Document 525
PRE-IMPLEMENTATION REPORT

CHAPTER: Rensselaer Polytechnic Institute
COUNTRY: Panama
COMMUNITY: Isla Popa 2 (Sandubidi)
PROJECT: Development of Clean Water Source
TRAVEL DATES: January 5th- 14th 2015

PREPARED BY
Alex Angilella, Kathleen DiMilia, Yuyang Dong, Jesse Freitas, Kyle Geisler, Kammi Shah, Ambar Mena, Vincenz Buhler, Zlata Chernyshenko, David Claxton, James Male, Jesse Diaz, Emily Bujnowski, Allison Luongo

June 15th, 2014

ENGINEERS WITHOUT BORDERS-USA
www.ewb-usa.org

Pre-Implementation Report Part 1 – Administrative Information

1.0 Contact Information

Project Title	Name	Email	Phone	Chapter Name or Organization Name
Project Lead	Jesse Freitas	freitas.jesse@gmail.com	978-303-7536	EWB-RPI
President	Zlata Chernyshenko	Zlata0407@gmail.com	914-382-0405	EWB-RPI
Mentor #1	Alexander Michaels	alexanderdmichaels@gmail.com	518-275-7621	EWB-RPI
Mentor #2	David Railsback	David.Railsback@arcadis-us.com	978-895-3220	EWB-RPI
Mentor #3	Susan Welt	SWelt@geosyntec.com	518-951-9212	EWB-RPI
Faculty Advisor (if applicable)	Chip Kilduff	kilduff@rpi.edu	518-276-2042	EWB-RPI
Health and Safety Officer	Vincenz Buhler	buhlev@rpi.edu	904-563-0917	EWB-RPI
Assistant Health and Safety Officer	Kathleen DiMilia	kathleendimilia@gmail.com	845-707-1481	EWB-RPI
Education Lead	Ambar Mena	menaa2@rpi.edu	857-919-5828	EWB-RPI
NGO/Community Contact	Rajan Patel	Rajan.Patel@ch2m.com		EWB-Panama

2.0 Travel History

Dates of Travel	Assessment or Implementation	Description of Trip
Jan. 7-12, 2012	Assessment 1	First trip to assess project feasibility, community's main problems, and create a relationship with the community members.

Aug. 12-21, 2012	Assessment 2	Second trip to collect additional data, forge partnerships with local organizations, and sign a contract with the community of Isla Popa II.
Aug. 11-19, 2013	Assessment 3	Third trip to assess construction site, complete water tests, and discuss preliminary design with community

3.0 Tentative Travel Team (Subject to Change):

#	Name	E-mail	Phone	Chapter	Student or Professional
1	Kyle Geisler	kgeisler52@gmail.com	845-399-1497	EWB-RPI	Student
2	Vincenz Buhler	vincenz541@gmail.com	904-563-0197	EWB-RPI	Student
3	Kammi Shah	kammishah@gmail.com	908-279-4875	EWB-RPI	Student
4	Jesse Freitas	freitas.jesse@gmail.com	973-303-7536	EWB-RPI	Student
5	Ambar Mena	menaa2@rpi.edu	857-919-5829	EWB-RPI	Student
6	Susan Welt	SWelt@geosyntec.com	518-951-9212	EWB-RPI	Professional
7	David Railsback	David.Railsback@arcadis-us.com	978-895-3220	EWB-RPI	Professional
8	Chip Kilduff	kilduff@rpi.edu	518-276-2042	EWB-RPI	Professional

Due to travel occurring in January 2015, the current travel team will not be selected until the fall of 2014.

4.0 Health and Safety

The travel team will follow the site-specific HASP that has been prepared for this specific trip and has been submitted as a standalone document along with this pre-trip report.

5.0 Planning, Monitoring, Evaluation and Learning (PMEL)

EWB-RPI has reviewed the template for the 901B – Progam Impact Monitoring Report for the upcoming trip. A member of the travel team will be focused on communication with the community and will be responsible for completing this report during the upcoming trip. This report will be submitted at the same time as the 526 during Post-Implementation.

6.0 Budget

6.1 Project Budget

Project ID: 8801
Type of Trip: I

Trip type: A= Assessment; **I**= Implementation; **M**= Monitoring & Evaluation

Trip Expense Category	Estimated Expenses
Direct Costs	
Travel	
Airfare	6500.00
Gas	120.00
Rental Vehicle	
Taxis/Drivers	320.00
Misc.	
Travel Sub-Total	$6940.00
Travel Logistics	
Exit Fees/ Visas	
Inoculations	
Insurance	
Licenses & Fees	
Medical Exams	
Passport Issuance	
Misc.	100.00
Travel Logistics Sub-Total	$100.00
Food & Lodging	
Lodging	100.00

Food & Beverage (Non-alcoholic)	460.00
Misc.	
Food & Lodging Sub-Total	$560.00
Labor	
In-Country logistical support	
Local Skilled labor	
Misc.	
Labor Sub-Total	$0
EWB-USA	
Program QA/QC **(1)** See below	$3,675
EWB-USA Sub-Total	$3675.00
Project Materials & Equipment (Major Category Summary) add rows if needed	
See Cost Estimate (Section 7)	1600.00
Prototyping at RPI	160.00
Contractor Expenses	200.00
Project Materials & Equipment Sub-Total	1960.00
Misc. *(Major Category Summary)*	
Report Preparation	
Advertising & Marketing	
Postage & Delivery	
Misc. Other	
Misc. Sub-Total	$0
TOTAL	$13,235

(1) Program QA/QC
Assessment = $1,500
Implementation = $3,675
Monitoring = $1,125

EWB-USA National office use:

Indirect Costs	
EWB-USA	
Program Infrastructure **(2)** See Below	
Sub-Total	$0

TRIP GRAND TOTAL (Does not include Non-Budget Items)	$0

(2) Program Infrastructure
Assessment = $500
Implementation = $1,225
Monitoring = $375

Non-Budget Items:

Additional Contributions to Project Costs	
Community	
Labor	
Materials	
Logistics	
Cash	80.00
Other	
Community Sub-Total	$80.00
EWB-USA Professional Service In-Kind	
Professional Service Hours	
Hours converted to $ *(1 hour = $100)*	$0
Professional Service In-Kind Sub-Total	$0
TRIP GRAND TOTAL (Includes Non-Budget Items)	$13315.00

Chapter Revenue

Funds Raised for Project by Source	**Actual Raised to Date**
Source and Amount *(Expand as Needed)*	
Engineering Societies	0
Corporations	0
University	10,000.00
Rotary	0
Grants - Government	0

Grants - Foundation/Trusts	0
Grants - EWB-USA program	18,500.00
Other Nonprofits	0
Individuals	1,403.54
Special Events	1,812.00
Misc.	
EWB-USA Program QA/QC Subsidy **(3)** See below	
EWB-USA Program Infrastructure Discount Amount	
Total	$31,715.54

Remaining Funds Needed	**$13,315.00**

(3) Program QA/QC & Infrastructure Subsidy:
Assessment = $1500
Implementation = $3,900
Monitoring = $1,000

6.2 Donors and Funding

Table 1 EWB-RPI Donations Since August 2012 Assessment Trip

Donor Name	Type (company, foundation, private, in-kind)	Account Kept at EWB-USA?	Amount
Boeing (F11)	Company	Y	$4,000.00
Arcadis (F11)	Company	Y	$2,000.00
Pratt and Whitney (S12)	Company	Y	$8,500.00
Boeing (S12)	Company	Y	$2,000.00
Arcadis (S12)	Company	Y	$2,000.00
SoE Dean's Global Initiatives Grant (F13)	University	N	$10,000.00
Boeing (F13)	Company	Y	
Pratt and Whitney (F13)	Company	Y	
EWB End of Year Giving Campaign	Private	Y	1,812.00
F12-S13 On Campus Fundraising	Private	N	$1,403.54
Total Amount Raised:			**$31,715.54**

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

Water Supply
____ Source Development
__X__ Water Storage
__X__ Water Distribution
__X__ Water Treatment
____ Water Pump

Sanitation
____ Latrine
____ Gray Water System
____ Black Water System

Structures
____ Bridge
____ Building

Civil Works
____ Roads
____ Drainage
____ Dams

Energy
____ Fuel
____ Electricity

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

Information Systems
____ Computer Service

8.0 Project Location

Latitude: -82.11667
Longitude: 8.183333

9.0 Project Impact

Number of persons directly affected: 350
Number of persons indirectly affected: 350+

10.0 Professional Mentor/Technical Lead Resume

Alexander D. Michaels
151 Jefferson Street, Building 4, Apt 2B, Saratoga Springs, NY 12866
Cell Phone: (518) 275-7621
alexanderdmichaels@gmail.com

EDUCATION

University of Rochester, 2009, Rochester, NY - Chemical Engineering

ACCOMPLISHMENTS

- Passed the Fundamentals of Engineering (FE) exam
- Mentor to RPI Engineers Without Borders Chapter
- Dean's List for multiple semesters at the University of Rochester
- Shelby A. Miller Award for best Chemical Engineering senior design project

WORK EXPERIENCE

L&S Energy Services, Inc., Clifton Park, NY – Energy Engineer (2013-Present)

Working as a consultant to identify and assess energy conservation opportunities for building systems.

- Working to complete energy audits for commercial and industrial buildings
- Reviewed NYSERDA and National Grid incentive applications to evaluate energy savings, cost savings and compliance with program requirements. Applications frequently included lighting, heating, cooling, ventilation, motors and controls.
- Supported the Policy Planning and Market Transformation group at NYSERDA. Consulting services offered for Emerging Technologies Accelerated Commercialization program and the Small Commercial Energy Efficiency Program.

Adviser to RPI Engineers Without Borders Chapter (2011-Present)

Working as a volunteer with RPI students, RPI staff and NGOs to help deliver water quality project in Panama.

- Advising students to help meet technical, organizational and reporting requirements of the project
- Helped plan and took part in three assessment trips to study current water quality conditions and understand community culture, wants and needs

Malcolm Pirnie, the Water Division of ARCADIS, Clifton Park, NY - Energy Engineer (2009-2013)

Worked with the Energy Services group to provide consulting services to identify and assess energy conservation opportunities for building and process systems.

- Completed multiple energy audits of municipal wastewater treatment plants, including assessment of water distribution systems.

- Worked with small team manage NYSERDA Existing Facilities Pre-Qualified Program.
- Managed company's review of NYSERDA Existing Facilities Pre-Qualified Program applications.
- Reviewed NYSERDA incentive applications to evaluate energy savings, cost savings and compliance with program requirements. Applications frequently included lighting, HVAC and process systems. Total amount of incentives reviewed exceeded $1 million.
- Coordinated with NYS farmers to carry out Measurement and Verification plans for NYSERDA program incentivizing electric generation from implemented anaerobic digesters.

NYS Energy Research and Development Authority (NYSERDA), Albany, NY - Intern (2008-2009)

Worked to help allocate funding for projects to maximize efficiency, limit emissions and reduce fuel consumption within the transportation group.

- Developed system to rank applicants and allocate funds from a legal settlement based on several criteria, most importantly total emissions displaced and region of NYS.
- Researched potential projects for the Clean Cities Challenge, which encouraged plans that accelerate the introduction of alternative fuel vehicles.
- Investigated projects to find which offered the best investment to reduce vehicle commuting miles and emissions in NYS.

Albany Molecular Research, Inc., Rensselaer, NY - Materials Management Intern (2007)

Completed projects focused on improving internal efficiency and customer satisfaction.

- Researched most popular packaging options and assembled selections into a standard packaging catalog for customers.
- Developed and implemented a coding system to maximize information in the limited space available when describing the company's inventory.

PERSONAL INTERESTS

Skiing

Golf

Traveling

David M. Railsback, PE
563 North Broadway, Apt 1 Saratoga Springs, NY 12866
978-895-3220
David.m.railsback@gmail.com

Education

M.Eng. Environmental Fluid Mechanics & Hydrology **January 2009**

GPA 3.86, Cornell University, Ithaca, NY

B.S. Civil & Environmental Engineering **May 2008**

GPA 3.29, Tech GPA 3.41, Cornell University, Ithaca, NY

Consulting Experience

Environmental Engineer, ARCADIS, Clifton Park, NY **February 2009 - Present**

Performed hydraulic and hydrologic analysis and design for a wide range of engineering projects. Gained experience in wastewater treatment facility design, stormwater drainage, dam safety analysis, water quality analysis, pumping systems and energy efficiency analysis. Responsible for reports, presentations, numerical modeling, field sampling activities, and data analysis.

Bypass Tunnel of the Delaware Aqueduct, Roseton, NY

-Developed dewatering methods for a rehabilitation project at the Rondout-West Branch Tunnel. The 45-mile long, 13.5-foot diameter tunnel is one of New York City's primary drinking water aqueducts.

-Examined dewatering options, including pumping operations, using WaterCAD and other modeling software.

-Analyzed construction alternatives using WaterCAD to determine hydraulic capacities.

-Collaborated with a multidisciplinary team to produce reports and PowerPoint presentations for delivery to the New York City Department of Environmental Protection.

Wastewater Treatment Facility Energy Conservation Study, Margaretville, NY

-Performed a facility-wide study of a 2-mgd advanced wastewater treatment facility, including an on-site audit of the facility to evaluate operations. Identified opportunities for greenhouse gas emission reduction, energy efficiency improvements and cost reduction.

-Analysis included pumping, membrane filtration, rotating biological

contactors, septage handling, UV disinfection and aeration.
-Collaborated with building system engineers to produce a report for the client, providing sufficient detail to allow improvement projects to be evaluated and prioritized for implementation.
-Prepared probable construction costs, estimated energy savings, and provided an economic analysis for each process improvement project. The recommended projects produced an annual cost savings of $20,000 with a capital cost of $170,000, resulting in a simple payback of 8.5 years. The recommended projects generate an annual energy savings of 200,000 kWh, reducing equivalent greenhouse gas emissions by 75,000 kg CO_2 per year.

United Nations Human Settlements Program (UN-Habitat), Mindanao, Philippines
-Provided post-flood urban development recommendations for the cities of Iligan and Cagayan de Oro, located on the Island of Mindanao in the Philippines.
-The cities were severely impacted by flooding which resulted from a tropical storm in December 2011.
-Coordinated with a multi-disciplined team to perform rapid assessments of the watersheds, affected communities, and damaged infrastructure. Prepared a report for each city and presented recommendations to city officials.

Onondaga County Water Authority Pump Station, Onondaga County, NY
-Performed an energy efficiency study of the Thurber Street and Seneca Turnpike Pumping Stations for the Onondaga County Water Authority. The study was performed under the NYSERDA FlexTech program.
-Reviewed baseline operating conditions and examined various equipment upgrades including variable frequency drive motors.
-Examined operational improvements, such as off-peak load shifting.
-The recommended energy conservation measures for pumping equipment upgrades and operational changes would result in an annual energy use reduction of approximately 128,000 kWh, and an annual savings of approximately $12,800.

Albany Combined Sewer Overflow Tributary Sampling, Albany, NY
-Performed wet-weather sample collection for a Combined Sewer Overflow (CSO) investigation of the Hudson River.
-Assisted with data analysis to isolate sources of fecal coliform.

Professional Certifications

Professional Engineer, NY (No. 091737) **December 2012**

OSHA 40-Hour HAZWOPER and Confined Space Entry **November 2012**

Construction Documents Technologist (CDT) **April 2010**

Related Skills

WaterCAD, Hammer, HEC-RAS, HEC-HMS, BioWin, CORMIX, Matlab, MathCAD, AutoCAD, ArcGIS,
Microsoft Office Word, Excel & PowerPoint, Intermediate Spanish

Professional Organizations

American Water Works Association (Events Committee)

New York Water & Environment Association

Engineers Without Borders

Additional Engineering Experience

Engineering Team Leader, AguaClara, Cornell University **Fall 2006 – Spring 2008**

-Led a Cornell Engineering team in economizing the design of gravity-powered water treatment plants being built in Honduras.
-Designed a gravity-powered automated chemical delivery system.
-Participated in two site visits in Honduras, in cooperation with a Honduran partner organization.

Research Assistant, Rapid Sand Filters, Cornell University **Fall 2007 – Spring 2008**

-Built an experimental test apparatus to study particle removal in chemically pretreated filters used for drinking water.
-Conducted computer-controlled experiments and performed data analysis.

Volunteer Experience

Engineering Mentor, RPI Chapter of Engineers Without Borders Present

Providing professional guidance to university students engaged in a water supply improvement project for an indigenous community in Bocas del Toro, Panama.

Engineering Mentor, Future Cities Competition 2009

Introduced middle school students at Saratoga Springs Catholic School to engineering principals through participation in an urban design competition.

Interests

Whitewater Rafting (DEC Certified Guide, Hudson River Gorge, NY)

Photography, Kayaking, Skiing, Sailing, PADI Advanced Open Water Diver

Awards

Cornell University John McMullen Dean's Scholar, Dean's List and Global Fellow

Eagle Scout

Pre-Implementation Report Part 2 – Technical Information

1.0 EXECUTIVE SUMMARY

The student chapter of Engineers Without Borders at Rensselaer Polytechnic Institute (EWB-RPI) has been working with the community of Isla Popa II since November 2010 to develop a sustainable, reliable, and clean source of drinking water for the approximately 350 community members. The chapter has spent the last three and a half years assessing the community conditions, analyzing alternatives, and engineering solutions. In preparation for entering the implementation phase and the fourth project trip, this document expresses a detailed understanding of the problem and presents a procedure and solution.

Student members and professional mentors have conducted three assessment trips to build relationships with the newly initiated community water board and other locals, and to determine the most feasible ways to address the concern of water quality and quantity. Chapter members have designed a rainwater catchment system to build on the community pavilion for use by the school which will incorporate a first flush mechanism and have also created documents and guidelines for single household rainwater catchment installation that detail required materials, construction directions, and maintenance plans. The water collected from the system will be filtered using point-of-use biosand filters separate from the catchment system.

Because the project is a collaborative effort, the community will contribute a portion of the construction materials and the majority of the labor. After completion, the project will be owned, operated and maintained by the community water board. In addition to the system design and engineering calculations, the project team has included plans to acquire and deliver construction materials before arriving at the island. The community president and Engineers Without Borders Panama, an in country partner, are involved in the material collection and storage. The construction plan is a five day building schedule for the system that includes gutters and pipes attached to the building's metal roof, the water storage tank and support assembly, the first flush piping system, and an isolated four point-of-use biosand filtration systems.

Lastly, because transfer of knowledge is necessary to keep the project sustainable, the trip will include community education and tank based water management plans. These major topics of general sanitation and hygienic practices will be detailed in documents distributed to community members and also explained during community meetings.

2.0 INTRODUCTION

The purpose of this document is to present the design for a rainwater catchment system to be constructed at the community center pavilion in the village of Isla Popa II (Sandubidi), Panama. Furthermore, it outlines the design of point-of-use bio-sand filters that will act at the primary method for water disinfection of this harvested rainwater. This rainwater catchment system will serve as a pilot program for the future implementation of the system throughout the entire community. The pilot program will allow the project team to demonstrate the system to the community as well as better prepare for the next phase of the project, wider implementation of home-based water catchment systems by the community and monitoring of the existing systems.

Isla Popa II has expressed their need and desire for an improved water system. Most of the community's 350 members drink, cook, and clean with water from contaminated water sources. The previous three assessment trips allowed the team to evaluate the community's situation. On the first assessment trip in January of 2012, the project team made several accomplishments. A relationship with the community was established as well as a better understanding of the community's water-related challenges. The project team collected data on the existing water sources and the geography of the community. A community water board was also created during this assessment trip. The second assessment trip took place in August of 2012. This trip consisted of making numerous local contacts, signing a local partner and community agreement, having water samples tested by a lab, collecting additional data on the water sources and geography, and visiting a nearby water source on the island, Ojo de Agua. The third assessment trip in August 2013 consisted of site surveys and water quality data for the upcoming implementation described in this document.

The three assessment trips provided the team with the information needed to perform an alternatives analysis on three different proposed solutions: an aqueduct, a rainwater catchment system, and a well. The team determined that a rainwater catchment system paired with bio-sand filtration is the most effective and sustainable way to provide potable water to the community members of Isla Popa II. The community center pavilion was chosen as the implementation site for the pilot program for several reasons. The structure is fairly new compared to the other structures in the community, it will serve as a central source of water for the school, and it has a very large roof surface area, 196 m^2. The community center pavilion is also not currently being used to collect water via a rainwater catchment system like the school building is. Another factor for choosing the pavilion is its proximity to the school. The children of the community have the most health problems associated with the contaminated drinking sources they are currently using based on communications with an international medical NGO, the Floating Doctors. The proximity of the pilot system to the school building and plan to implement four bio-sand filters in the school cafeteria will improve the children's daily access to clean water. The decision to use the pavilion as a public water catchment area for students at the school will minimize social conflicts that could have occurred if the system was implemented on a specific number of personal homes first. EWB-RPI spoke with multiple community members during the alternatives analysis. They agreed that a public rainwater catchment system on the pavilion is a good decision and provided input to different aspects of the design.

The system will be constructed on the pavilion. The pilot program will be used to evaluate the effectiveness of the designed system, and further assess the quality of gathered water.

3.0 PROGRAM BACKGROUND

The community of Isla Popa II does not have reliable access to clean water. During the first assessment trip, it was established that the community runs out of water during the dry season resulting in community members drinking unsanitary water from simple wells dug by hand. During the rainy season, water gathered by the existing rain catchment systems is generally available, yet this water is not deemed potable by the Panamanian government according to Engineers Without Borders Panama. Field and laboratory tests have shown that the water in the community's current storage tanks becomes contaminated with bacterial agents. This may be due to infrequent tank cleaning and openness of the tanks to the environment. The current rainwater catchment system is also not optimized to the amount of rainfall and the size of the roofs. Many members of the community constructed catchment surfaces near their homes but are using it in conjunction with a tank too large to fill. Other members have tanks that are too small and overflow very quickly causing a significant loss of water. See Appendix B for an analysis of the relationship of tank sizes to roof sizes.

If the family does not have a closed catchment system, they either use barrels open to the environment to catch rainwater or in many cases are forced to rely on shallow well water. These open tanks are not as sanitary because they are vulnerable to mosquitos and animals. Many such "wells" are shallow holes dug into the ground, which are exposed at the surface and are not protected from terrace runoff and contamination by animals. Residents without rainwater catchment systems will often drink this potentially unsafe well water. See Appendix A for water testing results. Due to exposure from animals on the island and runoff from terraces, the coliform bacteria present in the water is naturally much higher in the wells than the bacteria present in the tanks which is why rainwater catchment was selected over the use of wells.

According to a member of the Isla Popa II water board, government subsidized chlorine is given to the community free of charge in hopes that they will treat their contaminated water. Some families treat their water with the allocated chlorine, yet most do not use the appropriate dose of the treatment agent which renders it ineffective. Many community members do not actively treat their water with a sufficient dose of chlorine because it makes their water taste undesirable.

4.0 FACILITY DESIGN

4.1 Description of the Proposed Facilities

The pavilion has a metal roof with a large surface area of 196 m^2 which is excellent for collecting rainwater based on the simulation mentioned in Appendix B. Gutters, to collect and transfer water to the storage tank, will be attached to the facility using galvanized steel straps and will be composed of schedule 40 PVC sawn in half. The gutters will be connected using PVC couplings, bolts, and silicon sealant instead of standard PVC Cement to ensure that the gutters do not warp. This system was suggested by Footprint Possibilities, an NGO working with EWB-Panama and prototyped by a member of EWB-RPI to verify its stability. The catchment tanks will be supported using wooden stands, made from materials provided by the community.

The first one to two millimeters of rainfall that wash contaminants off the roof will be diverted into first flush storage. Once the 11 gallon first flush storage volume is full, the flow will be diverted into clean water storage tank where it will be further treated using bucket bio-sand filters. These filters will be constructed by each family for home use and will effectively treat the rainwater by removing bacteria and reducing turbidity, making the rainwater potable as defined by Panamanian law according to Engineers Without Borders Panama. Four point-of-use water filters will be installed in the community schools and cafeteria during as part of the pilot implementation system.

4.2 Description of Design and Design Calculations

Demand Simulation:
The rainfall data used in calculating the potential water supply for the community is from the Smithsonian Tropical Research Institute, approximately 20 kilometers from the site. See Appendix C.8 and C.9 for a map of the region and a site map. EWB-RPI has acquired more than 10 years of rainfall data with a resolution of 15 minutes. See Appendix B for a sample of a simulation which utilizes rainfall data from the Smithsonian Tropical Research Institute and quantifies the correlation between water use, roof area, and tank size. The full data file will be included as a separate attachment due to its size. The full data file provides information for dates from 5/17/2002 to 1/8/2013.

Gutter Calculation:
Gutters were designed to handle the region's highest-intensity rainfall, estimated to be 81mm/hr according to the rain data from the Smithsonian Tropical Research Institute. The maximum values of rainfall data led to an approximate intensity over a five-minute period to be 120 mm/hr. This was used as a conservative value. The gutters available in country are 4" diameter PVC pipes. Manning's equation for normal flow was used to determine the necessary gutter slope. The quantity of flow was calculated using the rainfall intensity and the planar area of the roof (about 1080 ft^2). The maximum flow that the gutters would need to contain is 5.57 L/s. When entered into Manning's equation a full gutter would need to be sloped about 0.3% in order to carry the maximum flow.

Piping System:
The piping system consists of three main units; gutters, pipes directing water into storage tanks and first flush systems. See Appendix C.5 for a diagram illustrating the entire piping system. Gutters will be constructed from 4'' schedule 40 PVC pipes that have been sawn in half. Sections of gutter will be attached to each other by use of standard PVC couplings. Prototyping performed by EWB-RPI has shown that it is easier to use silicone sealant along with nuts and bolts to fasten the pipe sections to the PVC couplings as opposed to traditional PVC pipe cement. This is due to the tendency of half pipe sections to warp inwards, thus requiring the use of clamps to ensure full contact of pipe and coupling while the PVC cements dries and occasionally did not result in a watertight seal. The use of silicone sealant along with nuts and bolts was chosen to avoid this complication.

There will be a first flush system on both sides of the roof to divert an initial amount contaminated rainfall. Water will be accessed from taps near the bottom of the tank. The tanks have built in outlet pipes to allow for emptying during cleaning and maintenance. All fittings will be pre-sized to allow for easy onsite installation.

First Flush System:

The first flush system will store the first 10 gallons (38 liters) of rain per 1,000 square feet (93 square meters) of roof catchment area. This first flush water will be stored in an 11 gallon pipe that must fill up with water before water is diverted to the storage tank. The decision to store water in a pipe instead of another tank will prevent any confusion as to which tank is holding potable water. Calculations based on the total catchment area that will be supplying water to each tank shows that the length of 4'' PVC pipe required for storage is 16 feet. Please see Appendix C.6 for calculations and references. The manual first flush system was chosen in addition to alternative filtration methods for the following reasons:

- The system is easiest to maintain for the water board
- The system does not require electricity
- The system is expected to last the longest without any damage
- The system will be the easiest to implement and replicate by members of the community
- Necessary materials can be easily obtained on Isla Colon

Biosand Water Filters:

The proposed point-of-use bio-sand water filter is designed to achieve a flow rate of 260 mL/min and is capable of 90% or greater removal of E.coli and Total Coliform water contaminants. The filter is deemed "point-of-use" because it will stand along from the water catchment system and will be fed with water manually at the discretion of the community members. The filter will also reliably reduce the turbidity of influent water to less than 1 NTU [1], meeting the World Health Organization's drinking water standards (<5 NTU acceptable)[2]. The filter was designed according to the Centre for Affordable Water and Sanitation Technology's (CAWST) Version 10 Biosand Filter Manual specifications, and was then scaled down for individual use. This filter design has proven to yield 100% removal of total coliform in many cases, further meeting the World Heath Organization's drinking water standards requiring no detection of coliform in any 100mL sample of filtered water[2]. The bio-sand filter was chosen as the primary method for water treatment due to its affordable cost, ease of use and maintenance, and ability to be integrated households. According to the CAWST Manual, the filter should be cleaned about every 30 days.

Bio-sand water filters are a variant of sand filters comprised of a container with layers of filtration sand (grain sizes less than 0.7mm in diameter) stacked atop of layers of gravel. Water is

[1] Bacteria Removal and turbidity figures from:
CAWST (Centre for Affordable Water and Sanitation Technology). (2010). *Biosand Filter Manual Design, Construction, Installation, Operation and Maintenance: A CAWST Training Manual*

[2] WHO (World Health Organization). (1997). *Guidelines for Drinking-Water Quality (Second Edition)*

poured into the top of the filter, slowly released into the layers of sand then exits the filter with lower turbidity and bacterial contamination. The filter operates by incubating a thin layer of microorganisms near the top that preys upon organisms in the influent water. The CAWST Bio-sand Filter design calls for 31.5 inch high concrete containers to be used as filter housing units. For the first implementation, the concrete will be replaced with 5-gallon plastic buckets (14 inches tall) due to time constraints and the desire to make filters family-based as opposed to community-based. Although the smaller filter will have decreased water treatment volume potential, it is appropriate for a family of moderate size and will be significantly easier to construct. Both the buckets and sand will be obtained from local hardware store, Sertebocas Hardware. The efficacy of the bucket-based bio-sand filter variants were tested by Kristen Lellison, Ph.D, et al. at Lehigh University[3]. According to the study's results which were averaged over a 38 week testing range, there were no significant performance discrepancies between the CAWST Concrete and 5-gallon Bio-sand Filters, and the bucket filters were proven to remove an average of 98.9% Total Coliform of and 99.5% of E.Coli. Thus, Lellison's tests indicate that the biolayer typically extends only 1 to 2 cm into the filtration sand layer of any biosand filter. This further establishes that a 14 inch total filter height used in the 5-gallon bucket design will be acceptable in filtering influent water when compared with the CAWST's filter which is 31.5 inches in height.

Motivated by Lellison' Lehigh bio-sand filter experiments, the 5-gallon bucket design will be comprised of the following layers:

Layer Number	Description	Layer Height (cm)	Note
Lid	Bucket Lid		Necessary to prevent contamination from external sources
1	Influent Reservoir	6.0	Holding area for influent water
2	Diffuser Plate	0.2	Moderates influent flow rate
3	Supernatant	4.0	Layer of permanently standing water above sand layer that nourishes and sustains the biolayer.
4	Fine Sand	16.0	Grain size: <0.7mm
5	Coarse Sand	4.0	Grain size: 0.7mm-6mm
6	Gravel	4.0	Grain size: 6mm-12mm

See Appendix C for design drawings and calculations

4.3 Drawings

See Appendix C for design drawings and calculations

[3] Lellison's tests were documented and published in "Optimizing the Biosand Filter" in 2011.

4.4 Names and Qualifications of Designers

Name	Student or Professional	Qualifications	Work Done
Kammi Shah	Student	Senior level student in civil engineering	Calculations for water system and Tank stand structure analysis
Kyle Geisler	Student	Junior level student in civil engineering	Designing of first flush system and drawings
David Railsback	Professional	Professional Engineer at Arcadis	Checked all drawings and calculations

4.5 524 Preliminary Design Report Comments

EWB-RPI has previously been granted to forgo submitting a 524; instead comments from the first 525 Pre-Implementation report, submitted in 2013, will be addressed here. The following table includes information pertaining to how EWB-RPI has either addressed or is planning to address comments arising from review of the 525 Pre-Implementation report.

Comment	**EWB-RPI Action**
How has communication been with your partners as you have been getting ready for this trip?	Communication has improved over the past 2 months. A community member or member of the water board awaits and answers EWB-USA RPI's calls every Friday at 5 PM Eastern Time or Sunday at 5 PM with solutions and answers to inquiries regarding future implementation workers, operation maintenance, funding of the project, and other unprecedented follow-up questions which will lead the team to a better understanding of a more functional system desired by the community. The team has established two native Spanish speakers, Vincenz Buhler and Ambar Mena as the primary communicators that lead the dialogue with the community, while a third native Spanish speaker, Jesse Diaz occasionally translates via Microsoft Word for the rest of the team to understand the conversation and communicate any concerns that either parties has to one another as well as keep a log of our conversations for future use

	and reference. The local hotel, Laguna Azul, is also extremely helpful and have always been enthusiastic to help however they can.
• It is very difficult to follow your tank sizing analysis and rainfall simulation. Have you summarized what a typical year looks like on a monthly basis? What months will there be overflow? What months will there be a shortage? Or do you think that there will never be overflow and there will always be some volume in the tank? There was little discussion on the tank sizing process other than the simulation you did with two 600-gallon tanks. This is the main calculation of a rainwater catchment system. Why 2 600-gallon tanks?	Appendix B includes a table summarizing the correlation between roof size, tank capacity and daily water consumption. Given the available roof size and water demand it was concluded that a minimum storage capacity of 900 gallons was required to meet the water demand of 250 litres per day. In order to avoid using three 300 gallon tanks which would require more wood, PVC fittings and PVC pipe the team elected to use two tanks which require more than the necessary amount of storage capacity.
I don't really follow the demand assumptions for this pilot. The pilot is on a community pavilion and the number of users is expected to be 5? I don't follow this. At a minimum justification needs to be included but I think the numbers will have to change.	This error has been corrected with the demand now being to supply the community's approximately 100 children with adequate water during school hours. Following the World Health Organizations recommendation that 7.5 liters of potable water be available per day, led to a demand of 2.5 liters per day for the eight or less hours that children will attend school on weekdays. This was used to establish a demand of 250 litres per day on the system.
What capture efficiency was assumed? I'm used to seeing values around 75%.	We assumed a capture efficiency of 80% based on a recommendation from our mentor, Chip Kilduff.
Why two tanks? Why not tie it into one tank?	We wanted to have two completely isolated systems so that if there were problems with one the other would still be functional. The team wanted the community to have other means of retrieving filtered water in case one tank needs maintenance or there was damage that needed repairs.
I saw no details on how the gutters will be mounted.	Gutters we be hung from the roof material through the use of galvanized metal straps, which will be anchored to the large rafters running parallel to the roof's edge. To ensure the gutters don't slip out of the galvanized

	straps a combination of construction adhesive and bolts, running through drilled holes in the gutter and the available holes in the galvanized strap, will be to join the gutters and straps.
It looks like there will be some sort of wood platform that the 600 gallon plastic tank will stand on? I saw no design of this. This will have to be designed and calculations and drawings clearly shown.	These have been done and included in Appendix C.
What about the tank plumbing? There should be a detail on this.	Included as Appendix C.5
How will the tanks be anchored to the wood platforms? When they are empty and there are strong winds couldn't they fall over?	Anything used to fasten the tanks to the stands will jeopardize the integrity of the tanks. The self-weight of an empty 600 gallon tank is enough to prevent it from blowing over based on the calculations in Appendix C. The tank is also cylindrical therefore wind corner magnification is not a concern. The protection around the tanks will also protect the tanks from wind strain.
What about the access points? I didn't see any details on the taps. Community should be involved with this part of the design.	Taps for the tanks are located at the bottom facing the community so that water pressure is high and the tanks can be completely emptied. The tank stands elevate the tank three feet so that water can be collected using a five gallon bucket and transferred to a biosand filter. The community agreed with this because they wanted biosand filters to be separate so filtering water would not be dependent on having a catchment system. The water board has been involved with the treatment solution and has provided input on how they would like to protect and access water from the tanks.
How will drainage be managed at the tap location and at the overflow and first flush cleanout locations?	Either through the use of gravel or shallow drainage ditches. The discharge points are directed towards the back of the pavilion which has a fairly steep, downward slope directly behind it. This slope does not lead to any existing structures and will ensure runoff does not compromise the tank stand or pavilion foundations.
What kind of contingency is built into your construction plan? There will be delays so it is important to plan for that.	The team has estimated that construction will take no more than six days and the plan is to stay in the community for eight days. The team

	has included this buffer to assist with potential issues including delays with arrival of needed materials such as wood or the hardware store and potential damages during the implementation of the system. The team will also ensure that the community is thoroughly educated on sustaining the system and maintaining it using the remaining time.
The tasks in the construction schedule only include construction tasks. Where are educational activities and community meetings in the schedule?	The community will be educated during construction on how to properly repair the system, but additional time will be set aside to demonstrate to the community how to properly maintain the system along with fabrication and maintenance of Bio-Sand Water Filters.

5.0 PROJECT OWNERSHIP

The president of the community, Daniel Viagra, has confirmed that the water board will be the entity responsible for the water catchment system that will be installed at the community center pavilion. During the first implementation trip, the first rainwater catchment system will be installed on the pavilion. The community water board is a group of five members of the community and will be in charge of maintaining the rainwater catchment system in terms of cleaning the apparatus and making sure that any damages are promptly fixed. The school will have access to the clean water produced by the rain water catchment system on a first come first serve basis, while the water board will be responsible for conducting the proper maintenance and understanding the system itself. The water board will also be in charge of acquiring the materials used for the system's construction and referring to the operation maintenance plan given to them for any repair purposes.

6.0 CONSTRUCTION PLAN

While the chapter travels for the construction phase, it will oversee the construction of the water catchment system over an estimated time of six days. Phase I will consist of using the community members' boats to transport the needed construction materials to Isla Popa from Isla Colon, a more commercialized island located approximately 20 kilometers away by water. The following days will be spent preparing the materials and site where the system will be installed. Then the system will be installed using the labor of five members of the water board who have volunteered and the EWB RPI travel team. Construction tasks are detailed in the table below. The entire construction process will be overseen by the construction mentor, Susan Welt[DR1]. After construction reaches completion, community water board members will be instructed on how to maintain the system to teach the members of the community. Finally, the biosand filters will be assembled and water board members will be instructed on how to use and maintain them so that they will be able to instruct others on their use.
The biosand filter construction process was created following the procedure outlined in the CAWST v.10 biosand filter manual. Sand acquired from Isla Colon will be transported to Isla

Popa II for use in the biosand filters. “Filtration sand” (Silica #20) available in the hardware store on Isla Colon will not be used because it contains grain sizes ranging from 40-50mm in diameter, too large for biosand filtration purposes. Instead, standard grade (“play”) sand will be purchased and will be sifted to obtain the appropriate grain sizes (<0.7mm in diameter) and cleaned. Grain size analysis (conducted on-campus) of generic play sand, available at Sertebocas, shows that 95.1% of the grains qualify for filtration use (<0.7 mm grain diameter). With such a large usable portion of the purchased sand, sifting will be easy, brief, and will produce little waste. Any unusable sand can be used by community members to garden or can be safely disposed of at the waterfront. Following the design outlined in Section 4.2, the appropriate filter layers are then placed into the 5-gallon bucket with an attached plastic outlet tube and fitted with a diffuser made from aluminum sheeting. The assembled filter will then be flushed and subjected to flow-rate tests. If a flow rate of approximately .27 quarts/min is not obtained as averaged by the Lehigh sand filtration research group, then the filter must be altered or remade. Four filters will be constructed within the span of the first implementation trip for use in the school.

Cleaning the sand and gravel will require approximately five gallons of clean water per filter. Flushing the filter and testing the flow-rate will requires an additional 2 gallons of water (does not need to be clean water). The Sandubidi water board has agreed to secure the clean water needed for prewashing the filter sand before EWB-RPI arrives.

To make effective use of the time in-country, EWB-RPI will prepare several prototypes of the 5-gallon biosand filter with various sources of sand and gravel prior to travel. Testing will provide additional information about construction, reliability, cleaning methods, and overall performance of the point-of-use bucket biosand filter.

To reduce the probability of delays due to material acquisition EWB-RPI plans to discuss the material requirements Sertebocas Hardware on Isla Colon at least one month prior to travel to ensure all materials are available for the community. The community is currently in the process of reconstructing the docks on the island to improve transportation of materials. The community water board will look over the supplies until EWB-RPI’s arrival; supplies will be stored at the fishing co-op building near the dock.

Once all materials have been transported to Isla Popa II, the project team will begin construction in conjunction with the water board of the community immediately. The construction plan below spans five days. While the travel team will be in the community for a total of eight days, three days are left to resolve unforeseen issues.

The construction schedule is provided below. Phases II and III can be done simultaneously as well as V and VI because of the number of people available to work on construction. The remaining time will be used in the event the team is ahead of or behind schedule. If the team is ahead, they will spend additional time surveying additional areas on the island that are fit for implementation. If the team falls behind, the remaining time will be used as a buffer to ensure the construction is completed properly. If for some reason construction cannot be completed in the time designated during this schedule, appropriate measures will be taken to ensure that the water board understands how to complete the system.

Materials to Transport:	Tanks, Pipes, Pipe Glue, Steel Straps, Nails, Tools, Measuring Tape, Level, Biosand materials	
Materials to Gather Locally:	Wood for Stand, Ladder	
Phase Number:	Task:	Estimated Time to Complete:
Phase I	Transport Materials to Island	1 Day
Phase II	Prepare wood, assemble stand	1 Day
Phase III	Install steel straps to roof, prepare gutter	1 Day
Phase IV	Install piping for first flush, Prepare ground for tank stands and drainage, install tank	2 Days
Phase V	Construct Tank Housing	½ Day
Step VI	Prepare filters and check system	1 Day

7 MATERIALS LIST AND COST ESTIMATE

On past assessment trips, EWB-RPI has established connections with two reliable hardware/construction supply stores, both located on Isla Colon. Our construction materials will be purchased from these two stores: Maderas and Sertebocas. Prices of items in the following chart are padded to allow for flexibility in the case of price changes and missing/broken parts. Sertebocas agreed to provide the materials at a cost that the store paid to acquire it providing a discount to EWB-RPI. This store is used wherever possible to decrease the cost of the catchment system and the filters. All prices are from direct communication from the stores on the team's last assessment trip.

Rainwater Catchment System

Item Name	Price	Qty	Extended Price
600 gallon water tank	$475.00*	2	$950.00
4" schedule 20 PVC 20' length	$18.00	12	$216.00
4" PVC end cap	$3.50	2	$7.00
4" PVC cleanout	$3.25	2	$6.50
90° 4" PVC elbow (R)	$3.50	6	$21.00
90° 4" PVC elbow (S)	$4.95*	4	$19.80
45° 4" PVC elbow (S)	$3.25*	2	$6.50
4" PVC wye	$5.95	2	$11.90
PVC purple primer & solvent cement	$8.26*	2	$16.52
PVC cement (8oz)	$4.50	1	$4.50
Galvanized pipe strap	$3.25	5	$16.25
Female unthreaded coupling	$1.95	12	$23.40
¾" garden hose outlet	$9.95*	2	$19.90
¾" Bulkhead Union	$11.77	4	$47.08
¾" PVC pipe 5' length	$2.00*	2	$4.00

¾” female unthreaded to male threaded	$0.35	2	$0.75
¾” PVC coupling	$0.35	4	$1.40
¾” PVC ball valve	$1.95	2	$3.90
3” stainless steel screws	$0.10	100	$10.00
3” drywall screws	$0.04	50	$2.00
3.5” galvanized nails (per lb)	$1.28	1	$1.28
¾” screws	$0.05	50	$2.50
2.8 oz silicone sealant	$3.95	4	$11.85
1 gallon of wood impregnating oil	$36.50	1	$36.50
Total			**$1440.53**

Supplies Needed to Construct Four Biosand Filters

Item Name	Price	Qty	Extended Price
5-Gallon Bucket	$3.98	6	$23.88
5-Gallon Bucket Lid	$1.88	6	$11.28
10 feet,¼” PVC Plastic Hosing	$4.37	1	$4.37
Male Threaded Brass Barb (1/4”)	$2.60	4	$10.40
50lb Play Sand	$4.00	3	$12.00
50lb Course Sand	$3.74	1	$3.74
50lb Gravel	$3.74	1	$3.74
Silicone Sealant	$3.98	1	$3.98
Aluminum Sheet Metal (3’x3’)	$22.00	2	$44.00
Total			**$117.39**

In accordance with EWB-USA’s community contribution agreement policy (launched after the commencement of our project), EWB-RPI is requiring a financial contribution to project efforts by the community members. While the total estimated cost of the project is roughly $1500, a $100 dollar contingency has been added for unexpected price changes and buffer for broken parts.

The community has agreed to contribute 5% of the cost of materials in order to establish ownership of the constructed system. Additionally, they agreed to fund future water board operations and system maintenance tasks. Their estimated contribution to building materials is $80.00 (5% of $1600 rough estimated cost).which has already been raised through holding community bingo nights.

8.0 SUSTAINABILITY

8.1 Background

Two major factors that will determine the project's sustainability are supplies and maintenance. The supplies need to be available locally and at a cost that is reasonable for the community members. The community leaders and members need to be able to fully maintain and repair any sub-system that is installed on the pavilion during the implementation phase. For instance, the availability of supplies is important because if any parts become damaged or weathered, the project team and community cannot allow the system to become inoperative. The community must be experts at using supplies and materials to replace the damaged parts.

Financial sustainability in the community is also one of the most important aspects of the operations and maintenance part of the project. After considering a fundraising plan or a credit initiative, the community has decided to have every household in the community be responsible for a monetary contribution. This money will be collected by a leader in the community and will be used towards the maintenance of the rainwater system to be installed in the community.

Maintenance also includes the transfer of knowledge necessary for the community to upkeep the system. Before EWB-RPI leaves the community, the travel team must teach the community how to properly clean and maintain the tanks and other systems such as the first flush system, gutters, pipes, and bio-sand filters. Without proper and regular cleaning any water that is stored in the tanks will become contaminated. The community will also be educated about proper water purification and better sanitation practices.

8.2 Operation and Maintenance

The primary function of any systems designed is to perform for the end user, the community of Isla Popa II. The community's water board will be responsible for continued maintenance of installed community rainwater systems. Household rainwater systems should be maintained by owners of the household. All operations and maintenance activities for the rainwater catchment system and tanks are identified below.

First Flush System:
The first flush system is fully manual, and the first flush pipe must be regularly maintained and emptied. In order to clean the system, the end cap must be removed and allowed to be drained of dirty water. Afterwards, any debris that has collected at the bottom of the pipe must be removed, and then the end cap must be reattached to the fixture. Maintenance of the first-flush system will require about ten minutes after every rainfall event and will be maintained by the community water board.

Gutters and Pipes:
PVC rain collection gutters should be checked monthly for any prominent leaks or blockages. Any associated metal components used to attach gutters to roofing should also be checked for

rust or breakage every month. Buildings with rafter supported gutters should also be checked monthly for any rotting wood. Cracks in gutters can be repaired with locally available adhesive materials but silicon sealant is recommended because it can be found in the Sertebocas Hardware store on Isla Colon. Minor rusting can be repaired through the sanding of the pipes. Any gutter blockages can be removed manually. In cases of major damage, replacement of parts is the most feasible option, given the abundance of available piping. PVC pipe is readily available in the nearby island of Isla Colon, at the Sertebocas Hardware store, and can be quickly replaced in case of damage. The time needed to maintain the PVC gutters will vary between roof sizes, but should take less than 2 hours per month.

Tanks:
Rainwater storage tanks should be thoroughly cleaned and disinfected four times per year, or if it is known that a tank has become contaminated. Tank contamination will be evident if community members experience sickness after drinking from a particular water container that needs cleaning. Recommending a tank cleaning interval of three months was done to most easily assimilate this practice into community member behavior, because the community members to actively observe lunar cycles. Currently the community members clean their tanks infrequently, so a quarterly cleaning regimen will improve sanitation on the island. Tank cleaning procedures will follow those outlined by the World Health Organization in their document "Cleaning and disinfecting water tanks and tankers" [4]:

1. Wash hands and wear appropriate protection (face mask, gloves)
2. Empty tank until it is filled to ¼ volume.
3. Use a brush and liquid chlorine to scrub the inside of the tank.
4. Mix 50g chlorine cleanser into 20L volumes of water for disinfection purposes.
5. Add 10L of the cleanser solution for every square meter in volume of your tank.
6. Allow 24 hour working time for the solution to disinfect the tank.
7. Empty the contents of the tank (including sediment) and rinse tank with water.
8. For a disinfection time of 8 hours, double disinfectant dosing for tank.

The water-chlorine solution should be disposed on the gravel located around the tank in order to avoid any damage to any nearby vegetation. The tank should not be used until 24 hours after cleaning to let the bleach dissipate. For enhanced cleaning ability, community members may want to enter the tanks. The WHO recommends that fresh air is blown into an empty tank before a person enters it for cleaning. The person entering the tank should always wear "protective clothing, including gloves, boots, a hat and glasses." It is essential that another community member watches the process from outside of the tank in case of an accident.[4] It is estimated that the time needed to clean tanks will be less than 6 hours per year. Additionally, tanks should be checked monthly to detect leaks and to remove any vegetation growing near or on them, decreasing the likelihood of water waste and tank water contamination. In the case of major tank damage, new tanks may be ordered from Isla Colon.

[4] WHO (World Health Organization). (1997). *Guidelines for Drinking-Water Quality (Second Edition)*

Bucket Biosand Filters:
The biosand filters should be used at least once every two days to ensure the healthy development, growth, and sustainment of the biolayer. When the filter is first constructed, this layer (not visible to the naked eye) should form within 30 days of regular use which will incrementally increase the level of water treatment. Before the 30 day mark, additional chlorine should be used to treat the water post-filtration to ensure it is potable. The amount of required post-filtration chlorine is based on a multitude of complex factors that will be different in nearly every situation; thus, community members should adhere to their current chlorine dosing for post-treatment until the filter is has a developed biolayer. When not in use, the filter lid should be tightly secured over the bucket opening. The filter should be cleaned approximately once a month or when the flow rate of the filter drops below 140 mL/min (about 50% of original flow rate). The CAWST Biosand filter manual explains, "The
filter is still effectively treating the water at this point [of reduced flow rate] ; however the length of time that it takes to get a container of filtered water may become too long and be inconvenient for the user." Cleaning to adjust for reduced flow rate is done to ensure community members don't resort to drinking unfiltered water after becoming impatient with the filtering process. Community members should clean the filter if they believe the flow rate is too slow for them to regularly use. To clean the filter, use the "swirl and dump method" as outlined in the CAWST guidelines[5]. This method was selected over rinsing the sand regularly to avoid degrading the filter:

1. Wash hands with soap and water.
2. Remove the filter lid.
3. If there is no water above the diffuser, add about 4 liters (1 gallon) of water.
4. Remove the diffuser.
5. Using the palm of your hand, lightly touch the very top of the sand and move your hand in the circular motion; be careful to not mix the top of the sand deeper into the filter.
6. Scoop out the dirty water with a small container.
7. Dump the dirty water outside the house in soak pit or garden.
8. Make certain that the sand is smooth and level.
9. Replace the diffuser.
10. Wash your hands with soap and water.
11. Set up the storage container to collect the filtered water.
12. Refill the filter.
    Repeat the swirl & dump steps until the flow rate has been restored to desired flow rate.

Cleaning will improve the flow rate of the water filter, motivating regular cleaning practices according to CAWST. The "swirl and dump" method does temporarily reduce the efficacy of the biolayer for a period of a few days, but the performance reduction is minimal. (Lellison et. al found a bacterial removal efficiency of 81-82% after bucket filter cleaning). However, the

[5] CAWST (Centre for Affordable Water and Sanitation Technology). (2010). *Biosand Filter Manual Design, Construction, Installation, Operation and Maintenance: A CAWST Training Manual*

CAWST guidelines[1] specifically instruct that chlorine should be added to the filtered water in the days following cleaning to ensure that the water is potable. It is important to note that chlorine should NEVER be poured directly into the filter for cleaning purposes because it will kill the biolayer. Additionally, the bucket designated to store clean water post-filtration should be cleaned weekly by scrubbing with the chlorine-water mixture stated earlier.

8.3 Education

The main goal of the education program is to communicate safe drinking water practices to the community members of Isla Popa II, including water storage strategies, filter and tank cleaning procedures, and clean water acquisition during dry weather. To ensure access to sufficient quantities of drinking water, it is important to instruct them how to better conserve, protect, store, and purify water. Community leaders and the water board will be educated on system maintenance and system procedures; this information will then be disseminated in the form of educational pamphlets to the water board for distribution to the communities (See Appendix D) which will help them understand the importance of basic sanitation and water treatment. These education pamphlets will serve as a guide for the leader of the community in charge of maintenance and for the water board itself. Approximately ten copies will be printed for the water board to keep and use as a reference.

Sanitation skills will be taught and strongly encouraged, such as hand washing when preparing food and using the bathroom, cooking food to remove harmful bacteria, and washing tools with boiling water to kill microbes. Community members will be strongly encouraged to clean their tanks and inlet tubes every three months, and to cover the tank and inlet tube to keep out insects and leaves. The practice of keeping lids on storage buckets containing filtered water will also be stressed to prevent recontamination of treated water. Furthermore, the water board will be instructed how to carry out the “swirl and dump” procedure necessary to clean the point-of-use biosand filters monthly. The water board will be in charge of educating the community about the necessary procedures needed to maintain the rainwater catchment system clean and working properly. Four filters will be implemented in the community grade school during the pilot implementation phase which will allow the children of the community to learn about the use of the filters in school. Integrating the use of these filters in the everyday lives of the children will hopefully allow them to utilize this knowledge at their homes.

Community members will also be taught methods of water decontamination by boiling and chlorine treatment. Appropriate boiling durations in order to ensure all bacterial hazards have been eliminated will be explained. When it comes to chlorine treatment, the community will be taught what amount of chlorine is appropriate for a specific amount of water, where it can/cannot be used and proper storage.

See Appendix D for a translated copy of the education pamphlet written for the community.

9.0 MONITORING

9.1 Monitoring plan for current project

The team will be conducting tests for water quality of the filters after construction has been completed. Below is a table of metrics that will be used to determine the effectiveness. These metrics will be measured for baseline values during this trip and compared to measurements during the monitoring phase.

Metric	Qualitative Measures	Quantitative Measures
Water Quality	Use of local water sources compared to bottled water	• Total coliform count • Iron content • Total dissolved solids • Turbidity • Other parameters
Community Health	Community opinion of health of individuals	• Health data as reported by Floating Doctors and EWB-Panama
Water Supply	Community opinion of sufficiency of water supply	• Length of the average drought • Average quantity of water delivered • Average quantity of water consumed per usage (cooking, cleaning, drinking)

<u>General Methods for Data Collection:</u>

Water Quality

Testing will be conducted using of each of the following procedures before and after passing water samples through the biosand filter to get a baseline metric for the monitoring phase.

Total coliform count – An assortment of water samples will be collected by the travel team (rainwater, rainwater from roof before first flush, rainwater from tank, water post-filtration) then a total coliform count will be performed on the samples using body heat coliform tests. This method is consistent with that used by WPI's chapter of Engineers Without Borders, and has been shown to be affective, as reported by Michele Mensing, President of the WPI chapter.

Total dissolved solids – An optical test will be performed in the field with a Hach DR/890 colorimeter. The stated detection limit of the colorimeter is 22.1 mg/L. The stated testing method requires blending the sample using a stirring rod.

Turbidity - An optical test of the water pre-filtration and post-filtration will be performed in the field with a Hach DR/890 colorimeter. The stated detection limit of the colorimeter is 1 FAU (Formazin Turbidity Unit), which is equivalent to 1 NTU (Nephelometric Turbidity Unit).

Usage – Survey the community members about their use of the biosand filters. The team plans to survey at least 10 families in the community. Survey questions will include frequency of use, frequency of cleaning, description of cleaning, and overall satisfaction with the taste and purity of the filtered water. Observation of community filtration practices will be carried out on all monitoring trips using a checklist to ensure water use is recorded in a consistent manner.

Community Health

Health Data – The Floating Doctors record the services that they provide for the people of Isla Popa II. Cataloging the incidences of water related illnesses will contribute to monitoring overall project effectiveness. The team will be logging these incidences in conjunction with community maintenance practices to determine the causes related to the catchment system and filters.

Community Opinion – Consistently surveying the community before, during, and after the implementation process will provide data for the community opinion of their own health. The survey will contain information on how often they are using it and what they would do in certain scenarios to get an understanding of their knowledge of maintenance.

Water Supply

Water Shortage – Collecting data on the average drought requires the help of the community. Selected community members will monitor and record the number of days without water in the tanks.

Average Water Quantity Delivered – Community water board and teacher will monitor water levels before and after rainfalls to understand the quantity of water collected.

Community Opinion - Consistently surveying the community before, during, and after the implementation process will provide data for the community opinion on the adequacy of the water supply.

9.2 Monitoring of past-implemented projects

No other projects have been implemented to-date.

10.0 COMMUNITY AGREEMENT/CONTRACT

10.1 Signed Community Agreement

A la Comunidad de Popa II

Para generar un acuerdo que establece claramente las responsabilidades que le corresponde a cada parte y que se espera que cumpla, hemos escrito este documento. Las dos partes, Ingenieros sin Fronteras Instituto Politécnico Rensselaer (EWB RPI) y la comunidad de la Isla Popa II, demuestran que aceptan los términos atreves de firmar abajo.

Los términos establecidos a los que la comunidad se va a ceñir incluyen el contribuir al proyecto para traerle agua potable a la comunidad atreves de financiamiento, del trabajo de la comunidad y/o materiales. La comunidad también va a ser responsable de inspeccionar regularmente, del mantenimiento y del arreglo futuro de los componentes de este proyecto una vez terminado, con la ayuda prometida y el respaldo técnico del capitulo de EWB RPI, aun cuando sea por teléfono, email o atreves del socio en el país. Además el representante designado por la comunidad de Popa II será responsable de comunicarse con EWB RPI.

EWB RPI va a tratar de buscar la mejor y mas apropiada solución para mejorar la obtención y calidad del agua de la Comunidad de la Isla Popa II, al igual de encontrarle y presentarle un ONG(s) a la comunidad de la Isla Popa II, para impulsar la cooperación entre las partes durante el tiempo que exista
SN este ~~contrato~~ acuerdo y asegurarse de que el ONG local sea aceptado por la comunidad de la Isla Popa II. La materia prima usada por el capitulo del EWB RPI se va a adquirir cerca de la Isla Popa II y se dará información de su origen, garantizando así que sea material que se encuentre en ese lugar. Las dos partes van a compartir la responsabilidad de conseguir los materiales en la fase de construcción.

EWB RPI va a ayudar atreves de conferencias telefónicas, instrucciones verbales y/o escritas y durante la fase de monitoreo. Del capitulo de RPI EWB se darán instrucciones verbales y/o escritas que cubren los métodos de inspección, mantenimiento y reparación del sistema del agua. Debe entenderse claramente que EWB RPI no garantiza que se va a dar ayuda luego de la fase de monitoreo.

Sin embargo, si la comunidad descuida en forma grave el sistema de agua a que hemos contribuido o los tanques, puede ser causal para terminar el ~~contrato~~ acuerdo entre EWB RPI y la Comunidad de SN
SN la Isla ~~de~~ Popa II. EWB RPI no va a determinar como va la comunidad a mantener o llevar a cabo las inspecciones requeridas de las partes que componen el proyecto del agua.

Sin embargo, los siguientes puntos son flexibles entre EWB RPI y la comunidad de la Isla de Popa II:

. Las cantidades exactas de contribuciones de la comunidad

. La cantidad de dinero (financiación)

. El trabajo aportado por la comunidad

. Componentes y materiales

SN

SN acuerdo Las dos partes EWB RPI y la Isla ~~de~~ Popa II están de acuerdo con los términos que contiene este ~~contrato~~ y acepta ajustarse y res petar las responsabilidades del mismo; en aceptación de esto lo firman sus representantes.

Firmado el diece -ocho de Augosto del 2012

Representante autorizado por la Comunidad de la Isla de Popa II

Representante de EWB RPI

Testigos

18-8-2012

Firma

Fecha

Nombre

10.2 Community Contract English Translation

To the community of Popa II,
To generate an agreement to understand clear responsibilities on what each side of our relationship will provide and be expected of, we have written out this agreement. Both parties, Engineers Without Borders Rensselaer Polytechnic Institute and the community of Isla Popa II, will show they agree to the terms when signing below.
The inflexible terms that the community will follow include forming a contribution to the project of bringing clean water to their community through funding, labor force from the community, and/or materials. The community will also be held responsible for standard inspection, maintenance, and future repairs to the completed project components, with promised aid and technical support from the EWB RPI chapter, even if it may be via phone, email, or through our in-country partner. As well, the community designated representative party of Isla Popa II will be responsible for communicating with EWB RPI.
EWB RPI will attempt to provide the most feasible and appropriate solution to improve the availability and quality of water for the community of Isla Popa II, as well as find and introduce a local NGO(s) to the community of Isla Popa II, foster cooperation among the parties for the lifespan of the agreement and ensure first that the local NGO is accepted by the community of Isla Popa II. Raw material used by the EWB RPI chapter will be acquired near Isla Popa II and information on its origin will be provided, guaranteeing locally available material. Both parties shall share the responsibility of acquiring resources in the construction phase.
EWB RPI will provide support in the form of community and telephone meetings, verbal and/or written instructions, and during the monitoring phase. From RPI's EWB chapter, verbal and/or written instruction is expected covering the methods of inspection, maintenance, and repair of the water system. It should be clearly understood that EWB RPI does not particularly guarantee that assistance will be available following the monitoring phase.
However, if the water system we have implemented or the existing tanks are neglected severely enough by the community, it could be cause for termination of the agreement between EWB RPI and the Isla Popa II community. Also, EWB RPI shall not define how the community maintains or performs required inspections to the installed components of the water project.
However, the following points are flexible between EWB RPI and the community of Isla Popa II:

- Exact amounts of contribution from community
- Monetary (funding)
- Community provided labor
- Supplies and materials

Both parties (EWB RPI and the Isla Popa II community) agree with the above mentioned terms of the agreement and agree to follow and respect their responsibilities per this agreement, as signed by their representatives below will sign below.
Signed on ____________ of 2012 by:

________________________________ ___________________________

Authorized representative from Authorized representative from EWB-RPI
the community of Isla Popa II
Witnessed by:
Signature: ______________________________________ Date: _____________
Name: _______________________________________

10.3 Memorandum of Understanding - EWB-RPI and EWB-Panama

Memorandum of Understanding

The purpose of this memorandum is to document the agreement between the parties as to the roles and responsibilities of each party to the proposed project to improve the Isla Popa II water system. To that purpose the parties to this memorandum of understanding are 1) The Student Chapter of Engineers Without Borders at Rensselaer Polytechnic Institute, and 2) Engineers Without Borders Panama. The scope of the proposed project is to investigate, design, construct, and maintain a clean, safe, and reliable water supply for the community of Isla Popa II in accordance with local standards and technology available in the Isla Popa II area.

It is understood that Isla Popa II is a community on the island of Isla Popa in the Archipiélago de Bocas del Toro in the Republic of Panama. It is also understood that the local and regional government entities in this area do not have the ability/desire to support or participate in this project.

Per this memorandum the following points are agreed to by the parties:

1. The Student Chapter of Engineers Without Borders at Rensselaer Polytechnic Institute will:
    a. Travel to the Isla Popa II community.
    b. Meet with representatives of the community and obtain support for the feasibility study, construction, and maintenance of the completed project.
    c. Investigate and develop a feasibility study on possible and cost effective means to improve/develop a safe reliable water supply for the community (including but not limited to:
        i. Treatment of the existing water supply.
        ii. Development of a new community well.
        iii. Construction of a pipeline to convey water to the community.
        iv. Development of a rainwater collection system.
    d. Should any of these water improvement projects prove feasible and have the support of the community, the student chapter will:
        i. Develop a design with construction documents.
        ii. Support the Community of Isla Popa II in the construction of the project by providing a portion of the monetary, material, equipment, and labor requirements.
2. Engineers Without Borders Panama will support the Student Chapter by:
    a. Providing on-site and in-country coordination of resources needed for the feasibility study and construction.
    b. Providing an on-site mentor to the Student Chapter while working on Isla Popa and by providing assistance to the community when the Student Chapter is off-site.
    c. Providing technical expertise in support of the study/construction.
    d. Support the community during the post-construction phase through technical expertise in the operation and maintenance of the completed project.
    e. EWB Panama support of the student Chapter's activities will continue until it is agreed by both parties that the project is complete.

Acknowledgement:

Name	Date	Name	Date
Kathleen OzMeln (signature)	8/14/12	(signature)	8/14/12
EWB Rensselaer Polytechnic Institute		EWB Panama	

11 SITE ASSESSMENT ACTIVITIES

After the completion of construction, assuming additional time is available, the team will conduct site surveys for public buildings to provide feedback for the water board regarding additional buildings fit for this type of public water source. We will refrain from surveying private homes to avoid conflict but will use the pavilion and other site surveys as examples for families looking to install a rain water catchment system.

12 PROFESSIONAL MENTOR/TECHNICAL LEAD ASSESSMENT

12.1 Professional Mentor/Technical Lead Name (who provided the assessment)

Professional Mentor – David Railsback

12.2 Professional Mentor/Technical Lead Assessment

The EWB-RPI team has made significant progress in the development of a pilot rainwater catchment system in the community of Sandubidi (Popa II). The pilot system will be constructed on the pavilion near the school, with the goal of increasing the quantity and quality of water at the community. Based on an evaluation of historical precipitation data, the system is designed to supply sufficient drinking water for the students during the school day. The system includes a first-flush system to remove large particles, as well as sand filters which will reduce turbidity levels and bacterial concentrations. Boiling or chlorine will be used for final treatment.

Attention has been paid to a host of design challenges including: structural integrity, aesthetics, material availability, cost, maintenance, operator education and community engagement. The EWB-RPI team has maintained weekly communication with the community water board, where EWB-RPI seeks feedback, gathers insight for design, and responds to community comments and concerns. Implementing a rainwater catchment project has a strong chance of success, as measured by water quantity and quality, system durability and community satisfaction.

I expect that this project will lay the groundwork for additional rainwater catchment systems. In the future, maintenance and optimization of existing rainwater catchment systems will require more attention. Before the EWB-RPI team became engaged with Sandubidi, the community installed a large number of household rainwater catchment systems. These systems can be optimized at minimal cost, which will reduce the frequency and duration of water shortages.

12.3 Professional Mentor/Technical Lead Affirmation

As a Professional Mentor I acknowledge my involvement in the project and I accept responsibility for the course that the project is taking.

12.4 Professional Mentor/Technical Lead Name (who provided the assessment)

Professional Mentor – Alexander Michaels

12.5 Professional Mentor/Technical Lead Assessment

The group has done a good job using assessment trip experiences, community input and mentor and NGO guidance to design a solution to provide improved water quantity and quality to the community. The project will be tremendously valuable to the well being of the students that attend the school nearby. The water will be available for students to drink and it will be available for the school kitchen to use in its cooking and cleaning. This is a significant improvement to current practices.

The first implementation trip will serve as a pilot project and if the effort is successful, there is potential for the community to realize more widespread adoption of systems similar to the current design. After necessary testing and community engagement, the group be able to learn how the system is performing and the level of community satisfaction. Drawing on this, and expanded talks with community leaders, the group may be able to design systems for other community buildings and residences.

The project is progressing well and the members are meeting all of its demands. With a carefully planned and diligent effort, the project can be move forward to the next phase. While moving forward, the team should always remember to leverage their resources well, keep an open mind regarding how best to meet project goals and to keep lines of communication with the community strong.

12.6 Professional Mentor/Technical Lead Affirmation

As a Professional Mentor I acknowledge my involvement in the project and I accept responsibility for the course that the project is taking.

APPENDICES

APPENDIX A: Water Quality Testing

APPENDIX B: Rainwater Data Simulation Sample

APPENDIX C: Design Drawings and Calculations

C.1 Photo of Community Center Pavilion
C.2 Galvanized Steel Gutter Strap
C.3 Rear View of Community Center Pavilion
C.4 Side View of Community Center Pavilion
C.5 First Flush Design
C.6 Tank Stand and Tank Protective Box
C.7 Design Slope Calculations
C.8 Biosand Filter Design
C.9 Map of Bocas del Toro
C.10 Site Map

APPENDIX D: Education Pamphlet (Translated)

APPENDIX A: Water Quality Testing

Coliform and Heterotrophic counts were conducted in August of 2012 on the chapter's second assessment trip. Samples were collected from an existing simple rainwater catchment system on the school and a covered well roughly 500 feet from the school. The samples were incubated and analyzed at a lab at the University of Panama using the APHA standard methods listed below. The coliform and heterotrophic counts for the sample collected from the school rain water catchment system are significantly lower than the counts for the covered well indicating that rain water catchment would provide better water quality standards.

School Rain Water (Collected 20/08/2012)			
Parameter	Result	Method	Reference
Total Coliform (MPN/100ml)	36	9221-B	APHA – Standard Methods
Fecal Coliform (MPN/100ml)	<30	9221-D	APHA – Standard Methods
Heterotrophic Count (CFU/ml)	1.1×10^5	9215-D	APHA – Standard Methods
Covered Well (Collected 20/08/2013)			
Parameter	Result	Method	Reference
Total Coliform (MPN/100ml)	2.4×10^4	9221-B	APHA – Standard Methods
Fecal Coliform (MPN/100ml)	1.5×10^3	9221-D	APHA – Standard Methods
Heterotrophic Count (CFU/ml)	2.7×10^5	9215-D	APHA – Standard Methods

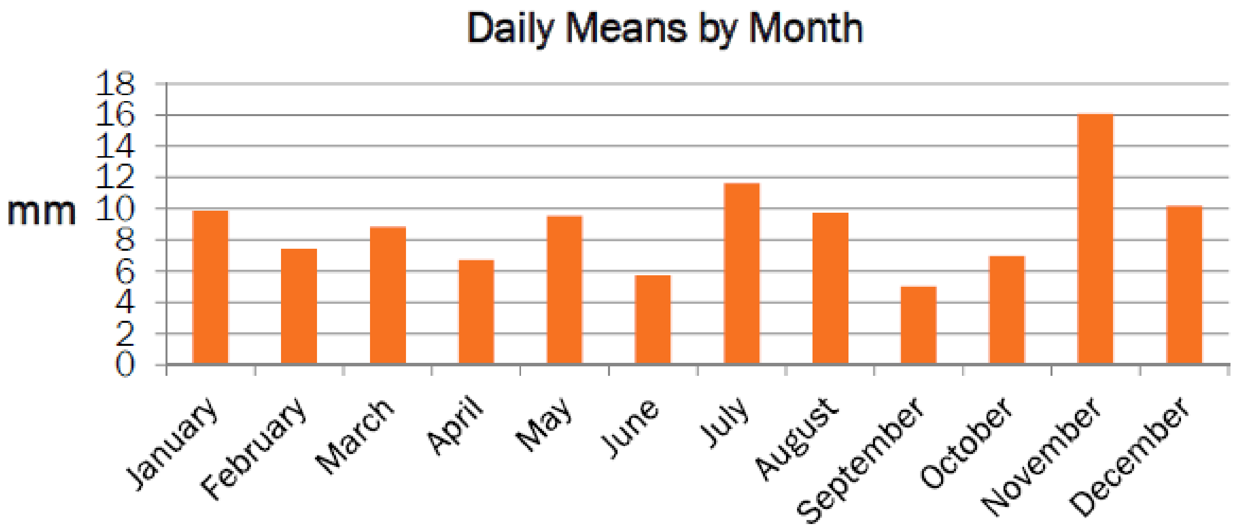
Physical measurements were also conducted in August of 2012. The results confirm that the quality of water from the catchment systems are much better than the wells in the community.

School Rain Water (Collected 20/08/2012)			
Parameter	Result	Method	Reference
Conductivity (µS/cm)	101.4	EPA9040B	APHA – Standard Methods
Turbidity (NTU)	1.02	EPA9050A	APHA – Standard Methods
Total Dissolved Solids (mg/L)	96	SM2540B	APHA – Standard Methods
Total Suspended Solids (mg/L)	39	SM2540D	APHA – Standard Methods
Alkalinity (mg $CaCO_3$/L)	<20	SM2320B	APHA – Standard Methods
Nitrates (mg/L)	1.14	SM4500NO_3	APHA – Standard Methods
Sulfates (mg/L)	0.53	SM4500SO_4^2E	APHA – Standard Methods
Covered Well (Collected 20/08/2013)			
Parameter	Result	Method	Reference
Conductivity (µS/cm)	135.3	EPA9040B	APHA – Standard Methods
Turbidity (NTU)	75.9	EPA9050A	APHA – Standard Methods
Total Dissolved Solids (mg/L)	198	SM2540B	APHA – Standard Methods
Total Suspended Solids (mg/L)	128	SM2540D	APHA – Standard Methods
Alkalinity (mg $CaCO_3$/L)	<20	SM2320B	APHA – Standard Methods
Nitrates (mg/L)	12.54	SM4500NO_3	APHA – Standard Methods
Sulfates (mg/L)	2.68	SM4500SO_4^2E	APHA – Standard Methods

APPENDIX B: Rainwater Data Simulation Sample

Simulations of the rainwater catchment system were run using data collected over a 12-year period at a resolution of 15 minutes by the Smithsonian Tropical Research Institute in Bocas del Toro.[6] A program was written to parse the data, calculate daily water levels, and compute statistics over the entire data set. The results are shown in the following graph.

Figure 1. Average daily rainfall data



Next, the following table describes the correlation of roof size, tank capacity, and water consumption in a rainwater catchment system in Bocas del Toro, with the condition that there may not be any month in which water is unavailable for more than 5 days. It is intended to allow individual households to determine their optimal tank size based on the roof size of their house and the amount of water expected to be used daily. Locally available storage tanks have capacities of 150, 300, or 600 gallons.

Figure 2. Tank sizes (gallons) required for sustained water use

		Water use, litres/day				
		100	**150**	**200**	**250**	**300**
	60	450	1200	n/a	n/a	n/a
	80	450	1200	n/a	n/a	n/a
Roof size, m^2	**100**	450	600	n/a	n/a	n/a
	120	450	600	750	n/a	n/a
	140	450	600	750	1200	n/a
	160	450	600	750	900	n/a

[6] http://biogeodb.stri.si.edu/physical_monitoring/research/bocas

180	450	600	750	900	1200
200	450	600	750	900	1200

For the proposed first implementation phase, the goal is to put in place a system to supply the students of the community school with water during school hours. There are approximately 100 students. The building to be used will be the school pavilion with a roof area of 196.2 m^2 as measured on site. According to the World Health Organization, 7.5 litres of water per day is generally sufficient for all uses for most people.[7] Since the proposed system will only supply water during school hours, 2.5 litres of water per student per day will be sufficient, which is a total of approximately 250 litres per day.

Using Figure 2, a catchment system with a roof size of 200 m^2 and required to supply 250 litres of water per day will need at least 900 gallons of tank capacity, which is feasible for implementation.The actual design uses a pair of 600 gallon tanks to achieve total capacity of 1200 gallons, which will allow for 250 litres of consumption daily without any month experiencing 5 days with empty tank. In months other than May, very few empty tank days, if any, are expected.

[7] http://www.who.int/water_sanitation_health/emergencies/qa/emergencies_qa5/en/

APPENDIX C.1: Photo of Community Center Pavilion

APPENDIX C.2: Galvanized Steel Gutter Strap

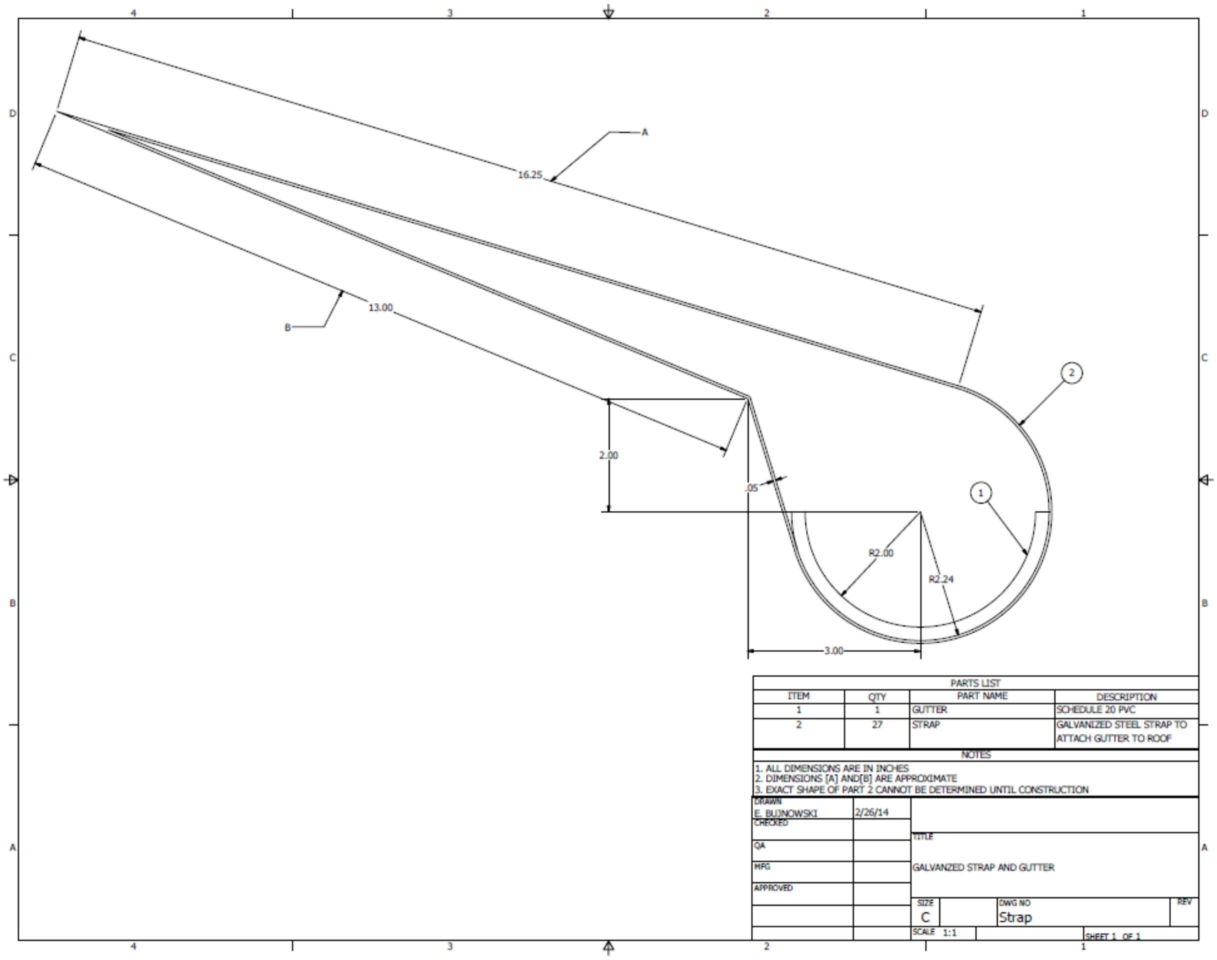
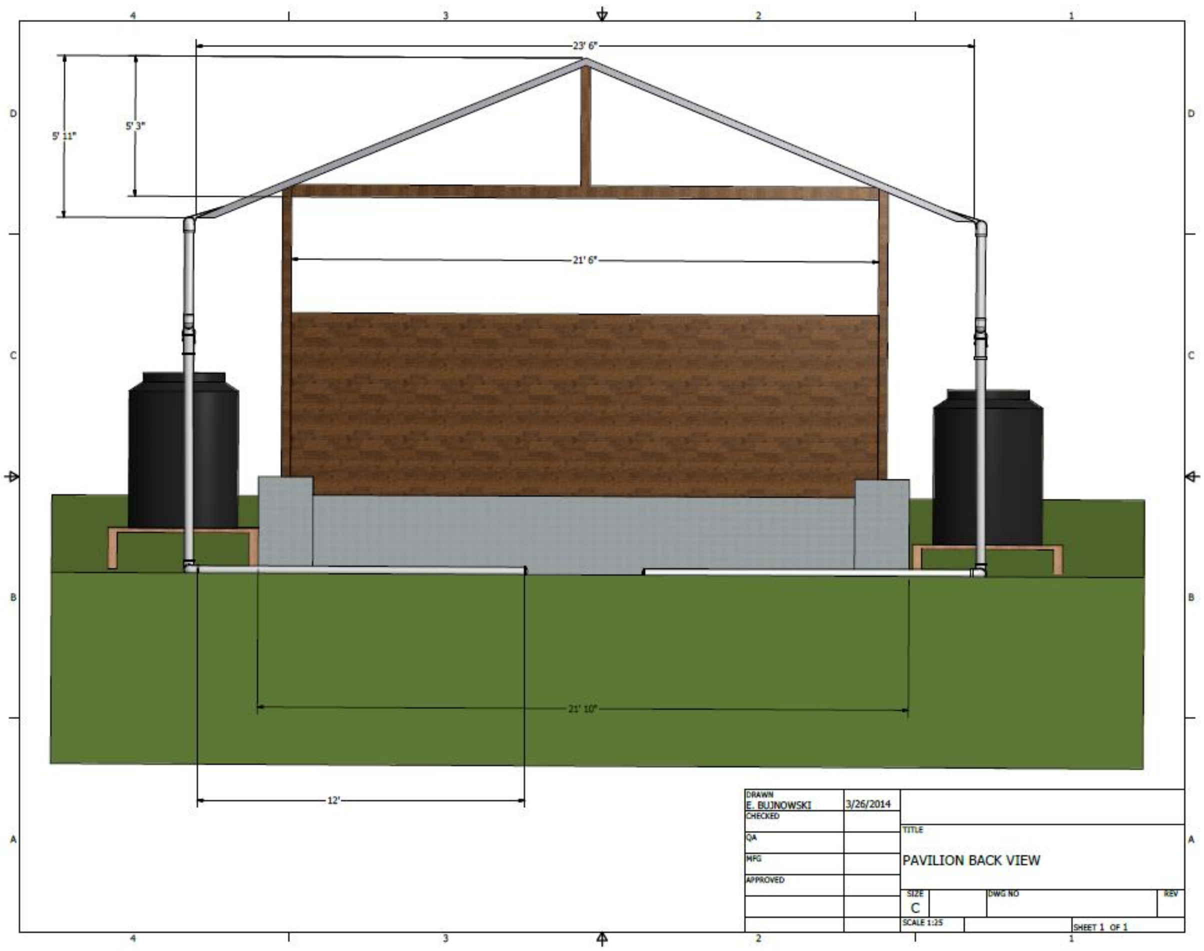
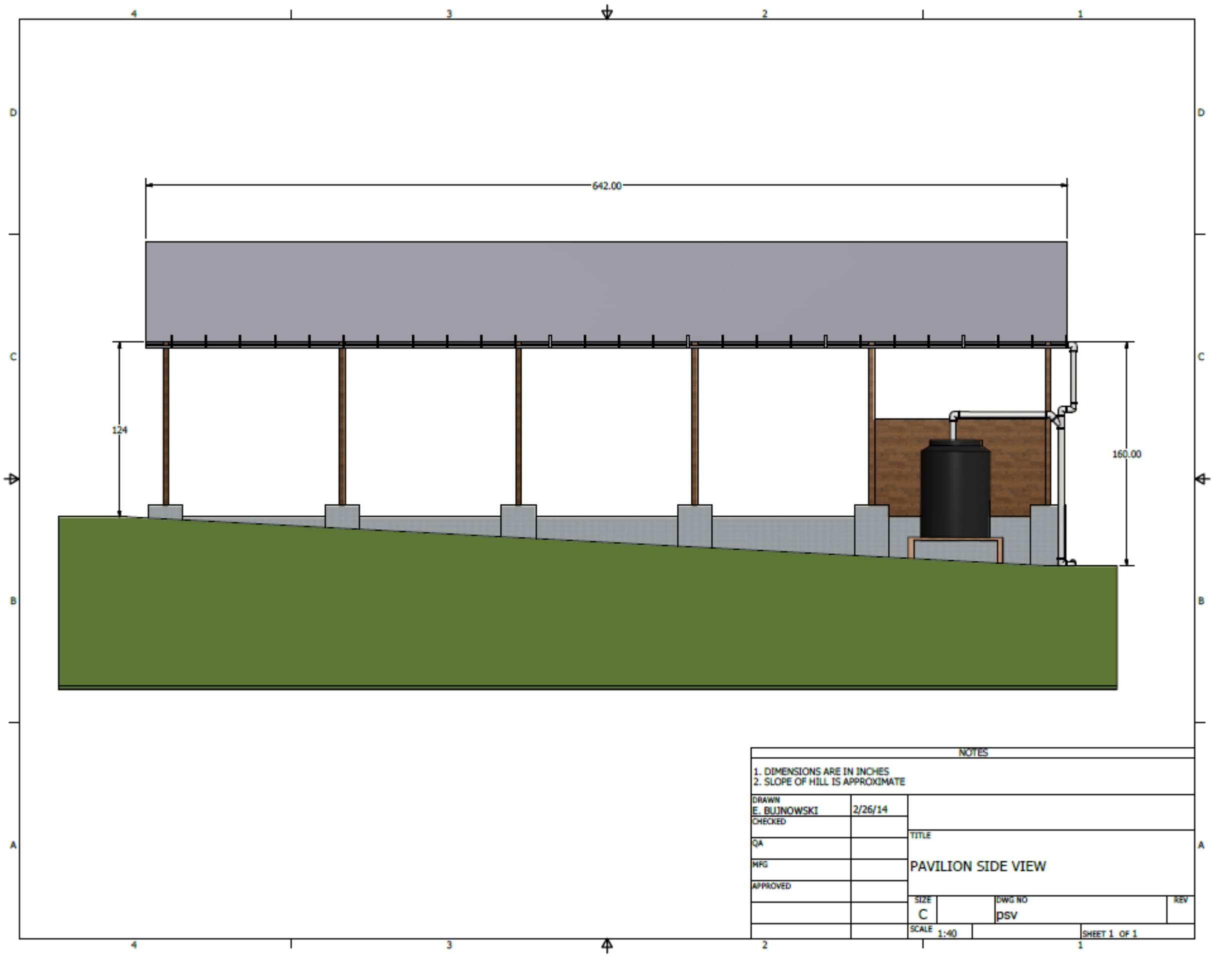


Figure: Galvanized Steel Strap Prototyping

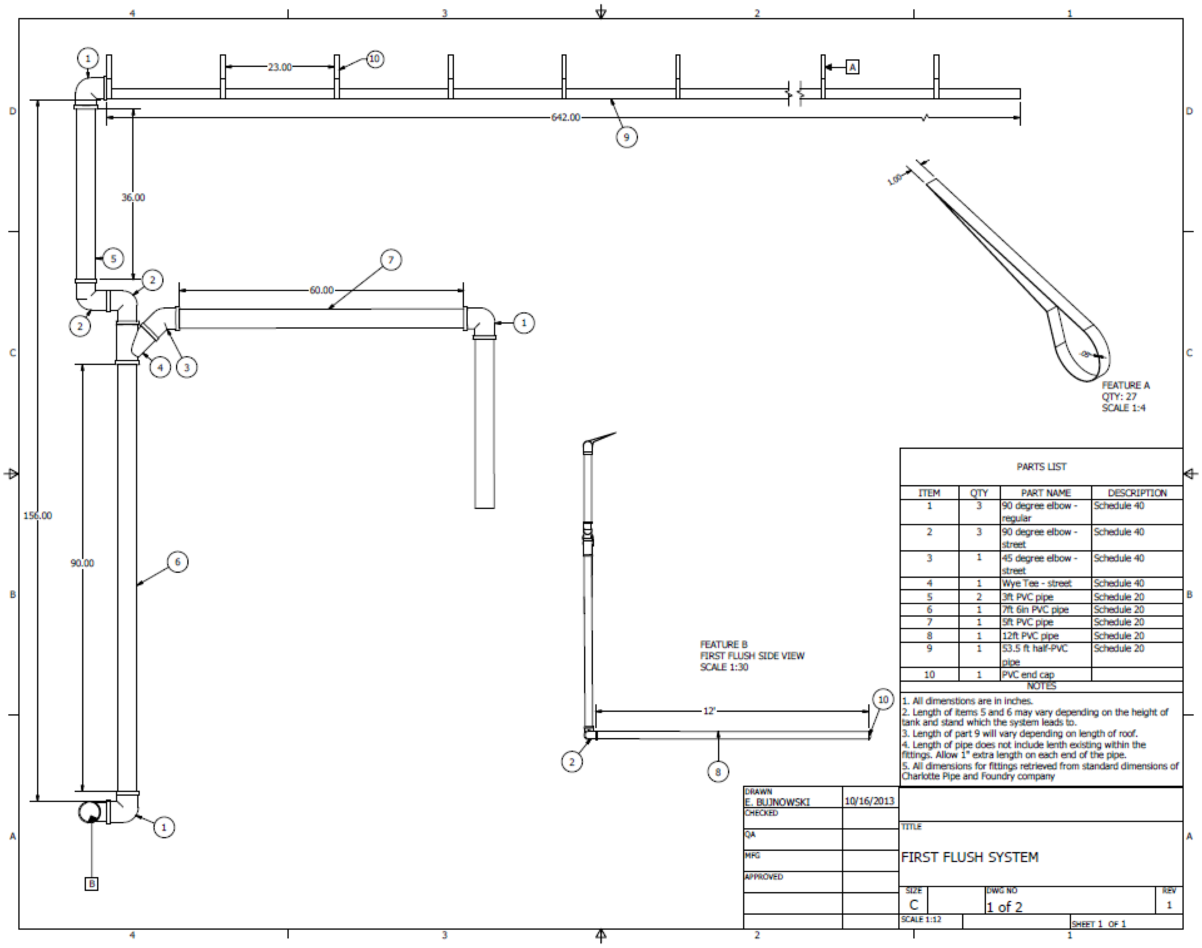
APPENDIX C.3: Rear View of Community Center Pavilion



APPENDIX C.4: Side View of Community Center Pavilion



APPENDIX C.5: First Flush Design



APPENDIX C.6: Tank Stand and Tank Protective Box

See attached appendix for complete drawing

APPENDIX C.7: Design Calculations[DR2]

First Flush System

Performed by: Kammi Shah

Checked by: Kyle Geisler

The intent of this calculation is to determine the minimum requirement for storage of first flush water. The storage requirement will be met through the use of a length of four inch PVC pipe. As shown below about 16 feet of four inch PVC is required per side of the roof to store the 11 gallons per Texas water Development Board recommendations.

First flush system recommended sizing[1] - $\frac{10\ gal}{1000\ ft^2}$

Size of Each Side of Roof – 1080 ft^2 – 11 gal flush system

Using 4” PVC pipe, $ID = 4.2'',\ r = \frac{ID}{2} = 2.1''$

$$V = 11\ gal = 2541\ in^3 = \pi r^2 h$$

$$h = \frac{V}{\pi r^2} = \frac{2541\ in^3}{\pi \times (2.1\ in)^2} = 183\ in = 15.25\ ft$$

15.25 ft of PVC Pipe for first flush system $\approx$ 16 ft

This length will be accomplished with 12 feet of horizontal pipe storage on the ground and 4 feet of vertical storage going up the side of the building. This allows a 3 foot buffer from the flush system end to the runoff into the water tank because the inflow into the tank is located 7 feet off the ground.

1) *The Texas Manual on Rainwater Harvesting 3rd Edition.* Texas Water Development Board.

Gutter Slope Calculation:

Performed by: Kammi Shah

Checked by: Kyle Geisler

The intent of this calculation is to determine the minimum required slope of gutters through utilization of Manning’s equation for open channel flow. In this calculation a conservative value for maximum intensity of rainfall, $200\frac{mm}{hr}$, is being used to ensure the gutters function during a heavy storm. This calculation yields a minimum slope value of .30%, EWB-RPI aim for a slope between .125% and .063% ($^1/_8$’’ to $^1/_{16}$’’ per foot) following the recommendations of contractors the team has spoken to.

$A = 1080ft^2 = 100.3m^2$

$Q = \left(200\frac{mm}{hr}\right) * 100.3m^3 = 20067\frac{L}{hr} = 5.57\frac{L}{s} = 0.00557\frac{m^3}{s}$

$n = 0.02$ for PVC pipe and $A = 81.07cm^2 = 0.008107m^2$

$Pw = 0.0628m$

$R = \frac{A}{Pw} = 0.129m^2$

$Q = \frac{AR^{\frac{2}{3}}S_0^{\frac{1}{2}}}{n}$

$0.00557 = \frac{0.008107(0.129^{\frac{2}{3}})S_0^{\frac{1}{2}}}{0.02}$

$S_0 = 0.0030 = 0.30\%$ Slope

<u>Maximum Horizontal Distance between Gutter Supports</u>

Performed by: Mike Kubista
Checked by: Kyle Geisler

The intent of this calculation is to determine the minimum spacing between gutter supports by use of an equation supplied by JM Eagle's Technical Bulletin(1). The calculations yield a minimum spacing of 4 feet and 8 inches, well above the 1 foot and 11 inches that EWB-RPI has designed for.

Schedule 20, 4 in. PVC pipe specifications:
Modulus of Elasticity: 360,000 psi(2)
Temperature corrections for modulus at 100 °F: 0.88(1)
Temperature corrected modulus: 316,800
D_O: 4.33 in(3)
D_I: 4.20 in(3)

$$L = \left[\frac{0.154\,EI}{W}\right]^{1/3}$$

$$W = 0.0113\,[(3.5D_o^2)-D_i^2]$$

$$I = 0.0491\,(D_o^4-D_i^4)$$

L = Maximum horizontal distance between pipe supports
E = Temperature corrected modulus of elasticity
I = Moment of inertia
D_O = Average exterior pipe diameter
D_I = Average interior pipe diameter

L = 56.28 in = 4ft 8in

Pipe Size (in)	SCHEDULE 40 PVC Temperature °F					SCHEDULE 80 PVC Temperature °F				
	60°	80°	100°	120°	140°	60°	80°	100°	120°	140°
¼	4	3½	3½	2	2	4	4	3½	2½	2
⅜	4	4	3½	2½	2	4½	4½	4	2½	2½
½	4½	4½	4	2½	2½	5	4½	4½	3	2½
¾	5	4½	4	2½	2½	5½	5	4½	3	2½
1	5½	5	4½	3	2½	6	5½	5	3½	3
1¼	5½	5½	5	3	3	6	6	5½	3½	3
1½	6	5½	5	3½	3	6½	6	5½	3½	3½
2	6	5½	5	3½	3	7	6½	6	4	3½
2½	7	6½	6	4	3½	7½	7½	6½	4½	4
3	7	7	6	4	3½	8	7½	7	4½	4
3½	7½	7	6½	4	4	8½	8	7½	5	4½
4	7½	7	6½	4½	4	9	8½	7½	5	4½
5	8	7½	7	4½	4	9½	9	8	5½	5
6	8½	8	7½	5	4½	10	9½	9	6	5
8	9	8½	8	5	4½	11	10½	9½	6½	5½

Figure 1 – Maximum horizontal distance between hangers recommended by Power-Utility Products Company.

The maximum horizontal distance allowed between supports is approximately 4 feet and 8 inches. The industry standard, for the most closely relatable pipe, is also close to this value, at 4 feet. A comparison is being made to schedule 40 PVC at 140°F (fairly flexible schedule 40 PVC) because little data is available about schedule 20 PVC due to it not typically being sold in the US. However, our proposed design calls for supports every 1 foot and 11 inches, well within the maximum spacing. Therefore, the design will be able to easily sustain the loads associated with daily use.

1) *Support Spacing for Suspended Water, Sewer, and Drain PVC Pipes.* JM Eagle. Jan 2009.
2) *PVC Pipe Specifications, Sizes & Pressure Ratings*. Professional Plastics Inc.
3) *Product Specifications: PVC Industrial Pipe Schedule 20.*SHRH Piping.

Tank Stands:

The tank stand will be constructed using 2x4" pieces of the locally found Nispero Wood. A failure in the stand would cause the entire system to become ineffective. The steps taken to analyze the tank stand design are shown below.

Design Elements

Platform Size	4'x4'
Fence Height	4'
Board Size	2"x4"
Height off Ground	3'

Elastic Modulus of Wood	1,720,000 psi

Maximum Weight on Stand

Empty Tank	105 lbs
600 Gal of Water	5,000 lbs
1 Person	200 lbs
4' Tall Fence	64 lbs

Factored Load

1.2 DL+ 1.6 LL	8525 lbs
Weight per Column	2130 lbs

Euler Buckling Required Column Size

By manipulating the Euler Buckling Formula, the equation below shows the minimum allowable column dimension based on loading capacity.

$$b = \left(\frac{12PL^2}{\pi^2 E}\right)^{0.25}$$

Minimum Column Size	0.5”~1”

The 2x4” design will have more than double the required column load capacity.

Platform Deflection

The maximum allowable deflection is L/240. The following equations show that using 2”x4” platforms will have adequate strength against deflection.

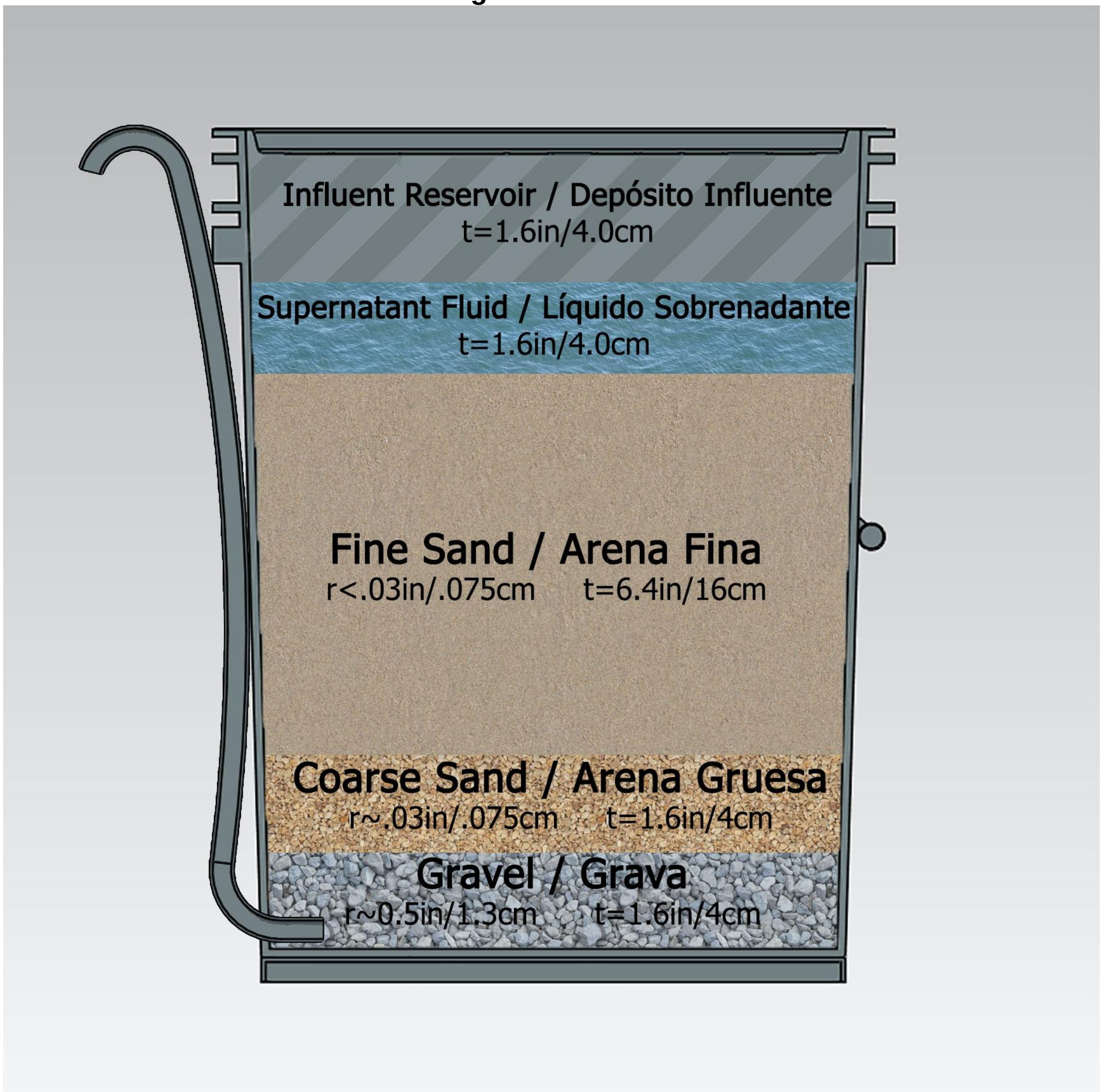
Plank Loading	15 lbs/ft

$$\Delta = \frac{5WL^3}{384EI}$$

Deflection at Center of Plank	2.4E-06”

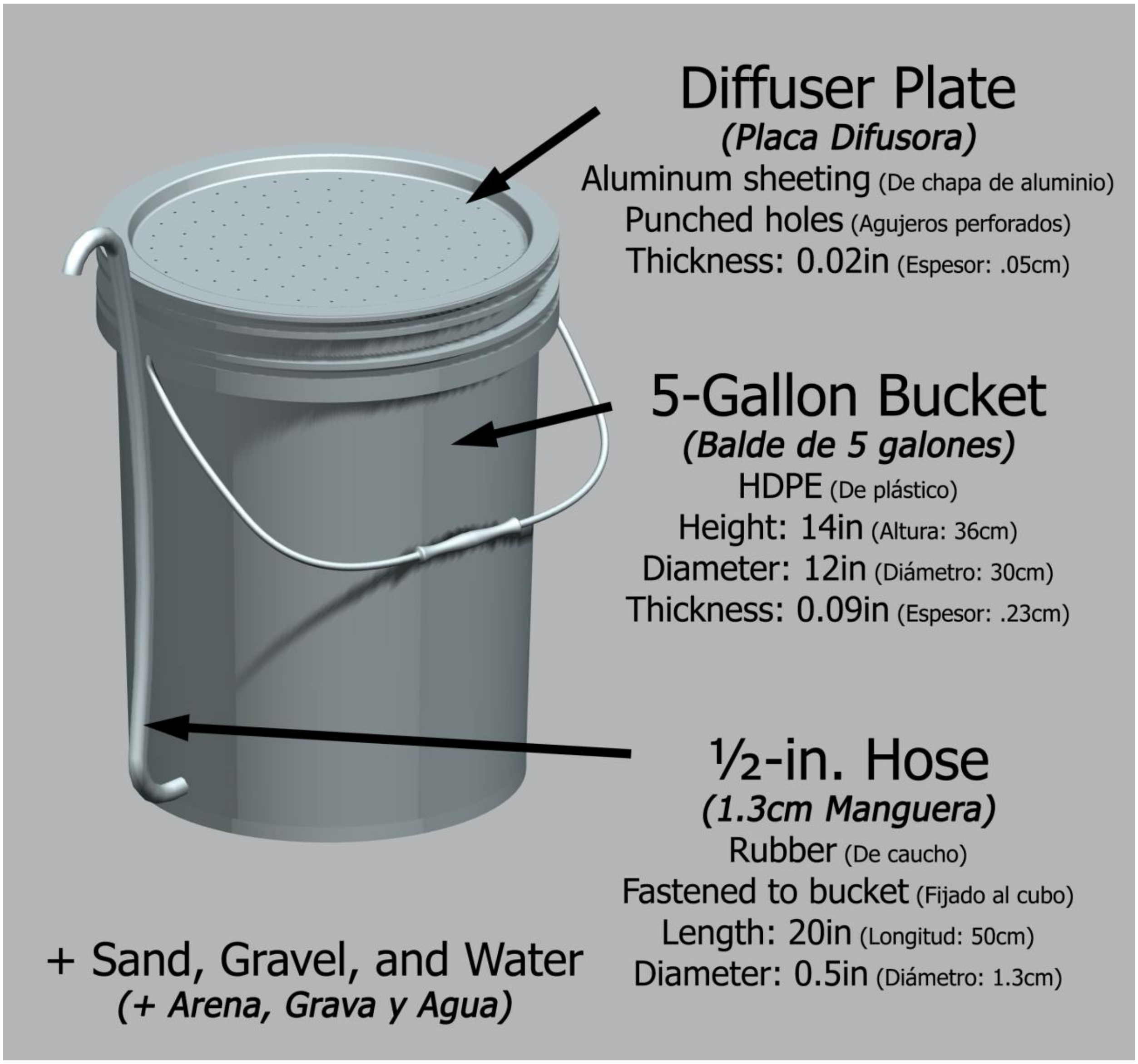
Since the plank deflection is well below the maximum allowable, a stand using 2x4s is adequate for this design.

APPENDIX C.8: Biosand Filter Design[8]

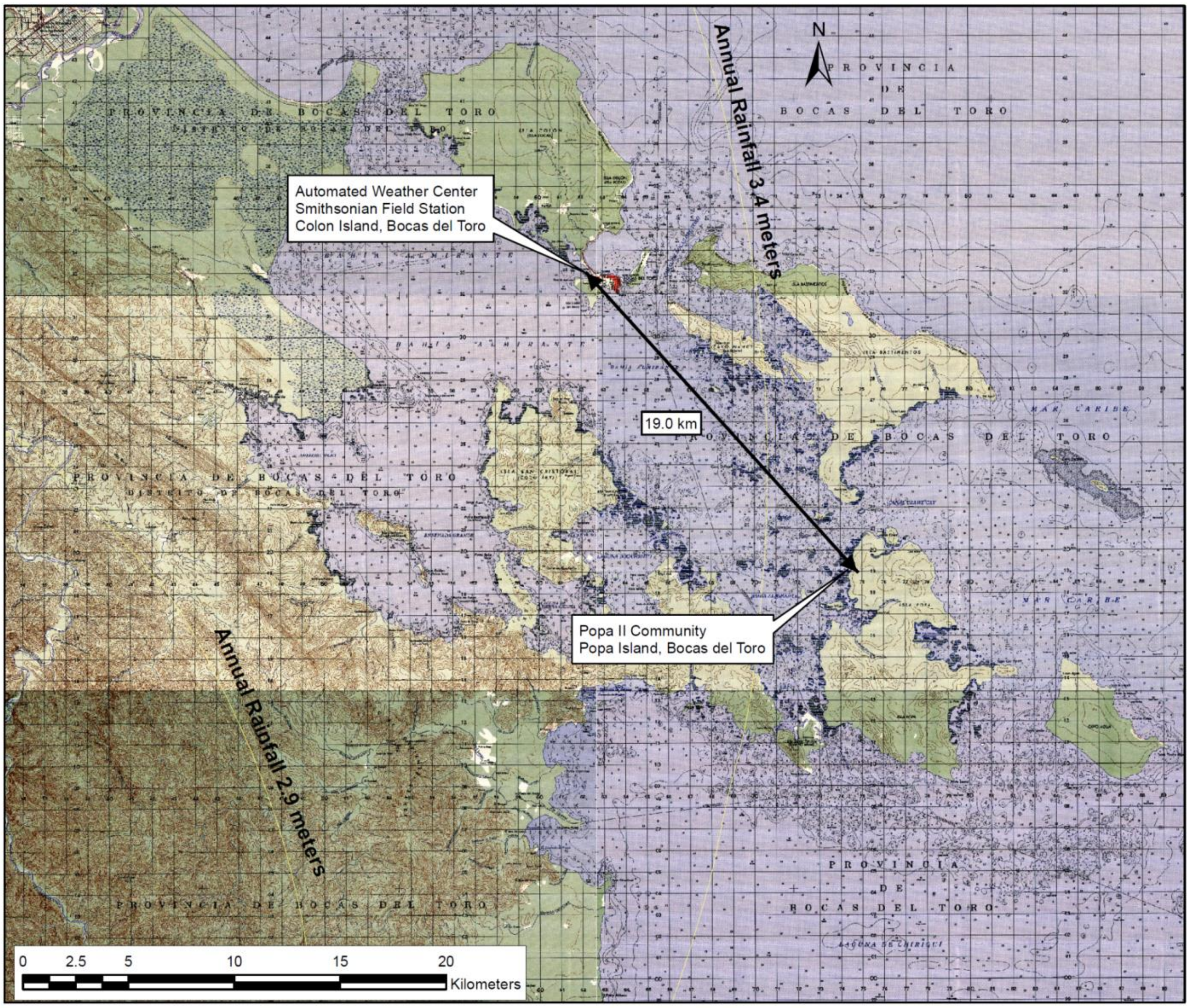


Note: 't' refers to thickness; 'r' refers to the grain of the sand used (applies to sand layers only)

[8] CAWST (Centre for Affordable Water and Sanitation Technology). (2010). *Biosand Filter Manual Design, Construction, Installation, Operation and Maintenance: A CAWST Training Manual*


Diffuser Plate
(Placa Difusora)
Aluminum sheeting (De chapa de aluminio)
Punched holes (Agujeros perforados)
Thickness: 0.02in (Espesor: .05cm)
5-Gallon Bucket
(Balde de 5 galones)
HDPE (De plástico)
Height: 14in (Altura: 36cm)
Diameter: 12in (Diámetro: 30cm)
Thickness: 0.09in (Espesor: .23cm)
½-in. Hose
(1.3cm Manguera)
Rubber (De caucho)
Fastened to bucket (Fijado al cubo)
Length: 20in (Longitud: 50cm)
Diameter: 0.5in (Diámetro: 1.3cm)
+ Sand, Gravel, and Water
(+ Arena, Grava y Agua)

APPENDIX C.9: Map of Bocas del Toro



Map Notes:
Smithsonian Field Research Station
Automated Weather Center
Colon Island, Bocas del Toro
Community of Sandubidi
Popa Island, Bocas del Toro
Precipitation Contours Generated in 2008 by the
Comision Centroamericana de Ambiente y Desarrollo (CCAD)
Map Generated in ESRI ArcMap 10.0

Designed by David Railsback (david.m.railsback@gmail.com)
Checked by Jesse Freitas (freitas.jesse@gmail.com)

APPENDIX C.10: Site Map
Map is too large to include in this document. Please reference the attached Appendix as a PDF.

APPENDIX D: Education Pamphlet (Translated)

See attached document labeled Appendix D