanks, only keeping water collected from the cleaned roof. The pipes that are a part of the first flush system must be inspected periodically. If there is a buildup of organic materials, the pipes must be cleaned by hand. This involves the removal of the pipes so that the buildup can be removed, as well as the rinsing of the pipes with a bleach solution. Each time the first flush is emptied, it also must be inspected. Any material found on the side of the pipes or on the ball needs to be removed using a brush.

2.4.6 Tank Calculations

Volcanic Rock Aggregate Stability:

Though volcanic rock, also known as basalt, is seldom used in the domestic construction industry, many countries have resorted to it as an alternative to steel rebar due to its high availability. Rwandan builders use volcanic rock aggregate as a substitute in many construction projects due to their proximity to the lava fields in the northwestern region of the country. Construction materials are seeing a high demand, so the cost and availability of certain materials such as concrete and steel have risen. Due to its high availability as well as its proven constructive success, volcanic rock is a viable option for a load bearing foundation.

Basalt is hardened volcanic lava. It is a dark-colored igneous rock found worldwide. These rocks are fine-grained and porous, can have a glassy texture, and contain rough minerals[1]. Russia has a large amount of basalt reserves, and because of that, has conducted many tests about its innate properties. The tests reveal that volcanic rock is reliable, strong, biologically safe, and a great insulator. This has led many to incorporate volcanic rock as a reinforcement of concrete slabs, replacing commonly used steel.

Dr. Jean De Dieu, Dr. Pranesh (University of Jain in India) and Dr. Wali (University of Rwanda) published a paper in January 2017, conducting a meta-analysis of the current information on volcanic rock, as well as their own experiments on the use of Rwandan basalt in the construction industry. One case study revealed that mixing volcanic rock aggregates with cement enhanced the material's overall flexural strength. Other studies discovered the compressive strength and durability of volcanic rocks as concrete mixtures, specifically related to density and porosity. The effect of volcanic rock aggregate when mixed with concrete materials was found to produce an overall better compressive and tensile strength.

Previous to this study, there was research surrounding the use of volcanic rocks as an acting aggregate, but not specifically with Rwandan basalt. All of the above studies produced slightly different results with different compressive strengths depending on where the tested basalt was from. As a result, the need to test the compressive strength and permeability of the basalt from Rwanda was seen as a priority for Dr. Dieu, Dr. Pranesh, and Dr. Wali[2]. Thus, the researchers began an experiment testing Rwandan volcanic rock, collecting ten samples of aggregates and recording their compressive strengths in megapascals (MPa). In the table below, the aggregates were classified using

[1] Irfan, T.Y. "Foundation Designs of Caissons on Volcanic Rock: A Technical Review." *Civil Engineering and Development Department (CEDD) of the Government of the Hong Kong Special Administrative Region.* Pp. 62-85. Accessed 13 Jan. 2018.
[2] Wali, Umaru Garba, Mutabaruka Jean De Dieu, and Dr. M.R. Pranesh. "Engineering Characteristics of Volcanic Rock Aggregates in Rwanda." *International Journal of Civil Engineering and Technology*, vol. 7, no. 7, 2016, pp. 83-88.. Accessed 13 Jan. 2018.

the Bell Classification system, where the compressive strength of the basalt is considered "Very High Strength" if it is more than 224 Mpa, and "High Strength" if the values are between 112-224 Mpa.

Samples	Compressive Strength (Mpa)	Bell Classification [18]
S1	125	High Strength
S2	133	High Strength
S3	197	High Strength
S4	354	Very High Strength
S5	324	Very High Strength
S6	299	Very High Strength
S7	247	Very High Strength
S8	189	High Strength
S9	226	Very High Strength
S10	229	Very High Strength

Source: Jean De Dieu, Mutabaruka; Pranesh, Dr. M.R.; Wali, Umaru Garba. "Engineering Characteristics of Volcanic Rock Aggregates in Rwanda." *International Journal of Civil Engineering and Technology*, vol. 7, no. 7, 2016, pp. 83-88. Accessed 13 Dec. 2018.

As seen from the table above, the majority of the volcanic aggregate samples tended to have a compressive strength of more than 224 MPa. The variance of compressive strengths is a result of the different locations across Rwanda where the samples were collected. Ultimately, the samples that rated "Very High Strength" can be a viable option for bearing the structural load of a constructed building, as the compressive strength of steel is 172 MPa (25,000psi), well under the compressive strength of the basalt rock. In concrete slabs, the majority of the compressive forces lie on the actual concrete (compressive strength of 27.5MPa), so the strength that the volcanic rock adds will act as a viable replacement to steel. In our proposed design in Kibaya, the force applied on the system by the water tanks is far lower than the pressure tested above. The maximum load that our system foundations will hold is 0.03612 MPa, which is far lower than the pressure tested. From this experiment, the researchers also came to the conclusion that the incorporation of the volcanic rock is relevant as a building material in modern infrastructure (Jean De Dieu, Pranesh, Wali 82).

The high rigidity and low elongation demonstrates that volcanic rock is a reliable and structurally sound replacement for steel in concrete slabs. Current practices use steel rebar to reinforce concrete slabs, but in Rwanda, the cost and availability of steel has led to the need for another alternative. Research has been done, both internationally and specifically in Rwanda, that prove that volcanic rocks have a high compressive strength. A shear analysis on the volcanic rock was not conducted because rebar is not to be used as reinforcement in the foundation for the tanks. Instead, the volcanic rock aggregate will serve the same purpose. Extensive research has been done on the feasibility of this design, and we are confident that this type of foundation will suffice for the needs of this system. Based on the relatively low seismic activity in the area, our calculations from previous structures, and our extremely high factor of safety, we decided that it was not necessary to conduct a seismic analysis. After reviewing calculations made in previous years, we decided that seismic loads were small enough not to endanger the integrity of the system as it is. We found the volcanic rock and concrete mixture that we are using has a high enough compressive strength to hold many times the weight of the tanks at the thickness that we have designed for.

Ultimately, using Rwandan volcanic rock combined with the low pressure applied makes the basalt a suitable construction material. A volcanic rock aggregate foundation has been used on previous implementation and was favored by the community, their labor force, and culturally conscientious design practice. The community has several structures with this design which have stood for many years, and our past systems have been implemented and maintained successfully with this design.

Tank Compression Loads

Using the density of water, the specific gravity of Roto Tanks from manufacturer specifications, and the average compressive strength of Rwandan Volcanic Rock aggregate, the pressure exerted by a full tank is only 0.042 MPa, which is much less than the compressive strength of volcanic rock aggregate at 224 MPa. See Appendix E for full calculations.

2.4.7 Column Calculations

An initial column design was proposed due to its simplicity. The columns will be built using a combination of brick and mortar and reinforced concrete. The bricks and mortar will form a square "shell" around the reinforced concrete which will be poured in the center. Layers of bricks and mortar will be added in this manner until the column in the specified height. Finally, four #8 rebar rods will run through the space in between the bricks and cement will be poured into the cavity. The strength of the column was calculated in, attachment E under the column section using the equation below. Explanations of variables and constants can be found in attachment E along with the calculations. This value was compared to the calculated LRFD value. The column load capacity was much larger than the factored load so the proposed column design does not need revision. The total weight felt on a column is only 2,361.09 lbs, while the maximum load capacity is 103,952.56 lbs.

Equation 1.2.2:
Pa = [0.25 * fprime * Acr + 0.65 * Als * Fs] * [1 - [h / (140 * ra)^2]]

Column footers are cylindrical reinforced concrete bases on which the brick columns will be built. In order to ensure the columns could support the weight of the structure and that we had an adequate amount of rebar in the footer design, the calculations in the attachments were conducted. To begin with, the dead load of the roof and trusses were added together to get the weight distributed on the middle columns. As the middle columns support more weight than a column on the perimeter, by showing that the middle column will be stable indicates that the perimeter columns will also be stable. The final maximum dead load on the column was divided by the soil bearing capacity of the column footers to determine the total footer area. After this value was divided by nine to find the individual footer area, it was found that an area smaller than the column would have been sufficient. This minimum area is 18.2461 in^2, whereas the footer area in our plans is 225 in^2. As making a base smaller than the column would be impractical during construction, it was arbitrarily decided to make the column footers 38cm (15in) wide so that the footers will be wider than the columns.

2.4.8 Trusses and Beams

In order to ensure that 75mmx75mm with 3mm thickness square steel sections are appropriate elements for the structure, it is necessary to find the maximum force that this type of roof would apply to a column and show that the steel can support the roof material, its own weight, and the weight of a person for operation and maintenance.

See the appendix for full details of the trusses and beam calculations. To find the maximum load of the roof on the columns, we found the load that would be expected on the central column if a person were standing towards the middle of the roof. This represents the maximum possible load on a column because the middle section supports more direct roof and truss weight than the side columns. The maximum load on a column was found to be 2719.35 N, which can be used in the column buckling calculations of the previous sub-section. This load is well below the threshold that would cause buckling of columns of our designated size. See the previous subsection for more details on buckling.

A simple king post truss structure was selected, repeated three times along the length of the system. This structure, though simple, was supposed to be sufficient, as the roof load is relatively small, accounting only for the weight of a thin metal sheeting roof, support beams, and the weight of a person. In order to confirm the strength and capability of this truss and material selection, we calculated the maximum shear stress and bending moment along the hypotenuse element of the truss, as this section is both the longest and receives the largest direct force. If this element can support its load, then the other elements should as well. First, the maximum shear stress was found to be 1085.95 N, and the maximum bending moment was found to be 2182.76 N-m at the center of the beam. From these calculations, the maximum bending stress is 4496.9 psi, which is well below the modulus of elasticity of steel, 20,00,000 psi. The maximum shear stress was found to be 4196.12 psi, well below the shear modulus of steel, 12,000,000 psi. This means that the maximum bending and shear stress caused by the force on the beam are much too small to cause rupture or failure of the system. Please see the appendix for the full details and equations used.

2.4.9 Wind Loads

To understand whether the system would be robust to wind loads it could reasonably be expected to experience in its planned lifetime, we analyzed the wind load using the ASCE 7-16 25-year wind standard. This wind planning tool is only available from the American Society of Civil Engineers for the United States, so our team extrapolated the predictions made by the tool in a region of the US with similar altitude and topography: Provo, Utah. This prediction makes sense because the variance is very small in maximum 25-year wind load across the entire United States.

Using professional recommendation, we assumed that the wind forces perpendicular to the face of the roof would pose the largest problem and be the first point of failure if our structure were to fail due to wind loads. Using a worst-case wind load horizontal and perfectly perpendicular to the structure, it was determined that the loads we were likely to see within a 25-year operational lifespan of our system would not exceed

71 mph in accordance with the ASCE wind risk bands. A storm of this magnitude encountered during the useful lifetime of our system would not cause our system to fail assuming the system is built with the materials we specify and without any major flaws. The maximum bending moment in perpendicular force was found to be 2546 N*m at the end of the beam, and max stress 36200 kPa, which is several orders of magnitude lower than the shear modulus of steel in Rwanda, around 7000000kPa. Our team did not calculate the forces from a wind perpendicular to the cross-brace's angle because the cross-brace's surface area is an order of magnitude smaller than the surface area presented to the wind for force perpendicular to the columns.

2.5 Material Specifications

Part of Structure:	**Material Specifications:**
Tank and Tank Foundation:	Tank Capacity: 10,000L Specific Gravity of Heavy Duty Roto Tank: 1.6 Density of Water: 1kg/L Average Compressive Strength of Volcanic Rock Aggregate: 224 MPa Tank Diameter: 2.4m
Truss and Beam Calculations	Truss and Beam Type: Square steel sections Steel Supplier: Safintra Rwanda Steel dimensions: 75mmx75mm with 3mm thickness. Sold in 6m lengths. Mass of steel per unit length: 6.78 kg/m Roof Type: Corrugated steel sheeting Roof Thickness: 0.25mm Density of Steel: 8000 kg/m^3 Modulus of Elasticity of Steel: 20,000,000psi Shear Modulus of Steel: 12,000,000 psi
Column Calculations:	Brick Weight: 5.25lbs/brick Steel Weight: 1.5lbs/ft Grout Weight: 132lbs/ft^3 Brick Dimensions: 215mm x 102.5mm

	Compressive Strength of Masonry: 1250 psi Yield Strength of Steel: 36000 psi #8 Rebar cross section: 3.142 in^2
Wind Load Calculations:	Cross-brace Type: Square steel sections Expected Shear Modulus of Steel: 7,720,000 kPa Expected Steel Yield Strength: 100,000 kPa Expected Steel Tensile Strength: 84,100 kPa Cross-brace dimensions: 75mmx75mm

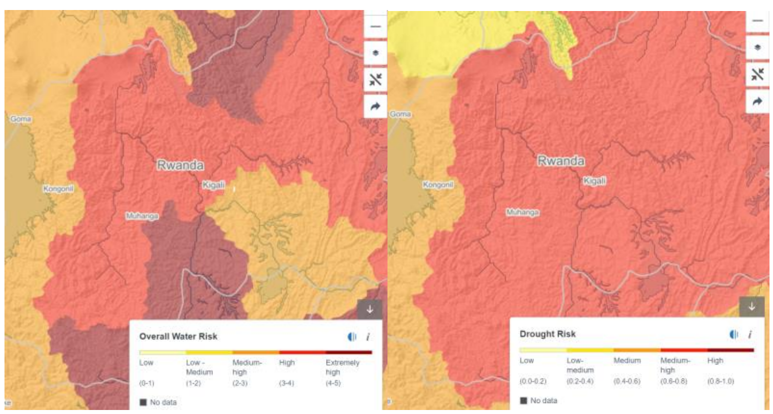
2.6 Climate Change

2.6.1 Estimated Lifespan of the Structure

The structure is estimated to last 20-50 years if minimal repairs are made.

2.6.2 Key Climate Indicators Relevant to the Project

Climate change is a significant factor to consider in Rwanda, as it is located in a mountainous, sub-tropical region where climate variation is expected to be high. The key climate indicator most relevant to this project is rainfall levels. According to the Aqueduct Water Risk Atlas, overall water risk in the Cyanika region of Northeastern Rwanda is between medium and medium-high levels, primarily due to drought risk, as shown in the figures below.



According to Rwanda's Climate Change Profile developed by the Netherlands Commission for Environmental Assessment[3], climate change is expected to intensify all seasonal variations in most regions of Rwanda, including the volcanic highlands of Cyanika. The rainy season is projected to become both shorter and more intense, with heavier rainfall that is brief but increases the risk of flooding. The dry season is expected to get hotter and drier, causing risk for drought. Small-scale agricultural practices are particularly vulnerable to these climating patterns, which is unfortunate considering that the majority of the Cyanika region depends on small-scale agriculture for their survival and livelihoods. Rwanda is ranked as the 13th most vulnerable to climate change of 178 countries in the ND-Gain Index. This index assesses a country's exposure, sensitivity, and ability to cope with changes in climate based on their food, water, and health infrastructure. Rwanda's high population density, widespread poverty, dependence on small-scale agriculture, and current lack of water access make it particularly vulnerable to slight climatic modifications.

2.6.3 Expected Changes to Design Considerations Based on Anticipated Climate Change

The Climate Change Profile[3] referenced above estimates that the average annual rainfall in Rwanda will experience a general trend of increased rainfall between now and 2050. The system was already designed with rainfall variability in mind, as solid data on rainfall was never available to begin with. In general, rainwater catchment systems themselves are inherently resilient; even if the timing and volume of rainfall changes, the system has the capacity to catch and store it for when water may be more scarce. In other words, the design is not as highly dependent on how much water flows or when it flows than other water distribution systems. In addition, the community this project will be in has a larger population than any other village the team has built in before. Because of this, the tanks will be depleted more quickly and the risk of tanks overflowing is very low. In the design of the tank spacing, uncertainty in rainfall data was already addressed by leaving space under the roof for the potential addition of another tank, if the capacity turns out to be too low. This could be a potential modification available in the future to mitigate climate change events.

Because the potential for significantly drastic changes in rainfall in the near future is low and moderate changes have already been accounted for, climate change effects should not cause an increase in project cost.

Climate change is likely to cause irregularities in the timing and intensity of rainfall in both the rainy and dry seasons of the Cyanika region of Rwanda. Rainwater catchment systems offer a feasible solution in the face of these risks, as they can capture large quantities of water when it is available and store it for when water is more scarce. With this in mind, it is important that our system has a high water-holding capacity so that it has plenty of space available, to make the most of water storage during intense storms that may be utilized in the event of a subsequent drought.

It is also important that our designs take carbon footprint into account, given that the region in which we work is highly vulnerable to the effects of climate change. This can

[3] "Climate Change Profile RWANDA." *Netherlands Commission for Environmental Assessment*, 2015, pp. 1–16.

be done by minimizing material use, buying as many local materials as possible, and using material options that produce less carbon dioxide in their production.
Although most of the material alternatives discussed in this report have negligible carbon footprint differences, column alternatives offer potential for a carbon footprint analysis. The use of brick columns versus steel decrease the carbon footprint of our system construction. The production of steel is a highly energy-intensive process, whereas the bricks used in Rwanda are locally hand-produced and dried using sunlight. Bricks are also locally available and familiar to the community, allowing them to more easily make repairs in the event of extreme weather and destruction.

The placement of tanks in our design also reflects climate change resilience. Because climate change presents a high chance of rainwater variability, our tanks are centralized under the structure, providing plenty of room in case a new tank needs to be added in the future.

3.0 Schedule

3.1 Schedule Overview

During the implementation of the system in Gasiza, the main goals will be to implement the new system, collect data on pre-existing systems, meet with the Community Vision Board and at INES, a local university. The first part of the trip will focus on organizing and purchasing remaining materials for the construction of the system. The rest of the trip will be spent ensuring that the system is built efficiently and soundly, meeting with the Community Vision Board to evaluate the existing systems and the future partnership, and meeting with student and in-country professional engineers at INES to evaluate water testing and the future partnership. At the end of the trip, the construction of the system will be complete and ready for use, the community will have a thorough understanding of the maintenance and upkeep, and there will be a plan for continued partnership.

3.2 Work Breakdown Structure

Gasiza Construction Work Breakdown Structure			
Task:	**Estimated Duration:**	**Location:**	**Who is needed?**
Clear rocks from the site	Should happen BEFORE travel	Gasiza Site	Community volunteers
Prepare site (digging, leveling, rock clearing)	1 day	Gasiza Site	Chapter members, community volunteers, translator, travel mentor

Prepare site for tank and column foundation concrete pours	2 days	Gasiza Site	Chapter members, community volunteers, travel mentor, translator
Pour concrete foundations	2 days	Gasiza Site	Chapter members, community volunteers, hired concrete/masonry worker, travel mentor, translator
Build Columns	10 days	Gasiza Site	chapter members, community volunteers, hired concrete/masonry worker, NGO Engineer, translator
Weld Steel Trusses	7 days	Have some pieces welded in Cyanika Central, then transported to site	Welders, Community members for transport, chapter member to check dimensions and quality, NGO Engineer, translator
Attach Trusses	1 day	Gasiza Site	Welders, community volunteers, chapter members, NGO Engineer, translator
Attach Roof	1 day	Gasiza Site	Welders, community volunteers, chapter members, NGO Engineer, translator
Attach Tanks and Piping	2 days	Gasiza Site	Community volunteers, chapter members, NGO Engineer, translator
Opening the water system	1 day	Gasiza Site	Community Vision Board, Chapter Members, NGO representative, translator

3.3 Detailed Task Description

Construction Element	Specific Steps:
Material Sourcing	Please see Attachment I for a detailed description of where the team plans to source each element of the structure.
Clear/Level the Site	The community will do most of this before the team arrives, using shovels and tarps. The team will check that the site is level upon arrival. The team will dig and move rocks by hand until the site is level. Finally, the team will measure the site to ensure that the dimensions match the dimensions found during assessment.
Column Footers	Dig, lay rebar at the base along the ground, mix concrete, pour the concrete while inserting the vertical rebar.
Build Columns	Let the concrete footers set for 24-72 hours. Lay bricks on all columns, roughly a meter per day so that they dry appropriately before the next layer is put down. Pour concrete in the middle of the columns while ensuring that the vertical rebar running through the middle sticks above the columns enough to attach trussing to.
Insert Cross Braces Into the Columns	Cut and size the cross-braces and attach them to the column during column construction by inserting a lag bolt into the column mortar, and having that lag bolt run through the cross brace to secure it.
Tank Footers	Dig and level a circular shape, lay rebar in a grid along the ground, make a circle out of mortar and volcanic rock, let it dry, and pour concrete into the remaining space in the center. Let set for 24-72 hours before placing the tank on top.
Build and Attach Trusses	While column and footer construction is taking place, bring plans and materials to the welder in Cyanika central. He should pre-fabricate the 3 triangular sections of truss. After columns are completed, transport these trusses to the site and weld the remaining structure. A generator will need to be used on-site.
Attach Roof	Nail long bolts through the roof and wrap around the bottom of the truss element (imagine a bolt in the shape of the letter "J"). Use a 2' to 3' between each bolt running both ways, and overlap the sheeting so there are not gaps in the roof.

Attach Tanks and Piping	Place tanks on top of the tank footers. They do not need to be secured. Drill holes in tanks where the pipes will connect. Measure the pipe lengths needed, and cut the PVC to the desired lengths. Cut PVC in half to make a gutter. Attach PVC and first flush together using purchased PVC attachments. Attach gutters to roof using wire and metal brackets.
Attach taps to tanks	Cut hole in the tanks (sized to fit the tap), attach taps to tanks and screw from the inside of the tank, and make a water-tight seal using epoxy. Build a support around the tap out of brick to hold it in place, and level out the ground underneath the tap to best accommodate a jerrycan.

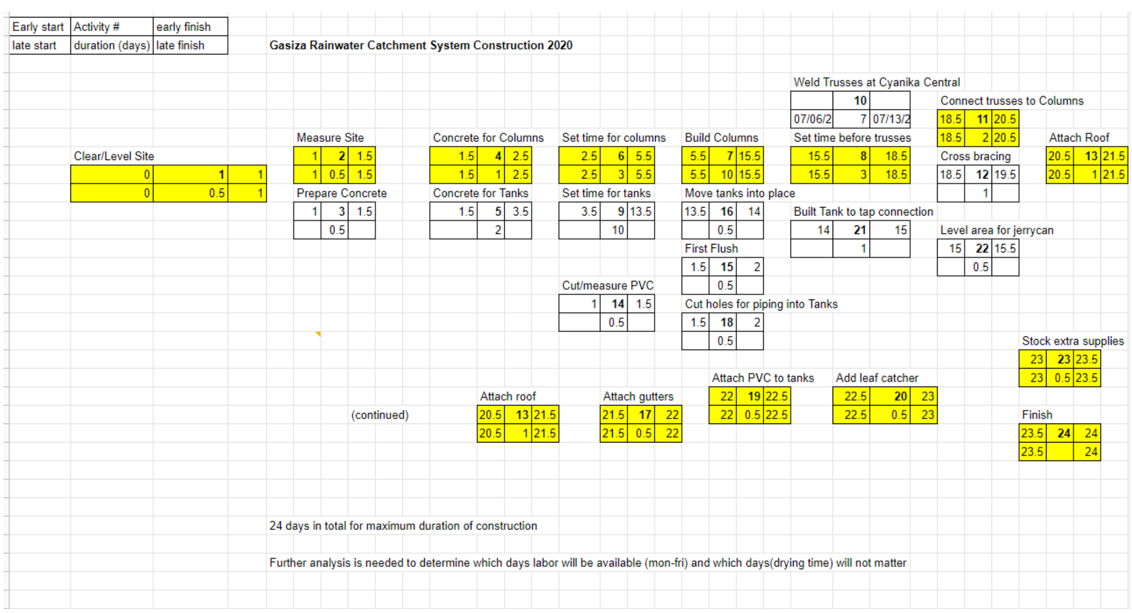
3.4 Schedule Analysis

Advance Task Scheduling

Tasks to be Completed Before Travel Team Arrival		
Task	**EWB Pre-Trip Action**	**How the Task Will Be Completed**
Clear all rocks from the site.	Contact Hasan from Village Makeover and Yvette and Jean from DRD to gather volunteers and laborers for rock clearing.	Community members manually removing rocks.
Begin to level the site (chapter members will ensure that this is finished off correctly upon arrival)	Contact Hasan from Village Makeover and Yvette and Jean from DRD to gather volunteers and laborers for site leveling.	Community members will manually level the site with shovels. The team will help finish this task upon arriving in-country.
Order tanks to be delivered by RotoTank	Call RotoTank via WhatsApp. Use Hasan as a translator if necessary.	Tanks will be delivered by truck to the site.
Order square steel sections and roofing from Safintra to be picked up upon arrival	Order materials by phone via WhatApp. Ask to either have them delivered to the site or be prepared by the day that travel team flies into Kigali.	Travel team will check on these materials at the Safintra warehouse upon arriving in Kigali and ensure that they get to the site.

Schedule specialized labor, such as welders and masons.	Contact Hasan from Village Makeover and Yvette and Jean from DRD to schedule specialized labor with the community	Welders and masons are hired by the day.
Schedule Community Vision Board meetings and operations/maintenance trainings	Contact Jacques from Village Makeover.	Jacques is capable of gathering all the village chiefs.
Pre-fabricate steel trusses.	Work with DRD to have the steel delivered from Kigali to the welder's shop in Cyanika central 1 week before the team arrives in-country. The team will need to provide DRD with very detailed, specific plans as to how the trusses should be welded together. The 6 triangle truss structures should be ready by the time that the team arrives in Cyanika.	The welder in Cyanika central will weld the triangle truss structures together according to our pre-planned dimensions and sizes.

Critical Path Analysis



Schedule Threats

The biggest schedule threat is if the column construction is delayed because the columns need about 3 days to set before trusses can be added. As planned, the 3 days occur over the weekend, so a delay would push the entire schedule back significantly.

Schedule Issue Mitigation

If the column construction is delayed, then the construction portion can be pushed a bit into the days at the end of the trip designated for extra time and community training. Community training will only require two team members while the other two may oversee the construction of the columns.

4.0 Construction Budget

The total cost estimate for the project this summer is $26,440.98. Materials, labor, and material transportation total $9.460.98 Please see Appendix C for the full construction cost estimate and budget breakdown.

4.1 Material Quantity Takeoff

Material quantities were estimated using the dimensions decided in our CAD model and designs. Steel suppliers were called to get prices by dimension, and other material prices were determined from the detailed cost records kept from the 2018 Implementation Trip.

4.2 Cost Estimate Summary

See the detailed cost estimate in Appendix C. Materials are tracked on a per-unit basis and suppliers were contacted to confirm prices. Total material costs are estimated at $7,550.98, total labor costs are estimated at $884, and total material transportation is estimated at $9,460.98.

5.0 Facilities Operations and Maintenance Plan

5.1 Description of Ownership

The rainwater catchment system built in Gasiza will be officially owned, operated, and maintained by chief Ignace, under the Community Vision Board. The Community Vision Board is a collection of village chiefs in the Cyanika sector who work together to determine the best ways to own and operate the system. As the system will be built on Ingace's land, he will have the power to determine when to open or close the taps, as well as the responsibility of collecting fees and conducting operation and maintenance. The system is owned by the chief, but the chief also understands that the system is a community resource. This community-centered mindset is checked and enforced by the Community Vision Board, as well as in-country representatives from the NGO DRD.

5.2 Description of Operations Activities

The chief of the village of Gasiza is ultimately responsible for the operation and maintenance of the new water catchment system, under the direction of the Community Vision Board. The primary operational activities include maintenance of the first flush system, cleaning the roof, maintaining the gutter and leaf catcher systems, and cleaning the tanks. Each of these is described below, with more thorough details included in the Operations and Maintenance Manual.

The rainwater catchment systems that will be installed use a first flush system to ensure the water that enters the tank is as clean as possible. In order to maintain the first flush system it must be emptied after each rainstorm so that it is allowed to fill at the beginning of the next rainstorm. This should help to remove any dirt buildup on the roof, and should remain full once it is filled so the water reaches the tank. If there is a 5 day period without any rain, the first flush should be emptied and cleaned out as specified in the pipes section under the cleaning system components section. After the flush has been emptied the ball should be placed back in the pipe and cap secured tightly to avoid leaks.

The roof of the system is made of corrugated steel sheeting by wooden rafters and beams. The roof is designed to support the load of a worker as well as applicable loads from rain, wind, gutters, etc. As for the cleaning of roof, it must be cleaned at least once every year, at the end of the dry season. Every day throughout the wet season the roof must be inspected to ensure that no debris has accumulated on the roof or has become lodged in the gutters. If any debris is found on the roof, it must be removed. Contaminants on the roof must be cleaned off using a broom.

The water will be transported from the roof to the water holding tanks using 110mm diameter PVC pipes. The pipes will be fastened to the roof, columns, and tanks to provide support and minimize stress on the suspended sections. Straight sections, elbows, and T-shaped connectors will be used. The pipes must be cleaned and inspected periodically. Every month the pipes that are connected to the leave screen must be inspected, if there is organic material buildup, the pipes will have to be cleaned and rinsed with a bleach solution. At the end of the dry season, the pipes should be inspected for any buildup of dirt or debris. Remove using a brush. If the pipes are experiencing a backup and water is flowing through less quickly (overflow of the gutters without heavy rain is a good indication) the pipe is most likely clogged. Follow step 2 to remove this. Inspect the first flush for buildup of dirt or organic materials each time it is emptied (described in the First Flush section under the Operations section). Remove any material on the sides of the pipe or the ball using a brush.

In order to prevent any large debris from entering the system a leaf catcher will be used. This will catch any larger objects, such as leaves or sticks, and allow them to be washed off the roof, without clogging the pipes leading to the tanks. The leaf screen will be located in the gutter drain into the pipes leading to the tanks. The leaf catcher needs to be checked regularly for debris buildup. If water is not draining into the tanks from the gutters, check to make sure the leaf catcher is completely clear of all debris. If the leaf catcher mesh breaks, replace the mesh. If the mesh is rusted, replace the mesh. If the

PVC component is broken, a replacement can be found at many hardware stores which sell piping.

To store the caught rainwater, 10,000L plastic tanks will be used. These tanks are sealed from the environment besides the inlet, outlet, and overflow to limit contact with environmental factors. The tanks are not see-through to limit algae growth. The tanks will have to be cleaned biannually. To clean the tanks, follow the steps listed below. Drain all water before cleaning. Disconnect the tank from the pipes. Remove tank lid and have someone climb into the tank for cleaning. Wash inside of tank by hand to remove buildup and debris from the walls and bottom, using their discretion on the dirtiness of the inside of the tank. Scrub the inside of the tank with a bleach solution. When scrubbing, do not expose yourself to the fumes/gas (smell) for extended periods of time without breathing protection. Drain ALL of the water used to clean the tanks and remove ALL debris found inside the tank. Replace and secure the tank lid.

5.3 Description of Maintenance Activities

If a hole is found in the tank, a patch can be applied using an adhesive sealant for small holes or these combined with a small piece of plastic for larger holes. If the hole is too large or the patch does not hold, the tank will have to be replaced. If the tank is leaking from one of the access points, the areas that this could be applied to are the tap where water is removed, the inlet where water from the roof enters the tank, and the overflow. Given a small leak, a sealant can be applied to the area to halt the leak. If this does not work or the leak is too large, the access point will have to be removed, cleaned, solvent reapplied, and reconnected as described in the Pipes section. If the structure of the tank is bulging, the structure has most likely partially failed in its chemical structure. Due to this failure, the tank will eventually fail completely, rupturing, while becoming more prone to defects such as holes until that time. The tank will need to be replaced. If the valve used to access the water is leaking, it will have to be replaced.

5.4 Part Replacement Schedule and Availability

Expected Replacements	**When to inspect/replace**	**Who to Contact/Where to find supplies**
leaf catcher screen	Inspect Monthly. Replace when screen is torn.	Musanze Goico Market. EWB will also leave 2 spare screens before leaving.
taps	Replace if leaking from the front of the tap during collection.	Find the identical tap, or another tap that fits the valve, at Musanze Goico Market.
gutters	Inspect monthly. Replace if	Musanze Goico Market.

	leaking or broken.	

5.5 Operations and Maintenance Cost Analysis

A fee of 20 rwf should be collected with each jerrycan taken from the system. The chief/system owner is responsible for keeping track of this collection, saving it, and using it only for operations and maintenance costs. As long as the system is built correctly, major repairs to columns, foundations, tanks, and trusses should not be necessary, as each material was chosen for durability and sustainability. The community will be provided with cleaning brushes, spare leaf catcher screens, bleach, and rags for regular operations and maintenance purposes. Bleach will need to be purchased periodically, but this cost should be covered by the water collection fee and is available either in Cyanika central or a short bus ride away to Goico Market in the nearby city of Musanze. Taps, gutter components, and epoxy may need to be purchased in the rare event of system damage, but this cost should only come once about every five years and should be covered by the remainder of the jerrycan collection fee as well.

5.6 Training Requirements and Roles

The chief of the Gasiza, Ignace, will be the main caretaker of the tanks since the tanks are hosed on his land. He will be in charge of helping direct our construction activities, pulling people and resources as contribution, and providing a connection between EWB and the community. The areas of the systems that need to be checked and inspected throughout the year include the tank, the roof, the pipes and gutters, the first flush systems as well as the leaf catcher. Reference earlier sections as to how to inspect each component as well as to clean it and how to repair any damages to each of the components.

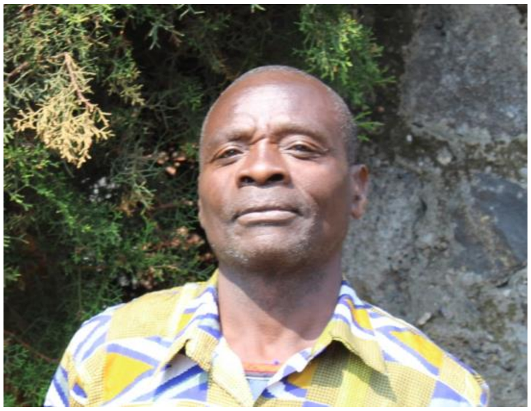
6.0 Community Based Organization CBO

6.1 CBO Structure

The CBO of the Cyanika community is called the Community Vision Board. This is a collection of chiefs of the villages we work in who are responsible for looking after the rainwater catchment systems and communicating with each other. Members of the CBO are chosen by their respective villages as a literate person who can sign official documents and show leadership. Meetings between members of the Community Vision Board are organized by Pastor Jacques, a leader in the community who also works for Village Makeover, one of the NGO's the EWB team partners with.

6.2 Roles and Responsibilities

Current CBO Roles and Responsibilities	
Pastor Jacques: Organizes meetings, communicates with other CBO members	
Hasan: University student who lives in Cyanika and works for Village Makeover. He helps facilitate the connection between EWB and the rest of the CBO through cultural explanation and direct translation.	
Chief Donatien: Chief of the village of Kibaya, in charge of speaking for his people, caring for the rainwater catchment system, and gathering local workers or resources.	

Chief Jean Baptiste: Chief of the village of Munini, in charge of speaking for his people, caring for the rainwater catchment system, and gathering local workers or resources.	
Chief Ignace: Chief of the village of Gasebeya, in charge of speaking for his people, caring for the rainwater catchment system, and gathering local workers or resources.	
Chief Wilson: Chief of the village of Nyarutosho, in charge of speaking for his people, caring for the rainwater catchment system, and gathering local workers or resources.	

Chief Japhet: Chief of the village of Ntarama, in charge of speaking for his people, caring for the rainwater catchment system, and gathering local workers or resources.	
Beatrice: Caretaker for one of the tanks of the Munini system after it was moved from the original site.	
Emmanuel: Caretaker for one of the tanks of the Munini system after it was moved from the original site.	

Chief Ignace: Chief of the village of Gasiza and owner of the rainwater catchment system to be built in Summer 2020. He will be in charge of helping direct our construction activities, pulling people and resources as contribution, and providing a connection between EWB and the community.	

6.3 CBO History of Prior Management

The traditional method for managing the rainwater catchment system is to collect a small fee of 20rwf per jerry can. The village chief* would open the taps for use during set times of the day and monitor the use while collecting fees. Water would sometimes be provided for free to families unable to pay for water. Fee collection and number of jerry cans extracted from the tanks is recorded in the operations and maintenance manual provided to the community. Reports of a month's worth of water use and fees collected is compiled and sent to Village Makeover every quarter, which is then directed to EWB. Fees collected are meant to be saved and used for repairs, operation, and maintenance of the systems.

There are two main potential gaps in the CBO's management abilities. The first is that the small fee collected with each filled jerrycan is sometimes not sufficient to cover maintenance costs such as tap replacement. The team plans to address the issue by training the community to ask for more donations in the event of a major repair and to improve communication with other members of the Community Vision Board so that they can all support each-other in times of need. The other potential gap is that water tank levels are sometimes not sufficiently recorded, making data analysis difficult for our team. The help of a new NGO, Developpement Rural Durable, can help with this issue, as they employ staff that can monitor data collection on a more regular basis and enforce more frequent water quantity recording.

6.4 Sources of Operations and Maintenance Funding

Operation and Maintenance activities and materials are funded by a fee of 20rwf with each jerry can extracted from the system. If funds are insufficient, the corresponding CBO representative is responsible for speaking with other CBO members to gather donations or redirect excess funds from other areas. The CBO may also decide to collect donations from the community in the event of insufficient funds.

6.5 Analysis of Risks to long term Sustainability

One of the greatest risks to the sustainability of the infrastructure is the potential for taps to break, as this was the largest issue observed on the previous monitoring and evaluation trip. The central issue with this is that if a tap is leaky or broken, the system caretaker has to empty the tank before the tap may be removed and replaced. One possible way to mitigate this issue is to install a valve before the tap so that the water can be shut off from the tap, allowing for it to easily be removed and replaced. This also enhances the caretaker's sense of control over the system as they may block water use during certain times by locking the valve without causing damage to the tap.

Another risk is the potential for the tanks to hold bacterial contamination and provide unclean water to the community. This may be mitigated by more consistent, easily understandable tank cleaning procedures.

Both of these mitigation measures would require training with new system caretakers, providing pamphlets to visualize the new procedures and materials involved.

6.6 Training Requirements

6.6.1 Installation of a pre-tap valve

Adding a valve before the tap does not add a significant increase in price to the implementation of the new systems. Communities should be taught how to open and close this valve, as well as when they should allow the community to access the water and when it should be restricted. The system caretaker may choose what times to allow water collection, but fees must be collected during this time, and the valve must be closed during the off time. In the event of a broken tap, the Operations and Maintenance manual details how to mitigate the issue, including shutting off water flow using the valve so that the tap can be removed and replaced.

6.6.2 Tank Cleaning Procedures

Tanks should be cleaned by the system caretaker at least twice per year using a bleach solution and a brush for scrubbing. Full instructions and details are included in the Operations and Maintenance Manual provided to the system caretaker. It is important to inform the system caretaker that the tanks, roof, and gutter systems must be cleaned whenever the tank is empty, as the water in the tank needs to be drained for thorough cleaning. In addition to the Operations and Maintenance Manual, which provides very detailed instructions, the team has also created pamphlets with simple graphics and instructions to remind caretakers to clean the tanks. These may even be pasted directly onto the tanks for easy access. These pamphlets are included in the Appendix. System caretakers will be informed about proper tank cleaning procedures at the final Community Vision Board meeting before the team leaves.

7.0 Monitoring Data Collection

7.1 Data Collection

The team plans to collect survey data during the construction process. Two travel team members will survey community members while the other two monitor the construction process. Printed multiple choice surveys will be used, similar to the surveys used in the Summer 2019 trip, and a translator will be used to aid communication. These surveys will aim to gain information about how much the community is currently walking to collect water, how they treat their water, and where they are sourcing their water from. Shown below are the results of survey data collection for Summer 2019. These will be used to determine what information needs to be collected as well as provide a baseline set of data to compare with this year's data collection.

Question	2017 Responses	2018 Responses
How many jerry cans of water does your household use per day?	N/A	2 jerrycans: 14.4% 3 jerrycans: 28.4% 4 jerrycans: 57.2%
How many people are in your household?	N/A	4-5 people: 57.2% 6-7 people: 14.4% 8+ people: 28.4%
Where do you collect most of your water during the dry season?	N/A	Rainwater Catchment System: 63.4% Tap Stand: 36.4%
Where do you collect most of your water during the rainy season?	N/A	Rainwater catchment system: 100% Tap stand: 0%
From where do you get water primarily? (circle all that apply)	Rainwater Catchment System: 44% Tap Stand: 29% Surface Water: 13% Ground Water/Well: 13%	N/A
When you treat your water, how do you do it?	No treatment: 3% Boiling: 38% Chlorination: 22% Filtration: 17% Iodine Tablets: 20%	Boiling: 70% Chlorination: 10% Filtration: 20%
Has your income changed since the rainwater catchment system was implemented?	Much less: 0% A little less: 0% About the same: 0% A little more: 44% Much more: 56%	Now make more money: 57.7% Now make less money: 0% Make the same amount of money: 42.3%

Figure 5: Indicator question findings after travel for the villages of Munini, Nyarutosho, Gasebya, Ntarama, and Kibaya

Indicator Question:	**Findings:**
Reduction in number of trips over 1 mile that community members must take to acquire water. This is answered with the average	Munini: 2.4 hours Ntarama: 2.0 hours Gasebya: 2.0 hours

amount of time collecting water that was gained with system implementation	Nyarutosho: 1.9 hours Kibaya: 3.5 hours
Increase in school attendance and local business productivity. This answer is reported as the percentage of participants who reported an increase in income after system implementation.	Munini: 100% Ntarama: 100% Gasebya: 100% Nyarutosho: 100% Kibaya: 100% Community members expressed satisfaction with the time they now have available to make money for their families and send their children to school.
Successful implementation of system and community training. System owners were asked the question: Are you able to and comfortable with repairing any problems you've had with the system? Their answers are recorded to the right.	Munini: Yes Ntarama: Yes Gasebya: Yes Nyarutosho: Yes Kibaya: Yes
Community completion of major repairs accurately without EWB-USA.	Munini: Yes, tanks were moved to new locations by the CVB, and progress is going well without EWB-USA. foundations look good, and gutters are being placed properly. Ntarama: Yes, the only major repair is a leaky tap, but the community already has plans to make a simple repair with a local technician. Gasebya: No major repairs to note. Nyarutosho: No major repairs to note. Kibaya: Yes, the only major repair is a leaky tap, but the community already has plans to make a simple repair with a local technician.
Existence of broken components.	Foundations, tanks, roofs, pipe connections, and gutters look fine at all sites. The only broken components observed were a few leaky taps at the sites of Ntarama and Kibaya. These leaks are due to a loose connection between the tap and the tank, but caulking materials were provided by the team, and plans were made within the community to consult a local technician to quickly fix the minor leak.
Level of cleanliness of water storage tanks and gutter system.	Water coming from the tanks has low turbidity and no noticeable smell. All community members report that the water tastes fine, but we still advise boiling or chlorination to disinfect drinking water from the systems. Qualitative coliform bacteria tests, however, all report that bacterial levels in the water may be damaging for human health.

Percentage of community members satisfied with the project.	Though our surveys do not provide a percentage of the community members satisfied with the project, the general consensus from speaking with the community is that the system has given them more time in their day for work/school, has allowed their income to increase, and has provided them with another reliable water source. The village chiefs express genuine gratitude for the systems and are happy with the effects our projects have had on their communities.
Quantity of water available to each household during dry and wet seasons. Exact quantities are not available, but the answer is reported as the percentage of participants that reported using our systems in the dry and wet season, respectively.	Munini: 60%, 100% Ntarama: 100%, 80% Gasebya: 50%, 75% Nyarutosho: 20%, 100% Kibaya: 40%, 100%
CBO Financial Management	Village chiefs are successfully collecting 20RWF fees for each jerry can of water collected, but this oftentimes does not provide enough financial capital for maintenance. The village chiefs seem to be making the necessary repairs anyway, using additional money gathered from the community. The CBO is also unable to provide 10% of the project cost but has agreed to offer free volunteer labor to build the systems in order to make up for this deficit.
Seasonal fluctuations and water quantity	In the Cyanika region, there are two main seasons in a year: the rainy season and the dry season. The main idea of the water catchment system is to gather water during the rainy season, filling up the tanks, so that water is stored and readily available for the dry season. All of the village chiefs reported having dry tanks for the last two months of the dry season, which is a concern we wish to address in future systems. The chief of the Nyarutosho system reported that his tanks are sometimes overflowing during peak flows of the rainy season as well. The next water level reports will be available in October.

7.2 Other Factors Contributing or Hindering Development

In Rwanda there are government tap stands, however many of them are not necessarily close to resident's homes. In Rwanda only 53% of the rural population has access to basic water services. The majority of those water services include government tap stands. In addition to the work that our NGO, Development Rural Durable, does in the construction and implementation of rainwater catchment systems, DRD also works with sustainable agriculture in Rwanda. DRD is a partner with N2Africa, an organization that is currently working on agricultural projects including growing legumes in Rwanda. DRD also works with Harvest Plus, an organization that is working to improve nutrition and public health in Rwanda. They do this by promoting the consumption of beans to provide more iron in people's diets. The organization provides the farmers with free seed packs which they are able to pay back the cost of after the beans are harvested. They also work in training farmers in crop management, marketing, and post harvesting management.

7.3 Beneficiary Analysis

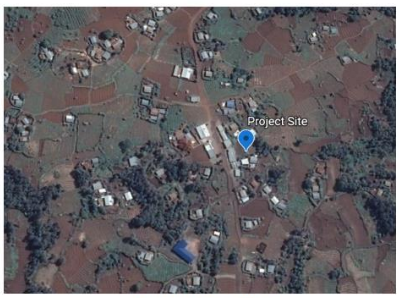
The number of beneficiaries for this project is 950. The definition for beneficiaries provided by EWB-USA for this type of project is the number of people that are collecting water for the system within a 30 minute round trip. So, there will be 950 that live within 30 minutes roundtrip of the system that will be collecting water from that system. The number of beneficiaries for this specific system will be updated and/or confirmed when in country. If there are more beneficiaries than reported here in this document that number will be recorded and will replace the current number expected. If the number of beneficiaries is less than expected the number will also be adjusted accordingly to accurately report the number of people using the system.

8.0 List of Attachments

Attachment A: Drawing Package
Attachment B: Schedule
Attachment C: Construction Cost Estimate/Material Takeoff
Attachment D: Specifications
Attachment E: Design Calculations
Attachment F: Construction Safety Plan
Attachment G: Operations and Maintenance Plan and Training Pamphlets
Attachment H: Partnership Agreement
Attachment I: Material Sourcing

Attachment A: Drawing Package

COUNTRY MAP



VICINITY MAP

Rainwater Collection System
Gasiza
Rwanda

DRAWING INDEX			
FIGURE	TITLE	DATE	REVISION
1	Title Sheet	01/17/20	A
2	Plan View	01/26/20	A
3	Model View	01/26/20	A
4	Special Components	01/26/20	A

1/17/20	A
DATE	REVISION

EWB Univeristy of Colorado - Boulder
Rwanda
Gasiza, Rwanda - Water Supply (RWC)

Drawing Package

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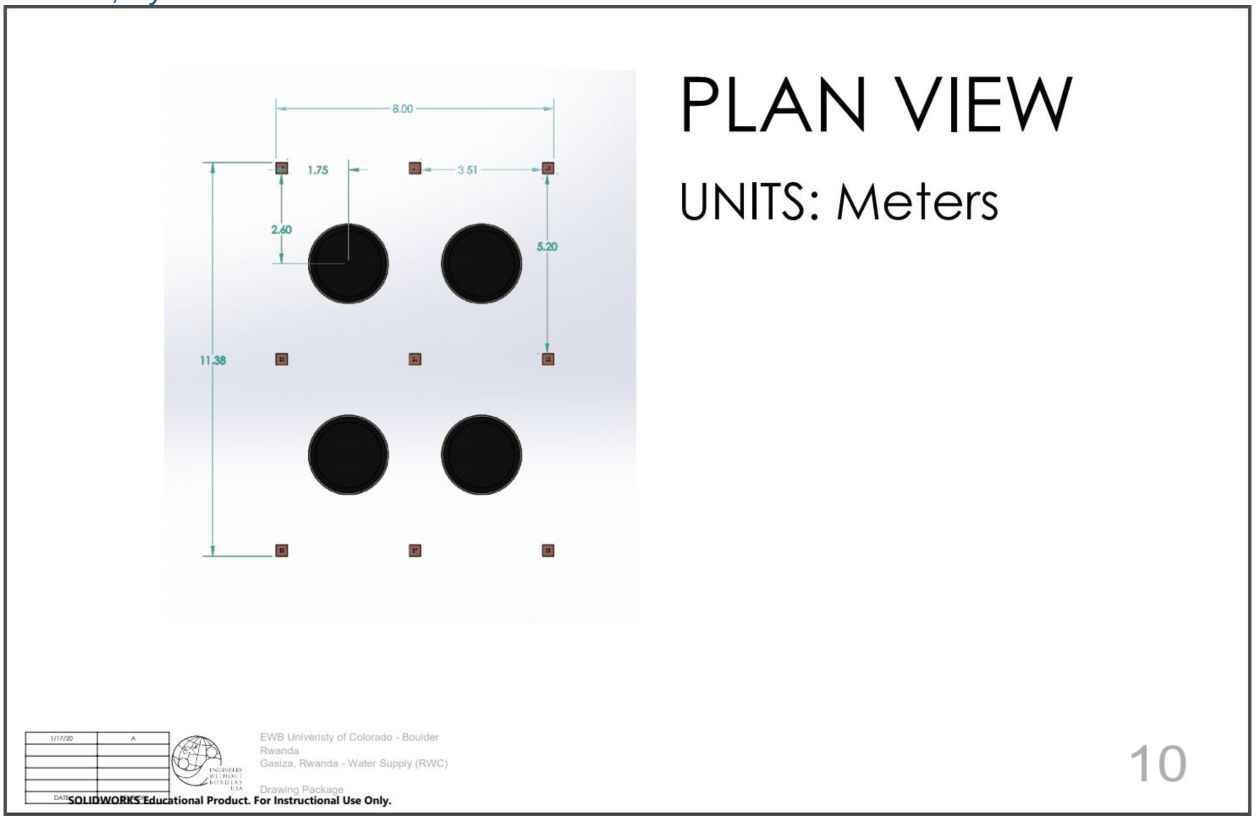
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2.60
5.20
11.38
1/17/20
A
DATE
ENGINEERS WITHOUT BORDERS USA
EWB Univeristy of Colorado - Boulder
Rwanda
Gasiza, Rwanda - Water Supply (RWC)
Drawing Package
SOLIDWORKS Educational Product. For Instructional Use Only.
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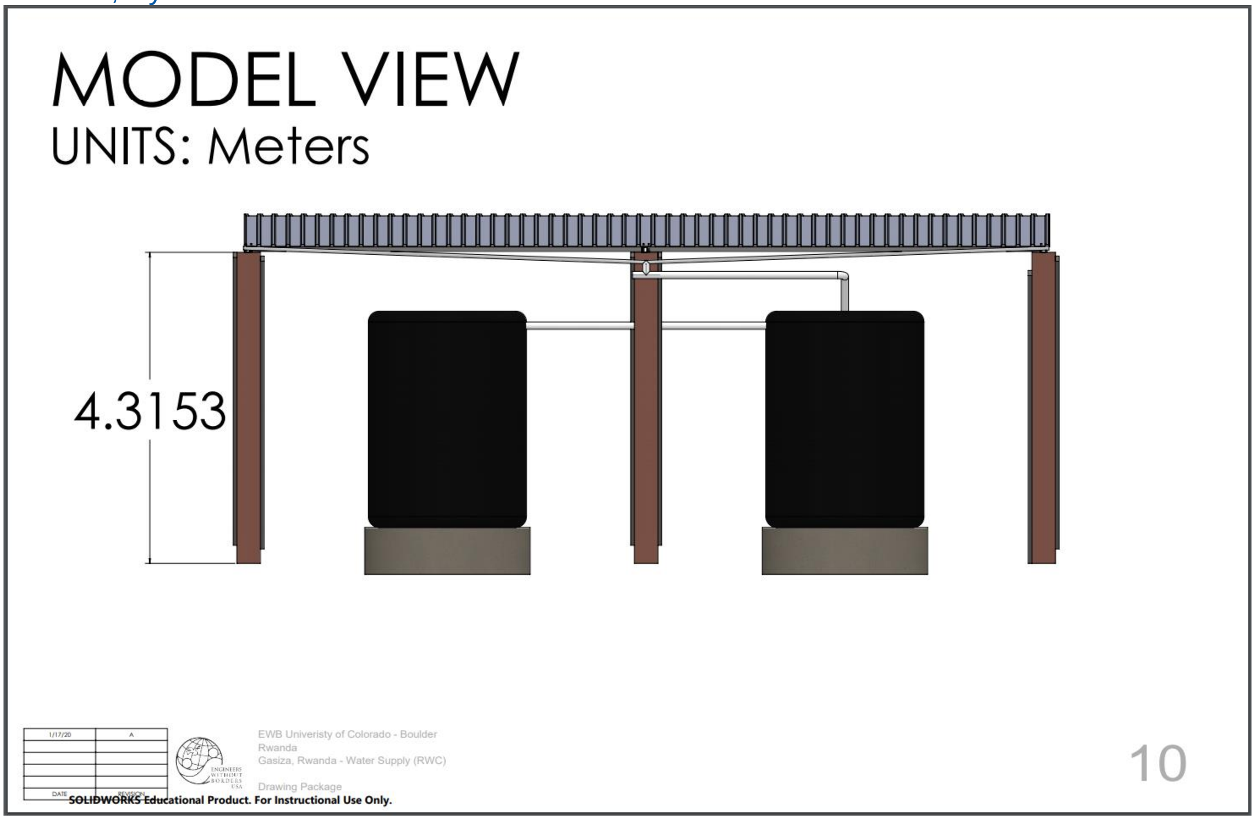
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Gasiza, Rwanda - Water Supply (RWC)
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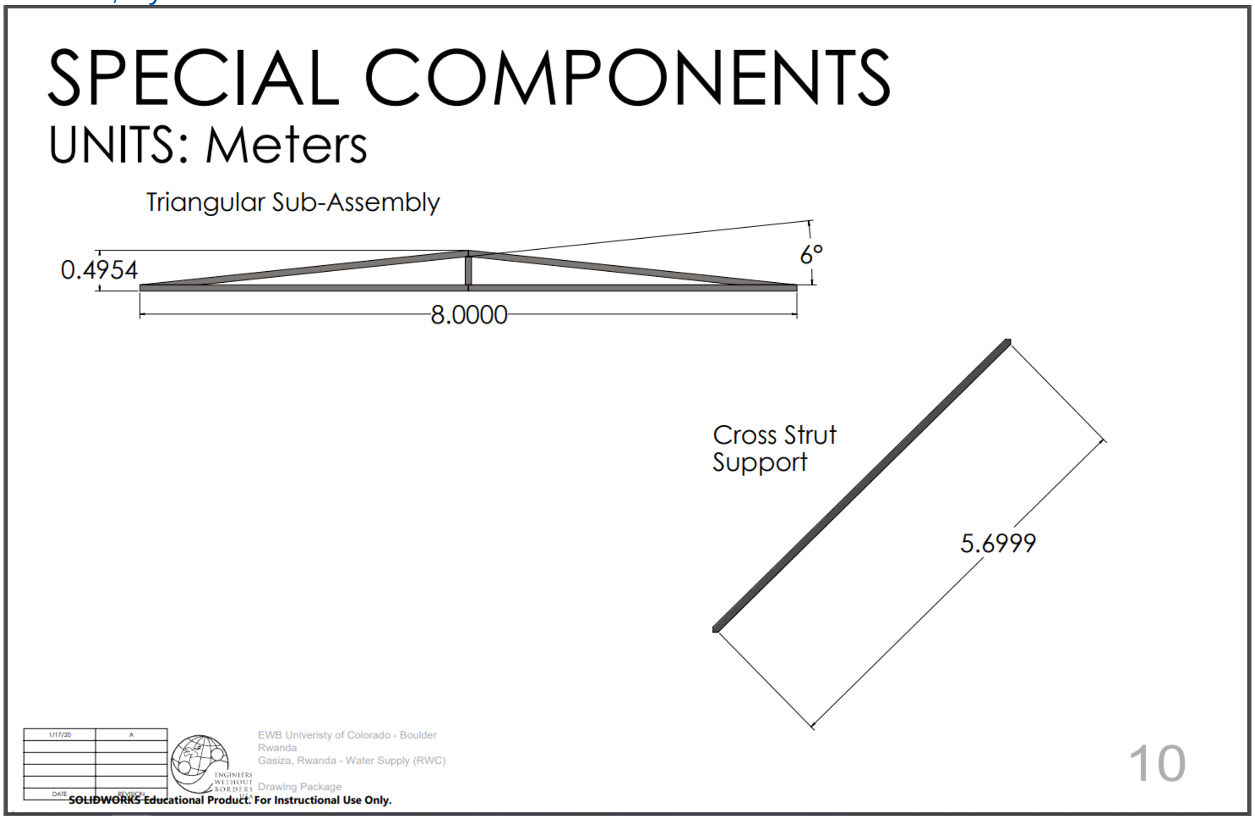
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6°
8.0000
Cross Strut Support
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Rwanda
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Attachment B: Schedule

Pre-Trip Itinerary:

EWB Rwanda 2020 Summer Travel Itinerary

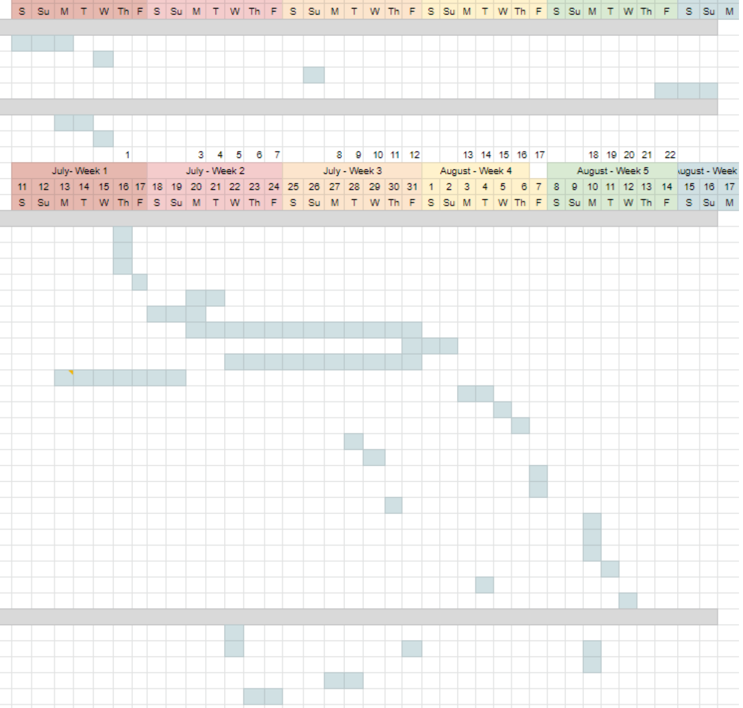
Week 1 | Week 2 | Week 3 | Week 4 | Week 5

#	Day	Date	Activities
Day 1	Saturday	11-Jul	Leave Denver
Day 2	Sunday	12-Jul	Travel
Day 3	Monday	13-Jul	Travel/Adjusting/Start Gathering Materials
Day 4	Tuesday	14-Jul	Get Materials in Kigali. Truss construction begins
Day 5	Wednesdi	15-Jul	Travel to Musanze, Check into Fatima, gather materials for concrete/site clearing
Day 6	Thursday	16-Jul	Clear/level the site, prepare column concrete pouring.
Day 7	Friday	17-Jul	pour concrete for columns
Day 8	Saturday	18-Jul	*set time for column foundations before bricks can go on.
Day 9	Sunday	19-Jul	
Day 10	Monday	20-Jul	Start building columns and pouring concrete for tank foundations
Day 11	Tuesday	21-Jul	Build columns and pour concrete for tank foundations
Day 12	Wednesdi	22-Jul	Build columns and check on truss construction, first meeting with the CVB, Community Surveys in Gasiza
Day 13	Thursday	23-Jul	Build columns and check on truss construction, visit INES
Day 14	Friday	24-Jul	Build columns, Visit INES
Day 15	Saturday	25-Jul	Safari?
Day 16	Sunday	26-Jul	Drop Kara off at airport, Genocide memorial
Day 17	Monday	27-Jul	Build columns
Day 18	Tuesday	28-Jul	Build columns, cut/measure PVC Piping
Day 19	Wednesdi	29-Jul	Build columns, finish first flush
Day 20	Thursday	30-Jul	Build columns, cut holes in tanks for PVC
Day 21	Friday	31-Jul	Build columns, Community Surveys in Gasiza
Day 22	Saturday	1-Aug	*set time for columns before trusses can be added
Day 23	Sunday	2-Aug	
Day 24	Monday	3-Aug	Attach trusses
Day 25	Tuesday	4-Aug	Attach trussses
Day 26	Wednesdi	5-Aug	Attach Roof, insert cross bracing and cross beams
Day 27	Thursday	6-Aug	Attach Tanks /Piping
Day 28	Friday	7-Aug	Attach Roof, gutters, tanks
Day 29	Saturday	8-Aug	
Day 30	Sunday	9-Aug	
Day 31	Monday	10-Aug	Attach PVC piping from gutters to tanks, build tank to tap connections, level area to place jerrycan, final meeting with CVB
Day 32	Tuesday	11-Aug	Opening the system/Community Vision Board Meeting/Operations and Maintenance Training
Day 33	Wednesdi	12-Aug	Finish up
Day 34	Thursday	13-Aug	Extra time
Day 35	Friday	14-Aug	Extra Time
Day 36	Saturday	15-Aug	Day in Kigali. Explore/fun stuff
Day 37	Sunday	16-Aug	Leave Kigali
Day 38	Monday	17-Aug	Arrive home

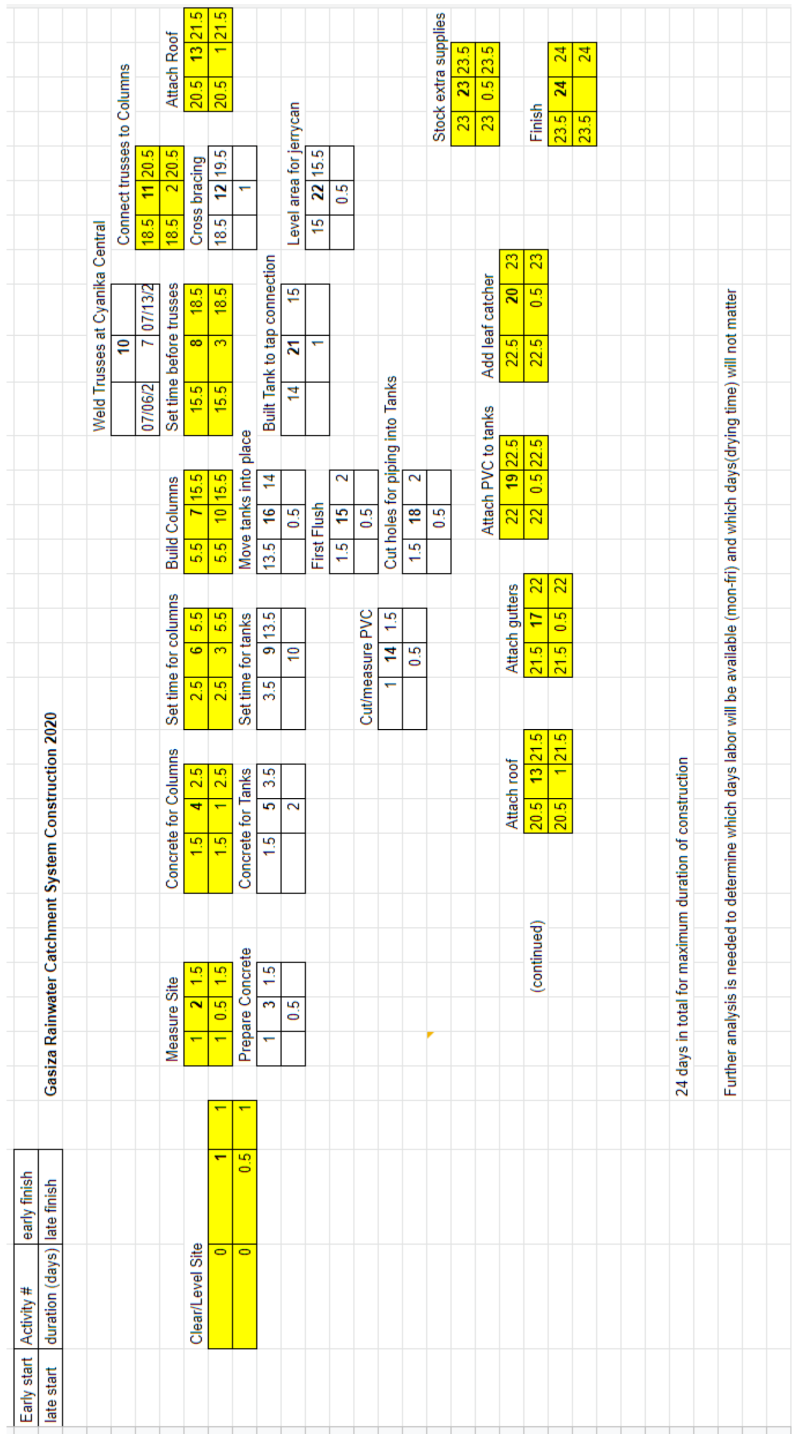
24 cure time for column foundation before bricks can go on (72 is better)
Tank foundations cure for 72 hours before you can put an empty tank on top
Completed columns must cure 72 hours before trusses go on top

Gantt Chart:

	Task	Dependent on	Start	End	Duration
	Task Category 1: Travel				
1	Flight to Kigali		Jul 11	Jul 13	3 days
2	Travel to Musanze		July 15	July 15	0.5 days
3	Bring Kara Back to Kigali		July 26	July 26	1 day
4	Travel Home		Aug 15	Aug 17	3 days
	Task Category 2: Gathering Materials				
1	Kigali Materials		July 13	July 14	1.5 days
2	Musanze materials for concrete/site clearing		July 15	July 15	0.5 days
	Task Category 3: Construction				
1	Clear/Level the Site		July 16	July 16	0.5 days
2	Measure column/tank footer distances and m	1	July 16	July 16	0.5 days
3	Prepare concrete to pour	1	July 16	July 16	0.5 days
4	Pour concrete for column foundations	2,3	Jul 17	Jul 17	1 day
5	Pour concrete for tank foundations	2,3	Jul 20	Jul 21	2 days
6	Set time for column foundation	4	Jul 18	Jul 19	3 days
7	Build Columns	6	Jul 20	Jul 31	10 days
8	Set time for columns before adding trusses	7	Jul 31	Aug 2	3 days
9	Set time for tank foundation	5	Jul 22	Jul 31	10 days
10	Weld trusses together at Cyanika Central		Jul 6	Jul 13	7 days
11	Connect trusses to Columns	8,10,11	Aug 3	Aug 4	2 days
12	Insert cross bracing and cross beams	8	Aug 5	Aug 5	1 day
13	Attach Roof	12	Aug 6	Aug 6	1 day
14	Cut/Measure PVC piping		Jul 28	Jul 28	0.5 days
15	Construct First Flush System	14	Jul 29	Jul 29	0.5 days
16	Move Tanks into place	9	Aug 7	Aug 7	0.5 days
17	Attach Gutters to roof	13	Aug 7	Aug 7	0.5 days
18	Cut holes for piping into Tanks	14	Jul 30	Jul 30	0.25 days
19	Attach PVC piping from gutters to Tanks	17,18	Aug 10	Aug 10	0.5 days
20	Add Leaf Catcher	19	Aug 10	Aug 10	0.25 days
21	Build tank to tap connection	16	Aug 10	Aug 10	1 day
22	Level area to place jerrycan	16	Aug 11	Aug 11	0.5 days
23	Stock extra supplies for repairs	20,22	Aug 4	Aug 4	0.5 days
24	FINISH	23	Aug 12	Aug 12	
	Task Category 4: Community Interaction, Assessment, Monitoring/Evaluation, Training				
	Initial Meeting With CVB		Jul 22	Jul 22	0.5 days
	Community Surveys in Gasiza		Jul 22	Jul 31	2 days
	Final Meeting With CVB/O&M Training		Aug 10	Aug 10	1 day
	Monitoring/Evaluation of Previous Systems		Jul 27	Jul 28	2 days
	Visit INES		Jul 23	Jul 24	2 days



Critical Path Analysis:



Attachment C: Construction Cost Estimate/Material Takeoff

Overall EWB USA Trip Budget for Summer 2020 Implementation:

EWB-USA TRIP BUDGET			
EWB-USA Chapter Name ::	**CU Boulder: Rwanda**		EWB-CU
Project Name ::	**Gasiza, Kavunda**		
Primary Trip Activity ::	**Implementation**		Implementation
Lines with an asterisk are automatically calculated.			
			BUDGET
			(2020 Summer Travel)
	Cost (1)	**Quantity**	*Caculated for 5 people over 5 weeks*
Expenses			
DIRECT COSTS TRAVEL			
Travel + Logistics			
Airfare	2200	5	$11,000.00
Food + Lodging (per person, per week)	120	27	$3,240.00
Taxis/Drivers, Exit Fees/Visas, Innoculations/Medical Exams, Insurance)	266	5	$1,330.00
In-Country Logistical Support	10	6	$60.00
Travel and Logistics Sub-Total*			**$15,630.00**
DIRECT COSTS CONSTRUCTION			
Capital Costs = Project Materials + Equipment (itemized)			
Project Materials			
Tanks	1000	4	$4,000.00
Other Materials	$887.75	4	$3,550.98
Equipment/Material Transportation	$147.33	6	$884.00
EWB Project Fee	1200	1	$1,200.00
Material Sub-Total*			**$9,634.98**
Labor			
Local Skilled labor	$171.00	6	$1,026.00
Labor Sub-Total*			**$1,026.00**
Labor and Material Sub-Total			**$10,660.98**
Owed by Chapter Sub-Total*			**$0.00**
Total Trip Cost*			**$26,290.98**
Program Costs			
Student Education and Enrichment (Cultural events, etc)			$30.00
Speakers			$0.00
Speaker Transportation			$20.00
Miscellaneous Program Costs			$100.00
Program Costs Sub Total			$150.00
Estimated Expenses 2019-2020			**$26,440.98**

Material Quantity Takeoff and Detailed Budget:

Detailed Budget (1/12/2020)							
Material	Amount Needed	Unit Cost (USD)	Total Cost (USD)	Unit Cost (RWF)	Total Cost (RWF)	Supplier Contact	Contact Dates
10,000 L Tanks	4	$1,000.00	$4,000.00	933,000.00	3,732,000.00	RotoTanks Rwanda	emailed 11/16
Trusses/Beams (Square Steel sections; 75mmx75mmx3mm, price per 6 m)	28	$49.31	$1,380.68	46,000.00	1,288,000.00	Safintra	called 11/25
4 in diameter PVC Piping (price/6m)	35	$8.00	$280.00	7,464.00	261,240.00	Buildmart	
Roof Sheeting (2.5mm corrugated steel sheeting, painted - price per meter length w/ 88cm width)	26	$13.79	$358.54	3,200.00	83,200.00	Safintra	called 11/25
Wood for Scaffolding	18	$2.50	$45.00	2,332.50	41,985.00	Community	
Bricks (16.67m unit)	2592	$0.03	$77.76	27.99	72,550.08	Musanze Daihatzu RAA	
Concrete (slightly more than Kibaya)	40	$12.50	$500.00	10,500.00	420,000.00	Musanze Market	
Water Taps	5	$12.00	$60.00	11,196.00	55,980.00	Sonatubes Kigali	
Gaskets for Water Taps (Kigali)	5	$10.00	$50.00	9,330.00	46,650.00	Sonatubes Kigali	
PVC Converters	10	$2.00	$20.00	1,866.00	18,660.00		
Elbow, T's PVC	15	$15.00	$225.00	13,995.00	209,925.00		
Teflon Tape	1	$5.00	$5.00	4,665.00	4,665.00	Musanze Market	
Rebar (foundations - need 273m)- 6 m s	46	$10.00	$460.00	9,330.00	429,180.00		
Tarp	1	$10.00	$10.00	9,330.00	9,330.00	Musanze Market	
Caulk	1	$10.00	$10.00	9,330.00	9,330.00		
Mesh (leaf catcher)	2	$8.00	$16.00	7,464.00	14,928.00		
Nails ($/kg)	1	$3.00	$3.00	2,799.00	2,799.00		
Gloves	2	$10.00	$20.00	9,330.00	18,660.00		
Spare Materials and Cleaning Supplies	1	$30.00	$30.00	28,050.00	28,050.00	Musanze Market	
TOTAL MATERIALS			$7,550.98		6,747,132.08		
LABOR							
Welding ($/day)	5	$20.00	$100.00	18,660.00	93,300.00		
Skilled Labor ($/day)	15	$6.00	$90.00	5,598.00	83,970.00		
Unskilled Labor ($/day)	12	$3.00	$36.00	2,799.00	33,588.00		
Jacques & Hassan			$400.00	373,200.00	373,200.00		
Sangwa & Manirere			$400.00	373,200.00	373,200.00		
TOTAL LABOR			$1,026.00		957,258.00		
Transportation							
Private Van from Kigali to Musanze (DR	2	$120.00	$240.00	111,960.00	223,920.00		
Taxi to gather materials in Kigali	1	$94.00	$94.00	87,702.00	175,404.00		
Tank Transportation	1	$100.00	$100.00	93,300.00	186,600.00		
Masonry & Cement(Musanze to Gasiza	1	$150	$150	139,950.00	279,900.00		
Steel Trusses(Kigali to Cyanika)	1	$100.00	$100.00	93,300.00	93,300.00		
Transport from Cyanika Central to site		$200.00	$200	186,600.00	186,600.00		
TOTAL TRANSPORTATION			$884.00		959,124.00		
TOTAL MATERIALS AND LABOR			$9,460.98		8,663,514.08	RWF	