Improvement of the Water Distribution System in Chaguarpamba, Ecuador: An *Engineers Without Borders* Program.

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Abstract

EWB-Miami has been working on a collaborative initiative with the community of Chaguarpamba, Ecuador for the past four years to find a sustainable solution to disinfect the community's water supply and provide an adequate supply of clean water. The project was opened in 2011 and since then the chapter has taken four trip to the community for assessment and implementation. On the first trip in March 2012, six student chapter members and our professional mentor traveled to Chaguarpamba to conduct a comprehensive assessment of the water quality. During that trip they identified fecal coliforms as the primary cause of water contamination. The health clinic overseen by the Peace Corps confirmed that parasites and diarrhea due to consuming contaminated water were the leading health care issues in Chaguarpamba. Therefore, EWB-Miami partnered with the Chaguarpamba municipality and community to engineer a sustainable water disinfection solution as well as work on a water source development project. EWB-Miami engineered a solution to improve capture at the water collection sites while eliminating pipe obstructions such as sediment blockage which frequently impedes water flow into the distribution system.

Another group of students traveled to Chaguarpamba in January 2013 to implement their solutions to these two projects, mainly an improved water chlorination system, as well as search for and test the viability of a new potential source of water for the village. At the request of the community, EWB-Miami shifted the focus of the project work in 2014 to building an AutoCAD map of their existing water distribution system. This involved collecting the data necessary to create a map of the city's water system, such as the locations of the piping, meters, valves, and other parts of the system. Beyond the map, EWB-Miami found it necessary to begin developing a hydraulic model, made in EPA NET, based on the map. Currently, the city does not receive enough water to support its growing population and does not have a map of its drinking water system. The map and especially the model are necessary to determine the locations of leaks and areas where water is being used but not being paid for. By creating a map and model of their system, we can provide a way to determine what changes should be made to increase the amount of water available for the city of Chaguarpamba.

The municipality is also considering constructing a new pipeline from an additional water source in the future. This project is highly dependent on funding, such as government loans. Because of this very long term aspect to the project and the fact that Chaguarpamba does have

college-educated engineers, EWB-Miami and the municipality have come to an agreement to end our project partnership approximately one year early. Before a complete program close out EWB-Miami will take a final trip to the community to provide an updated version of the AutoCAD map, a complete hydraulic model, and training for the local engineers on how to use the model software.

Introduction

ENGINEERS WITHOUT BORDERS

Engineers Without Borders (EWB) is a nongovernmental, nonprofit organization whose mission is to "support and implement sustainable engineering projects, while creating transformative experiences and responsible leaders". They currently have over 14,700 members in professional and university chapters who are working with 684 communities in 39 countries to find suitable solutions for water supply, sanitation , energy, agriculture, civil works, and information systems. Engineers Without Borders-Miami University (EWB-Miami) is a student chapter that was founded in 2011. This report summarizes the the work done for the chapter's main program since its founding four years ago and documents, in depth, their most recent project work.

COMMUNITY DESCRIPTION

Geographical Size and Population

EWB-Miami applied for and received their first program from EWB-USA during the 2011-2012 academic year. The chapter was partnered with a community in Chaguarpamba, Ecuador. Chaguarpamba is a small city which can be traversed on foot. The town is relatively condensed, as the majority of the people that live in the urban part of Chaguarpamba live on one of two streets. The community is in an urban environment with shops, restaurants, and 3 schools (an elementary school, Junior High school, and High School). The Catholic Church is the focal point of the community.

The population of the community is approximately 1,000 people. The primary occupation for the majority of the town's people involves farming, small business operation, and coffee production. There are 356 housing arrangements in Chaguarpamba's central urban area. Of these arrangements, 305 are one or multiple story houses, 11 are apartments, 20 are rented rooms, and 20 are huts. There is also a firehouse, a police station, a church, and two hotels in the area. .

Figure 1: Overall Aerial View of Chaguarpamba, Google Maps.

Water/Sanitation

Chaguarpamba is located on the slope of a mountain. As a result of this location, Chaguarpamba obtains its water from several streams that originate towards the top of the mountain. These streams are completely exposed to the elements, including animals that are believed to defecate in the streams. Additionally, during the rainy season in Chaguarpamba, rainwater can cause soil erosion and unstable ground, making Chaguarpamba prone to landslides.

This affects the stability of many areas of the pipeline from the sources to the water plants.

There are two water plants serving Chaguarpamba, one for the upper section of the city and the other for the lower section of the city. Each water plant consists of a sedimentation tank, slow sand filter, and a chlorination house. Chaguarpamba water systems were built and are maintained by the municipality. Engineers estimate that they are able to achieve about 50% water capture from two of their water sources. Each house, business, or other building in the city has a water meter where residents pay according to their consumption quantity. Currently they charge $1 for every 10 m^3 and 20 cents for each additional m^3.

Background

PROGRAM HISTORY

This flow chart below displays the Chaguarpamba Water System. The numbered boxes represent water sources in the form of streams that are directed toward the sedimentation tanks. The water is run through a large sand filter and then directed to two separate plants where it is chlorinated. This chlorinated water is then delivered to customers by pipes. During

EWB-Miami's March, 2012 assessment trip in Chaguarpamba, the community and municipality expressed concerns regarding a water shortage during the dry season. In particular, the municipality cited water intake obstruction from sediment accumulation at the Coco Sur collection site as a major concern. In response, EWB-Miami designed a weir containing a blowout valve to be implemented during a trip in January 2013 and increase source development.

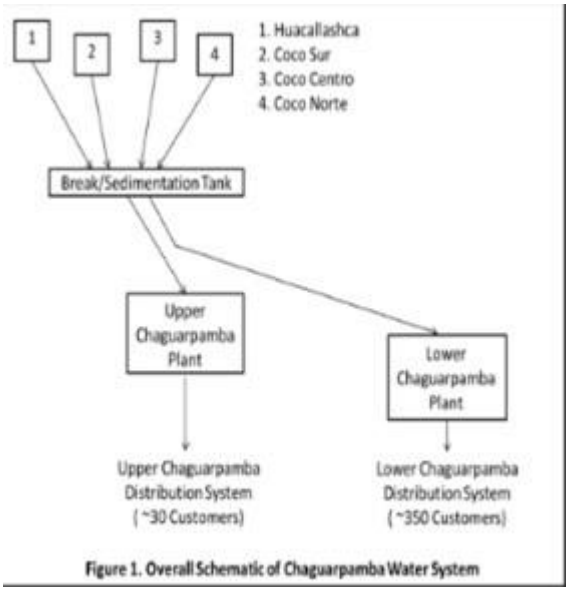
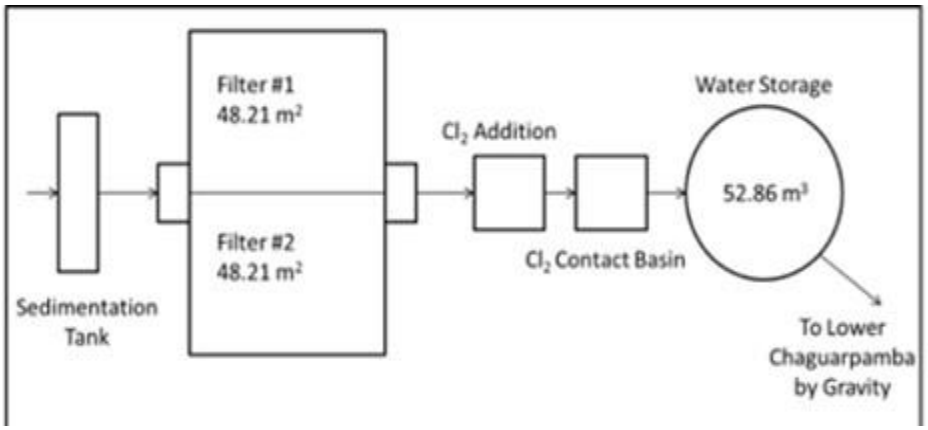


Figure 2a (above) describes the overall schematic of the Chaguarpamba water system.

Figure 2b (below) provides a more detailed schematic of the Lower Chaguarpamba Water Treatment Plant.



A Peace Corps volunteer working in the Chaguarpamba health clinic noticed a large number of disease-causing bacteria in the community's water supply. Water quality tests conducted during EWB-Miami's March, 2012 assessment trip identified coliforms to be the primary source of water contamination. The team found this contamination to be due to a lack of chlorination and mixing in the tank. Therefore, modifications to the chlorination system were to be implemented during the EWB-Miami trip of January 2013.

PAST TRIP SUMMARIES

Improving Water Treatment with Chlorine Dosing and Mixing

After receiving the results from water quality tests conducted during EWB-Miami's March, 2012

assessment trip, coliforms were determined to be the primary source of water contamination. The table below shows the water quality data collected during that assessment trip.

Table 1: Water Quality Data (Measured at Chlorination Basin)

Test	Value	Acceptable Value (WHO Standards)
Phosphate	10 ppm	5 ppm
Chloride	~ 0 ppm	No health-based guidelines exist
Total Chlorine	0 ppm	5 ppm
Free Chlorine	0 ppm	1 ppm
Hardness	85 ppm	No health-based guidelines exist
Alkalinity	60 ppm	200 ppm
pH	7.8	6.5 - 9 (note chlorine not effective at pH > 8)
Nitrate	0 ppm	50 ppm
Nitrite	0 ppm	3 ppm
Turbidity	<5 NTU	< 5 NTU
Sulfide	0 ppm	0.01 ppm
E. coli	Present	Absent

From January 1 to 13, 2013, EWB-Miami returned to Chaguarpamba to implement the designs that the team had been working on, as well as assess more needs of the community. The team found that, since its first assessment trip in March, the community began chlorinating and a chlorine residual of 0.5 mg/L was found in restaurant tap water. The community chlorinates by using a chlorine drip method and then tests the residual in the tanks daily. If the residual begins to get to low or high, the drip is adjusted accordingly.

We also found during the implementation trip that a blowout valve system had already been implemented by the community at their current sources. (This was the design that the team had been hoping to implement). Workers go up to the sources weekly to release the sediment buildup and check that everything is running smoothly. However, the community **e**xpressed their concern about animals defecting in and around the sources. Fences were built during the trip to protect against this.

Mapping the Water Distribution System of Chaguarpamba

Although improvements had been made to the system to ensure quality, the municipality in Chaguarpamba and the EWB-Miami determined that the current system would need improvements in order to meet the needs of the population of the city. The current water system is undersized and cannot meet the daily demands of the community, especially during the dry season. From there the team began mapping and modeling Chaguarpamba current system in order to find problem areas in the system that could be fixed. It was found many areas for improvement, including houses without meters that were therefore receiving free water, leaks throughout the system from the source all the way to the city center from several kinds of piping materials, and an uneven distribution of chlorine throughout the system.

The overall goal of this program is to collaborate with the Chaguarpamba community to improve water quality, facilitate the expansion of their water systems, and satisfy their increasing water demand. The purpose of our next trip will be to implement these two systems in the municipality in Chaguarpamba. We will train the engineers there on how to run AutoCAD and EPA NET and make sure they can sustain the system. A hydraulic model will be delivered in order to allow for the detection of problem areas in the system, including those previously determined by EWB-Miami like leaks and high or low pressures areas.

Data Collection & Analysis

MAPPING

During the most recent trip in August 2014 the final necessary data was gathered in order to build an AutoCAD map of the existing water system. Other information collected included water flow rates, gauge pressures, pipe diameters, and meter usage so we could build a WaterGEMS hydraulic modeling system of the existing water system. Below is a image of our current map. The finalized AutoCAD version will be sent to the community.

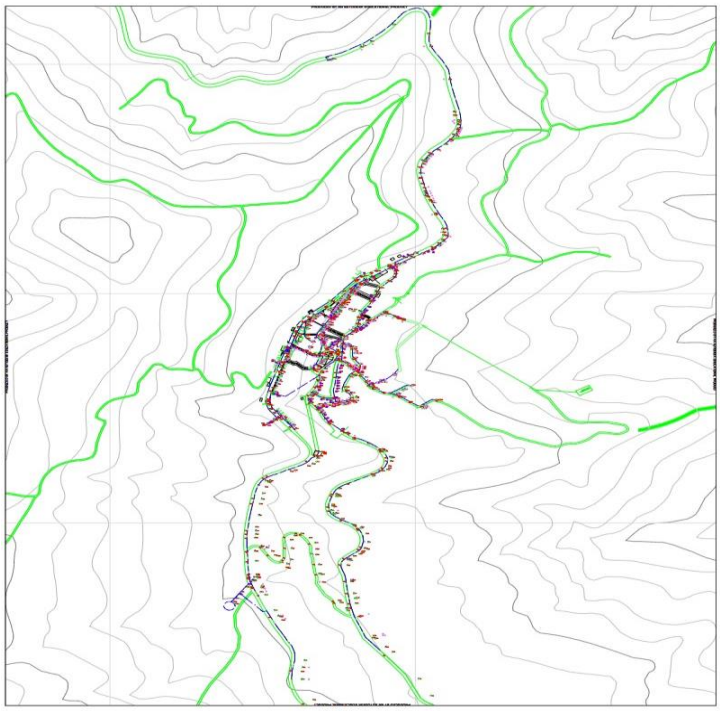


Figure 3. Current version of the AutoCAD map of the Chaguarpamba water distribution system.

HYDRAULIC MODELING

Not only was this data used for the map of the system, but also for creating a hydraulic model. The data was collected using hand devices. Pressure readings, waypoints, and elevations were gathered throughout the city as data for the hydraulic map. Tables two through four give the data gathered.

Table 2. Pressure readings and locations from August 2014.

Location Code	Location Description	Day	Time	Reading (psi)
G	Vulcanizado	8/12/2014	8:45 AM	29
F	Next to Tank A	8/12/2014	11:00 AM	23
H	Last house (near school)- lower plant	8/12/2014	11:30 AM	63
I	Last house- upper plant	8/12/2014	12:00 PM	60
J	House with pressure readings taken by system operator	8/13/2014	6:00 AM	54
J	House with pressure readings taken by system operator	8/13/2014	8:00 AM	32
J	House with pressure readings taken by system operator	8/13/2014	10:00 AM	35

J	House with pressure readings taken by system operator	8/13/2014	12:00 PM	45
J	House with pressure readings taken by system operator	8/13/2014	2:00 PM	35
J	House with pressure readings taken by system operator	8/13/2014	4:00 PM	34
J	House with pressure readings taken by system operator	8/13/2014	6:00 PM	40
J	House with pressure readings taken by system operator	8/13/2014	8:00 PM	44

Table 3. Elevation Data and Locations collected during August 2014.

Location	**Coordinates**	**Day 1 Elevation (m)**	**Day 2 Elevation (m)**
Upper Break Tank	S 03°53.110'	1368	-
	W 079°38.762'		
Upper Plant	S 03°53.201'	1411	1412
	W 079°38.862'		
Lower Plant	S 03°52.768'	1365	1367
	W 079°38.795'		
Tank A	S 03°52.704'	1349	1351
	W 079°38.783'		
Vulcanizado	S 03°53.109'	1390	1391
	W 079°38.476'		
Last House (Lower)	S 03°52.770'	1234	1236
	W 079°38.425'		
Last House (Upper)	S 03°53.299'	1332	1333
	W 079°38.573'		
Front of Hotel	S 03°52.478'	1331	1333
	W 079°38.658'		
Half Way to Source	S 03°87.466'	1340	-
	W 079°64.442'		

Source	S 03°53.522'	-	1588
	W 079°39.188'		

Table 4. Waypoint and location data collected during August 2014.

Point on Map	Elevation (m)	Description
II	1344	intersection near circle and police station
III	1355	across from discobar
IV	1358	top of crisscross stairs
a	1336	bottom of crisscross stairs
b	1329	intersection near municipal building
c	1321	5-way intersection
d	1328	intersection neat church
e	1331	---
f	1333	---
g	1337	old municipal building
h	1335	---
i	1325	---
j	1315	---
k	1308	---
l	1302	---
m	1290	---
n	1270	---
o	1247	---
p	1283	---
q	1307	---
r	1314	---
s	1312	---
t	1310	---

u	1314	---
v	1316	---
w	1336	---
x	1342	---
elevation check at hotel= 1338 (actual elevation=1340, adjust above by 1m)		
y	1347	---
z	1354	---
aa	1357	---
bb	1356	---
cc	1359	---
dd	1362	---
ee	1376	---
ff	1384	---
gg	1394	---
hh	1401	---
ii	1424	---
jj	1368	---
kk	1381	---
ll	1273	---
mm	1308	---
nn	1290	---
oo	1297	---
pp	1337	---
qq	1332	---
rr	1338	---

elevation check at hotel= 1334 (actual elevation=1340)

A current image of the working hydraulic model is shown in Figure 4. The modeling work is being done in EPA NET software and includes the data listed above as well as the material specifications of the system. The AutoCAD map created by EWB-Miami was imported into EPA NET as a base for the model.

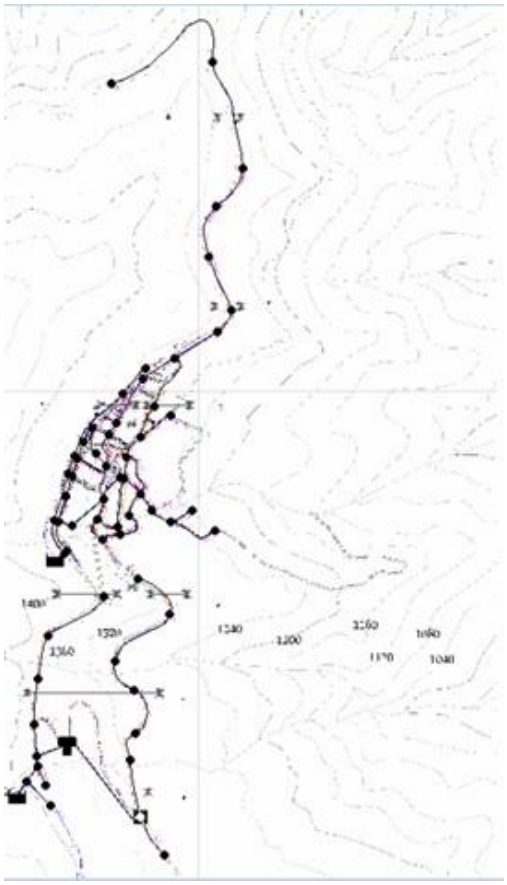


Figure 4. Working hydraulic map of the water system in Chaguarpamba, Ecuador.

Project Status

TIMELINE

With progress being made on the hydraulic model, EWB-Miami has tentative plans to travel for a final close out trip to Chaguarpamba in January 2016. In the mean time there are plans in the workings for summer 2015 and fall 2015 to complete the model, develop modeling training materials and further develop community outreach efforts.

Over the summer, general body members will assist on the completion of the hydraulic model by verifying and inserting data, such as pipe diameters and elevations at nodes. They will also develop training materials to be used on the trip, like a presentation on EPA

NET and translated user manuals. This presentation will include background information, scenarios that would most likely be useful for them to run, potential expansions of model for the future, screenshots of the program "in action", links/ video tutorials, and more. EWB-Miami will also be in contact with the lead engineer from Chaguarpamba's municipality to provide them with instructions on how to download and test the software prior to the trip.

In the fall semester, the modeling training presentation will be finalized and translated into Spanish. Separately, community surveys that have been developed will be completed. An education program for the local schools will also be expanded upon through the creation of an updated curriculum focusing on water, sanitation, and hygiene and informational pamphlets. Longer term projects include developing a trip budget, applying for grants to secure funding for the trip, and completing EWB-USA mandated travel paperwork.

GOALS

With the expected close out of the program tentatively planned for January 2016, the last trip to be taken to Chaguarpamba by EWB-Miami aims to monitor previous project work and complete technical and outreach goals. On this trip EWB-Miami will:

1. Goal 1: Train municipality engineers in hydraulic modeling software (EPA NET) Objectives: (1) Present the hydraulic model developed by EWB-Miami (2) Give tutorials on the software to the local engineers (3) Explain the uses of the software for performing hydraulic analyses (4) Demonstrate how the software can be used for the planning and development as the community grows over time

2. Goal 2: Provide the community with additional resources

   Objective: (1) Provide an updated version of the AutoCAD map of Chaguarpamba's water distribution system (2) Deliver and explain operations and maintenance manuals related to our design work (3) Connect the municipality with ASTM standards database for further reference

3. Goal 3: Conduct surveys and evaluations

   Objectives: (1) Conduct thorough community surveys (2) Collect quantitative data on the effectiveness of previous works, such as water testing to evaluate the chlorination system that we implemented in 2013 (3) Collect qualitative data using the "most significant change" method to determine the biggest impacts our projects have made in the community

4. Goal 4: Educate the community on the importance of water, sanitation, and hygiene

   Objectives: (1) Implement improved educational program at the local schools focusing on the relationship between water and health (2) Relay to the students the importance of our project, as it relates to clean, readily available water

Conclusion

Over the past four years EWB-Miami has been working with a partner community in Chaguarpamba, Ecuador. The chapter has worked to 1) provide access to clean drinking water through the implementation of a chlorination system for disinfection and 2) to provide the community with tools to expand their water distribution system in the future. As the project comes to a close within the next year, tentatively January 2016), a final trip to the community will be taken to provide an updated version of the AutoCAD map, a complete hydraulic model, and training for the local engineers on how to use the model software. This map and especially the model are necessary to determine problem areas of the system and provide a way to determine what changes should be made to increase the amount of water available for the city of Chaguarpamba.