Muramba and Mugonero, Rwanda January 2006: DESIGN REPORT

"Sustainability Through Stewardship"

Prepared by:

EWB-University of Colorado at Boulder
www.ewb-cu.org

EWB-Johnson Space Center Chapter
www.ewb-jsc.org

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

Prepared: February 2006

TABLE OF CONTENTS

1.0 INTRODUCTION

1.1 Project Description

As a result of being broken in a landslide and healing without medical treatment, the farmer's femur, arm and wrist were badly misaligned. Now, years later, visiting orthopedic surgeons were helping Mugonero's resident doctor to re-break and re-set the bones correctly. Suddenly, the power failed and the surgery lights went dark, plunging the operating room into equatorial darkness. Instead of suspending the surgery while nurses fumbled to light emergency kerosene lamps, the surgeons reached above their heads and pulled two switch chains, flooding the rooms with light produced by solar panels and batteries installed only a few days earlier by Engineers Without Borders-USA.

During this visit in January 2006, EWB-USA's sixth to Rwanda since 2004, a team from University of Colorado at Boulder Chapter and the Johnson Space Center Chapter visited two Congo border communities and implemented a coordinated array of projects aimed at developing healthy societies and partnerships.

1.2 Background of Project

This project has been in development since June 2003. Background documents are listed below.

"Assessing Engineering Solutions for Muramba, Rwanda," EWB-USA, Spring 2004.

"EWB-USA Muramba Project Health Metrics Survey Report," Frances Feeney, Spring 2004.

"EWB-USA Rwanda: May 2005 Design Report," EWB-USA, May 2005.

"Developing Another World: Mugonero Hospital, Rwanda" EWB-JSC, http://www.ewb-jsc.org/mugonero.htm

"Rebuilding After the Time of the Running", Colorado Engineer Magazine http://cem.colorado.edu/archives/fl2004/rwanda.html

1.3 Contacts and Partnerships (community & chapter)

Rwanda Contacts

EWB – Rwanda Project Cell Phone	00 250 08440607
Peter Muligo – USAID 00 250 08683263	jmuligo@usaid.gov
George Learned – US Embassy	LearnedG@state.gov

ConsularKigali@state.gov
Avenue de la Révolution
Tel: (250) 505601, 505602, 505603 **Extension**: 3241

Dr. Jean Damascene Ntawukuliryayo ntdamas@yahoo.fr
00 250 08301612
Minister of Health

Dr. Mark Rangzinger Mail4ranz@aol.com
Director, Mugonero Hospital
00 250 08305600

Mugonero Hospital Administrator Kamali Kalisa Kamali.kalisa@yahoo.fr

Sister Donota uwimanimpayedon@yahoo.fr
Headmistress, Muramba College

Jean Pierre Habanabakize jeanpierre_habanabakize@yahoo.com

Jean Paul Eyadema eyademapaul@yahoo.com

Victor Monroy
Director, L'Esperance Children's Aid Orphanage v.monroy@freenet.de
0025008545731 lesperancerwanda@ao.com

Violette Uwamutara vuwamuta@yahoo.com
First Secretary Rwandan Embassy
250.08.641745
250.08.613.211

Ambassador Zac Nsenga, Rwandan Embassy zacnsenga@hotmail.com
202.232.2882

Manna Energy Foundation Collaboration

The Manna Energy Foundation also participated in this project. Manna Energy Foundation founder Ron Garan as well as EWB-JSC/Manna member Kiran Vinta were part of the travel team. The Manna Energy Foundation is a non-profit 501(c)(3) organization that was created to achieve four goals:

1. Promote renewable energy awareness to mainstream consumers and assist global markets to transition to sustainable permanent renewable energy systems.
2. Fund and/or conduct charitable projects to impoverished areas with the goals of improving public health, establishing renewable energy infrastructures and sustainable renewable energy based local entrepreneurial enterprises.
3. Promotion of research and development that supports the advancement of renewable energy technology.

4. Promotion of renewable energy education to students of all ages

The Manna Energy Foundation is dedicated to the promotion of renewable energy awareness and is not affiliated with any governmental, industry, religious or environmental organization.

The primary purpose of the Manna Energy Foundations participation on this project was to assess the feasibility of establishing a partnering relationship between the two organizations. The driving force between the collaboration was the awareness that the two organizations share similar and complementary goals. Manna founder Ron Garan was extremely impressed with the dedication and professionalism of the team. He was especially pleased to see that EWB shares Manna's belief that sustainable solutions that involve partnering with local communities are a requirement to break the cycle of dependence in the developing world.

Ron Garan intends to seek formal partnering agreements with EWB-USA and hopes to be able to fund a significant portion of EWB's renewable energy projects through the commercial activities of the foundation.

1.4 Professional/Student Chapters Involved

The team was composed of University of Colorado at Boulder engineering students Kate Beggs, Iain Elliot, Max Gold, John Jannetto, Niko Kalinic, and Evan Thomas, along with volunteers from the EWB-Johnson Space Center Chapter Kiran Vinta and Ron Garan, and professional engineer Dr. Edward Winant. Jean Pierre Habanabakize of Rwanda also joined the team.

This project was lead by EWB-CU with collaboration from EWB-JSC.

EWB-CU

1. Professor Bernard Amadei amadei@colorado.edu
   - Project mentor
   - Instructor for EDC component of project
2. Robyn Sandekian robyn.sandekian@colorado.edu
   - Project budget management
3. Evan Thomas, ethomas@colorado.edu
   - Project Lead
4. Meg VanSciver, EWB-USA Projects Coordinator meg.vansciver@colorado.edu
   - Liaison with EWB-USA and EWB-UW
5. Ed Winant ed_winant@yahoo.com
   - Technical mentor / CVEN 4838 Class Advisory Board Member
6. Cathy Leslie, EWB-USA President
7. Mark Reiner, EWB-USA Projects Director
8. Max Gold Maximilian.Gold@colorado.edu
   - Rainwater catchment, water filtration
9. Iain Elliott iain.elliott@colorado.edu
   - Community health assessment and education
   - Water quality testing
10. Niko Kalinic niko.kalinic@colorado.edu

- Solar powered lighting

11. Johnny Jannetto john.jannetto@colorado.edu
    - Solar powered lighting
12. Christine Chatterley cchatterley@yahoo.com
13. Darby Odell darby.odell@colorado.edu
14. Mitchell Benson bensonm@colorado.edu
15. Kate Beggs Katherine.beggs@colorado.edu
    - Community health assessment and education
    - Water quality testing
16. Evgenii Matrosov evgenii.matrosov@colorado.edu
17. Becky Brosnz rebecca.brosz@colorado.edu
18. Jordan Spatz Jordan.spatz@colorado.edu
19. Shivali Bidaidah shivali.bidaiadh@colorado.edu

EWB-JSC

EWB-JSC website: www.ewb-jsc.org
Heather Paul, EWB-JSC VP: hpaul@ewb-jsc.org
Kiran Vinta, EWB-JSC Secretary: kvinta@ewb-jsc.org
Dan Gargulio, EWB-JSC Treasurer: dagargulio@ewb-jsc.org

2.0 BUDGET & FUNDING

2.1 Detailed Budget

Date	Description	Vendor	Cost per unit	#	Total	Paid By	From which grant
10/10/2005	UV Filter	Creative Energy Technologies Inc	$332.00	1	$332.00		NCIAA
11/1/2005	PV Panels / Charge Controllers for PV, UV systems	The Alternative Energy Store			$4,223.84		4000 FDWU
11/1/2005	Evan's Plane Ticket + ISIC Card	STA Travel			$1,795.30	Evan	Reimbursed from NCIAA
11/1/2005	Niko's Plane Ticket + ISIC Card	STA Travel			$1,795.30	Niko	Reimbursed from SOFO
11/1/2005	Johnny's Plane Ticket	STA Travel			$1,773.30	Johnny	Reimbursed from SOFO
11/2/2005	Iain's ticket	STA Travel			$1,792.05	Iain	Reimbursed from EPA
11/2/2005	Ed's Ticket	STA Travel			$2,376.80	Ed	Reimbursed from NCIAA
11/2/2005	Max's Ticket	STA Travel			$1,810.30	Max	Reimbursed from NCIAA
11/1/2005	FiBoxes	Consolidated Parts	$55.00	4	$239.49		EEF
11/8/2005	Kate's Plane Ticket + ISIC Card	STA Travel			$1,788.30	Kate	Reimbursed from EPA
11/29/2005	Lightbulbs	Creative Energy Technologies Inc			$648.99	Niko	P3
11/29/2005	Misc Home depot / inverter/drill	Home Depot			$572.84	Evan	EWB-USA
11/28/2005	Misc battery wire	McGunkins			$48.15	Niko	EWB-USA
11/17/2005	Misc junction boxes, terminals, etc	Home Depot			$153.45	Niko	EWB-USA
11/27/2005	Wire, connectors, etc	McGunkins			$103.56	Niko	EWB-USA
11/26/2005	Conduit, screws, connectors	Home Depot			$98.66	Niko	EWB-USA
11/28/2005	Panel Wire large system	CED Electric			$109.13	Niko	P3
	Panel Wire small system	CED Electric			$175.22	Niko	P3
	DC Pigtails	Boston company			$121.00	Niko	P3
	Water quality supplies					Kate	P3
12/1/2005	Connectors	Home Depot			$16.74	Evan	P3
	Packaging				$540.00	Johnny	EDC EEF
	Shipping				$1,300.00		EDC EEF
	Ron's ticket	Ron Garan			$434.60	Ron	P3
	Rwanda expenses (see below)				$13,302.32	Evan	
		Total:			$35,551.34		

EWB-CU Rwanda Project January 2006 Travel Advance Accounting

Date of Purchase	Description	Vendor	Amount RF	USD	Type	Deduct from Account
12/20/05	EWB-USA Advance	EWB-USA		$4,404.07	Advance	EWB-USA P3
12/20/05	EWB-CU Advance	EDC		$14,000.00	Advance	EDC
12/27/05	Traveller's Checks fee	Wells Fargo		-$80.00	Logistics	EDC EEF
12/27/05	Leatherman tools	REI		-$356.93	Tools	Eng Dean Matching Grt
12/27/05	Hole saw, fieldbooks	McGuckins		-$39.78	Tools	EWB-USA P3
12/27/05	Mini DV tapes	Ultimate Electronics		-$32.39	Tools	EDC EEF
12/27/05	Router for Mugonero Hospital	Circuit City		-$75.70	Supplies	EDC EEF
12/27/05	RWC supplies, tools, tshirts	Max Gold Misc		-$188.00	Supplies	EWB-USA P3
12/27/05	Tool Engravings	Fast Fix Flatirons		-$100.00	Tools	Eng Dean Matching Grt
12/31/05	Excess baggage charge	Delta Airlines		-$150.00	Logistics	EWB-USA P3
12/31/05	Team dinner + Rwandan partners	The Republic, Kigali		-$250.00	Logistics	Eng Dean Matching Grt
12/31/05	Water	Chez Venant	-12000	-$21.82	Logistics	EDC EEF
1/1/06	Cell phone card	Hotel Castel	-5000	-$9.09	Logistics	EDC EEF
1/1/06	Rental Truck	Peter Muligo		-$100.00	Logistics	Eng Dean Matching Grt
1/2/06	Misc Hardware	Sofar Sarl	-6800	-$12.36	Supplies	EDC EEF
1/2/06	Misc Hardware	Sofaru Sarl	-5500	-$10.00	Supplies	EDC EEF
1/2/06	Water, Bleach	Mini Market	-120500	-$219.09	Logistics	EDC EEF
1/2/06	Wire, grounding poles	Altec Quincaillerie	-230000	-$418.18	Supplies	EWB-USA P3
1/2/06	2 cars rental 12/31 - 1/2	Peter Muligo		-$500.00	Logistics	Eng Dean Matching Grt
1/2/06	Peter Muligo Fee 12/31-1/3	Peter Muligo		-$200.00	Logistics	Eng Dean Matching Grt
1/2/06	Gas for trucks, cars	Peter Muligo	-120000	-$218.18	Logistics	Eng Dean Matching Grt
1/2/06	Rental trucks, flatbed 1/3	Peter Muligo		-$500.00	Logistics	Eng Dean Matching Grt
1/3/06	Hotel Castel stay 3 nights	Hotel Castel	-306,000	-$556.36	Logistics	Eng Dean Matching Grt
1/3/06	Unloading fee in Muramba	JP Habanakize	-5000	-$9.09	Logistics	EDC EEF
1/3/06	5000 liter tank	Sofaru Sarl	-425,000	-$772.73	Supplies	EWB-USA P3
1/3/06	distilled water, rubbing alcohol	Kipharama, Kigali	-10300	-$18.73	Supplies	EDC EEF
1/3/06	bolts	Muhirwa, Kigali	-1,300	-$2.36	Supplies	EWB-USA P3
1/3/06	bolts, screws, battery terminals	CPQ, Kigali	-8420	-$15.31	Supplies	EWB-USA P3
1/3/06	Misc Hardware	Shahjahan Patel, Kigali	-3,625	-$6.59	Supplies	EWB-USA P3
1/3/06	2 PV panel frames	Casements Africa LTD	-262339	-$476.98	Supplies	EWB-USA P3
1/3/06	Misc Hardware (silicone tubes, x2)	Sofaru Sarl	-5,000	-$9.09	Supplies	EWB-USA P3
1/3/06	Batteries	Sulfo Rwanda	-634,945	-$1,154.45	Supplies	EWB-USA P3
1/6/06	Stay in Muramba 5 days	Father Bosco Muramba Parish	-374999	-$681.82	Logistics	Eng Dean Matching Grt
1/6/06	Lunch for 6 Muramba school girls 5 days	Pamela Muramba College	-15000	-$27.27	Logistics	EDC EEF
1/6/06	160 bricks	Louie Muramba College	-5000	-$9.09	Supplies	EWB-USA P3
1/7/06	JP Habanakize fee 12/31 - 1/7	JP Habanakize	-44000	-$80.00	Logistics	EDC EEF
1/7/06	JP Habanakize transportation fee	JP Habanakize	-10500	-$19.09	Logistics	EDC EEF
1/7/06	Work fee 4 days	Louie Muramba College	-15000	-$27.27	Logistics	EDC EEF
1/8/06	Work fee 4 days	Pamela Muramba College	-15000	-$27.27	Logistics	EDC EEF
1/8/06	Water	Chez Venant	-6000	-$10.91	Logistics	EDC EEF
1/9/06	Water	Mini Market	-60000	-$109.09	Logistics	EDC EEF
1/9/06	hardware, zip ties, terminals, bolts	Shahjahan Patel, Kigali	-19300	-$35.09	Supplies	EWB-USA P3
1/9/06	large PV frame, small PV frame	Casements Africa LTD	-413959	-$752.65	Supplies	EWB-USA P3
1/9/06	Misc Hardware	CPQ, Kigali	-25300	-$46.00	Supplies	EWB-USA P3
1/9/06	Ring terminals, brackets	Niko Kalinic	-15000	-$27.27	Supplies	EWB-USA P3
1/9/06	JP, Peter lunch 1/9	German Buchery	-5000	-$9.09	Logistics	EDC EEF
1/9/06	JP, Peter dinner 1/9	New Cactus	-5000	-$9.09	Logistics	EDC EEF
1/9/06	Peter Muligo Fee 1/8-1/11, 1/16, 1/17	Peter Muligo		-$300.00	Logistics	Eng Dean Matching Grt
1/9/06	Hotel Castel stay 2 nights	Hotel Castel	-184000	-$334.55	Logistics	Eng Dean Matching Grt
1/10/06	5 spools wire	Altec Quincaillerie	-165000	-$300.00	Supplies	EWB-USA P3
1/10/06	Mille Collines 1 night Ron Garan	Hotel Mille Collines	-73600	-$133.82	Logistics	Eng Dean Matching Grt
1/15/06	Mugonero Hospital stay 7 days	Mark Ranzinger, Mugonero	-385000	-$700.00	Logistics	AmCom Insurance Grt
1/15/06	JP Habanakize fee 1/8-1/17	JP Habanakize	-55000	-$100.00	Logistics	Eng Dean Matching Grt
1/16/06	Mille Collines 1 night 10 people	Hotel Mille Collines	-272500	-$495.45	Logistics	Eng Dean Matching Grt
1/16/06	Customs fee for PV panels	Coimex, Kigali	-138250	-$251.36	Logistics	EDC EEF
1/16/06	Truck rentals 1/18, 1/9, 1/10, 1/11, 1/16	Peter Muligo		-$1,400.00	Logistics	Eng Dean Matching Grt
1/16/06	Gas for trucks, cars	Peter Muligo	-300000	-$545.45	Logistics	EDC EEF
1/17/06	Truck, car, mini van 1/17	Peter Muligo		-$350.00	Logistics	Eng Dean Matching Grt
1/17/06	Rwanda Foam	Max Gold	-9600	-$17.45	Supplies	EDC EEF
1/19/06	Reimburshable from ET 1 leatherman	Evan Thomas		$100.00	Advance	ET
1/19/06	Remaining Cash on Hand	Travellers Checks		-$4,000.00		
1/19/06	Remaining Cash on Hand	USD		-$540.00		
1/19/06	Remaining Cash on Hand	RF	-364900	-$663.45		
		Total difference:		-$1.71		Contribution from ET
		Total Spent:		-$13,302.32		

2.2 Funding Sources

Funding for the project came from the Rotary Club of Boulder, First Data Western Union, the Engineering Excellence Fund, the Undergraduate Research Opportunity Fund, the CU-Boulder Outreach Committee, EWB-USA, EWB-CU, EWB-JSC, the Manna Energy Foundation, AutoCom Insurance, The UNESCO Mondialogo Engineering Award, the EPA P3 grant, and private donations. The total cost of the project totaled approximately $35,000.

2.3 Donated Hours

A number of people put varying amounts of work into this project. Six students donated between 15 and 35 hours each per week for the project, and mentors and additional students donate approximately 4 hours per week.

3.0 SUMMARY OF PROJECT IMPLEMENTATION

3.1 Summary of Component Implementation & Engineering Outcomes

Muramba

The community of Muramba is defined only informally by the presence of the Muramba Roman Catholic Parish, which lies near the border of the Congo in the Rwandan province of Gisenyi. The community's tranquility was shattered when on April 7, 1994 the assassination of the country's Hutu President touched off a premeditated and well-planned massacre of the Tutsi minority.

In Muramba, the EWB-USA team partnered with Muramba College (a boarding high school for 600 girls) to conduct water quality testing of the region, review hygiene standards, evaluate the health and lifestyle of the community, and educate the residents about the health-saving, sustainable technologies installed by EWB-USA.

Working with 15-year-old Pamela Iliza Turatsinze - an aspiring engineer herself - the team conducted tests for E. Coli, Total Coliforms, pH, Alkalinity, Ammonia, Hardness, Turbidity, Conductivity, Temperature, Nitrate/Nitrite, Free/Total Chlorine Demand, Dissolved Oxygen as well as samples taken for later analysis of All Metals and Total Organic Carbon.

Pamela also assisted the team as a translator of conversations with the subsistence farmers living in the mountains surrounding the College. Members of the EWB-USA team met with 47-year-old Dencilla Nyirangeza in an effort to gain a first-hand understanding of the conditions of the poorest people in the country. Mrs. Nyirangeza lives in a small, pressed-mud brick home with dirt floors and roof of thatched banana leaves. She has lived her whole life in Muramba as a farmer, growing between 30 and 50 kilograms of sweet potatoes or beans per year to support a family of six. At less than 23 grams of food per person per day, the family never has enough nourishment. Though they live and work in a group of ten families, none share their food – no one ever has enough. Mrs. Nyirangeza works part-time as a medicine woman, making less than four dollars a year, which she uses to buy clothes and additional food. The family also raises some animals strictly to sell – they eat meat only once a year, on Christmas.

The team also expanded the rainwater catchment installed in May 2005. The team added an additional 5,000-liter tank to the existing 6,000-liter tank system, for more than 200,000 liters of additional water collection throughout the year. Another 6,000-liter brick tank was repaired and made operational. Finally, an existing gravel filter, which had been revived by the team in May 2005, was now converted to sand for better filtration.

At the Muramba College cafeteria, the team installed a 102-watt solar panel and associated charge controller as well as a 200 amp-hour truck battery to power five compact fluorescent lights. This lighting system now allows the schoolgirls to study after dark. An identical system was installed at the Muramba Clinic to provide lighting for the delivery room and patient rooms.

Mugonero

After returning to Rwanda's capital Kigali to gather supplies, the EWB-USA team headed up to the Mugonero Hospital. The Mugonero Hospital sits atop a hill on the western border of Rwanda, accessible only by a red dirt road riddled with bumps and hairpin switchbacks. Constructed by the Seventh Day Adventist Church early in the 20th century, the complex relies on facilities and utilities that deteriorated through the decades, or were destroyed in the national holocaust. In 1994, 3,000 people hid in the Hospital Chapel to escape the genocide which eliminated a third of the population in the province of Kibuye. The priest in the church wrote an appeal to a neighboring church leader that in part said, "We wish to inform you that tomorrow we will be killed with our families." Treacherously, the receiving priest directed the Hutu military to the complex where they killed almost every person in the building.

The EWB-USA team conducted a full survey of the water needs at the hospital, including quality testing, pipeline layout, GPS data points, and building dimensions for rainwater catchments.

Additionally, the team visited the nearby L'Esperance Children's Aid Orphanage. Founded in 1995 for genocide orphans, the facility now houses younger AIDS orphans as well as adults who grew up there and have nowhere else to go. The team discussed possible future projects with the director, Victor Monroy, including solar lighting, biogas, rainwater catchments and water purification.

The lights provided for the hospital operating room, first requested by resident American Surgeon Dr. Mark Ranzinger in May 2005, were installed as part of a larger system providing lighting for the surgery prep room, two nursing stations, the delivery room, and hallways leading to patient rooms. This system consisted of three 102 watt solar panels, and ten fifty amp-hour batteries. A smaller system lights the administration building and dental clinic. This system also powers emergency internet communications.

The team also had the opportunity to meet with Minister of Health Jean Damascene in Mugonero. Dr. Damascene has been a friend to the project since 2004, and was instrumental in ensuring that the solar panels cleared customs in Kigali tax-free. Dr. Damascene visited the Mugonero Hospital, met with the team, and inspected the work. He continues to encourage and support EWB-USA activities in Rwanda.

3.2 Lessons Learned and Future Evaluations

Team dynamics, preparation and awareness along with community partnership remain the key components of a successful Engineers Without Borders project. The EWB-USA team prepared for this phase of the project starting in May 2005, by identifying objectives, and following through with designs, assembly, test protocols, training, and education. Most team members had worked together for months, and this resulted in high-efficiency work in Rwanda - all day, nearly every day, for three weeks.

While in Mugonero, Dr. Ranzinger stated, "The best thing you can do for Rwanda is kick out all the NGOs … except EWB." He went on to explain that many NGOs, as well as the UN and other non-profits, have fostered corruption and victim mentality in Rwanda by promoting charity. Rather than expecting community partnership, some Rwandans in all levels of the socio-economic spectrum expect money to be handed to them. This attitude has led to failed projects, as well as significant frustration on the part of EWB-USA teams.

EWB-USA's model of community partnership, providing capital infrastructure that is sustained and expanded by the communities, is foreign to many people. Volunteerism, as exhibited by all EWB-USA team members, is also an unusual concept, and has led to long conversations with partners in Rwanda, some of whom have expected money from EWB-USA to aid in the projects.

While these attitudes can be frustrating, many other developments make the projects worthwhile. By partnering with these communities for many years, trusting friendships are developed with key players in Rwanda, who honestly do understand the objectives, motivation and methods of EWB-USA and the team members that travel to their country. Cultivating these relationships is a slow but rewarding process.

The importance of maintaining and improving community partnerships is also considered when developing EWB-USA teams while still in the United States. Team members must be familiar with these methods, with the history of the communities, and must travel with experienced team members to ensure that the partnership continues to develop appropriately. EWB-USA teams working in the same community must work in concert while in the United States as well.

4.0 NEXT PHASE OF PROJECT

The EWB-USA team devised preliminary plans for a May 2006 return to these communities. These projects will be a continuation of the cooperation between EWB-CU and EWB-JSC.

4.1 Biogas

The EWB-USA is actively developing a partnership with the Kigali Science and Technology University (KIST) to install biogas reactors in both Muramba and Mugonero. Biogas reactors take human and animal waste and capture methane produced in decomposition. This technology helps remove contamination from the surface water, promotes hygiene, reduces uses of firewood, and provides fuel for cooking, cleaning, heating, and powering a generator for electricity. Finally, the carbon dioxide produced is a lesser greenhouse gas than methane.

4.2 Rainwater Catchment and Water Filtration

In both Muramba and Mugonero, the team intends to provide a reliable source of drinking water at the clinic and hospital. This will include rainwater catchments, and water filtration and purification. A trade study will be conducted to determine the most appropriate solution. One avenue being evaluated is a stand-alone solar powered UV water sanitizer that would be developed and made available to provide clean drinking water to the general community.

4.3 Kigali Sustainable Housing

EWB-USA now has been recruited to assist in a development project in Kigali where the majority of the population lives on a very low income basis. Due to the short history of planning strategies and regulation, as well as changing land law, most Kigalians live in the unplanned areas which cover about 60% of the city. These housing areas are subject to poor sanitation conditions and problematic access to water. The project focuses on achieving high impact by introducing simple technological methods, which are easy to multiply and which address a high proportion of the population.

4.4 Education

The EWB-USA team will continue to develop education and partnership initiatives in synergy with the engineering projects.

4.5 Project Monitoring and Direction Determination

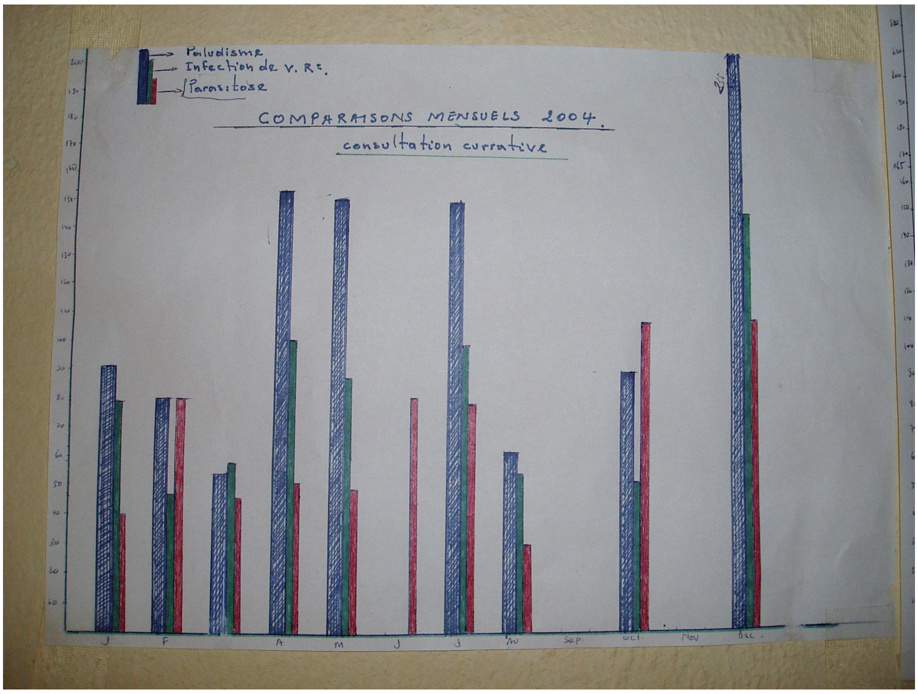
These engineering projects are put in the context of public health. However, we have yet to qualitatively evaluate the success and direction of these projects. A concerted effort in the next phase, building on health assessments presented in this report, will evaluate these projects and future direction in the context of the health of the communities.

Muramba, Rwanda

5.0 HEALTH ASSESSMENT

5.1 Overview of Community

Community health problems in Muramba were broken down into four major categories. Malaria is by far the biggest health problem in Muramba, with respiratory illness and diarrheal/stomach illnesses following second and third respectively. There are charts posted on the wall with the number of cases of each particular illness, broken down by month.



Malaria is blue, Respiratory illness is green, stomach illness is red

The other illness that is monitored and tested for is HIV. There are 43,970 people that are served by the Muramba clinic. Not all of these people have been tested for HIV, and this isn't necessarily the number of people that live in the area. The people that have access to the clinic are funded through outside sponsors or their own financial independence.

Approximately 9 percent of the total population of Muramba is HIV positive, but only 5 percent of pregnant women are HIV positive. Since 2004, aid money has come into the health clinic to increase the number of people that can be tested and treated for various illnesses. HIV testing has increased over the past year, as more and more people are coming in to get tested. All pregnant women who are to give birth in the maternity ward are tested for HIV. If a woman that is HIV positive is treated when pregnant the transmission rate to her child decreases from approximately 25% to 8% probability of transmission.

Malaria is the biggest threat to people's health in the Muramba area. Figure 1 shows the comparison between malaria, respiratory illness, and stomach illness. The biggest thing that can be done to prevent malaria according to Joseline, the head nurse at the clinic, is to give people mosquito nets and to cut bushes. "Water is a gift from God", so she doesn't want to mess with it. Big puddles were not observed, though some of the water pipes did have standing water near them.

Respiratory illness is the next highest affliction in Muramba. According to Joseline it is caused by not having the money to afford clothes and blankets, and from dust. Kitchens could play a large role in this by not having adequate ventilation. The smoke from the cook fires would not necessarily be the cause of all these cases, but it would surely exacerbate the problem. Joseline did not have any ideas on solutions to these problems. She said the poverty is the underlying problem in that people can't afford to provide adequate clothing or food for their children.

Parasites and stomach illnesses are the third largest health problem faced at the clinic. The causes of these according to Joseline are drinking unboiled water and not washing vegetables or fruits. People don't boil their water for several reasons: many people do not have dishes with which to boil their water, firewood is expensive and scarce, and people just don't really care that much. Her solutions are to keep animals in pens or at home so they can't pollute the water supply, create toilets at home, and supply a tap near the home that provides cleaner water. Many people use whatever water source is closest which often constitutes an open stream that has animal and human waste very near it. We tested an open stream up near the source that had a cow five feet from it, and visible waste from some small animal, probably a goat, in the stream. This is further discussed in the water quality testing section of this report.

Health Table for Muramba

Illness	Occurrence	Cause	Potential Solution
Malaria	1^{st}	Mosquitoes	Mosquito Nets
Respiratory	2^{nd} or 3rd depending on month	Dust, Lack of warm clothes, Kitchen Ventilation	Decrease poverty, increase kitchen ventilation
Stomach	2^{nd} or 3rd depending on month	drinking unboiled water, Lack of dishes to boil water	Pen in animals, a tap that provides clean water close to home, Toilets at home
HIV	9% of population	Sexually transmitted disease	Beyond our scope

5.2 Community Interviews

We interviewed a local farmer on our way up to the source of the Parish's water. We sat and spoke with her for about an hour. She has six people living in her home, her husband, herself, and four children ranging in age from 3 to 24. None of her children are married, and the older ones farm with her on their small plot of land. All children attend primary school and can move on if they pass the exams. They grow either 50 kg of sweet potatoes or 30kg of beans per year. They alternate crops each year. They also grow bananas to make banana beer that they sell on market days. Rabbits are grown and sold on market days for 1000rwf a piece. They keep goats, 3 were seen in the home, and they are stewards for a cow. They are paid 4000rwf a year to take care of the cow, and are paid 10000rwf every five years if the cow produces an offspring. When the money is available they buy Irish potatoes at the market. They grow sunflowers for the oil and seeds. Wood is collected from bushes and trails for cooking.

They carry up two 20L jerry cans of water per day. This is used for drinking, washing, and cooking. They get their water from the open stream that is below their home. The latrines that are used are a short distance up the hill. The latrines consist of holes that are dug a few feet deep, and are unlined.

The woman farmer also worked as a traditional healer and earned 2000rwf per year from her work, though most of her time was spent farming and works as a healer only to earn some extra money to purchase food at the market. The area that she lives in has a coalition of sorts with her 9 other closest neighbors. They elect a leader that sits as leader for three years, then can either be re-elected or a new leader elected. Either women or men are eligible for the position. They all grow different crops, but do not share as a co-op. They are there primarily as a support system; if one family has a problem with a sick child for instance, there are nine other families that are available to help out. All of the kids that were in the room during the interview were from these ten families. They don't wash their hands because they have no ready access to water, and no means to buy soap. No irrigation is used, they just use rain water for farming.

Household waste is taken outside and used as fertilizer, no treatment or composting is used. A typical day in her life begins at 6am when she goes to farm in the field. At 12pm she cooks a meal for her children and herself, if there is food. She then goes back to the field to farm until 4 or 5pm when she cooks another meal for her family. Bedtime is usually about 8 or 9pm. She works 6 days a week, and goes to church on the 7th day. She did not volunteer the information about the goats and the cow, only when asked did she tell us about them. She said that their greatest needs were clothes and shoes. Her family can't afford to buy clothes for everyone, and they are all barefoot.

5.3 Muramba College Assessment

A. Sister Donata

Sister Donata is the headmistress of the boarding school for girls that we have worked with in the past. Two team members sat down with her to talk about what their issues are and where they could use help. We also learned from her how our projects have been impacting the community. According to Sister Donata, the water systems installed by EWB have increased the time that the girls can study every day as there is no need to collect water for the school. The school hopes to see the pass rate of the national exam increase from 35% to 50% this year in part due to our water system improvements. She would like to see Biogas implemented in the college. Their second largest expense at the college is on fuel in the form of diesel for the generator and wood for the cook stoves. Sister Donata would like to see biogas implemented to decrease their dependence on wood and potentially diesel, while decreasing the amount of smoke that they emit from the kitchen.

The strengths of the college and Muramba according to Sister Donata are the center for internet they have on the property, although they can't always afford to pay the monthly bill. It has taught many people about computers, and it is the only site with internet access in the region. The cost of using the internet is 300rwf per hour when it is available. Kindergarten is taught in every village, so every child has the opportunity to go to school for a limited amount of time.

The three main expenses at the college are food, fuel, and salaries to teachers. Food is by far the largest expense, with fuel and salaries following. Below is an outline of where the money is spent.

Food Budget
11584500 – 1st term
8293500 – 2nd term
8293500 – 3rd term
28177500rwf – total for the school year 600 pupils plus teachers

Salary
1920000 – 1st term
1920000 – 2nd term
1920000 – 3rd term
5260000rwf – total yearly salary

Fuel
1807500 – 1st term
1807500 – 2nd term
1807500 – 3rd term
5422500rwf – Yearly total for fuel

Fuel for generator – 3600000
Wood for cooking – 1822500

Health is not emphasized in classes at the boarding school. Sister Specioza works with the girls on health. She gives them basic medicines, but a health class is not in the school curriculum. When a student gets malaria, they get tested at the clinic. At the college, malaria is the largest health problem, with stomach illness following as the second most common affliction. Sister Donata said that she thinks that most of the students have worms. The girls don't cook, and don't inhale concentrated wood smoke. That could be a reason that respiratory infection is not as high. Most of the girls have access to sufficient clothing, which could be another reason that they don't have as high an occurrence of respiratory disease.

B. Students

Pamela, a 15 year old female student at the Muramba college, and the other girls were interviewed about health, education, and needs. Everyone in Rwanda attends primary school, if they are in reasonable proximity to a school. In Muramba, the attendance is high as it is paid for by the government. School fees are not a problem until secondary school. The science behind germs and bacteria are taught in Primary 4, 5, and 6. Most children are taught about washing hands, but don't have the access to soap and water that is needed to accomplish this. At the college in Muramba there are three study tracks that a student can follow. Biology and Chemistry is one track, Math and Physics is another, and History and Geography is the third track. All students are taught a small amount of a foreign language in secondary, all children learn French in primary school. The college does have a library, but it lacks sufficient science books. All of the technical books are in French, with some storybooks in English. Few girls go on to University from the college. The identified causes according to Pamela are the lack of books, the inexperience of some teachers, and the lack of preparation for exams. KIST (the Kigali Science and Technology University) does come to the college to teach about what they do, but only for a short amount of time. Only a few of the teachers at the college have graduated from a university.

Most girls drink water straight from the tap if they are thirsty. Pamela gets her water boiled at the kitchen once a week. She shares a 20L jerry can full of boiled water with her friends as drinking water for the week. Sister Donata said that all the girls drink boiled water when they can, but some don't care. Boiled water is provided in the dining hall for drinking during meals, but not at other times.

Many girls don't use soap because they can't afford to bring enough for the entire semester. No soap is available at the taps. Pamela thinks that girls get sick when drinking from the white rainwater catchment tank. This tank was in place before EWB-CU installed separate RWC systems. The school was instructed to not drink from this existing tank and use it for irrigation, but apparently some students have not headed this advice.

Certain foods can cause stomach illness as well. Pamela gets sick when she eats Irish potatoes. This raises the question of where these stomach illnesses are coming from. There is less sickness this year than the last, but Pamela and the girls don't know why. Water treatment medicines are available sometimes from the government, but they are rarely used. The girls think that they won't be able to give birth if they drink water that has been treated. This is also a common thought by people in the surrounding community. They know that washing hands helps keep you healthy, but they don't have the soap, the extra water for washing, or the time generally. The sicknesses that are regularly occurring in the rainy season are cough, diarrhea, and stomachaches. When it rains, the water from the taps appears visibly dirty, and more people are sick.

The needs in Muramba as identified by the girls include clothes, shoes, dishes and kitchen materials, and clean water depending on the tap. People eat without washing their hands, worms enter the feet when no shoes are worn. The main issues perceived by the students seem to be economic issues; public health is not as emphasized as material goods. The strengths of the college according to the girls are the ability to be a teacher when you graduate and that they are generally healthier when at the college than when at home.

C. EWB Muramba

A club to educate both the pupils and the surrounding community about public health issues was loosely formed while we were visiting Muramba. The club was formed by desires from both the EWB-CU chapter and from Pamela and other students as a way to pass on engineering knowledge and ideas. A list of goals was developed by both CU and the Muramba college girls. The goals of EWB-Muramba are to educate people about ways to keep healthy, and helping to provide basic solutions through various different household treatments. The items to be completed by May are as follows:

For the girls:

-Make a connection with the Joseline at the clinic
-Make a connection with Father Bosco
-Start an Official Club at the school
-Supplies List of what would be needed in order to run effectively
-Teacher/Mentor at the school
-Talk to Sister Donata about the club's goals

For EWB-CU:

-Grant Research
-Finding donations or sources of discounted books on engineering and health in French.

The things that would be needed to run this effectively are books on science, health, and engineering in the form of appropriate technology for the library. Also needed are materials include costumes for dances, markers and paper for posters, and money to pay musicians. Different grants are being investigated for funding of the club. A packet will be put together so that they write the original draft.

The potential issues that we can address in Muramba are public health ones. We cannot have a large impact on HIV, although we could potentially have an impact on the respiratory and stomach illnesses. There are different ways of going about doing this, and hopefully the EWB Muramba club will be the best way to address community education about these illnesses. The underlying cause of most of these public health concerns is poverty. How we can address that as a whole is lending our support to the community in a positive manner, without creating dependence on outside resources.

6.0 WATER QUALITY TESTING

6.1 Tests Conducted

On this visit, tests were conducted in order to gain a full perspective of the issues at hand for Muramba water quality. The existing data did not provide a good overview of the water quality in the area. In order to gain a better perspective, more comprehensive testing was done. In reviewing the past water quality data, concerns arose over the conclusions that had been drawn with incomplete data. Many of the tests were done using test strips, which are subjective and do not always lead to accurate results. The team decided to complete a broad array of tests in order to get a better general picture of the water system. This information will allow us to make informed decisions on how to better help improve the water quality in the future by allowing us to have a better understanding of the current water quality.

This testing was done at the beginning of the dry season, and therefore results must be considered as such. During the rainy season or even after a day or two of rain, results may vary greatly as water runs through areas that are not typical channels and may contribute to an increase in turbidity, bacteria counts, and generally decreased water quality.

The tests done and the justification/reasoning for each test can be found below:

Using the Hach sensION 156

pH is a measurement of the concentration of hydrogen ions water. A one-unit change in pH indicates a 10-fold change in acid level. Acidic water can be corrosive and may also contribute to dissolved metals in the water. The ideal pH is between 6.5 and 8.5 in surface water systems. The ideal groundwater pH range is between 6 and 8.5. Rainwater typically is a bit acidic and has a pH around 5.6. Low pH values can be caused by contaminants as well as by low alkalinity, such that pH is easily changed by additions or removals to the water system.

Water with a pH below 6.5 could be corrosive, acidic and soft. These conditions could allow for water to contain metals such as iron, copper, lead, etc. The conditions of pipes could be impacted as well as the smell and taste of the water. To raise the pH, a neutralizer such as soda ash could be added to the water, though this process also increases the sodium levels.

Water with a pH above 8.5 can be hard. Hard water does not pose a health risk and in fact may deliver extra nutrients, though it also causes aesthetic problems such as scale buildup and soap lather can be difficult. The taste of the water can also be unpleasant.

(http://www.freedrinkingwater.com/water-education/quality-water-ph.htm - accessed on 22 January 2006)

Previous water quality tests showed reports of very low pH values, as low as 4.5 in Muramba at the primary school tap. This brought up a great concern of possible dissolved metals or other contamination. The previous pH tests had been done with test strips, which bring in a great deal of uncertainty as the range is based on color determination by the viewer. In order to address these questions, we decided to repeat testing of pH in key areas in the community. We decided to use a more sensitive piece of equipment, the Hach SensION 156 for measurements.

Many of the tested samples fell within the acceptable range of 6.5 to 8.5. Some lower values were found at Tap #1, Tap #2, Parish Tank, Tap by Kitchen and both clinic samples. These lower values could be caused by the fact that most of the water is rainwater and has a low alkalinity, such that the water has little ability to keep a neutral pH. With the clinic water, it appears that the "medicines" added for treatment may also impact the pH.

Conductivity or specific conductance is a measure of ability of water to conduct electrical current. Conductivity is related to the amount of dissolved substance in water, though it does not give an indication of what substances those might be. Conductivity is measured as mhos/cm or microS/cm at 25 degrees Celsius. The typical values would be about twice the hardness as mg/L CaCO3. If conductivity is much much greater than twice the hardness then human influence should be investigated by testing for the presence of sodium, chloride, nitrate, and sulfate. Changes in conductivity may indicate changes in water quality. There is no health standard for conductivity, though a normal value is considered to be about twice the hardness of un-softened water. Mention here what the values were in relation to the hardness, when you mention what values should be talk about what the values actually were and if these values were acceptable.

Conductivity tests had not been done in the past. This test helps to give an indication of dissolved solids in the water, especially metals relating to the low pH values reported.

In general the data we collected showed very low values for conductivity (around 100 microS/cm). This data was backed up by low values seen in total dissolved solids, meaning that there is not a large amount of dissolved matter in the water that is able to conduct electricity. On average the conductivity values were between 2 and 4 times greater than the hardness. This indicates a need to investigate human impacts. Nitrate tests were done, but not chloride, sulfate or sodium.

(http://www.uwsp.edu/cnr/etf/interpre.htm#Conductivity - accessed 22 january 2006)

Total Dissolved Solids is a secondary contaminant as defined by the EPA. The advised limit for TDS is 500 mg/L. Low values of TDS may relate to low alkalinity, as there are few dissolved solids in the water to help absorb changes in the acidity of the water. High TDS may indicate the possibility of higher alkalinity, which will help to provide a greater buffering capacity of the water.

TDS values would give similar information as conductivity – an indication of particulate in the water that may relate to the low pH.

In general, the TDS data values averaged at about 50 mg/L, well below the recommended 500 mg/L.

Dissolved oxygen is a measurement of how much oxygen is dissolved in the water. Aquatic organisms like fish and water plants need dissolved oxygen in water to live. Oxygen dissolves from the atmosphere into water at the surface of a lake or river. Oxygen diffuses very slowly, and the speed of distribution is dependent on many factors such as turbulence, aeration, flow rate and wind. A low dissolved oxygen level indicates a high demand of oxygen in the system. Pollutants such as inadequately treated sewage or decaying organic matter can help contribute to a high demand. Organic materials can accumulate in the bottom of a river or other body of water and may help sustain microorganisms, which consume oxygen as they break down materials. Large populations of aquatic organisms like fish can also produce a large oxygen demand on a system. Dissolved oxygen levels may be high in areas of high turbulence or from cascading water. In general, dissolved oxygen levels below 3 ppm cause stress to most aquatic organisms. (http://www.rwater.com/education/chem.htm)

Due to time constraints, we were not able to measure dissolved oxygen, though it is an important indicator of water health. It would be advisable to do some dissolved oxygen testing in the future to add to the general water data collected.

Tests Using the Hach Colorimeter

Turbidity is a measure of the cloudiness of water. Turbidity is an indication of water quality and can be used to show filtration effectiveness. Higher turbidity measurements are associated with higher levels of disease causing organisms such as viruses, parasites and some bacteria, which can cause nausea, cramps, diarrhea and headaches. Viruses and bacteria from human and animal waste can attach to particles, which allow for bacterial, viral or pathogenic transport. With lower turbidity, there is less particulate in the water so not as many disease-causing items can be found in the water.

Turbidity plays a large role in what type of contamination can occur due to the adhesion of bacteria to particulate in the water. As UV disinfection had been considered as a possible solution, it was also important to find the turbidity levels as there are necessary limits for UV to be effective. High levels of turbidity can protect microorganisms from the effects of disinfection, stimulate the growth of bacteria and give rise to a significant chlorine demand.

(http://www.who.int/water_sanitation_health/dwq/GDWQ2004web.pdf)

Most of the samples had a low turbidity value, below 5 NTU. A few samples had higher values, such as the Main Pipe, Brick Tank, and the Old Tank. These measurements make sense as the main source water was visibly murky and the brick and old tanks had not been properly maintained before testing.

Nitrate can be a component and is also formed during the decomposition of waste, manure or sewage. If infants drink water with high levels of nitrogen, they have an increased susceptibility to methemoglobinemia or “blue-baby syndrome,” which interferes with the blood’s ability to carry oxygen.

Nitrite is an unstable form of nitrogen that occurs during the decomposition process. The EPA’s recommended total nitrogen level including both nitrate and nitrite is 10 mg/L. Between 0 and 2 mg/L is considered to be natural levels. Between 2 mg/L and 10 mg/L shows a human influence on water quality. Above 10 mg/L the levels are considered unsafe. (Did we see unsafe levels of nitrites?)

Nitrate and nitrite are a good indication of human influence, as either fertilizer or human/animal waste.

Most of the samples had low nitrate and nitrite levels, though the gravel filter and the tap by the kitchen had values over 10 mg/L or very close to that. These high levels are most likely caused by human contamination and need to be addressed.

Hardness is caused by dissolved calcium and magnesium. Hard water is beneficial to health, though it can also cause lime buildup and reduce the cleaning ability of soap. Water that is too soft may be corrosive.

0 – 150 mg/L CaCO3 – soft water
150 mg/L – 200 mg/L CaCO3 – ideal water
200 mg/L + CaCO3 – hard water

In general the hardness values were in the range of soft water, between 20 and 50 mg/L CaCO3. This makes sense as there was little opportunity for calcium or magnesium deposits to get into the water. The one exception was the clinic water with medicines that had a value of 124 mg/L CaCO3. This still falls in the soft water category, though it shows that the medicines used greatly influence hardness.

Tests Using Hach Test Strips

Alkalinity is a measure of the ability to neutralize acids and is therefore directly related to pH. Alkalinity results primarily from dissolved limestone or dolomite minerals. Alkalinity and total hardness are typically about equal in terms of mg/L CaCO3. If alkalinity is much higher than total hardness, there could be a need to test for sodium. If alkalinity is much lower than total hardness, it might be wise to test for anions such as chloride, nitrate, and sulfate. Water with a low alkalinity is more likely to be corrosive whereas water with a high alkalinity is more likely to contribute to lime buildup. Between 0 and 150 the water is often corrosive with a low pH. Between 150 and 200 is the ideal water hardness. Over 200 the water may cause lime buildup.

There is no health standard for Alkalinity, though it is ideally about 150 mg/l (~75 – 100% hardness value). Alkalinity is related to the buffering capability that was especially important relating to the low pH values. All of the alkalinity results were below 150, meaning that there was little buffering capacity of the water.

Tests Using Coliscan Easygel and 3M Petrifilm Tests

Coliform bacteria are microorganisms found in surface water, soil, feces or human/animal bacteria. Many coliform bacteria do not cause disease, except for fecal matter which may be carrying harmful bacteria, viruses or pathogens which can cause gastrointestinal disease, hepatitis, or other diseases. The indicator for fecal bacteria is E. coli, which can be directly tested in isolation from other coliforms. For the US, the acceptable limits of coliforms and heat resistant coliforms (primarily looking at e. coli) are both zero (0) colony forming units (CFUs)/100 ml water.

Total coliforms are not as much as a concern in the developing world. People that drink water in these countries are used to regular coliform bacteria and have a gut that is able to handle them. The prime concern is fecal contamination, tracked through the heat resistant coliform bacteria, E. coli.

The previous water quality test results had shown both positive and negative results for E. coli presence, which was a motivation to re-test to get a better understanding of what was going on in the system.

Several sites showed no sign of E. coli contamination, though most had fairly high counts of total coliforms. Both of the samples taken from the clinic did show E. coli indicating human contamination that must be investigated and addressed. The fact that E. coli was still found in the treated sample is a great concern as their treatment is obviously not effective. One possible reason that contamination of the clinic water is so great would be that the source is closer to the clinic and may possibly also be closer to homes and latrines that contribute to the pollution.

After careful review and discussion with numerous members of EWB and CU faculty it was decided that the tests above, along with a metals tests of key samples would give a clear picture of the system.

Medical information

In Muramba, diarrheal diseases were listed as the third most common cause of illness after malaria and respiratory diseases. Diarrheal diseases can be caused by drinking contaminated water, eating unwashed food or from poor personal hygiene practices. Diarrheal causes dehydration and if not treated properly can even be fatal. Other water borne illnesses of interest include cholera and typhoid. For more information about health and its relation to water quantity and quality, please see the health section of this report.

Procedures

Procedures were followed as detailed in the manuals for each of the meters as well as for the Coliscan and Petrifilm tests. From an ease of use standpoint, it would be recommended to further investigate the usage of the 3M Petrifilm tests as the equipment needs and waste produced are both much less than for the Coliscan Easygel tests.

In Muramba, all testing was conducted with Pamela Iliza Turatsinze, a student at the Muramba College. Pamela, an aspiring water engineer and student leader at the college speaks excellent English, French and Kinyarwanda and has expressed a great interest in learning more about the work done by Engineers Without Borders, with a special focus on the water projects.

Working on water quality testing with Muramba College students

6.2 Results

General Observations

Test sites were chosen based on information gathered from community members and team members who had prior knowledge of the water system. The first test site was the source in order to establish baseline data. The source is located approximately six kilometers from the parish along a series of trails. It is across the valley and up in a separate collection basin. The water system was installed approximately seventy-five years ago by Catholic missionaries. Unfortunately, there is not a map available of the system and those with previous knowledge of the system perished or moved away from the area due to the genocide of 1994. The system is made up of a series of pipes and collection boxes that create a spider web of collection points. To map the entire system would take a team of engineers a large amount of time to survey the area. A general schematic is available from the March 2004 EWB-USA Assessment trip report.

The hike out to the source took approximately two hours. The source lies at the bottom of a granite wall slab in a field surrounded by sparse housing and family farming. There are trails throughout the area crossing over and through the streams contributing to the source waters. The source is fed by surface runoff from the hillside as well as some groundwater leeching throughout the year. The water tested was at the point that the water enters the pipeline that continues on to Muramba, The water was visibly murky with mud and grass.


Water source visible in distance

The other tests conducted at the source were done at two nearby taps, both taps were used during the time we were testing, indicating common usage. The first tap tested was a collection box with a tap on it, located approximately seventy-five meters from the start of the pipe. The water in the collection box is fed by a pipe from the main source as well as from water that seeps in through the soil. There also appeared to be another stream that in the wet season could contribute to this collection box, though at the time of testing, it was dry.

The second tap was approximately 200 meters from the start of the pipe. This second pipe has a concrete structure that it empties from, but no tap to stop the flow. This tap appeared to be used heavily as there was a constant flow of children with buckets waiting in line at the pipe.

The raw data from these three test sites is presented below:

Muramba Water source testing results

Test Site Name	Date	GPS Point	pH	Temperature	Alkalinity
	dd/mm/yy	*Waypoint #*		*Celsius*	*ppm CaCO3*
Main Pipe	4/1/06	70	6.86	28.5	40
Tap #1	4/1/06	71	5.74	22.7	20
Tap #2	4/1/06	72	5.45	21.6	20
WHO Standards	-	-	6.5 - 8.5	-	Ideal 150
	TDS	**Turbidity**	**Conductivity**	**Nitrate**	**Nitrite**
	mg/L	*NTU*	microS/cm	*mg/L NO3-N*	*mg/L MO2*
Main Pipe	31.1	27	60.2	0	No Measure
Tap #1	64.5	1	128.1	No Measure	No Measure
Tap #2	52.6	2	103.7	No Meaure	No Measure
WHO Standards	EPA - 500	-	-	Total N < 10 mg/L	

	Ca Hardness	Mg Hardness	Total Hardness		
	mg/L CaCO3	*mg/L CaCO3*	*mg/L CaCO3*		
Main Pipe	No Measure	No Measure	No Measure		
Tap #1	LIMIT	3.59	No Measure		
Tap #2	LIMIT	3.73	No Measure		
WHO Standards	1- 150 soft, 150 - 200 ideal, 200 + hard				
	Coliscan Easygels			**3M Petrifilm**	
	E. Coli	**Total Coliforms**		**E. Coli**	**Total Coliforms**
	CFU/100 ml	*CFU/100ml*		*CFU/100 ml*	*CFU/100ml*
Main Pipe	400	6000		0	5000
Tap #1	0	0		0	0
Tap #2	0	200		0	1000
WHO Standards	0.0	0.0		0.0	0.0

From these results, the main element that draws attention is the count of 400 CFUs/100ml sample of the main pipe. This shows that there is animal or human contamination at the stream headwaters. (It is interesting that the Petrifilm test did not show E. coli contamination. This test was done at a 1:10 dilution which could provide and explanation of the difference in results. It would be a good investment of time to further compare these two tests.) It is interesting to note that no E. coli was found at either of the taps. This might be explained in part by the large drop in turbidity as bacteria needs suspended solids to grab onto. This drop in turbidity may be due to the settling that is taking place in the collection boxes. Other measurements to take note of are the low pH values at the taps along with the low alkalinity of all of the samples. This low alkalinity makes sense with the low values of total dissolved solids measured. Unfortunately due to some errors in testing, hardness and nitrates and nitrites were not measured. It would be expected for the water to have a low total hardness reading.

The pipeline carries the water from the source, down the valley and the back up to the Parish, where it is first stored in the Parish Tank. The parish tank is approximately 20 meters off the ground. The parish tank provides water for all the parish taps and also feeds water to the college water system. The water flows from the tank into a sand filter and then into the college tank. From the college tank, water is distributed throughout the college to all of the taps.

At the Parish, we tested the water in the tank as well as at one of the taps. The tank on the day that we tested was very empty, with only approximately 3 inches of water in the bottom. The sample was taken from what appeared to be the influent to that tank, coming from the source pipeline. We also took a sample from a tap just outside of the kitchen. All water to the parish had been shut off for an unknown reason, and this tap was turned on so we could test.

The results from the parish tank and kitchen tap are below:

Parish tank testing results

Test Site Name	Date	GPS Point	pH	Temperature	Alkalinity
	dd/mm/yy	*Waypoint #*		*Celsius*	*ppm CaCO3*
Parish Tank	6/1/06	0	5.68	22.5	20
Tap By Kitchen	6/1/06	0	6.18	21.1	20
WHO Standards	-	-	6.5 - 8.5	-	Ideal 150
	TDS	**Turbidity**	**Conductivity**	**Nitrate**	**Nitrite**
	mg/L	*NTU*	*microS/cm*	*mg/L NO3-N*	*mg/L MO2*
Parish Tank	45.6	1	90.9	4.9	2
Tap By Kitchen	47.5	2	96.8	6.9	3
WHO Standards	EPA - 500	-	-	Total N < 10 mg/L	
	Ca Hardness	**Mg Hardness**	**Total Hardness**		
	mg/L CaCO3	*mg/L CaCO3*	*mg/L CaCO3*		
Parish Tank	9.7	10.7	20.4		
Tap By Kitchen	21.1	10.3	31.4		
WHO Standards	1-150 soft, 150 - 200 ideal, 200 + hard				
	Coliscan Easygels			**3M Petrifilm**	
	E. Coli	**Total Coliforms**		**E. Coli**	**Total Coliforms**
	CFU/100 ml	*CFU/100ml*		*CFU/100 ml*	*CFU/100ml*
Parish Tank	0	400		0	8000
Tap By Kitchen	0	100		0	1000
WHO Standards	0.0	0.0		0.0	0.0

From these results, it can be seen that there is a significant difference in coliform counts between the Coliscan and Petrifilm tests. There are several possible reasons for this result. As for the first set of tests, the Petrifilm data is from a 1:10 dilution whereas the Coliscan test is from a straight sample. Also, there could have been a problem with settling such that the Coliscan sample did not have the same amount of turbidity, bacteria as the Petrifilm sample. It is important to distinguish which test is more trusted, though in this case as neither test showed E. coli contamination, there is not the need for too much concern. The pH of the Parish Tank is lower than ideal, though again the low alkalinity and TDS values help to explain this. Without buffering capacity, the water pH will vary much more easily. The relatively high total nitrogen counts (Nitrate + Nitrite) is somewhat of a concern. This is most likely from human or animal waste as fertilizers are not used in the area. This high level could, like E. coli counts be used as an indicator of the possibility of other human or animal pathogens being present in the water.

The college water system was also tested at key points. The first test point was the effluent from the filter. (During our stay, the filter was upgraded from a gravel filter to a sand filter. Due to timing, we were not able to test the sand filter, so all results are from the gravel filter.) We also took a sample from the college tank, which is fed from the filter. During our brief survey of this part of the system, we saw that the college tank can be fed from the filter, or straight from the parish tank, depending on how the system is being operated. This is important to note as it indicates that some of the water may not be filtered depending on the operation. The last sample from the piped system was a sample from a commonly used tap in the cafeteria.

Besides the piped system, the college has several rainwater catchment systems, all of which EWB-CU has been involved with. One tank was already in place and was cleaned and maintained by CU during a past implementation trips, while the other catchment systems were put in place with EWB-CU in May 2005 and were adjusted during this trip. We took samples from the old tank and the brick tank. We were not able to test the pre-fabricated tanks as they were drained before we were able to get a sample. The water in both the brick tank and the pre-fabricated tank was visibly dirty due to incorrect operation of the foul flush. These maintenance issues were addressed by the team, and testing of these systems is recommended for the next trip.

The results from the college testing are below:

Muramba College testing results

Test Site Name	**Date**	**GPS Point**	**pH**	**Temperature**	**Alkalinity**
	dd/mm/yy	*Waypoint #*		*Celsius*	*ppm CaCO3*
Gravel Filter	5/1/06	0	7.36	27.1	not done?
College Tank	5/1/06	0	7.50	26.8	0
Student Tap	5/1/06	0	7.07	23.6	20
Old Tank	5/1/06	0	6.97	23.0	20
Brick Tank	5/1/06	0	7.38	26.5	0
WHO Standards	-	-	6.5 - 8.5	-	Ideal 150
	TDS	**Turbidity**	**Conductivity**	**Nitrate**	**Nitrite**
	mg/L	*NTU*	microS/cm	*mg/L NO3-N*	*mg/L MO2*
Gravel Filter	42.5	0	85.7	9.5	1
College Tank	46.1	3	91.7	6.4	2
Student Tap	53.3	0	109.3	6.3	1
Old Tank	34.3	22	69.8	1.2	0
Brick Tank	35.9	14	71.5	0.6	0
WHO Standards	EPA - 500	-	-	Total N < 10 mg/L	
	Ca Hardness	**Mg Hardness**	**Total Hardness**		
	mg/L CaCO3	*mg/L CaCO3*	*mg/L CaCO3*		
Gravel Filter	12.9	12.1	25		
College Tank	10.2	12.3	22.5		

Student Tap	28.6	7	35.6		
Old Tank	5.5	40.6	46.1		
Brick Tank	28.7	20.8	49.5		
WHO Standards	1- 150 soft, 150 - 200 ideal, 200 + hard				
	Coliscan Easygels			**3M Petrifilm**	
	E. Coli	**Total Coliforms**		**E. Coli**	**Total Coliforms**
	CFU/100 ml	*CFU/100ml*		*CFU/100 ml*	*CFU/100ml*
Gravel Filter	0	0		0	3000
College Tank	0	0		0	2000
Student Tap	0	100		NOT DONE?	0
Old Tank	0	400		0	2000
Brick Tank	0	0		0	1000
WHO Standards	0.0	0.0		0.0	0.0

The results show that again there is a disparity between the two coliform tests. It would appear that either the 3M tests overcount or the Coliscan Easygels undercount as the Petrifilm seems to be consistently larger by a factor of 10. The pH of all the water is within a reasonable range despite low alkalinities and total dissolved solids measurements. The turbidity measurements for the old tank and the brick tank are both relatively high. In the case of the brick tank, this makes sense as the foul flush had not been properly used and the tank was full of debris. Regarding the old tank, water test results may lead to some further education and maintenance being done on the next trip.

The last area that was tested in Muramba was at the health clinic located up the road from the parish. The clinic was once connected to the water system, though due to water shortages, the pipes to the clinic have been turned off. The clinic currently relies on gerry cans full of water being carried from a nearby river as their only water source. Each patient must have family members collect water for their consumption as the hospital does not provide water to most patients. The only patients that the hospital does provide water to are those in maternity. The water is treated with an unknown “medicine.” The clinic also boils some of the water for use and consumption by the nurses. Two samples were tested from the clinic: one treated sample from maternity and one untreated sample.

The results from the tests are below:

Muramba Clinic Testing Results

Test Site Name	Date	GPS Point	pH	Temperature	Alkalinity
	dd/mm/yy	*Waypoint #*		*Celsius*	*ppm CaCO3*
Clinic w/ meds	6/1/06	-	5.62	22.7	80
Clinic w/o meds	7/1/06	-	6.32	21.5	20
WHO Standards	-	-	6.5 - 8.5	-	Ideal 150

	TDS	Turbidity	Conductivity	Nitrate	Nitrite
	mg/L	*NTU*	*microS/cm*	*mg/L NO3-N*	*mg/L MO2*
Clinic w/ meds	54.6	5	108.4	3.4	2
Clinic w/o meds	60.3	2	117.2	2.7	0
WHO Standards	EPA - 500	-		Total N < 10 mg/L	
	Ca Hardness	**Mg Hardness**	**Total Hardness**		
	mg/L CaCO3	*mg/L CaCO3*	*mg/L CaCO3*		
Clinic w/ meds	65	69	134		
Clinic w/o meds	14.2	9.5	23.7		
WHO Standards	0 - 150 soft, 150 - 200 ideal, 200 + hard				
	Coliscan Easygels			**3M Petrifilm**	
	E. Coli	**Total Coliforms**		**E. Coli**	**Total Coliforms**
	CFU/100 ml	*CFU/100ml*		*CFU/100 ml*	*CFU/100ml*
Clinic w/ meds	800	30,000		NOT DONE?	Not Done?
Clinic w/o meds	500	20,000		5,000	100,000
WHO Standards	0.0	0.0		0.0	0.0

The results from testing at the clinic bring up the major issue that the treatment being done for the maternity water is not effective. The treatment method is unclear, but it is an additive to water. The specific word used was "medicine." The method of treatment is being investigated. The bacterial count results show higher contamination in the treated water than in the untreated water. As the samples were taken on different days from different cans of water, this variation is not unreasonable. The treated water does have a lower pH, higher alkalinity and much higher hardness than the untreated water. The bacterial counts are again approximately off between tests by a factor of 10. Regardless of the exact count, e.coli presence at either 500 CFUs/100ml or 5,000 CFUs/100ml is of great concern. This water is taken from a source that we were not able to visit due to time constraints. It is on the other side of the ridge from the direction of the source. This source is thought to be closer to the clinic than the stream at the bottom of the valley, although the distance to source or whether it is an open stream or not is unknown.

Included below are GPS data points collected in Muramba in January 2006, corresponding to the water quality test points.

GPS Data from January 2006 Implementation Trip				
Point #	**Description**	**Lat/Long**	**Elevation (ft)**	**Elevation (m)**
Muramba Deanery				
70	Source Visit - Main Pipe	S1 45.799 E29 35.633	6739	2054
71	Source Visit - Tap 1	S1 45.819 E29 35.652	6738	2054
72	Source Visit - Tap 2	S1 45.803 E29 35.721	6597	2011

73	Parish water tower (top)	S1 46.004 E29 37.020	6296	1919
74	Parish water tower (top)	S1 46.006 E29 37.022	6295	1919
75	Parish water tower (bottom)	S1 46.006 E29 37.019	6269	1911
76	Elevated Votech RWC tank	S1 46.112 E29 36.949	6246	1904
77	Ground Votech RWC tank	S1 46.092 E29 36.947	6287	1916
80	Goretti Courtyard tap	S1 45.914 E29 36.771	6085	1855
81	2nd Goretti courtyard tap	S1 45.914 E29 36.785	6240	1902
82	3rd Goretti tap	S1 45.907 E29 36.796	6294	1918
83	4th Goretti tap	S1 45.905 E29 36.809	6261	1908
84	Goretti Kitchen with 5 taps	S1 45.910 E29 36.797	6266	1910
86	Goretti Valve box	S1 45.858 E29 36.881	6231	1899
87	Goretti int road	S1 45.861 E29 36.913	6252	1906

6.3 Conclusions and Recommendations

At this point in the analysis, results cannot be completely conclusive until we receive the metals test results. From the initial analysis, it appears that there are several issues affecting the different areas of water supply in Muramba.

The concerns for the piped system are the potential for bacterial contamination of the source. Though the general results were quite low for both total and fecal coliforms, it would be predicted that in the wet season, these numbers could greatly increase. This prediction lines up with the comments made by members of the community who stated that there is greater illness from the water during the wet season. This correlation between higher bacterial counts was also illustrated in Mugonero. Two tests were performed on the same source of water on a rainy day and on a non-rainy day. E. coli counts were much greater during the rainy period.

For the clinic, the primary concern is not just the quality of the water, but the quantity. For a medical facility to have no reliable source of water on site and to be forced to rely on carrying jerry cans from the river is a major concern. Water is boiled only for the nurses' use and is treated ineffectively for the maternity ward.

One of the challenges that we will face with our continued work in the community is that many people in the community don't see water quality as the main concern. Poverty is the underlying cause of poor health and many of the community members identified other needs as being more important such as clothes, shoes and food. To help address this challenge we will need to be sure to include community involvement and education.

A summary of recommendations from the water quality findings are:

1. Investigate disinfection methods
2. Education of how contaminated water makes you sick
3. Education of current systems and ideas for the future
4. Maintenance of old tank
5. Compare Petrifilm and Coliscan Easygel tests
6. Gather wet season data

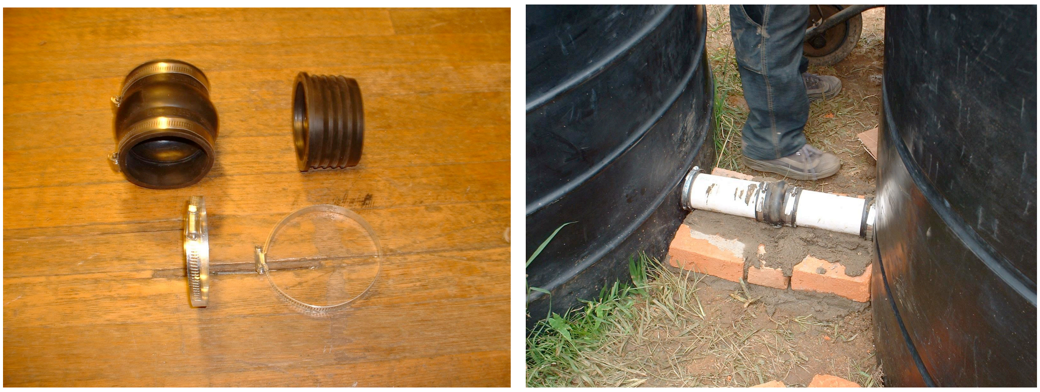
7.0 RAINWATER CATCHMENT IMPROVMENT

7.1 Dormitory Rainwater Catchment System Expansion

The rainwater catchments installed on our previous visit were limited by the capacity of their storage tanks. On this visit, the team added an additional 5000L of storage capacity to the dormitory rainwater catchment at Muramba College. Our estimates indicate that this expansion will be able to provide an additional 220,000 L of potable water over the course of a year. This is enough potable water to serve an additional 60 people at 10 L per day.

Elevated view of the expanded system. The foul flush unit is visible in the lower left corner.

The expansion was accomplished by joining a new 5000 L tank to the existing 6000 L tank for a total of 11000 L of storage. The new tank was about 6” shorter than the old tank and their bases are both at the same elevation. This disparity in height ensures that there is no tank space wasted. Due to the position of the overflow pipe on the old tank, the maximum water level of the system coincides with the top of the new tank. The new tank was connected to the old tank with two lengths of 3.5” PVC pipe and three flexible PVC pipe fittings. The existing tank was drained and the water was stored in 55 gallon drums. Holes were then drilled at the bottom of the tank walls and pipes were anchored in each of the holes with the flexible PVC fittings, water-proof epoxy and silicone caulk. The two pipes were then joined with a flexible PVC junction and secured with large hose clamps. The flexible junction was used to prevent the pipes from coming loose in the event of differential settling between the tanks. The connection pipe was then enclosed in a masonry housing to protect it from foot traffic and the elements. After installation, both tanks were cleaned to ensure maximum water quality.



Left: Flexible PVC fittings and some hose clamps. Right: Connector pipes with flexible PVC fittings.

The expansion was designed with simplicity in mind; the configuration of the expanded system will allow the water form both tanks to be accessed with the original tap. The same is true for the original maintenance drain: when it becomes necessary to drain the tanks for cleaning, the drain in the old tank is capable of draining both tanks simultaneously. Likewise, the foul flush mechanism from the initial installation now serves both tanks.

Tank junction with masonry housing. The new tank is on the left and the old tank is on the right. The dents in the new tank were caused during transport and will disappear when the tank is filled for the first time. The masonry boxes in the lower right corner are the tap and drain housings.

Dormitory Rainwater Catchment Repairs and Recommendations

Dormitory foul flush tank lid seal

After the initial installation of the dormitory rainwater collector in May ’06, the foul flush was observed to be leaking profusely from the lid. This problem was noticed when it rained on our final day in the community and were unable to fix the problem due to lack of time. This problem was resolved on our most recent trip.

The leak was caused by a faulty seal between the foul flush tank and its lid. The sealing solution that the team used during the initial installation consisted of copious amounts of caulk applied to the lid-tank junction. This was not capable of containing the pressure developed by the 5' column of water that is contained in the foul flush down pipe. The result was that during rainfall, when the foul flush was full, the tank would leak a significant quantity of water from the tank-lid junction.

To resolve the problem, the original caulk sealant was removed and replaced with a large rubber gasket. The gasket was fabricated from a bicycle inner tube and placed around the tank opening so as to from a strong compression seal between the lid and the tank. With the gasket in place, the lid is now very secure, requiring the strength of two people to disengage the lid from the gasket. In addition, a layer of caulk was applied to the gasket to enhance its sealing capability. Unlike the previous caulking, this caulk was only applied to one side of the junction so as to not permanently bond the components. The lid is secured with a steel pin opposite the lid hinge.

A flaw in the original configuration was the fact that the lid was bonded to the tank with caulk. Even if it were not leaking, the original solution was a poor choice because the seal would have been permanently compromised when the foul flush tank was opened for maintenance. The new configuration should survive many maintenance cycles because the lid can be removed and replaced without compromising the seal.

Recommendations

While we believe that the new seal is adequate, we were unable to observe it in action because it did not rain enough to fill the foul flush tank during our visit. The team is waiting for a report from the community on how the gasket is functioning. Future implementations of this style of foul flush system should seek an alternative to the 250 L Afritank that was used on this system. Afritanks are not designed to contain upward water pressure and should be substituted with a vessel that is designed to contain water pressure on the lid. On alternative is a plastic 55 gallon drum with a snap-on lid. Implementations using plastic 55 gallon drums with snap-on lids should place all pipe fittings on the walls of the drum rather than on the lid. This is because any plumbing attached to the removable lid will require a secure mechanism for decoupling and re-coupling the fixed down pipe from the lid fixtures.

If a tank with a non-sealing lid is the only thing available, it is possible to make it work correctly. Fabricating a gasket as explained above can work but a stronger alternative would involve permanently sealing the lid in place with epoxy. With the lid affixed permanently, maintenance access could be supplied through a 6" fixture with a screw-in plug placed on the bottom of the tank wall. Maintenance personnel could then remove the plug and reach inside the tank to clear accumulated debris. Obviously, this configuration would not require a separate maintenance drain as the water could be drained through the fixture.

Dormitory foul flush drainage system repair

During our inspection of the system, we found that the drainage system on the foul flush tank was not functioning correctly. The foul flush tank was designed to drain automatically over the course of three days. This was to be achieved with a ~2 mm hole placed in the bottom of the tank wall. Some time between May '05 and Jan '06, someone had plugged the hole, rendering the foul flush useless. It is likely that whoever plugged the hole mistook it for a leak and thought they were being helpful by fixing it. The team predrilled the hole and informed people of the hole's purpose. To prevent it from being plugged again, we will request that the maintenance personnel label the hole with instructions to leave the hole as is. On our next visit, we will implement a more thorough solution as explained below.

Recommendations

The situation with the foul flush drain highlights the need for informing the users of these systems of the concepts involved in their operation. This would prevent well intentioned people from inadvertently causing problems. If this is not feasible, systems should be designed to avoid presenting characteristics that would attract would-be do-gooders. In the case of automated foul flush drainage systems, the drain effluent should be directed into the ground with a tube rather than having it leak directly from the tank. The drain effluent should be directed, via a tube, to a small seepage pit to prevent soil erosion.

7.2 Cafeteria Rainwater Catchment Improvements

The cafeteria rainwater tank was only two thirds complete when we left Muramba in May, '05. It was two weeks later when we got word that the workers had finished the job. We left explicit instructions on how the tank was to be finished, however some of those instructions were not followed. There were also some minor design flaws that became apparent when we inspected the completed tank. What follows is an explanation of these problems and their solutions.

The cafeteria rainwater cistern

Improperly located foul flush tank inlet

The foul flush system on the cafeteria was built in to the main cistern using a dividing wall to separate the main tank and the much smaller foul flush tank. The principle behind this foul flush mechanism was that the down pipe would lead to a “T” junction that branches off to the foul flush tank inlet with the remaining arm of the “T” going on to the main tank inlet. The main tank inlet was supposed to be positioned a few inches higher than the foul flush inlet so that all water coming from the down pipe would be diverted to the foul flush tank until it was full. Once the foul flush tank was filled, the rest of the water would proceed on to the main tank. In our absence, the masons placed both inlets at the same height. This would result in part of the foul flush being washed into the main tank thus contaminating the water.

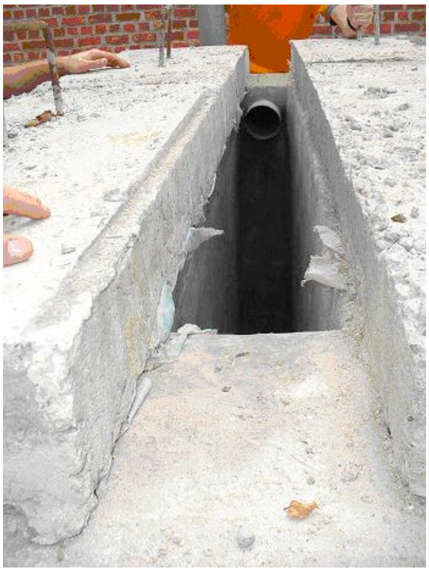
Recommendations

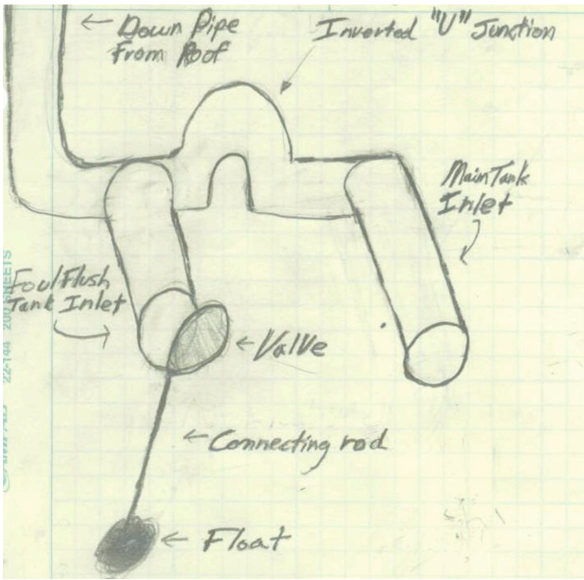
Nothing was done on this trip to fix this problem as the proper materials were not on hand. On the next trip, we intend to fix this problem by introducing an inverted “U” into the pipe that connects the foul flush to the main tank. This will prevent water from entering the main tank before the foul flush has been filled. If a “U” junction were to be installed, the pressure in the system at the foul flush tank would have to be high enough to push the water over inverted “U”. To achieve this pressure it will be necessary to install a float valve on the foul flush inlet. This mechanism will block the foul flush inlet when the foul flush has filled, allowing the pressure to build up in the down-pipe and force the additional water over the inverted “U”. Without a float valve, water will leak from under the foul flush cover as the water tries to overtop the “U” junction. This is because the summit of the “U” junction will have to be above the maximum water level.

An alternative to the installation of an inverted “U” junction and a float valve is to relocate the foul flush inlet 4” inches downward as dictated by the original design. This would also accomplish the goal of preventing foul flush water from entering the main tank however; the water in ending up in the main tank would be of slightly lower quality due to the clean water mixing with the foul flush water as it travels by the foul flush inlet. This alternative would require some fairly difficult masonry to implement but it would allow us to avoid using a float valve resulting in a simpler system. A decision between these two alternatives will be made before our next visit.

A photograph of the improper placement of the tank inlets. The inlet closest to the down-pipe is the foul flush inlet, the other one is the main tank inlet.

To prevent something like this from happening again, it is important that those left in charge of finishing our work be better informed, through discussions, drawings, and calculations, of critical design items like the locations of tank inlets. It would also be helpful to have inspection visits performed by local team members like Jean Pierre or Pamela to insure that the work is completed as designed and that further questions are dealt with appropriately.





Left: Cafeteria foul flush chamber. Right: Proposed modifications to the foul flush design

Leak repair

We found the cafeteria tank to be leaking at the junction between the pipe that supplies the tap and the tank itself. This was a result our improperly reinforcing the pipe wall interface. The original installation involved a modifying the pipe by cutting four lengthwise slits in the end opposite the tap and bending the “tabs” 90 degrees outward from the axis of the pipe producing a flare in the pipe. The flared pipe was then imbedded in the tank wall with mortar. Due to loads introduced by daily operation of the tap, the pipe became loose in the tank wall and a gap formed between the pipe and the mortar. This gap allowed a steady trickle of water to leak form the tank.

To remedy the situation, the team removed the mortar surrounding the flare in the pipe and dislodged the pipe so it was free to slide in and out. While removing this mortar, we found that the “mortar” behind the parge was actually a mixture of sand and lime. This inferior material had never fully hardened and was allowing water to infiltrate through the wall. The lime mixture extended approximately three inches inward from the inner surface of the inner wall. This material was also removed and the surface of the real Portland cement mortar was cleared of lime residues. The pipe was then pulled inward and slathered in silicone caulk. The pipe was then pushed back out which caused the caulk to be distributed along the pipe-wall interface. This action served to form an impermeable gasket around the pipe. The crater was then filled with a pure Portland cement mortar using a modified hypodermic syringe. The cement was made flush with the inner surface of the wall while a broom stick was used to keep the pipe clear.

Recommendations

Future installations of pipes in masonry tank walls must insure that that proper mortar is used to fix the pipe in place. In addition, fixtures that will see daily use must be reinforced to withstand the stress of frequent operation. This reinforcement could be achieved with a masonry housing designed to secure the pipe against torsional loads induced by a user operating the tap. On our next visit, we intend to implement this solution.


Left: Water leaking from the pipe-tank junction. Right: A photograph of the repair in progress


Left: Internal view of the repaired pipe-tank junction. A broom handle was used to keep cement out of the pipe while the cement harded. Right: External view of the repaired junction

General improvements

In addition to the repair of the leaking pipe, the team also performed some improvements on the cafeteria cistern. As initially constructed, the cistern did not have a proper access point for users to draw water from the system. There was simply a tap protruding from the tank wall which provided two feet of clearance for users to place their buckets. We improved access to the tap by constructing a masonry collection point and removing a section of fence to make the tap more accessible. The team also took measures protect the foul flush drain, the main tank drain and the overflow pipe from foot traffic. Sections of rubber hose were used to connect the drainage taps to a preexisting waste water pipe and the lines were then enclosed in protective masonry housings.

Left: JP Habanabakize applies a parge coat to the access point masonry. Right: The improved access point

Protective masonry housings for the tank drains and the overflow pipe. The image in the upper left shows the situation prior to our improvements. The pre-existing wastewater line is buried along the edge of the concrete walkway.

While working on the tank, we found that it was quite difficult to remove the sections of the cover that were designated for maintenance access. On our next visit, we intend to replace these two reinforced concrete slabs with a new slab containing an integral maintenance hatch. The new slab be 35” wide and 92” long with a depth of 5”. There is an offer on the table from Father Bosco to have the Muramba Vocational school students fabricate this hatch in their welding shop.

7.3 Performance assessment of May, 2005 rainwater harvesting systems

When we arrived, both systems would provide water if the taps were turned on however, the water was visibly contaminated. Overall there were a variety of factors that contributed to our systems not performing in an optimal fashion. It appears that, due to the faulty lid seal on the dormitory system foul flush tank, the storage tank was never filled to capacity. This was indicated by a line of scum that accumulated at the apparent high-water mark. We believe that the scum was present due to the foul flush being inoperable as explained above. Because we don’t know when the foul flush drain was plugged, it is impossible to know for sure if the tank was ever completely filled. It could be the case that the tank was filled with clean water prior to the foul flush being compromised, in which case the scum-line would be misleading. Regardless, the faulty foul flush lid seal defiantly caused a reduction in the amount of rainwater harvested.

The misplacement of the foul flush inlet on the cafeteria system is likely compromising the system’s water quality as part of the foul flush is getting washed into the main cistern. It was not possible to ascertain exactly how much foul flush is being introduced into the cistern due the fact that the foul flush was not being drained after storms. During the period where the foul flush was not being drained, rainwater passed directly into the main cistern, roof debris and all. Thus the foul flush was not serving its purpose and the cafeteria system was supplying substandard water. As with the plugging of the dormitory foul flush drain, this situation is a result of the team not doing enough to communicate the workings of the systems to the community.

During this visit, the team made efforts to clarify the misunderstandings that led to these problems. We spent some time explaining the operations of the rainwater collectors to the College technician, the headmistress and some of the students. However, we believe that more drastic measures are in order. We are currently creating a set of weatherproof instructional placards that will be installed in prominent locations on the systems. These placards should ensure that the community will operate the systems properly in the future. Both of these situations illustrate the need for strong communication between EWB teams and their host communities.

As part of our assessment of the performance of the rainwater harvesters, we conducted a series of interviews with to get community members’ opinions on the systems. These interviews yielded some conflicting stories; some people claimed that the systems were working perfectly while others said that they were rarely used. In particular, Sr. Donata has told us that the systems were working well while some of the school girls reported that they never used the because of more attractive alternatives were available such as faucets on the existing water system. Other school girls reported that they used the systems about every other week and Bruce Finley, a journalist from the Denver Post, says he saw them being used during his visit to the community in October, 2005. It could be the case that they were used in the months following our installation but fell out of favor after contaminants accumulated due to faulty foul flush mechanisms. It could also be the case that different people maintained different usage habits and these accounts are reflecting that. This experience highlights the difficulties that can be encountered when trying to gather information from community members that may not feel comfortable delivering bad news to a foreign aid organization. The lesson learned here is that one should consult multiple sources when asking questions are likely to receive sugar-coated answers.

While we have encountered some difficulties with the implementation of these systems; the repairs, improvements, and training performed on this visit should significantly improve their performance. The dormitory system should now be functioning optimally with no water loss, a fully functional foul flush unit and expanded capacity. The cafeteria system should also not experience any water loss; however, it will continue to operate with compromised foul flush system until we are able to make the necessary modifications in May '06.

Left: A member of the team indicates the apparent high-water line in the dormitory system. The excess of dirt in the tank is a result of the foul flush being non-operational for an unknown period of time. Right: Contaminated water in the cafeteria cistern as a result of faulty foul flush construction and operation.

8.0 SAND FILTRATION

8.1 Muramba College Filter improvements

In order to improve the water quality at Muramba College the team implemented a rapid sand filter to treat water before it enters the College reservoir. This was accomplished by upgrading our previous implementation of a gravel filter in a pre-existing filter body that had fallen into disuse. It is our understanding that the filter body was originally constructed in 1989. According to the locals, the filter had been abandoned less than a year after its installation and had remained so until our gravel filter implementation in May, 2005. The reasons cited were a lack of qualified technicians, the community's lack of understanding of the relationship between clean drinking water and improvement overall community health and technician apathy. Upon our arrival this January, the gravel filter was functioning properly. With the appropriate filter body, plumbing for backwashing and distribution lines already in place, the upgrade of the gravel filter to a sand filter was a fairly straight forward task.

Photograph of the filter body and valve house taken from the top of the backwash tank

Deviations from the original plan

The original plan was to procure graded sand with an effective size between 1 and 2 mm. However, graded sand was not available so we purchased ungraded sand instead. The sand was transported to Muramba by truck with the intention of grading the sand ourselves while in the community. Due to time constraints, the team decided to use the ungraded sand in the filter. The grain size distribution of the ungraded sand was determined to be mostly within the accepted limits for sand to be used in a rapid sand filter. The grains that were too large can be defined as fine gravel and were integrated with the existing gravel layer through differential settling during the initial backwash. The particles that were too fine for use were mostly removed during the same backwash process. Any remaining fines will be removed with future backwashes or will settle out in the cleanout chamber.

Another part of the original plan that was changed was our intent to remove some of the gravel to make room for the sand. We had anticipated 30” of gravel in the filter, but when we arrived there was only 19” remaining. The possible reasons for this will be addressed below. Because of this, we did not have to remove any gravel. The sand was simply placed above the remaining gravel.

Media Upgrade

The sand was transported in buckets one quarter mile from the nearest road to the filter; this was done with the help of ten student volunteers from Muramba College. The filter was deactivated and 11” inches of sand was placed above the existing 19” of gravel for a total media a depth of 35”. The filter was backwashed to clean and re-grade the media and to remove ultra-fine particles. The filter was then reactivated. The filter now has a maximum freeboard of 24” and was observed to be operating properly. The filter effluent was clear to the eye but we were unable to scientifically test the effluent due to lack of time.

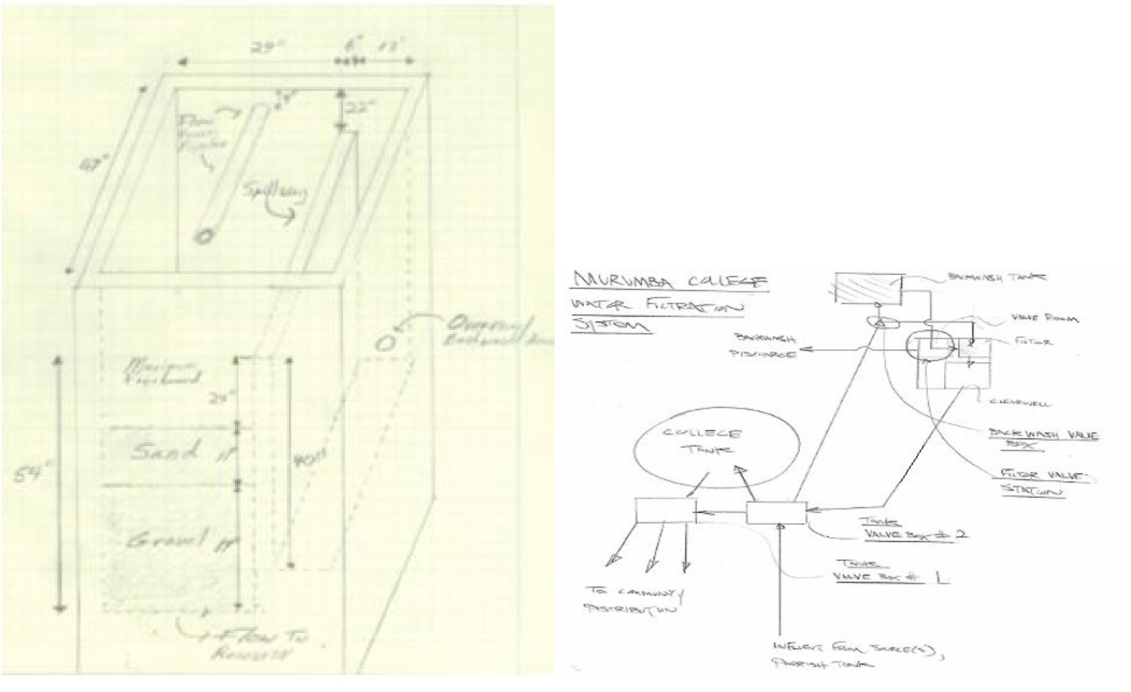
Left: Water flowing over the spillway during the initial backwash. Right: Filter effluent after the backwash. While the water looks clean, it may still be contaminated.

Technical Details

The total filter area in this system is 9.6 ft^2 and the total depth of the filter body is 54”. This volume is now filled to a depth of 30” with filter media: 11” of sand on top of 19” of gravel, leaving the remaining 24” as freeboard. The gravel layer sits on top of steel underdrain plate that is perforated with a grid of 0.5” drainage holes at 1” intervals. The combination of the gravel layer and the underdrain will prevent the loss of sand during filter operation. Some of the sand may percolate down into the gravel layer during normal operation however, that sand should be brought back into position during backwash. Based on a wet season flow rate of 2.4 g/m, the peak filtration rate that the filter will handle is 2.0 ft/h.

The recommended filtration rate for a ***slow*** sand filter is 0.33 to 0.98 ft/h. while the recommended filtration rate for a ***rapid*** sand filter is 16 to 49 ft/h. Thus filtration rate at which the filter will be operating is much closer to that of a SSF. However, we used larger media characteristic of a rapid sand filter to prevent the formation of a bio-layer (schmutzdecke). The reason for doing this is that a bio-layer would prevent the bed form becoming fluidized by the backwash process. The media must be fluidized during the backwash to remove the accumulated filtration residue.

The existing backwash system consists of a large metal water tank on top of a ~ 18' tower. During the backwash process, the flow to the filter is diverted to the water tower and the tank is filled to capacity. The contents of the backwash tank are then routed to the bottom of the filter bed where it flows upwards though the media. During this process, accumulated debris that have been removed from the influent are dislodged from the media and the media is re-graded. The re-grading of the media is caused by the differential settling of the individual particles after being disturbed by the backwash. The backwash water is discharged over the spillway and out of the overflow drain.



Left: Sand filter plumbing diagram. Right: A diagram of the Muramba College sand filter plumbing

Maintenance Directives

For proper operation, the sand filter must be maintained on a regular basis. For this purpose, we have enlisted the help of Louie, the college maintenance technician. He has been instructed to perform the following maintenance operations at specified intervals. The filter must be backwashed at least twice per month. The filter must also be backwashed if the filter is found to be overflowing, which could occur due to debris accumulating more quickly than expected. Debris may accumulate more rapidly during periods of heavy rainfall, when erosion introduces soil at the source. There is no hard and fast rule for the backwash interval, it must be determined through experience. Backwashing may even be required on a weekly basis depending on the weather conditions. The cleanout chamber beneath the filter should be cleaned out every six months. This requires the access hatch to be removed in order to remove sediments and mud that may have accumulated beneath the filter. Normal backwash operations with the access door open would easily remove the sediments.

The complete filter maintenance manual is included in appendix of the May 2005 report.

General Issues

While the filter upgrade appears to have been successful, there remain some issues that the team must keep an eye on in the future. These issues relate to the functioning and maintenance of the filter as well as community's interactions with this system. These issues are explained as follows.

Overflow Drain

A woman who lives adjacent to the filter house made it known that, during the rainy season, the filter house overflows it's uppermost walls, depositing water on the ground surrounding the structure. It is almost certain that this is being caused by the media not allowing the water to pass through at an equal or greater rate than the rate at which the water is entering the filter. This in itself is not a problem; it is simply an indication that it is time for routine maintenance. The matter of concern is that the excess water is coming out of the top of the filter house rather than passing over the spillway and out of the overflow pipe. The overflow pipe is larger than the pipe that delivers water to the filter house and, given the pressure in the line, the overflow pipe should be able to handle the entire flow to the filter in the event of a media clog. This indicated to us that the overflow was clogged. The team investigated the overflow drain and found a number of large sticks lodged within. We removed these obstructions however, due to the inaccessibility of the overflow drain we could not determine if we had completely removed the obstruction. It is possible that there are more obstructions blocking the overflow. When the filter was backwashed after the media swap, the overflow drain was able to handle the backwash flow without any backup into the drainage side of the filter body. This means that any remaining blockage is minor.

Maintenance Issues

During the implementation of the gravel filter in May, '06, it was necessary to run the backwash process to clean the media prior to filter activation. Louie, the college technician played an active role in this initial backwash by operating the valves with the EWB team. During the process, the functions of the valves and the concepts involved with the backwash were explained to him through an interpreter. A pipe schematic was drawn detailing the function of each component and written instructions for maintaining the filter were conferred to Louie. We departed believing that we had properly instructed Louie on the proper operation of the filter. Upon arrival this January, we asked Louie how the filter was operating and he claimed that it was working correctly; we would later find out that, while the filter was working, some of our maintenance instructions were misunderstood. In the days leading up to the media upgrade, Louie was informed of our plans and seemed to understand our intended course of action.

On the day of the implementation, a bucket brigade was marshaled from the student population and eight cubic feet of sand was transported to the filter house. We had begun loading the media into the filter when a visibly distraught arrived on the scene. He explained to us, through an interpreter, that we were about to make his job a lot harder because he was going to have an extremely difficult time removing the sand from the filter. We were curious as to why he thought his duties included removing the media from the filter as this is not part of the specified maintenance procedure. He explained that the “backwash procedure”, which he had performed four times in the previous 6 months, was an incredibly difficult process requiring a full day’s work and the labor of four hired men. Further discussion revealed that Louie had been performing the backwash process as follows: deactivate the filter, remove and wash the media, perform the backwash operation on the empty filter, replace the media, and finally reactivate the filter. Given his understanding of the backwash process, it is easy to see why he was distressed about the prospect of our addition of sand to the filter media. We explained that the purpose of backwashing the filter was to clean the media in-situ, thus abrogating the need for washing 800 lbs of filter media by hand with the assistance of four day laborers. Needless to say, Louie’s concerns vanished without a trace and he was visibly pleased about the fact that he no longer needed to remove the media from the filter on a regular basis.

We went on to explain how the backwash procedure cleans the media in situ by forcing a stream of water through the media and washing debris out of the overflow drain. The circuitous method that Louie had been using did accomplish the goals of the backwash process; however, the correct process is much simpler to perform. We believe that this new understanding of the process will encourage Louie to perform that process on a more regular basis as it is much less arduous than previously thought.

The fact that Louie had removed and replaced the media four times since our departure in May also explains why there was eleven inches of media missing from the filter. It is very likely that this media was lost during the transfers.

Local Children

During our many visits to the filter, we were constantly surrounded by a gaggle of young rascals. These feisty and curious children are likely responsible for the blockage of the overflow drain mentioned above as well as some other minor nuisances. It appears that these children like to play in an around the filter house and adjacent reservoir. Both these structures are without locks to protect their inner workings thus giving these children easy access to the valves that control these systems. In addition to the blockage of the overflow drain, which we believe was caused by the children throwing sticks into the top of the filter body; we believe these juveniles are also responsible for filling the narrow valve-key hole with pebbles. The valve keyhole provides access to an underground valve that controls whether incoming water is directed to the filter or the backwash tank. This valve is operated with a 6 foot long metal key. Louie reports that the keyhole is often jammed with pebbles and that this is a significant nuisance. The figure below shows the key in the valve keyhole.

Flow diversion valve area. The valve keyhole is the hole on the ground with the metal rod sticking out. The metal rod is the valve key.

Recommendations

From a maintenance perspective, there are two main issues. The first issue is with Louie's misunderstanding of the maintenance procedures necessary to operate this filter. We spent a good deal of time talking with him about all aspects of filter operation and we now believe that he has a good understanding. Just to be sure, the team intends to provide a weatherproof placard which is to be mounted on the filter body above the reach of small children. This placard will explain the concept behind the filter's operation and the proper maintenance procedure. In addition, we will be providing Louie with an updated version the manual that was originally written after our visit in May, 05.

In retrospect, our failure to properly convey the principles of filter operation teaches a valuable lesson: Sometimes, especially with complicated systems, showing community members how to use a system is not enough. Even if extensive documentation is provided and demonstrations are performed, an EWB team cannot be sure that true understanding has been achieved until they have witnessed community members correctly perform the operation in question. To avoid this pitfall, future EWB teams should run supervised practice sessions where community members responsible for systems are encouraged to practice the operation on their own until full understanding is demonstrated.

It should also be noted that, were it not for the conversation that took place during the media swap, we never would have known of the misunderstanding. It was by chance that this conversation happened. This shows that something must be done to ensure that finding out about such misunderstandings is not left up to chance. Future EWB teams should follow up on maintenance education by interviewing maintenance personnel on subsequent visits to ensure that a solid understanding is still in place.

The second issue that is complicating the maintenance and operation of the filter is the group of kids that play in and around the filter house. To prevent further problems, we intend to install locks on the filter house door and the valve keyhole. This should prevent them from causing problems for maintenance personnel. There is also the matter of these children throwing things in to the top of the filter house. There is currently a metal grate that is supposed to be covering the hole in the top of the filter, however, when we arrived, the grate was not in place. To ensure that this grate is used properly, we intend to install hinges connecting the grate to filter house. These hinges should encourage proper use of the grate and prevent objects from ending up in the overflow drain in the future.

In addition, the team should continue to monitor the performance of the filter during subsequent visits. While we believe that the filter will perform as intended, there is a chance that further modifications will need to be performed to ensure optimal performance. Depending on how effectively the filter is handling the large flows associated with the rainy season, we may have to increase the maximum freeboard of the filter. This would provide the higher filtration pressure necessary to handle large volumes of water. The maximum filtration rate is directly related to the maximum freeboard level; any flow to the filter that exceeds this maximum rate will cause the excess water to overtop the spillway and go to waste. As it stands, the filter has a maximum freeboard of 24”; increasing this value by removing some gravel or raising the spillway will enhance the capacity of the filter should the need arise. Increasing the freeboard level would also lengthen the backwash interval as the extra pressure would allow the filter overcome more head loss in the media.

Measurement of the maximum freeboard during the backwash process. The end of the tape is resting on top of the sand layer; the waterline is at 24".

Performance assessment of the Muramba College water filter

The initial implementation of a gravel filter at Muramba College can be considered a success. Between May and January, the gravel filter was removing contaminants from the water. Likewise, the media upgrade performed on this visit also appears to be successful. However, we did not have enough time to test the water quality of the new sand filter on this visit. On our next visit to Muramba, we will test the filter effluent in order to quantify the improvement in water quality due to the media upgrade.

While it proved difficult to work on a pre existing system about which we had little information, we did save quite a bit of resources by salvaging this piece of abandoned hardware. Building a comparable system from scratch would have been difficult due to the magnitude of such a project. Future EWB teams should be on the lookout for such opportunities to repair instead of rebuild. However, this should be done with caution. Abandoned hardware can be a sign that the technology in question is inappropriate and not wanted by the community. This is especially true when dealing with systems that were installed by foreign NGOs and later abandoned by the community. Many NGO's are notorious for introducing advanced technology to developing communities and then not doing the follow-up and educational activities necessary to ensure community acceptance. In this particular case, we believe that we have avoided this pitfall as evidenced by the filter still being in operation six months after the initial implementation. However, we can not be sure until we see what is happening five years down the line. True sustainability must be measured on a scale of years, not months.

9.0 SOLAR LIGHTING INSTALLATION

Muramba Maternity Clinic

The Muramba Clinic consists of half a dozen buildings smattered about a small hill near the Muramba Parish. The clinic has no connection to the national grid, and was illuminated using kerosene lamps and incandescent lights powered from a small diesel generator. After meeting with the clinic staff, it was decided that the most important structure to illuminate was the maternity building. In the birthing room, up to 70 babies are born each month, up to half of these in total darkness if no kerosene or diesel is available. The building is a single story structure, composed of two rooms that require lighting: the birthing room and a large patient room. Upon arrival the patient room had no lighting and was not being occupied by any patients.

Muramba College Cafeteria

The college cafeteria, one of the largest buildings at the college, is used as a study room at night. Existing lighting consisted of three solar powered 11W DC compact fluorescents (CFL's), and fluorescent tubes powered by a diesel generator. The generator is expensive to operate and can only be run for roughly two hours a night. The existing solar powered lights were dim and could not be used for a long period of time.

9.1 Design

The two systems installed at Muramba were identical, and consisted of one panel powering five 13W DC compact fluorescent light (CFL) bulbs, and a 200 amp hour battery bank. They were designed so that the lights could be on for 5 hours per day, with three days of autonomy. Also included was one 12V DC pigtail for each system, for powering inverters, cell phone chargers, and other DC appliances.

System Sizing

The system will incur loses from temperature, battery, wiring, and charge controller. Loses due to the charge controller are factored into the wiring efficiency.

Calculating lose due to temperature

Information obtained from NASA website (http://eosweb.larc.nasa.gov/sse/)

Average temp. during 10am to 3pm	24^{o} C
Average peak sun hours	4.76 hrs

Assuming loss of 0.5% per degree C over 25^{o} C, and panels operate at 25 degrees above ambient temperature in Rwanda.

Operating temp. of panels	24^{o} C + 25^{o} C = 49^{o} C
Degrees above ideal temp. of 25^{o} C	49^{o}C – 25^{o} C = 24^{o} C
Lose due to temperature	24^{o} C x .005 = .12

- So panel alone will be 88% efficient
- We assumed a battery efficiency of 85% and designed for a wiring and charge controller efficiency of 97%

Overall panel factor	.88 x .85 x .97 = .73

- So our system has a total efficiency of 73%

Small System Load Summary:

Quantity	**Load**	**Watts**	**Hours Used Per Day**	**Watthours per day (Whrs/day)**
5	CFL	13	5	325

Panels Required:

Determining the peak watts of array that is required for our load

Compensated load	325 Whrs/day / .73 = 445.2 Whrs/day
Watts peak for array	445.2 Whrs/day / 4.76 hrs/day = 93.53 W

- Since our system is not 100% efficient, the system will need to be able to provide for 325 Whrs/.73.
- The peak sun hours define how many hours the panels will be receiving energy from the sun. So the power our panels need to produce is the compensated load/ peak sun hours.

Determining number of panels required

Number of panels required *(using 102W panels)*	93.53W / 102W = 0.92 panels

- Which corresponds to using one 102W panel.

Battery Sizing:

Depth of discharge	= .5
Days of autonomy	= 3 days

- Depth of discharge of .5 means the battery charge will not drain below 50%
- Days of autonomy are consecutive days without sun

Adjusting total Whrs/day defined by our load for losses from battery and wiring

Adjusted total Whrs/day	325Whrs/day / (.85 x .97) = 394.2 Whrs/day

- This is the total amount of Whrs/day that the battery needs to be able to supply to the load to compensate for the losses

Calculating the battery bank size

Bank size in Whrs/day	(3 days / .5) x 394.2 Whrs/day = 2365 Whrs
Bank size in amphrs	2365 Whrs / 12v = 197 amphrs

- Since the depth of discharge is 50%, and there are 3 days of autonomy, the battery bank will be 6X larger than the adjusted total
- Since our system is 12V, the amphrs required are found using I=P/V

Determining the number of batteries to be used

Number of batts. for bank size *(using batts. rated at 200 amphrs)*	197 amphrs / 200 amphrs = 0.98 batts.

Which corresponds to using one 200 amp hour battery.

Charge Controller Sizing:

Determining total current from loads using I=P/V, V=12V

Quantity	Load	Power (Watts)	System Voltage	Current (Amps)
5	CFL bulbs	13	12	5.42 amps

- The panels used have a short circuit (Isc) rating of approximately 7 amps.
- To meet NEC 2005 code, a charge controller that is capable of handling 1.56x the maximum current will be used.

Wire Sizing:

Using sizing tables from Green Empowerment for a design with a 2% voltage drop

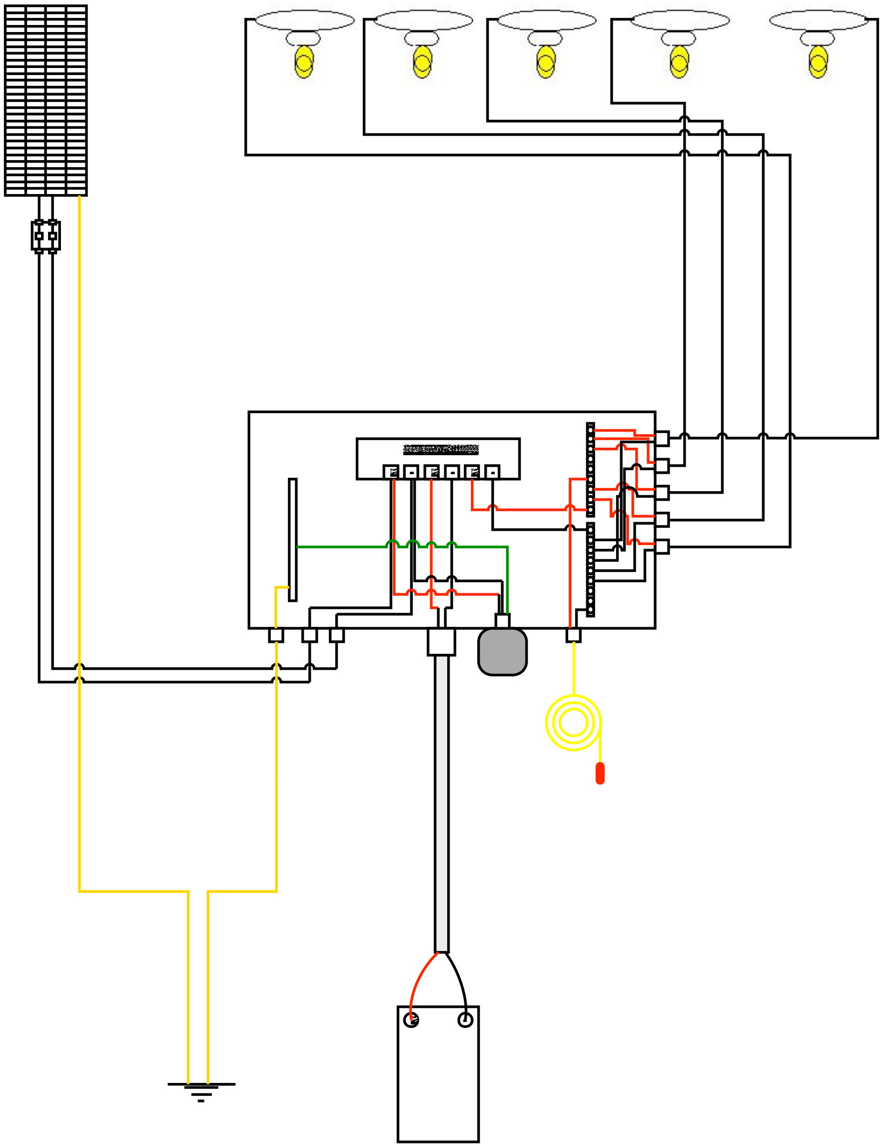
	Distance	Gage
Panels to charge controller	50 ft	6awg
Charge controller to batts.	10ft	8awg
Charge controller to loads	118ft	6awg

- Assuming typical short circuit current for panels of 7amps
- Current from batteries is 6.08 amps (value from total current of system)
- The largest wire that the charge controller can handle will be used from the batteries to the controller
- Maximum current to each application is 2amps
- The value of 118ft for the loads is a maximum distance

9.2 Component Description

Major Components:

Solar Panels	102W (1)
Batteries	200amphr (1)
Charge Controller	10amp (1)
Wire	6awg, 8awg
Bulbs	13 Watt CFLs (5)



Muramba Clinic and Cafeteria Solar Lighting Schematic

9.3 Materials and Logistics

Acquiring the necessary materials and equipment for four solar systems, was a complex, multifaceted task. Ideally, we would acquire all the materials locally in Kigali rather than transport them there. However, this could not be the case. The system needed to be tested in Boulder first, and after remote checks for equipment available in Kigali, it was found that many of the materials needed were either very expensive or unavailable. The matter of transportation also needed to be taken into account. For example, an estimated 500 meters of wire was needed to run to the lights, a bulky item in that quantity. Most of our solar equipment (panels, charge controllers etc) was purchased through the online Alternative Energy Store, who provided a 5% discount. The panel and battery wire was purchased through a local electrical supply shop, while the wire from the charge controller to the lights was purchased in Kigali. Miscellaneous materials, which included Arlington strain relief connectors (essential), light fixtures, and conduit, were purchased at The Home Depot. The frames for the panels were custom manufactured in Kigali.

Materials Acquired In United States

102 W Evergreen Solar Panel (6)– The Alternative Energy Store
Morningstar SHS-10 Charge Controller (3) – The Alternative Energy Store
Morningstar ProStar 30A Charge Controller (1) – Alternative Energy Store
Della DC Lightening Arrestor (4) - The Alternative Energy Store
Fibox electrical enclosure (4) – Fibox Distribution Denver
ELS 13W 12V DC CFL (50)
Panel and Battery Wire (4 and 6 Gauge) – Local Electrical Supplier
Arlington Strain Relief Connectors – Home Depot
Pull Chain Light Fixtures – Home Depot

Materials Acquired In Kigali

200 amp hour ‘FB’ truck battery (2)
100 amp hour ‘FB’ truck battery (2)
50 amp hour ‘FB’ truck battery (10)
Copper Grounding Rods (4)
Wire (12 Gauge, approx. 500m)
Panel Frames

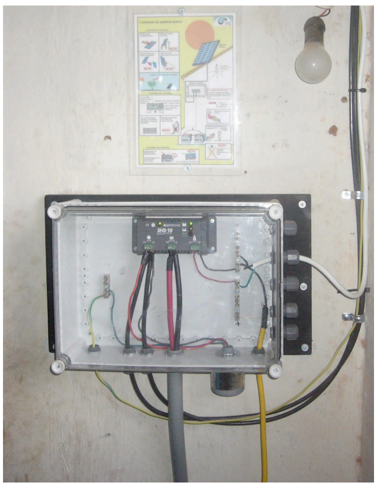
Despite the large volume of the equipment acquired in the United States, the solar panels were the only pieces of equipment that could not be transported in suitcases. After much deliberation, it was decided that it would be best to use a major commercial shipping company (DHL, FED-EX, UPS etc) rather than an independent shipping broker. This was because the larger companies are generally more reputable than small, obscure shipping brokers. Economically it also was the obvious choice as everything going to Rwanda from the West must be air-freighted in, which is very expensive with a shipping broker. FED-EX was deemed the cheapest, most reputable option. The panels were put into individual plywood boxes and shipped in early December. They were scheduled to arrive in Kigali within one week, but after two days they disappeared of the tracking radar, and nothing was heard from them for more than two weeks. Numerous emails and phone calls to our contacts in Kigali, FED-EX and East African Couriers finally located the panels at Rwandan Customs a few days before the teams scheduled departure. With help from the Rwandan Ministry of Health and the First Secretary of Rwanda's US embassy, the panels made it through intact and duty free. Once in Rwanda, the solar equipment was transported to Muramba and Mugonero in rented flatbed trucks without incident.

9.4 Installation Details

Muramba Maternity Clinic

Upon arrival in Muramba, the team decided to install the first lighting system at the clinic. An initial assessment of the maternity building deemed that the clinic roof was not a suitable location for mounting the solar panel, because it is made out of old, extremely fragile fiberglass. Instead, the panel was installed on the clinic's metal porch awning. The rest of the installation went very smoothly. Heavy duty zip ties, clear silicone, and masonry anchors proved vital to the installation.

Inspecting the maternity building's metal awning, where the panel was installed.



The charge controller, inside the Fibox electrical enclosure, and informational placard, located in a closet. One line ran from here to all the lights, which were wired in parallel. The battery was placed on the floor directly below this box.

Niko installing a light fixture in the patient room. Two lights were placed in the patient room, two in the birthing room, and one under the awning at the clinic entrance.

Muramba College Cafeteria

The panel was mounted on the roof of the kitchen, adjacent to the cafeteria. The battery and controller were placed in a storage room directly below the panel. Again, one wire was run from the electrical box and the lights were wired in parallel. Although all the lights did work, sometimes they did not turn on all at once. This was due to the voltage drop in the line from the controller to the lights. The run was roughly 50 ft, causing a large voltage drop for a 12V dc system. We believe that running separate lines to each light during the next visit will fix this problem.

Installing the solar panel on the kitchen roof.

The finished product. The five lights installed by EWB-CU can be seen here alongside the three existing solar lights (white colored lights, on left), providing total illumination.

9.5 Plan for Village Participation and Sustainability

When the team arrived at the maternity clinic to perform a site assessment, two disused solar systems were found. The solar panel of one system was stolen during the war. The other system, which had supplied LED lighting to the birthing room, had been installed by EWB-CU in March of 2004. The clinic staff informed us that the system had stopped working, possibly because the battery was not working, and that nobody knew how to fix it. We found that the load had been wired up to bypass the controller, and that this most likely was the cause of the destroyed battery. Prior to our arrival in Rwanda we knew that this EWB-CU system had fallen into disrepair, so ensuring that the same thing did not happen to our system was a top priority. The team designed informational placards (translated into French, modeled off Green Empowerment examples) which were mounted on the wall beside the electrical enclosure. The placards included information on system maintenance, how long to use the lights, and troubleshooting. The charge controller manuals (also in French), tools required for maintenance, and extra bulbs were also left with each system.

The team also sought to remedy the lack of knowledge by encouraging community involvement during the installation process. The installation at the clinic took place under the watchful eye of many citizens of Muramba. Abdul, a clinic employee, helped us set up the battery and electrical box. Louie, the town technician, and his friends volunteered their time to help with mounting the panel, running wire, installing fixtures, and even kill wasps. These community members were very enthusiastic and stayed with us well into the evening to ensure the job was completed. The installation at the college, gated off from the rest of the community, was not as much of a spectacle, but lacked nothing in terms of community members who were willing to help.

Mugonero, Rwanda

10.0 HEALTH ASSESSMENT

10.1 Overview of Community

Health issues that were seen at the district hospital in Mugonero cover a vast array of illnesses and injuries. Women come in to give birth, tumors are removed, bones set, etc. The main illnesses that we are concerned with fall in the realm of preventable diseases. Malaria is the largest public health issue that the hospital faces. More cases of malaria come in than either ARI (Acute Respiratory Infection) or stomach and diarrheal diseases. The hospital does see cases of typhoid coming in, between 80 and 100 per year with a high percentage of these cases ending up in fatalities. The hospital at Mugonero also offers community education, preventative medicine, condom distribution and birth control/family planning services. Mental health is a huge issue in the Mugonero area due to the events of the 1994 genocide. There were many atrocities carried out in this area, so there are a large number of both genocide survivors and genociders. There still is an underlying tension in the area according to Lodz Joseph, a Master's of Public Health student working with health clinics in the Mugonero area. Addressing the mental health issues of the community is an enormous challenge that in some ways is being addressed by the current Gacaca proceedings. The Gacaca is a series of community trials which are opportunities for community members to make accusations and either admit or deny their actions.

In conversations with both Dr. Ranzinger and Lodz, the causes of the main health issues, malaria, ARI, and stomach illness were identified and discussed. The largest number of cases of malaria are seen from communities near the lake, although there are also cases at the higher elevations. Mosquito nets would be an effective solution to curb malaria at all levels. There were bed nets donated to a large amount of people, but no string to hang them. This is an example of failed good intentions.

Stomach illnesses are caused in part by having livestock too close to water sources and not having good hygiene practices. Clean water is not readily available and people for the most part are not able to carry extra water to their homes in order to wash and bathe. Soap is not readily available in the community, and when it is many people don't have the money or the desire to buy it. According to Dr. Ranzinger, people use their hands to wipe themselves after going to the bathroom and then don't wash their hands. These poor hygiene practices coupled with not having clean drinking water all the time can cause severe stomach illness. These health problems are reported to be much worse during the wet season. This could indicate poorer water quality in the wet season. Reference the water quality section for more on this subject. The solutions to these problems would be to keep livestock away from open streams when not getting water, using some sort of treatment of the water, and education of the reasons why hygiene is used and ways to make soap.

Dr. Ranzinger thought that one of the main causes of ARI is the lack of sufficient clothing for people. Despite the tropical climate, nights can get fairly cold, and without the proper blankets or clothing, pneumonia can be a big issue. These respiratory infections are exacerbated by the cooking methods. Wood is used as fuel in most homes, and generally there is very little ventilation for these kitchen areas. The heavy particulate matter that is given off will most certainly have a negative affect on respiratory infection.

HIV is on the rise in the area of Mugonero. No concrete numbers were available from the two medical professionals we interviewed, but the percentage of the population with HIV is increasing. HIV testing is becoming free at the district hospital and at different health clinics around the area. There is an HIV and maternity clinic about half an hour down the road at a Catholic church. They offer free HIV and testing services.

The hospital at Mugonero does run into issues with the attitude of the community towards it. People think of the hospital as a place to go to die. Dr. Ranzinger thinks that this is a self-serving prophecy, because people come in so late for treatment there is often nothing that the hospital can do to help them. There is a mutual, a cooperative health program, in place to help people afford service at the hospital. People pay 600rwf per year to be part of the mutual and then a 200rwf co-pay (a huge reduction of typical bills) when they need treatment. One dollar is equal to approximately 550rwf. This program is designed to allow people to come to the hospital for help if they need it. Problems are run into with this program so there are some questions that the hospital administration would like to know in order to better tailor outreach programs.

-Have you heard of the mutual?
-Are you planning on joining next year
-How do people respond to people coming out into the community?
-People's attitudes on vaccination
-Do people actually use the free toilet paper
-Wash Stations – what is the cultural take on them

Hospital hygiene is a large issue. The nurses do not always use proper hygiene when attending to patients despite their training, as hand washing is not easily accomplished. Wounds are looked at without using gloves, and then they don't always wash their hands before they move on to the next patient. There are no cultures used at this hospital to tell what would be the best antibiotic for a certain bacteria. During the dry season (June, July, August) the hospital does not have enough water to meet its needs.

The needs of the hospital include water quantity during the dry season, water quality, and energy for cooking. Right now wood is burnt in a communal kitchen. This wood is expensive, and the smoke can cause further health issues.

Rwanda as a whole is having some large issues with public health at the moment. As of January 16^{th} there were 375 cases of cholera in the eastern part of the country. Measures were being put into place to prevent the spread of the disease to Kigali. We are trying to get updated information at the moment, but communication into and out of the country can be very slow.

Three of our main contacts in Mugonero are Dr. Ranzinger, Lodz, and Victor Monroy, the orphanage director, all of whom have said that they will stay in contact with us to give any information that we need. Dr. Ranzinger is the hospital administrator at the Mugonero district hospital. Lodz is a student working on her research for a Masters in Public Health. She is from

New York and will be in Rwanda for 9 more months. Victor is the director at Les Esperance Orphanage. He is Guatemalan and has lived in Europe for the approximately 20 years. He will be in Rwanda for the next four and a half years.

10.2 Community Interviews

Louise Umutesi

Louise is twenty four years old, is a farmer and has a husband and an infant child. She attended school until she was 18 years old. Her family grows cassava, beans, and maize on a rented field about 4 hours away. The total of the land she farms is about twenty meters by twenty meters. The family grows about sixty kilograms of food per year, and eats most of it. They may sell 1 kilogram per quarter for soap, salt, etc. She generally gets about 150 francs for it.

Louise and her husband work half the month on their field and the other half on a landowner's field to pay the rent. The rent on their house is 5000rwf per month, and the rent on their field is 5000rwf per quarter. They get their water in town and at the hospital. They all use about 60L/day for the whole family.

Family and friends often have malaria, their baby had malaria at the time of the interview. They don't have the money to go to the hospital when they are sick. They use a pit toilet behind the house, and wash their hands afterwards. They work six days a week and rest the seventh. Saturday is their day of rest (by influence of the Adventist church). They use firewood for cooking. They use ¾ of a 2meter piece of wood per day. Louise and her family use paraffin or candles for light, rather than wood.

Poverty is the main problem, because they have no means to obtain necessities. Louise said that she is happy. She stated that she has nothing else that she could be doing, so she is happy.

L'Esperance Children's Orphanage

Les Esperance is an orphanage funded by a German NGO called Les Esperance. Victor Monroy, the director, is a Guatemalan who has been living in Europe and working as an agricultural engineer for many years. His goal is to have a financially self-sustaining orphanage in the next three years. His plan is to have a large scale tropical fruit orchard which are grown and harvested by members of the orphanage and community. The plan would then be to gain an organic certificate and dry the fruit for export and sale to Europe and the United States. There are 103 children at the orphanage grouped into houses of about 20 children per house with one den mother per house to take care of the kids. Jeanne is the caretaker at the orphanage and during our visit acted as an interface between Victor and the children. Victor cannot speak Kinyarwanda, so he needs to use a translator much of the time.

Basic Health

The main health problems that are associated with the children are malaria and stomach related illnesses. On average, there are 4-6 cases of malaria per month, with the worst months being

January, May and August. Stomach illnesses affect 8-10 children per month. The illness typically lasts about 3 days and sometimes is serious enough to require that the children go to the hospital in Kibuye. The sickness is difficult to get rid of, and treatment doesn't always work. Jeanne thinks that it might be malnutrition, or a poor lifestyle. Many of the older kids at the orphanage were orphaned in the genocide. There could be things associated with the genocide that cause the sickness, although a more complete survey must be done in order to determine for sure what the causes are. The sickness reportedly occurs mainly in the older kids, but before a definite cause can be determined though, we need to find out where the kids are getting their water. The kids wash their hands in unboiled water when they wash them at all. Sometimes there is soap available, though these are rare occasions. The sickness could also stem from flies moving from the latrines to the kitchens, though Jeanne thinks this is unlikely. Lights in the latrines would be beneficial to hygiene so that they stay clean at night. This could reduce some of the stomach diseases, but would not be the only solution necessary. Jeanne thinks that it is a dietary problem and that if the kids could get milk and other nutritious foods that the stomach problems would be diminished. The two kids interviewed said that they both drank boiled water all the time, but Victor doesn't think that this is accurate. He doesn't think that many of the children drink boiled water ever due to the energy it takes to boil it and the time to wait for the water to cool enough to drink.

10.3 Les Esperance Community Assessment

There were cows that were donated to the orphanage, but the land could not support all of them due to a lack of grazing area. There are small amounts of subsistence food being grown on the orphanage grounds, however most of that will be taken up by fruit trees in the future. The goal is to use the money from exporting fruit to pay for all of the food needed in the orphanage. Water storage is needed on the property both for human consumption and agriculture. Irrigation is planned for the property to be more productive, and as of right now the children must walk to fetch water every day.

The orphanage has a lot of land, and the potential for being a productive fruit plantation is high. Things are developing very quickly since Victor has taken over. He has been there for six months and already they are producing pineapples, and have started the process of growing avocado trees. The orphanage does face some problems though, and overcoming these will be the challenge. Right now insufficient water is available to meet the needs of the orphanage. Energy is needed for study, as well as sanitary reasons. The cost to connect to the electrical grid is 25 million rwf. This is the equivalent of $45,000. That money in itself can provide a solar system to meet the needs of the orphanage as well as provide money for other projects. The orphanage currently has a small solar system to provide some lighting to the houses in the evenings. Victor mentioned that there was a potential future project to expand this system with the help of a German NGO. Energy for cooking besides wood would be very useful due to the high cost of wood and emissions that it gives off. Biogas would be an effective alternative. The kids when on holiday from school work for four and a half hours in the fields helping with the farming. They only work when not in school though, so there are outside workers who are paid employees that tend to the farming when school is in session. All of the kids that are old enough at the orphanage go to school.

Ecotourism is another project that Victor is working on. He envisions taking people on three week canoe trips around Lake Kivu. The area is definitely beautiful and could support such an endeavor.

A vocational school is planned, with the buildings already in place. The classes to be offered eventually include sewing, auto mechanics, and carpentry among others. These will provide people with an opportunity to improve their skill base and improve their economic stability.

Interview With Orphans

We also spoke with a girl named Marie Nyiransengimana and a boy named Pheniase Banganabose. The girl is twenty years old and in 3rd grade of primary school, and the boy is fourteen years old and in the 5th grade of primary school. It takes them ten minutes three times a day to get water, and everyone has to do it. They both said that most kids get boiled water, although Victor doesn't think that this is accurate. They both said that mosquito nets and shoes can keep you healthy by keeping mosquitoes out of your bed at night and by preventing cuts on the feet. The boy identified clothes and shoes as the biggest needs. The girl identified water and electricity as the greatest needs.

Conclusions

Les Esperance could potentially be a great partner with EWB. Victor has the right attitude about what we do, and how we can help. Having an effect on the orphanage would have an impact in several places. Firstly, it will provide the kids there with the opportunities and education about what we do, and give them a chance to make something for themselves. Secondly, it will provide work to people in the community by providing farming jobs, packaging jobs, and opportunity for education through the vocational school. Ecotourism and export of dried fruit will bring in outside money into the community and could have a great impact on the local economy, depending on how that money is then spent. The plan would be to buy food at the local markets, which would provide money to farmers for their excess crops. The help that we could provide would be to increase the productivity of the orphanage by freeing them up from obtaining water for human and irrigation use, and by potentially decreasing hospital costs. The first meeting was extremely positive, and a relationship should be pursued in the future.

11.0 WATER QUALITY TESTING

Engineers Without Borders is just beginning its partnership with the Mugonero Hospital and the L'Esperance Orphanage. In order to begin to collect baseline data to help direct future projects done in both of these locations, a broad range of water quality tests were conducted.

The weather patterns in Mugonero were drastically different from those in Muramba. It rained much more during our stay in Mugonero than in Muramba. We were told that the weather patterns vary greatly between the areas and it would be useful to further research weather patterns in both areas. Drastically different results were seen for E. coli counts from a wet day to a dry day which has given us some insight to the changing nature of the water quality.

After careful review and discussion with numerous members of EWB and CU faculty it was decided that the tests below would give a good overall understanding of the system.

11.1 Tests Conducted

The tests done and the justification/reasoning for each test are identical to those conducted in Muramba, and presented earlier in this paper. Only the results will be presented here.

Tests Using the Hach sensION 156

pH: Many of the tested samples fell within the acceptable range of 6.5 to 8.5. Some lower values were found throughout the hospital water system as well as at the Tank Down Hill at the orphanage. The pH is not extremely low in any of these cases, though it is something to keep in mind and do further research into.

Conductivity: In general the data we collected showed very low values for conductivity (around 100 microS/cm). This data was backed up by low values seen in total dissolved solids, meaning that there is not a large amount of dissolved matter in the water that is able to conduct electricity. On average the conductivity values were between 2 and 10 times greater than the hardness. This indicates a need to investigate human impacts. Nitrate tests were done, but not chloride, sulfate or sodium.

Total Dissolved Solids: In general, the TDS data values averaged at about 50 mg/L, well below the recommended 500 mg/L.

Tests Using the Hach Colorimeter

Turbidity: Most of the samples in the hospital water system had a low turbidity value, below 5 NTU. The orphanage samples, however, had quite high turbidities with Source 2 having a count of 68 NTU. High turbidity can be an indicator of high contamination levels. The high turbidity readings were found in House Rainwater, Source 1, Source 2, and the source to be pumped.

Nitrate and Nitrite: All the samples had a total nitrogen count of less than 10 mg/L. The site with the highest total nitrogen was the House Rainwater, with a value of 7.5 mg/L.

Hardness: In general the hardness values were in the range of very soft water, between 2.5 and 27 mg/L $CaCO_3$. This makes sense as there was little opportunity for calcium or magnesium deposits to get into the water.

Tests Using Hach Test Strips

Alkalinity: All of the alkalinity results were below 150, meaning that there was little buffering capacity of the water.

Tests Using Coliscan Easygel and 3M Petrifilm Tests

Coliform bacteria: The hospital system showed no signs of E. coli contamination, though there was some general coliform bacteria contamination. The orphanage system had very large E. coli counts and total coliform counts for the future source, which is a large concern.

After careful review and discussion with numerous members of EWB and CU faculty it was decided that the tests above, along with a metals tests of key samples would give a clear picture of the system.

Medical information

We had the opportunity to discuss health issues in the area with several key members of the community. We interview Dr. Ranzinger, Lodz Joseph as well as Jean and Victor at the orphanage. Details are available in the health section of the paper. We found that malaria, stomach illnesses and respiratory diseases are the three major illnesses, similar to Muramba.

Procedures

Procedures were followed as detailed in the manuals for each of the meters as well as for the Coliscan Easygel and Petrifilm tests. From an ease of use standpoint, it would be recommended to further investigate the usage of the 3M Petrifilm tests as the equipment needs and waste produced are both much much less than for the Coliscan Easygel tests.

In Mugonero the samples taken from the source water were carried back to the hospital due to time constraints. This may have affected some of the results of the tests. All tests were done as soon as possible.

11.2 Results

General Observations

Tests sites were chosen based on information from Dr. Ranzinger and on the knowledge of team members who had previously visited the site. The first test site was at the source of the pipeline that feeds the hospital water system. The source is about a 20 minute drive from the hospital on 4wd roads. The source is groundwater which is then piped to a holding tank and then distributed to the hospital system. We were shown the source system by Phillipe the maintenance foreman for the hospital. The initial pipe from the source is buried as it is collecting ground water from the hillside. The pipe location was pointed out to us and is located at the bottom of the hillside. On and near the hillside were cattle grazing which could be a possible source of contamination, especially during the wet season.

The first sample we could take from the system was at the first collection box, which due to the order of testing was named Box #2. Box #2 was located in a marshy area, though the water was primarily piped in from the source. There could be marsh water seeping into the box, which should be noted as a possible source of contamination. The next sample taken was from the next full box down the line, improperly labeled Box #1. This box was fed by Box #2. The last sample taken from the source was from a box, Box #3 that was further down the pipeline. A sample was also taken from the holding tank, located about 1mile from the source.

The data from the source and tank samples are below:

Source and Tank results

Test Site Name	**Date**	**GPS Point**	**pH**	**Temperature**	**Alkalinity**
	dd/mm/yy	*Waypoint*		*Celsius*	*ppm CaCO3*
Box #2	11/1/06	96	6.11	20.1	Not Done?
Box #1	11/1/06	95	5.79	20.1	0.0
Box #3	11/1/06	102	5.84	19.9	0.0
Tank Inlet	12/1/06	103	6.12	22.0	0.0
WHO Standards	-	-	6.5 - 8.5	-	Ideal 150
	Conductivity	**TDS**	**Turbidity**	**Nitrate**	**Nitrite**
	microS/cm	*mg/L*	*NTU*	*mg/L NO3-N*	*mg/L MO2*
Box #2	40.4	20.5	1	0.9	1
Box #1	37.2	19.3	1	1.7	2
Box #3	36.9	19.4	?	1.4	2
Tank Inlet	41.7	21.6	1	1.6	1
WHO Standards	~ 2x hardness	EPA - 500	-	Total N < 10 mg/L	
	Ca Hardness	**Mg Hardness**	**Total Hardness**		
	mg/L CaCO3	*mg/L CaCO3*	*mg/L CaCO3*		
Box #2	13	11.7	24.70		
Box #1	1.55	1.21	2.76		
Box #3	1.56	1.17	2.73		
Tank Inlet	2.17	0.89	3.06		
WHO Standards	1- 150 soft, 150- 200 ideal, 200 + hard				
	Coliscan Easygels			**3M Petrifilm**	

	E. Coli	**Total Coliforms**		**E. Coli**	**Total Coliforms**
	CFU/100 ml	*CFU/100ml*		*CFU/100 ml*	*CFU/100ml*
Box #2	0	0		0	100
Box #1	0	0		0	200
Box #3	0	0		0	1000
Tank Inlet	0	200		0	500
WHO Standards	0	0.00		0.0	0.0

From this data, it appears that the water piped to the Mugonero hospital is fairly pristine. There is some general coliform contamination, but no E. coli was counted. This is surprising in some ways as we witnessed a number of cows grazing in the area. It could be that as this is a groundwater source, the contamination takes longer to reach the water, and it is generally protected by pipes in most of the system.

Tests were also conducted at the other end of the hospital pipeline, from two different representative taps – one at the nurses' station and one from the large guesthouse. The results are below:

Hospital taps

Test Site Name	**Date**	**GPS Point**	**pH**	**Temperature**	**Alkalinity**
	dd/mm/yy	*Waypoint #*		*Celsius*	*ppm CaCO3*
Nurses' Station	13/1/06	-	6.11	23.3	20.0
Main Guesthouse	13/1/06	-	6.26	21.1	20.0
WHO Standards	-	-	6.5 - 8.5	-	Ideal 150
	Conductivity	**TDS**	**Turbidity**	**Nitrate**	**Nitrite**
	microS/cm	*mg/L*	*NTU*	*mg/L NO3-N*	*mg/L MO2*
Nurses' Station	40.4	18.2	1	1.9	2
Main Guesthouse	41.7	24.2	1	1.8	2
WHO Standards	~ 2x hardness	EPA - 500		Total N < 10 mg/L	
	Ca Hardness	**Mg Hardness**	**Total Hardness**		
	mg/L CaCO3	*mg/L CaCO3*	*mg/L CaCO3*		
Nurses' Station	1.68	1.23	2.91		
Main Guesthouse	1.04	1.74	2.78		
WHO Standards	1- 150 soft, 150- 200 ideal, 200 + hard				
	Coliscan Easygels			**3M Petrifilm**	

	E. Coli	Total Coliforms		E. Coli	Total Coliforms
	CFU/100 ml	*CFU/100ml*		*CFU/100 ml*	*CFU/100ml*
Nurses' Station	0	1500		0	3000
Main Guesthouse	0	2000		0	1200
WHO Standards	0	0.00		0.0	`

From the data the pHs of the water are still a bit low, though in line with the source water data. The alkalinity values are also low, indicating the low buffering capability of the water. There is a fair amount of total coliform bacteria in the water, though no E. coli.

The other tests done during the stay in Mugonero were focused at the orphanage, L'Esperance. Several sites were tested, some tested twice due to unexpected high counts of bacterial contamination.

The first sample taken was from the tap that the children collect their water from currently. This is also where community members come to collect their drinking water and to bring their animals to get water.

The other samples were taken from a source that will eventually be pumped up to the orphanage to help stop the need for the children to hike to get their water. This project is being funded by a German organization. There are two tributaries that contribute to the water that will be pumped. We tested the water to be pumped as well as one of the tributaries. After testing this water and finding the bacterial results to be disturbingly high, we retested the water – this time the source to be pumped and both of the tributaries. The first samples from this area were taken on a rainy day, whereas the second samples were taken on a dry day. The difference in results is great and gives a small insight into rainy season contamination numbers.

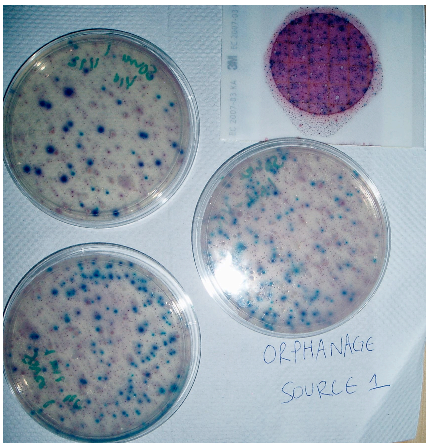
The data from the orphanage tests can be seen below. The results are separated into two sets: the source to be pumped and the other tests sites. First is the source to be pumped:

Orphanage pumping source results

Test Site Name	Date	GPS Point	pH	Temperature	Alkalinity
	dd/mm/yy	*Waypoint*		*Celsius*	*ppm CaCO3*
Source 2 - Contributed to pump source - current alternate.	12/1/06	0	6.47	-	0
Source 2 - second tests	15/1/06	0	-	-	-
Source 1 - Not used in isolation	15/1/06	0	-	-	-
Orphanage - Source Confluence to be pumped	1/12/06	0	6.85	-	0
Orphanage - Pump source - second test	15/1/06	0	-	-	-

WHO Standards	-	-	6.5 - 8.5	-	Ideal 150
	Conductivity	**TDS**	**Turbidity**	**Nitrate**	**Nitrite**
	microS/cm	*mg/L*	*NTU*	*mg/L NO3-N*	*mg/L MO2*
Source 2 - Contributed to pump source - current alternate.	68.3	35.4	19	2.7?	3
Source 2 - second tests	-	-	-	-	-
Source 1 - Not used in isolation	-	-	-	-	-
Orphanage - Source Confluence to be pumped	72.8	37.7	68	1.7	0
Orphanage - Pump source - second test	-	-	24	-	-
WHO Standards	~ 2x hardness	EPA - 500		Total N < 10 mg/L	
	Ca Hardness	**Mg Hardness**	**Total Hardness**		
	mg/L CaCO3	*mg/L CaCO3*	*mg/L CaCO3*		
Source 2 - Contributed to pump source - current alternate.	10.4	16	26.40		
Source 2 - second tests	-	-	-		
Source 1 - Not used in isolation	-	-	-		
Orphanage - Source Confluence to be pumped	9.1	11.6	20.70		
Orphanage - Pump source - second test	-	-	-		
WHO Standards	1- 150 soft, 150- 200 ideal, 200 + hard				
	Coliscan Easygels			**3M Petrifilm**	
	E. Coli	**Total Coliforms**		**E. Coli**	**Total Coliforms**
	CFU/100 ml	*CFU/100ml*		*CFU/100 ml*	*CFU/100ml*
Source 2 - Contributed to pump source - current alternate.	650	6,250		1,000	80,000
Source 2 - second tests	0	1,300		0	50,000
0	2,100	10,000		2,000	40,000
Orphanage - Source Confluence to be pumped	12,500	-		20,000	60,000
Orphanage - Pump source - second test	2,200	15,000		1,500	50,000
WHO Standards	0 CFUS/100 ml			0 CFUS/100 ml	

The major concern from these results is the high levels of E. coli contamination found in both the contributing streams and the main source that will soon be pumped directly to the orphanage. The E. coli counts at the Orphanage – Source to be pumped was 12,500 CFU/100ml on the rainy day. This is approaching contamination levels of raw sewage. (Image shows plates – blue dots are E.coli, pink are total coliforms).



Bacteria testing results for the Orphanage

There was a significant drop from the rainy day to the dry day, though 2,200/100ml is still a very high level of contamination. There is also an incredibly high amount of total coliforms in all the samples tested in this area. This level of contamination is a major concern, especially as this water will soon be pumped to the orphanage and the children will begin to get their drinking water from this source. The water that they are currently drinking (see below for results) is of a far higher quality, and if this project is completed, it would be expected for stomach related illnesses to skyrocket. The team informed Victor Monroy, the director of the orphanage of these concerns. We hope to continue to work with Victor to help come up with a solution that will benefit the children and keep them healthy.

Current Orphanage source results

Test Site Name	Date	GPS Point	pH	Temperature	Alkalinity
	dd/mm/yy	*Waypoint #*		*Celsius*	*ppm CaCO3*
House rainwater	12/1/06	0	6.52	0.0	-
Tank Down Hill	11/1/06	0	6.24	20.1	-
WHO Standards	-	-	6.5 - 8.5	-	Ideal 150
	Conductivity	**TDS**	**Turbidity**	**Nitrate**	**Nitrite**
	microS/cm	*mg/L*	*NTU*	*mg/L NO3-N*	*mg/L MO2*
House rainwater	39.3	20.0	38	2.5	5
Tank Down Hill	80.0	41.8	0	3.7	1
WHO Standards	~ 2x hardness	EPA - 500		Total N < 10 mg/L	

	Ca Hardness	**Mg Hardness**	**Total Hardness**		
	mg/L CaCO3	*mg/L CaCO3*	*mg/L CaCO3*		
House rainwater	12.3	5.5	17.8		
Tank Down Hill	1.6	13.6	15.2		
WHO Standards	1- 150 soft, 150- 200 ideal, 200 + hard				
	Coliscan Easygels			**3M Petrifilm**	
	E. Coli	**Total Coliforms**		**E. Coli**	**Total Coliforms**
	CFU/100 ml	*CFU/100ml*		*CFU/100 ml*	*CFU/100ml*
House rainwater	0	900		0	20,000
Tank Down Hill	0	500		0	200
WHO Standards	0	0.00		0.0	0.0

These sample sites are the two areas that the orphanage is using for drinking, cooking and bathing water at the moment. It can be seen that the tank down the hill has a far superior quality than the future source. The rainwater that the children are collecting also did not give cause for alarm, though there could be contaminants from the roof, etc. that we did not specifically test for. The turbidity of the rainwater is quite high and the color of the water was grey. It is still recommended that this water is further treated before drinking.

11.3 Conclusions and Recommendations

The largest concern from testing in Mugonero is the future water source of the orphanage. Due to the lack of good food and water, this contaminated source being pumped directly to the orphanage could have disastrous results. This water must be treated before drinking to stop illness from becoming spread throughout the orphanage. It is recommended that all water be boiled or otherwise treated before consumption. Even though not all waters showed major human contamination, open surface water that is close to homes and latrines should be treated for safety.

From the community interviews conducted, water quality was not a major concern. Most of the responses regarding greatest needs centered on clothing, shoes and food. The children at the orphanage appear to know that they should boil their water for drinking, though the opinion of the Victor and Dr. Ranzinger was that this was not actually done due to time and resource limitations.

Recommendations are as follows:

1. Work with Victor and the orphanage to inform German NGO of water quality.
2. Research ways to increase quantity of water at orphanage
3. Research disinfection possibilities for orphanage and community of Mugonero.
4. Work with community to educate on the importance of clean drinking water and basic hygiene.

12.0 COMMUNITY SURVEY

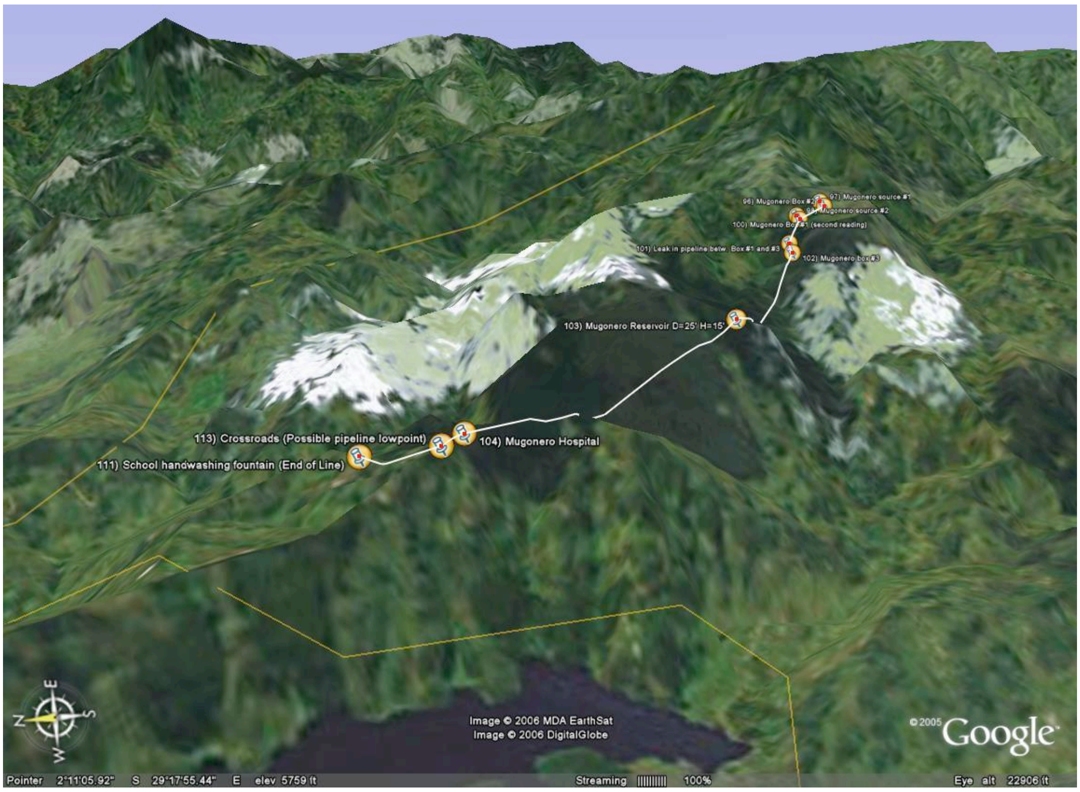
12.1 Water System Evaluation

Mugonero Hospital Pipeline Survey

A comprehensive survey of the water system was undertaken at Mugonero Hospital. The goal of this survey was to gain an understanding of the layout and performance characteristics of the gravity fed water system that supplies water to about 1,500 people at the hospital. The survey included a GPS survey of system nodes, mapping the of node connections and data collection on the characteristics of individual nodes.

The water system at Mugonero was installed many years ago by the Adventist Church. The system is a gravity fed pipeline that runs a distance of 2.9 miles with a total elevation change of just under 700 feet. The system is fed by two sources that collect runoff from a mountainside. Surface and ground water is collected in gravel collection pits which are located below grade. These sources are connected to a series of collection boxes. Water from these boxes flows to a large reservoir located at the midpoint of the pipeline. From this reservoir, water flows to the hospital distribution network.

Our research shows that there are three fundamental areas that need improvement in the Mugonero water distribution system: quantity, quality, and security. From a quantity perspective, the system is inadequate because the sources do not provide enough water during the dry season. The quality of the water is compromised by the fact that the watershed that feeds the sources doubles as a pasture. On all three visits to the source area, cattle were observed grazing in the collection area. Cow dung was observed in some of the streams that feed the collection pits. For more information on the water quality of the Mugonero pipeline, see Section 11. There is also some concern about the security of the pipeline; there are reports of people who live along the pipeline intentionally breaking the pipe to access the water. There is also some concern about what someone with more sinister motives could accomplish given the accessibility of the pipeline and reservoir.



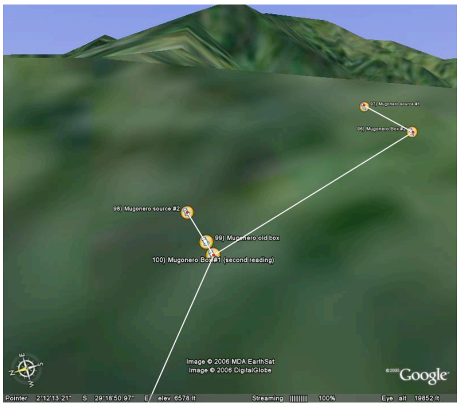
Mugonero Hospital water pipeline (Elevation exaggerated 3x)

Pipeline Nodes

Source

The source area is located just under 6500 ft in elevation, this is approximately 100 ft below the summit of the mountain. The area is somewhat marshy and is used by locals as a cattle pasture. The pipeline is fed by a combination of surface and ground water that flows down the mountainside into at least two gravel collection pits. Because the pits are located below grade, we were not able to examine them. The purpose of the gravel pit is to filter the water and channel it into a pipe so it may continue down the line.

There were two collection pits identified by a hospital technician who accompanied us to the source area, however, we believe that there may be a third pit whose location is unknown. The presence of a third collection pit is evidenced by a flow of unknown origin entering collection box #1.

Left: A herd of cattle grazing at the source area. Right: Map of source area

Collection Boxes

There are four brick collection boxes near the source area. They range from three to five feet in depth and lie mostly below ground with about a foot of the structure extending above grade. They are covered with reinforced concrete manholes which, in some cases, were attached to the boxes with mortar. Each box has at least one influent pipe, an effluent pipe, and an overflow drain. All the plumbing is located in the lower portion of the boxes. The fact that the overflow pipes are located a few inches above the effluent pipes means that these boxes are not intended to store any water. Flow rates into the collection boxes were measured with a vessel of known volume and a stopwatch. Due to the difficulty of accessing the pipes, these flow rates are only approximate, with an uncertainty of about 10%.

	Inflows (L/m)		
Collection box 1	5.4	2.5	~37
Collection box 2	13.5		
Collection box 3	45		
Reservoir	40		

Flow rates at collection boxes and reservoir taken in Jan. '06. Flow rates for box #1 correspond from top to bottom to the pipes in the photo of box #1 below.

Collection box #1 is fed by source #1 via collection box #2 and by source #2 directly. In addition, this box is fed by a pipe of unknown origin. As stated above, it is likely that this pipe is fed by a third, unidentified collection pit. Flow rates were only recorded at two of the three inlets as the third was submerged. It was not possible to figure out which inlet corresponds to which source as we were not able determine the flow rates out of the two known sources because they were buried. Collection box #1 flows to collection box #3 through a perforated plastic fitting as pictured on the right side of the photograph. Between source #2 and collection box #1 there is an abandoned collection box of similar design. The pipe travels directly through the old box the water does not interact with this box in any way.

Left: External view of collection box #1. Right: Internal view of collection box #1. The pipe in the lower left corner is submerged

Collection box #2 receives water only from source #1 and discharges that water to collection box #1 as stated above. The flow entering box #2 was measured to be 13.5 L/m. This flow rate is much larger than the two measured flow rates into box #1 so the flow from box #2 to box #1 is likely delivered by the submerged pipe whose flow was unable to be measured.

The contributions from all sources merge in box #1 and travel to box #3 along ~500 ft of ~3" pipe. Midway along this pipe is a large hole that is sometimes plugged with a piece of tree bark. It is likely that this hole was created intentionally by local residents. Box #3 receives water only from this pipe and discharges only to the reservoir located another mile down the pipeline. The flow into box #3 was measured to be approximately 45 L/m. This value represents a large fraction of the total water production at the source, with any losses attributable to the aforementioned leak. Water is discharged through a perforated plastic fitting similar to the one on box #1.

Left: Internal view of box #2. Right: Internal view of box #3

Reservoir

One and a half miles from the source is a large reservoir measuring 25' in diameter and with a depth of 15'. The total volume of this tank is 7300 cubic feet of 200 cubic meters. The reservoir is constructed of reinforced concrete and looks to be of sound construction. When we inspected it, the reservoir was nearly empty. Locals report that this is normal and that the reservoir is rarely filled to capacity. At the time of our visit, the flow rate into the reservoir was 40 L/m. This is somewhat less than the flow rate measures at box #3 indicating that there are some losses in the intervening pipeline. It is likely that these losses are due to impromptu "tap" made by the locals.

An EWB team member collects a water sample at the reservoir inlet.

Pipeline

The pipeline between the reservoir and the hospital runs for 1.5 miles and frequently runs along a road. Hospital staff claims that the pipeline is frequently damaged by vehicle traffic and local farmers who intentionally break the pipe to access the water. The resident doctor is also concerned that someone with a grievance against the hospital may attempt to poison their drinking water. Dr. Ranzinger mentioned that poisoning is a common method of revenge in Rwandan society.

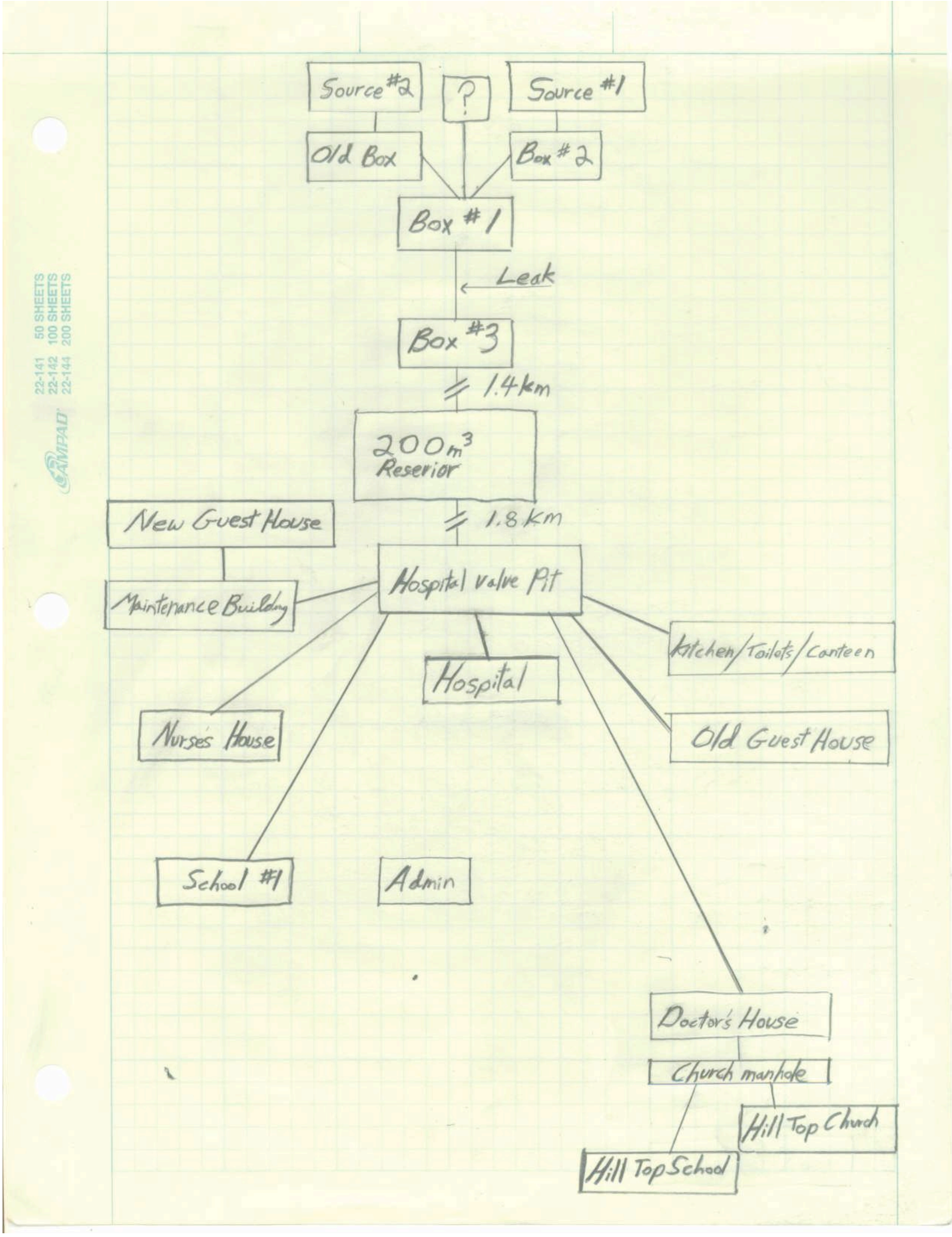
Valve box and Distribution Network

The main pipeline terminates at a valve box located at the south-east corner of the hospital complex. This valve box distributes water to the hospital distribution network via a series of eight smaller pipes which are controlled with gate valves. The distribution network is fairly complex, serving at least 14 buildings and more than 50 individual taps. Many taps were found to be leaking from the closed position or simply left on without regard to water conservation.

Mugonero valve box (above) and valve labels (below)

- A – Goes to school
- B – Ranzinger House
- C – Goes to main hospital
- D – Goes to worker's house (Nurses)
- E – Kitchen Toilet Canteen
- F – Admin Building
- G – Guest House
- H – Maintenance Building

Left: Map of the pipeline near the hospital. Right: Hand washing fountain at hilltop school. This is the end of the pipeline.



Pipeline Schematic

Recommendations

As stated above, there are three fundamental areas that need improvement in the Mugonero water distribution system: quantity, quality, and security. These issues can be by modifying the existing system or by diversifying the water portfolio of the hospital by installing alternative water sources such as rainwater collectors. This section will only discuss the possibility of improving the existing pipeline. For information about rainwater catchments at Mugonero hospital, see section 12.2.

To improve the water quality, there are a variety of options, all of which involve some kind of treatment. The installation of a sand filter would be one option for removing the bacteria introduced by the animal feces. Another measure that can be taken would be to install a fence around the source collection pits to prevent animals from defecating directly on the source water. The area enclosed by a fence would have to be very small as local cattlemen would likely destroy any fence that severely limited their cattle grazing. The entire watershed is currently being used for cattle grazing so a small fence enclosing a few square meters above the collection pit would only improve water quality limited amount.

To increase the quantity of water delivered by the pipeline, additional collection pits could be installed as only a small fraction of the water present at the source area is actually being captured. Judging by lay of the land and the high quality of the system installation, it is likely that the original locations of the collection pits are the best the source area has to offer. Additional collection pits would likely be placed in locations that would cause them to be less effective than the ones already in place. Since we were not able to access the collection pits, we are unable to say if they could be modified to collect more water. Future efforts to improve the collection capabilities of the system might investigate the feasibility of improving the existing collection pits.

From a security perspective there is little that can be done to prevent people from stealing water from the pipeline. Short of installing a massive protective housing along the entire length of the pipeline, a determined individual will always be able to locate and break the pipe to divert water for his own needs. By the same logic, there is little that could be done to stop an individual who is committed to poisoning the pipeline. It might be a good idea to install taps along the pipeline so that people could take water from the system without damaging it. This would likely have a positive effect on water quantity as the taps could be shut off when not in use rather than then the holes that locals currently use which constantly bleed water from the system. Installing taps on the mountain side may also help to increase goodwill towards the hospital and decrease the likelihood of someone deciding to poison the pipeline.

Included below is GPS data collected at the Mugonero Hospital in January 2006.

GPS Data from January 2006 Implementation Trip				
GPS Point #	**Description**	**Lat/Long**	**Elevation (ft)**	**Elevation (m)**
Mugonero Hospital				
95	Mugonero Box #1	S2 12.210 E29 18.834	6122	1866
96	Mugonero Box #2	S2 12.313 E29 18.856	6434	1961
97	Mugonero source #1	S2 12.305 E29 18.883	6464	1970
98	Mugonero source #2	S2 12.203 E29 18.852	6427	1959
99	Mugonero old box	S2 12.207 E29 18.836	6403	1952
100	Mugonero Box #1 (second reading)	S2 12.208 E29 18.830	6408	1953
101	Leak in pipeline betw. Box #1 and #3	S2 12.144 E29 18.746	6362	1939
102	Mugonero box #3	S2 12.142 E29 18.700	6329	1929
103	Mugonero Reservoir d=25' H=15'	S2 11.730 E29 18.037	6179	1883
104	Mugonero Hospital	S2 10.862 E29 17.550	5938	1810
105	Front of Ranzingers house	S2 10.743 E29 17.459	5772	1759
106	Exposed 3/4" pipe on road	S2 10.681 E29 17.443	5794	1766
107	Exposed pipe and "T" junction	S2 10.686 E29 17.443	5797	1767
108	Exposed pipe and "T" junction	S2 10.640 E29 17.435	5807	1770
109	Exposed 3/4" pipe on road	S2 10.620 E29 17.452	5824	1775
110	Church Pipe	S2 10.599 E29 17.490	5848	1782
111	School hand washing fountain (End of line)	S2 10.591 E29 17.498	5846	1782
112	Church manhole	S2 10.600 E29 17.481	5852	1784
113	Crossroads (Possible pipeline low point)	S2 10.802 E29 17.467	5792	1765
114	Flag Pole	S2 10.848 E29 17.556	5856	1785
115	Admin building front door	S2 10.843 E29 17.558	5857	1785
116	Lab front door	S2 10.839 E29 17.587	5852	1784
117	George Bush AIDS clinic	S2 10.855 E29 17.581	5859	1786
118	George Bush AIDS clinic toilets	S2 10.835 E29 17.601	5860	1786
119	Laundry	S2 10.853 E29 17.587	5860	1786
120	Washroom B	S2 10.848 E29 17.598	5860	1786
121	Washroom A	S2 10.852 E29 17.564	5867	1788
122	Hospital	S2 10.864 E29 17.557	5864	1787
123	Ward B	S2 10.856 E29 17.554	5862	1787
124	Salon/Canteen	S2 10.858 E29 17.555	5861	1786
125	Kitchen	S2 10.864 E29 17.566	5864	1787
126	Maintenance	S2 10.869 E29 17.572	5858	1786
127	Valve pit	S2 10.871 E29 17.569	5860	1786

12.2 Mugonero Hospital Rainwater Catchment Survey

Dr. Ranzinger, the hospital director, had expressed interest in increasing the water supply at the Mugonero Hospital. Rainwater catchment systems were discussed as a potential solution to relieve water quantity problems at the Mugonero Hospital. As part of the Mugonero assessment, a survey of the Mugonero Hospital was conducted in order to assess possible areas for future implementations of rainwater catchment systems. After an initial evaluation of the hospital grounds, it was determined that two sites next to the main hospital would serve as the best areas for rainwater catchment systems.

A rainwater catchment system next to the main hospital is attractive because the main hospital building has the largest roof of any building in the Mugonero complex. Figure 12.2.1 identifies the locations of the two sites that were identified for possible rainwater catchment systems. From the figure, one location is behind the hospital and the other is in a grass area between Ward A and the Washroom.

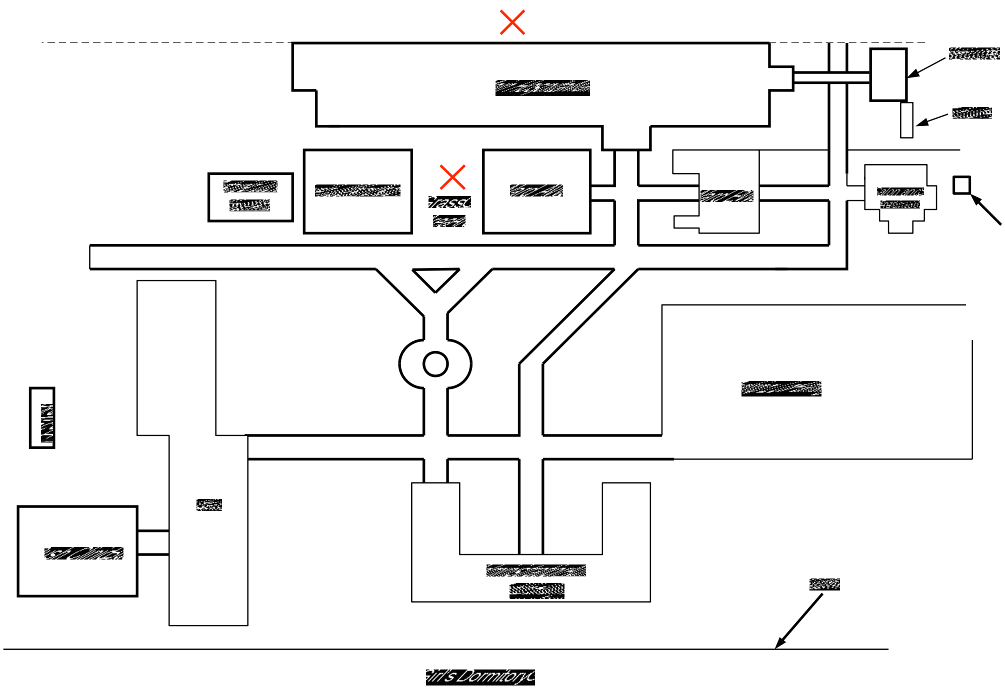


Figure – 12.2.1 Potential RWC sites with a red “X”.

Figure 12.2.2 shows the layout at the back of the hospital.

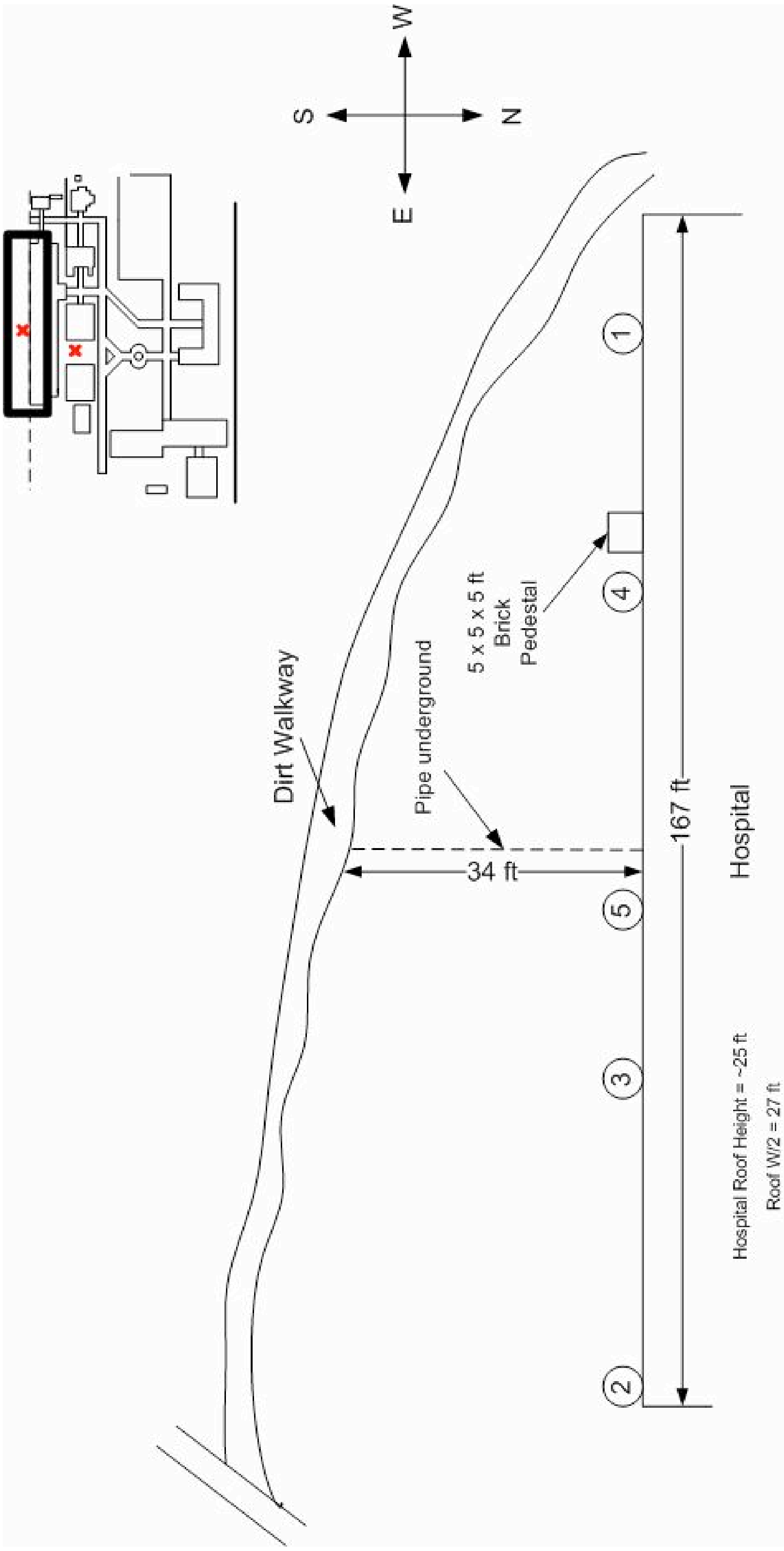


Figure 12.2.2 – Layout of the back of the main hospital building.

It was determined that a central location behind the hospital would be best because gutters can be placed along the backside of the roof. A collection point can be placed in the middle and the water can collect in the centrally located tank. System designers should note that there is a pipe running on the ground from the middle of the hospital. Design steps should be taken to avoid damaging the pipe. A pedestal is located at the back of the hospital in the western corner. Our assessment concluded that this structure would be too weak to support a full storage tank. Future teams can further assess the structural integrity of the pedestal.

The following photographs illustrate the area behind the main hospital building. Images numbers correspond to numbers on Figure 12.2.2.

Figure 12.2.3 (Image 1) – Back of the hospital (Picture taken facing the East)

Figure 12.2.4 (Image 2) – Back of the hospital (Picture taken facing the West)

Figure 12.2.5 (Image 3) – Back of the hospital (Picture taken facing the Northeast)

Figure 12.2.6 (Image 4) – Back of the hospital (Picture taken facing the Northwest)

Figure 12.2.7 (Image 5) – Back of the hospital (Picture taken facing North)

Figure 12.2.8 shows a layout of the grass area between Ward A and the washroom.

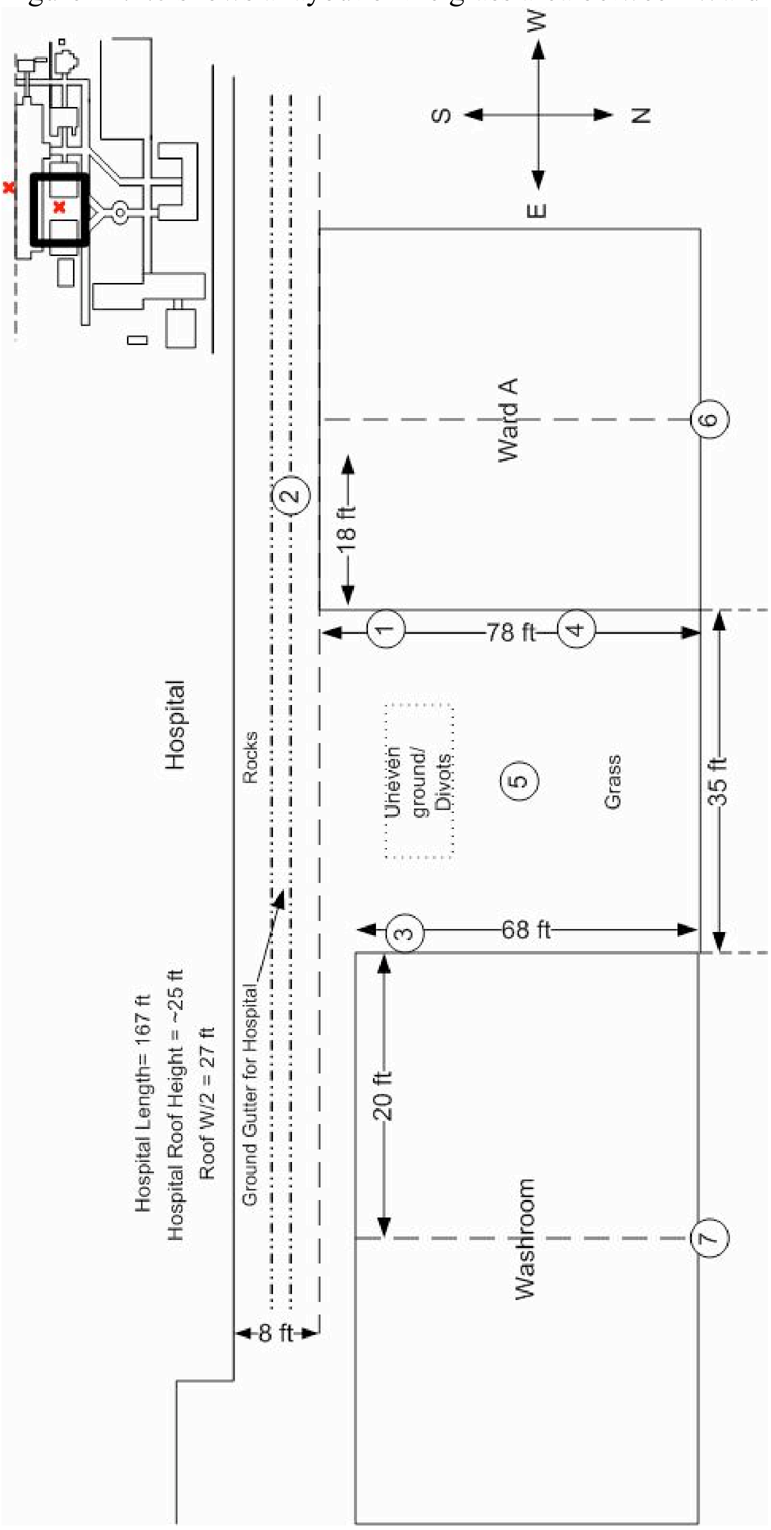


Figure 12.2.8 – Illustrates the area between Ward A and the Washroom. Numbers correspond to picture numbers found in the section.

In the area between the Washroom and Ward A, a storage tank can be placed between both buildings in the grass area. To the south of the grass area is the main hospital. Between the grass area and the main hospital is a ground gutter which catches water from the hospital roof. Future teams can choose to utilize either the hospital, Washroom, or Ward A roofs. Some parts of the grass area uneven and have several divots. Design steps should be taken to neutralize the negative impacts the divots may have.

The following photographs illustrate the grass area between the washroom and Ward A. Images numbers correspond to numbers on Figure 12.2.8.

Figure 12.2.9 (Image 1) Ward A (Picture taken facing the North)

Figure 12.2.10 (Image 2) – In between Ward A and the main hospital building (Picture taken facing East)

Figure 12.2.11 (Image 3) – The Washroom (Picture taken facing the Northeast)

Figure 12.2.12 (Image 4) – Side of Ward A (Picture taking facing the Northwest)

Figure 12.2.13 (Image 5) – Grass area in between the Washroom and Ward A (Picture taken facing North)

Figure 12.2.14 (Image 6) – Front of Ward A (Picture taken facing South)

Figure 12.2.15 (Image 7) – Front of Washroom (Picture taken facing Southeast)

12.3 L'Esperance Children's Aid Orphanage

The team also visited a nearby orphanage. Founded in 1995 for genocide orphans, the facility now houses younger orphans as well as adults who grew up there. The orphanage complex consists of 6 homes, 1 office, 4 toilets, the director's home, and a main kitchen. A vocational school consisting of 2 identical buildings also resides on the orphanage grounds. While at the orphanage, the team surveyed the area for potential rainwater catchment sites and other water quantity issues. The team also briefly examined the orphanage's current solar electrical system.

Water

The director, Victor Monroy, expressed interest in having multiple rainwater catchment systems at the orphanage. His initial plan consisted of having rainwater catchment tanks at each of the six homes in the orphanage. Additionally many of the six homes have gutters and only the necessary piping and tanks would be needed to install a rainwater catchment system. Figure 12.3.1 shows the layout of a basic home and surrounding area. The "X" denotes the suggested location for having the storage tanks.

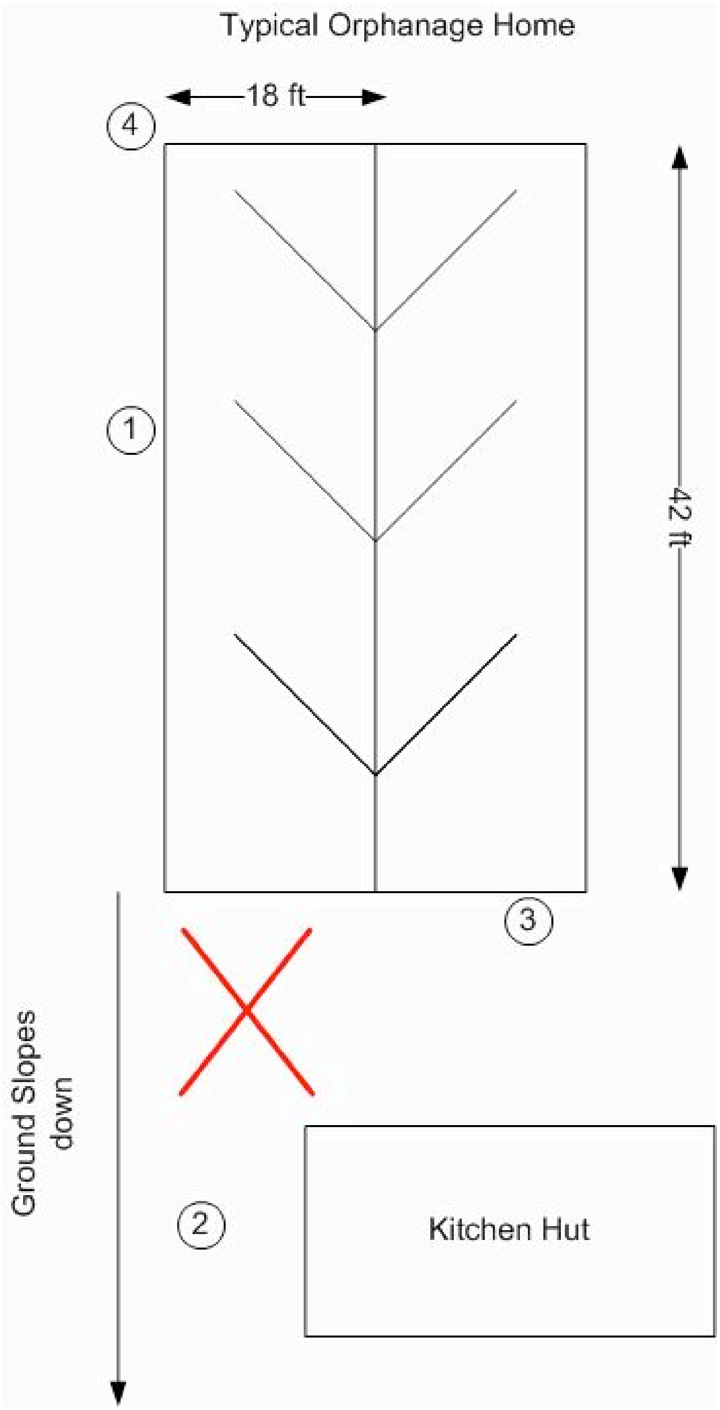


Figure 12.3.1 – Layout of typical orphanage home. Numbers correspond to image numbers found in the section.

The following photographs illustrate the typical home in the orphanage. Images numbers correspond to numbers on Figure 12.3.1.

Figure 12.3.2 (Image 1)- Side of home and entrance to the home

Figure 12.3.3 (Image 2) – Back side of home (Picture taken standing next to the kitchen hut)

Figure 12.3.4 (Image 3) – Backside of home and water collection using buckets

Figure 12.3.5 (Image4) – Shows the typical gutters installed on some of the homes

In addition to providing water to the homes, Mr. Monroy described the plans for an in-ground cistern that will provide water to an irrigation system for the farm. Mr. Monroy believes that he may have outside funding and builders for the project but is still awaiting confirmation. Figure 12.3.6 illustrates the layout of the vocational school.

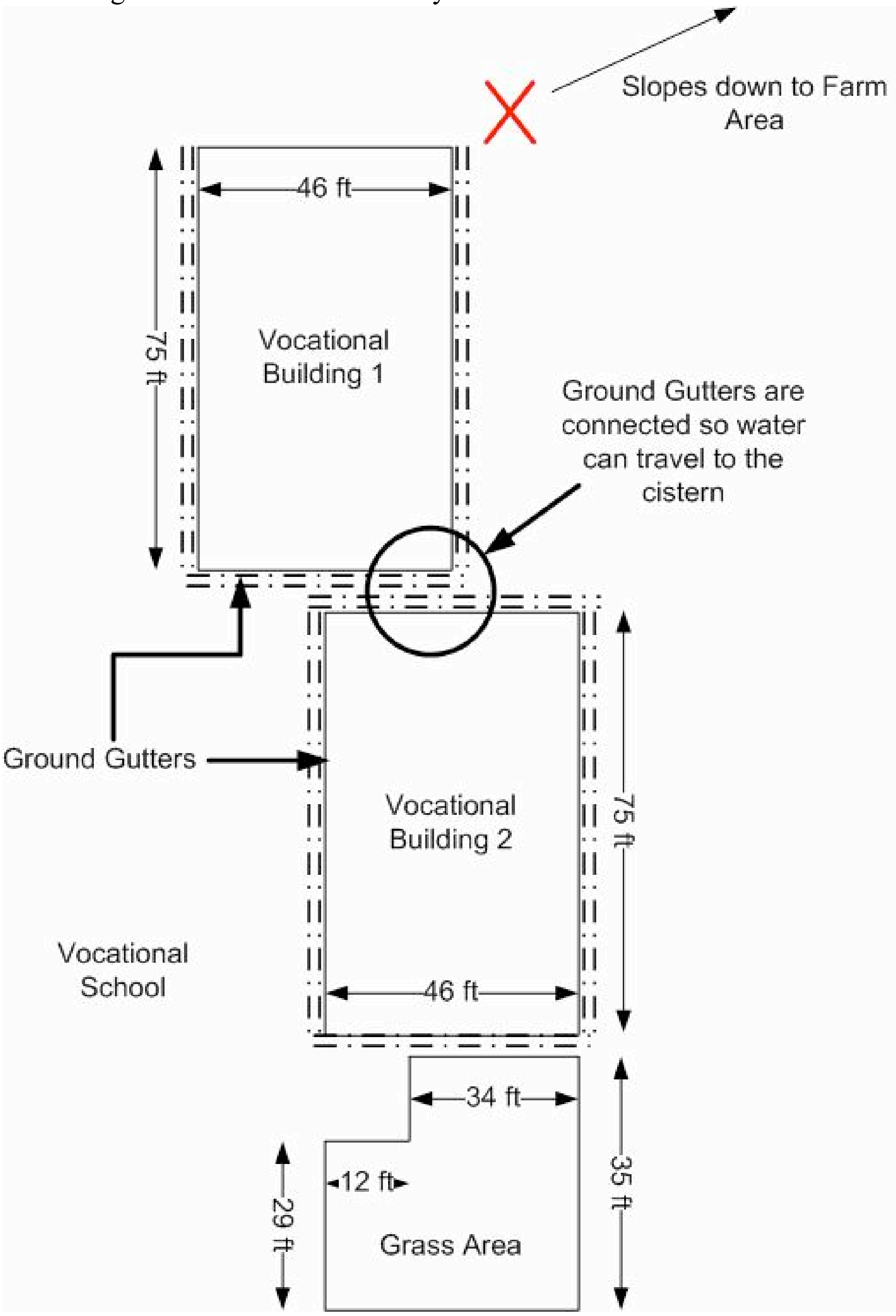


Figure 12.3.6 – Layout of vocational buildings and rainwater catchment system for irrigation

As Figure 12.3.2 shows, ground gutters are placed on next to both buildings to capture water from the roofs. The ground gutters from both buildings connect and funnel the water to the collection point marked by the red “X”. Mr. Monroy plans to have a 10,000-20,000L in-ground cistern built at the collection point to provide water for irrigation. As mentioned before, he is currently awaiting confirmation from his funding sources as to whether the project will be completed. The irrigation tank could be a site where Engineers Without Borders can provide assistance in either planning the tank or implementing irrigation. Figure 12.3.7 shows the ground gutter as well as the location for the collection point.

Figure 12.3.7 - The photograph below shows the ground gutter as well as the location for the collection point

Energy

Currently 6 solar panels are installed on the roof of Mr. Monroy’s office. The panels are connected to a charge controller which charges the batteries. The battery bank consists of two 12 volt batteries wired in series yielding a final voltage of 24 volts. The output of the batteries is sent to an inverter which is then connected to the loads. (Generally, the inverter should also be connected to the charge controller, as this is good practice.) The loads are several lights in the homes of the orphanage. All power may not be utilized in the current configuration and future work can be done to maximize efficiency. Figure

12.3.8 shows the six panels on the roof. Figure 12.3.9 illustrates the current configuration of the system.

Figure 12.3.8 – Six solar panels on the roof of the office

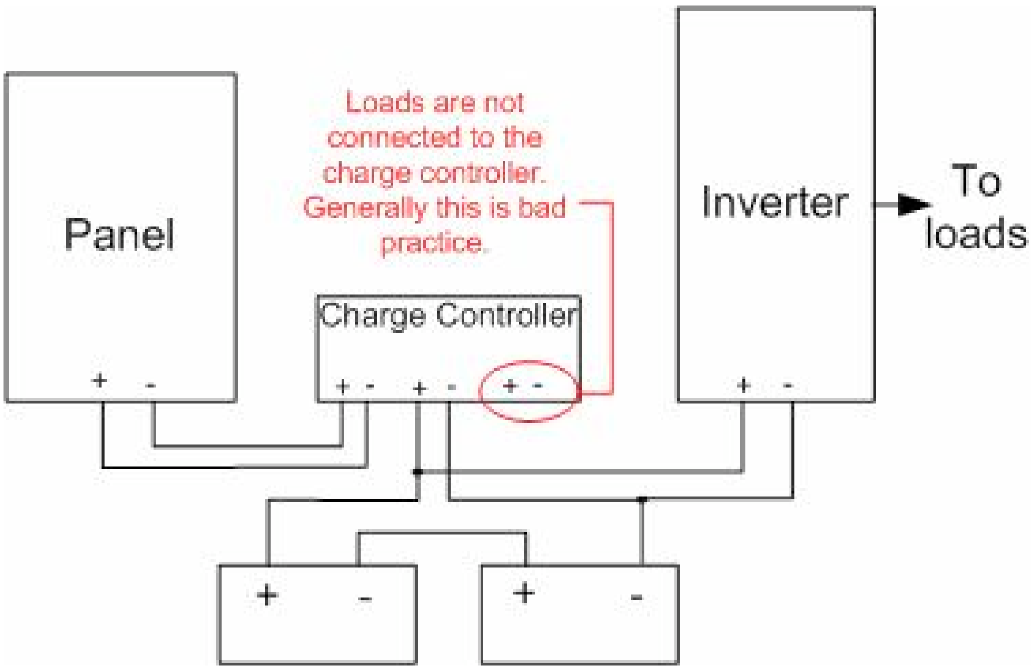


Figure 12.3.9 – Shows the current configuration for the solar lighting system at the orphanage

13.0 SOLAR LIGHTING INSTALLATION

The hospital in Mugonero is currently powered by the national grid and a back up diesel generator. Site assessments revealed that the 220V AC power from the grid is precarious and unreliable. When the hospital loses power from the grid the diesel generator is used. The wiring of the generator and the power from the grid are dangerous and extremely disorganized. When the power from the grid is interrupted, the staff and patients at the hospital must wait for several minutes for the generator to be started. On several occasions, the hospital has been left powerless when there is no fuel readily available for the generator. In January 2006, chapters of EWB from CU and JSC witnessed first hand frequent blackouts at different times through the day. The most important rooms in the hospital are the operating room, the delivery room, nurse’s stations, and many patient rooms. In Rwanda, many patients are actually living in the patient rooms with their families. Both the OR and ER are roughly 15ft X 15ft, and the patient rooms are approximately the same dimensions. The hospital is a two story building with a nurse’s station and patient rooms on each floor, and the OR, ER, delivery room, and surgery preparatory room on the bottom floor. It is estimated that powering the hospital comprises 40% of the annual budget.

The administrative building in the Mugonero Hospital complex is located roughly 83 meters away from the main hospital. The most important rooms in the administrative building are the offices of the hospital director and the resident American surgeon Dr. Ranzinger, a dentist’s office, and a computer room with internet access.

13.1 Design

The smaller system installed is identical to those in Muramba, described earlier. The larger system is described here.

Implementation reports from previous PV lighting projects completed in Rwanda were thoroughly researched. A conference call was made with Elliot Goldman, giving our team the opportunity to ask questions about lessons he learned while installing solar powered lighting at the Muramba parish. Our used sizing spreadsheets created by Green Empowerment. Our systems are modeled after several designs that have been implemented by Green Empowerment and Seth Kassels. Seth served as a mentor and expert throughout the design process. Our team worked in conjunction with members of the Johnson Space Center chapter of EWB. The JSC solar team focused on the surgical headlamp for the doctor at the hospital.

Design choices

The following design constraints were decided upon through the identified needs, available budget and trade studies.

- 12VDC, eliminating the inefficiency and complications of an inverter

- Compact fluorescent bulbs, providing light that is comparable to AC high wattage incandescent bulbs, average life of 6,000 to 8,000 hours
- Edison style pull chain fixtures, eliminating the use of a separate switch
- Unsealed lead acid batteries, locals are very familiar with their maintenance
- Solar panels, most cost effective panels that are available
- Morningstar charge controller, model with LED state of system indicator lights
- Commercial off-the-shelf headlamp

System Sizing

The system will incur loses from temperature, battery, wiring, and charge controller. Loses due to the charge controller are factored into the wiring efficiency.

Calculating lose due to temperature

Information obtained from NASA website (http://eosweb.larc.nasa.gov/sse/)

Average temp. during 10am to 3pm	24^{o} C
Average peak sun hours	4.76 hrs

Assuming loss of 0.5% per degree C over 25^{o} C, and panels operate at 25 degrees above ambient temperature in Rwanda (http://www.fallingrain.com/).

Operating temp. of panels	24^{o} C + 25^{o} C = 49^{o} C
Degrees above ideal temp. of 25^{o} C	49^{o}C – 25^{o} C = 24^{o} C
Lose due to temperature	24^{o} C x .005 = .12

- So panel alone will be 88% efficient
- We will assume a battery efficiency of 85% and we will design for a wiring and charge controller efficiency of 97%

Overall panel factor	.88 x .85 x .97 = .73

- So our system has a total efficiency of 73%

Load Summary

Quantity	Load	Watts	Hours Used Per Day	(W hrs/day)
11	CFL Bulbs	13	5	715
1	AAA Battery charger	6	2.7	16
Total:				731 W Hrs / day

Panels Required:

Determining the peak watts of array that is required for our load

Compensated load	731 Whrs/day / .73 = 1001.36 Whrs/day
Watts peak for array	1041.4 Whrs/day / 4.76 hrs/day = 210.37 W

- Since our system is not 100% efficient, the system will need to be able to provide for 731 Whrs/.73.
- The peak sun hours define how many hours the panels will be receiving energy from the sun. So the power our panels need to produce is the compensated load/ peak sun hours.

Determining number of panels required

Number of panels required *(using 115W panels)*	210.37W / 102W = 2.06 panels

- Which corresponds to using three 102W panels wired in parallel, using three panels will create an extremely robust system with room for other loads

Battery Sizing:

Depth of discharge	= .5
Days of autonomy	= 3 days

- Depth of discharge of .5 means the battery charge will not drain below 50%
- Days of autonomy are consecutive days without sun

Adjusting total Whrs/day defined by our load for losses from battery and wiring

Adjusted total Whrs/day	731Whrs/day / (.85 x .97) = 886.6 Whrs/day

- This is the total amount of Whrs/day that the battery needs to be able to supply to the load to compensate for the losses

Calculating the battery bank size

Bank size in Whrs/day	(3 days / .5) x 886.6 Whrs/day = 5319 Whrs
Bank size in amphrs	5319 Whrs / 12v = 443 amphrs

- Since the depth of discharge is 50%, and there are 3 days of autonomy, the battery bank will be 6X larger than the adjusted total
- Since our system is 12V, the amphrs required are found using I=P/V

Determining the number of batteries to be used

Number of batts. for bank size *(using batts. rated at 50 amphrs)*	461 amphrs / 50 amphrs = 8.8 batts.

Which corresponds to using at least 9 batteries wired in parallel.

Charge Controller Sizing:

Determining total current from loads using I=P/V, V=12V

Quantity	**Load**	**Power (Watts)**	**System Voltage**	**Current (Amps)**
11	CFL bulbs	13	12	11.9
1	AAA Battery Charger	6	12	.5
Total				12.4 amps

- The panels used have a short circuit (Isc) rating of approximately 7 amps, so if we are using three panels wired in parallel the current will add. Producing a maximum current of 21A.
- To meet NEC 2005 code, a charge controller that is capable of handling 1.56x the maximum current was used.

Wire Sizing:

Using sizing tables from Green Empowerment for a design with a 2% voltage drop

	Distance	Gage
Panels to charge controller	34 ft	6awg
Charge controller to batts.	10ft	4awg
Charge controller to loads	50ft	12awg

- Assuming typical short circuit current for panels of 7amps
- Current from batteries is 12.4 (value from total current of system)
- The largest wire that the charge controller can handle will be used from the batteries to the controller
- Maximum current to each application is 2amps
- The value of 118ft for the loads is a maximum distance

13.2 Component Description

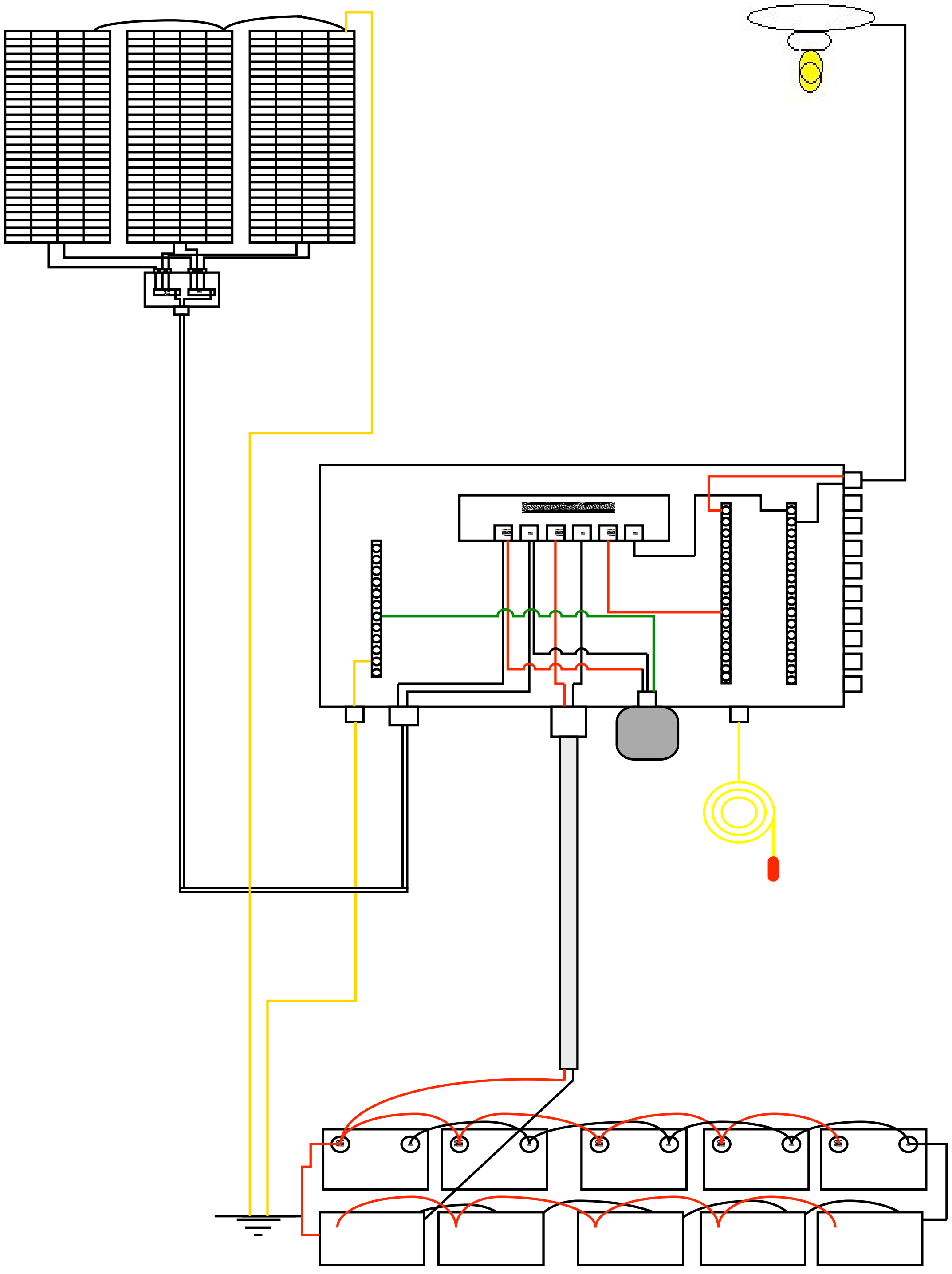
The entire system was assembled in Boulder, dismantled, and shipped/carried to Rwanda.

Connections
- All connections were made using correct adaptors and fasteners, following US codes
- All wiring requiring protection was run through durable flexible conduit that was properly secured at each location

Enclosures
- Batteries were raised from the ground with wood supports
- Charge controller and connections were housed in a see-through heavy duty Fibox enclosure

Panel Mounting
- Sturdy frames were constructed in Kigali to our exact specifications
- Panels were aimed towards the north
- Panels were slightly below horizontal to allow rain water to run off, and directed 1-2 degrees north for maximum solar energy.

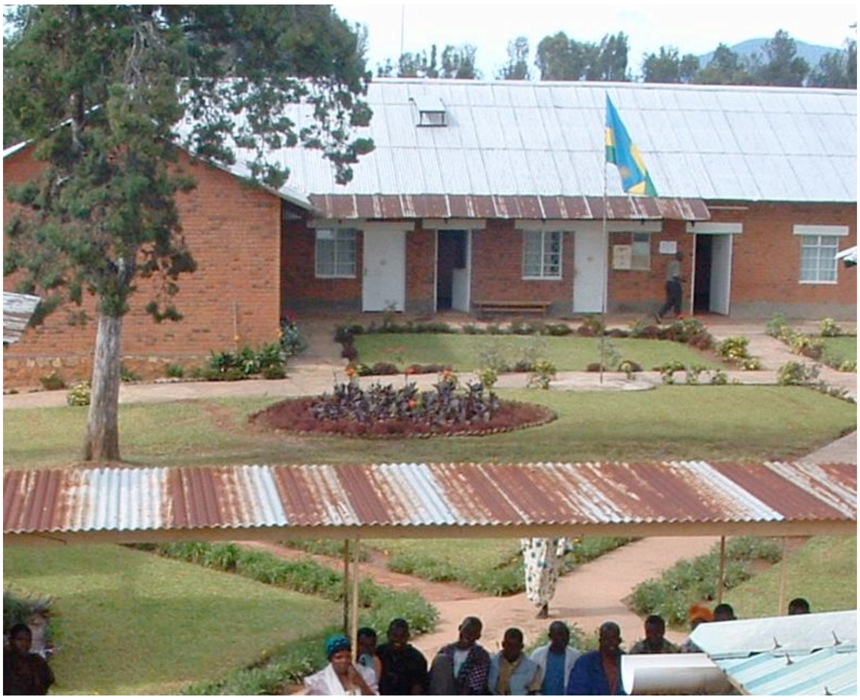
COMPONENT	TYPE (quantity)
Solar Panels	102W (3)
Batteries	50 amphr (10)
Wire	4awg, 6awg, 2awg solid copper, 12awg
Bulbs	13W CFL (11)
Headlamp	3 LED, 6,000 candle power (1)
AAA Charger	Charges 4 AAA (1)
Charge Controller	30amp (1)



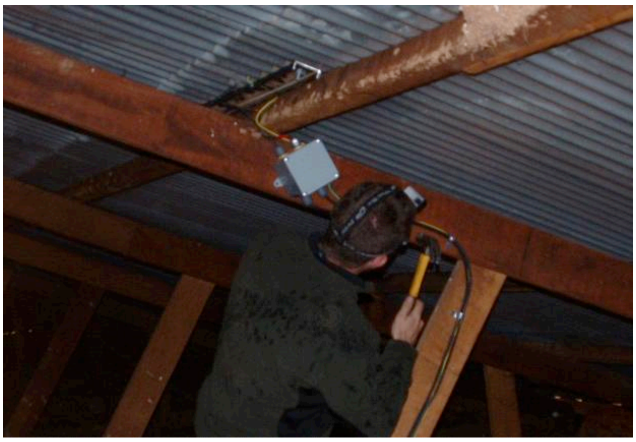
Mugonero Hospital Wing Solar Lighting Schematic

13.3 Materials and Logistics

The team arrived in Mugonero after already installing two similar systems in Muramba and spending a day in Kigali replenishing crucial supplies. As learned from the installation in Muramba, tubes of clear silicone, ring terminals, heavy duty zip-ties, and masonry anchors "mollies" were an integral part to a smooth installation. Ring terminals allowed for a clean connection to the light fixtures, being that the wire we purchased in Kigali was stranded.



Admin. Building as viewed from the roof of the hospital, single panel mounted on steep roof



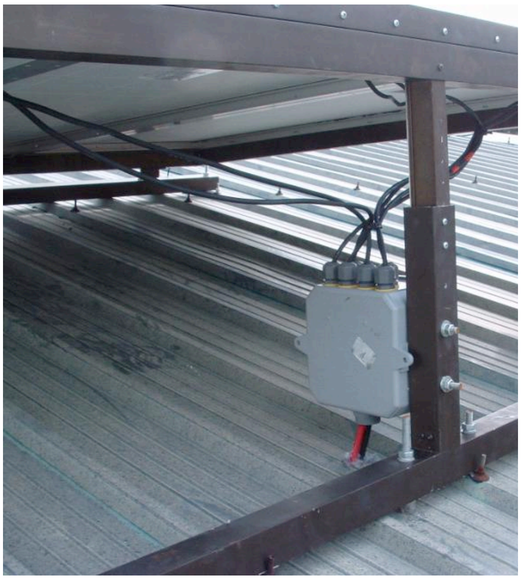
Johnny securing wires from panel (+,-, ground), step down waterproof junction box mounted on beam, aluminum cross section secured to panel frame with bolts.


Charge controller mounted in Fibox enclosure in the computer room, yellow DC pigtail powering small inverter, Five separate lines for each light fixture.

Hospital

The system at the hospital was the largest system installed during the implementation trip. The frame constructed for the three panels was the same as the frames for one panel, just larger with a little more support. The frame and panels were mocked up on the ground, allowing for an easier installation on the roof. The charge controller and batteries were installed on the first floor. The hospital staff bore a large hole through the first floor, allowing us to run wires to the downstairs lights.

Three solar panels mounted on rooftop



Junction box mounted to frame on roof

Hole through first floor to bottom floor

Installing a fixture in the operating room, the concrete ceilings made it very difficult to secure wires and fixtures, using the strong mollies bought in the states proved to be the best method of securing screws.

Controller mounted in closet

Running wire on bottom floor, nurse's station is to the left

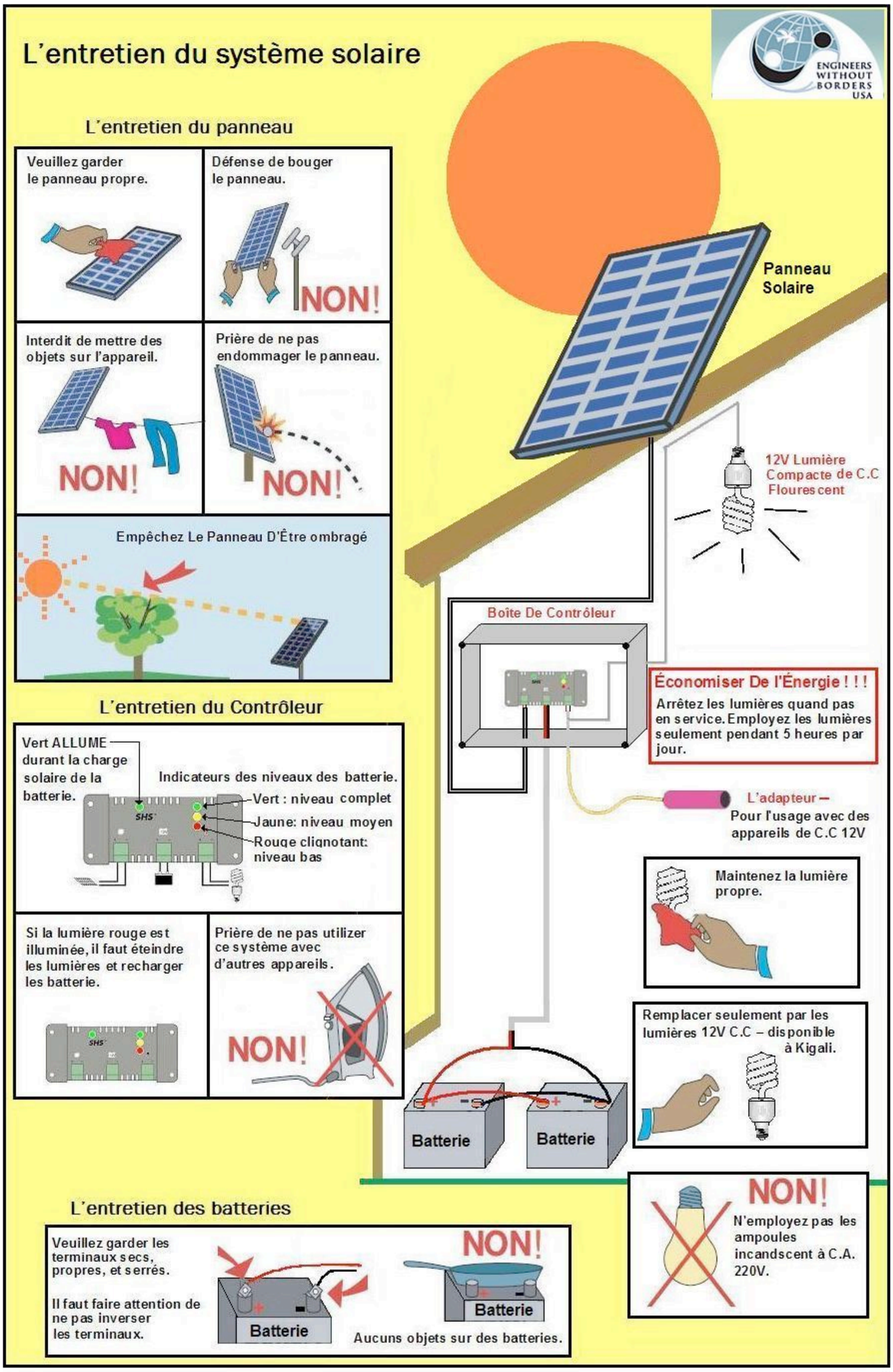
Closet with controller and batts

13.4 Plan for Village Participation and Sustainability

At the Mugonero hospital complex, there are several employees who maintain the grounds. During both of the installations employees from the hospital were trained on how to maintain the system and diagnose problems. Several employees helped install all aspects of the PV systems. Tools that are required for maintenance of the system were left with the staff at the Hospital. Our team decided to use unsealed lead acid batteries instead of deep cycle solar batteries because the unsealed truck batteries are commonly used in Rwanda. Many people are very familiar with their proper maintenance and use. The decision to use the unsealed lead acid batteries made the systems more sustainable due to the fact that they can be properly maintained and repaired.

The compact fluorescents that were purchased in the US are rated for marine applications and have an average lifespan of 6,000-8,000 hours. At each location that a system was installed, at least one replacement bulb was left for each fixture. Replacement bulbs of a similar power rating can be purchased in Kigali. Although the bulbs in Kigali are rather expensive, if the Hospital uses the PV systems as much as possible, they will be saving a certain amount of money each year that could be allocated to replace light bulbs and maintain the batteries.

Additionally, placards were left with each system describing the operation and maintenance. The image below shows the placard left with the large system.



Placard mounted with 102 watt systems