EWB PROJECT: DESIGN REPORT

Prepared by the:
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Abstract
This document details the December 2007 Engineers Without Borders – Oregon State University (EWB-OSU) student chapter implementation trip to the communities of Las Mercedes and El Naranjito, El Salvador. Background on the project is presented with emphasis on the continued partnership with the communities. The decision process and design process for the implemented system, a rainwater catchment project based at a school serving 150 students, is outlined. Details on the implementation process are reviewed. GIS mapping and community mapping and health assessment surveys were conducted in parallel with construction during the trip; information is presented from this data. Many lessons were learned and are presented within this document. The report concludes by listing potential future projects within the community.
# Table of Contents

Abstract .......................................................................................................................... 2

Background Information .................................................................................................. 4
  Previous Trips .................................................................................................................. 4
  Transition to December 2007 ...................................................................................... 5

Design .............................................................................................................................. 7
  Pre-Design Activities and Considerations ...................................................................... 7

Design Implementation .................................................................................................... 8

Implementation .................................................................................................................. 11

Additional Projects Considered ...................................................................................... 20

Health Assessment .......................................................................................................... 24

Lessons Learned .............................................................................................................. 26

Conclusion ....................................................................................................................... 28

Appendix I – Deadman Calculations ............................................................................... 29
Background Information

The December 2007 EWB-OSU implementation trip to Las Mercedes and El Naranjito, El Salvador (LM/EN), was a continuation of the assessment and implementation efforts within those communities extending from January 2006. The communities of Las Mercedes and El Naranjito are oriented from north east to southwest, respectively, along three mountain ridges with a mountain spine providing a high connection between them. Ravines well over 300 meters deep separate the ridge tops. Several sub-communities are also present, including Escobar, a part of El Naranjito further to the south, and La Cumbre, another part of El Naranjito which is situated on the middle of the three ridge tops. This section of the report attempts to briefly provide some history to the project especially concerning project activities in the time since the prior trip.

Previous Trips

The development of this water project was initiated by a Peace Corps Volunteer (PCV) living in LM/EN. The PCV proposed a project to improve water quality and accessibility for the area, having heard of EWB-USA via another development project within El Salvador. EWB-OSU had recently formed and applied for the project to involve students internationally. The project was awarded to EWB-OSU during fall of 2005, and EWB-OSU began learning about El Salvador, fundraising, and collecting the necessary skills for a project assessment.

The first official EWB-OSU visit to LM/EN was during March 2006 with the purpose of assessing the community for a water project, becoming acquainted with the community structure and geography, and in general understanding the community’s problems and desires. The 4-person team returned to the US confident that a project was feasible although community support and involvement could be difficult. In addition, this assessment team acknowledged that due to the community’s geography and population dispersion, no single project could completely satisfy the water needs. Water, however, was confirmed as the greatest need and desire within the community, with cooking improvements and latrines following in necessity.

A second assessment trip was organized for September 2006 with the goals of collecting water quality data from various sources, taking detailed surveys of potential project locations, and creating a design for the first implementation trip. Due to land ownership confusion, it quickly became clear that a design could not be completed during the trip. Also, the planned technology (pumps) would not be feasible for some portions of the community due to extreme head requirements, variable water table depths, and source ownership issues.

The trip was able to demonstrate the effectiveness of a Potters for Peace filtration unit design in purifying contaminated water within the community, and identified significant community desire for rapid implementation of the units. The team returned to the US with the intent to design enormous rainwater catchment systems for parts of the community, and to develop pump and/or small dam
designs as appropriate for other portions of the geography. Subsequent design attempts and communication with the community showed that tanks of this size were not particularly feasible due to soil composition and geology. Furthermore, such large constructions were not desired by community members partially due to perceived danger. The design efforts again shifted to a pumping with some water storage.

A trip was organized for March 2007 with three primary purposes: carry out a distribution of point-of-use Potters for Peace water filters, establish a local Water Committee to sustain the water filter system, and survey several streams for pumping possibilities. The trip occurred near the end of El Salvador’s dry season, in order to document the spring emergence locations at the water table’s lowest point. Unfortunately the team discovered that the major streams all emerged even lower than previously thought, and had very weak outlets. Thus, EWB-OSU’s design efforts were forced to shift once again from pumping. The filter distribution and Water Committee establishment went very well.

**Transition to December 2007**

Following the March 2007 implementation trip, several challenges faced the EWB-OSU – LM/EN partnership. The Peace Corps Volunteer that initiated the project and partnership had completed his assigned term and was attempting to coordinate replacement by a new Peace Corps Volunteer so that the project could continue. On the technical side, there was the significant challenge of actually finding a sustainable design. Community support was falling due to the long period between the March filter implementation and the planned December trip. Furthermore, some community members were beginning to lose hope since no actual construction projects had been carried out and the Water Committee had not been meeting regularly. Finally, since this span of time included OSU’s summer break, student support was low, making it hard to resolve any of the issues.

Eventually, an ultimatum had to be sent to the community. The letter explained the difficulties that the project faced, and emphasized that the partnership required collaboration and support in order to have success. The bottom line was that if the Water Committee did not resume its duties, there was no way that EWB-OSU could continue its work, because we could not ensure sustainability. If the community would not organize, then any further efforts would be a waste of the chapter’s time. The Water Committee resumed its activities and the partnership continued to move forward.

On the design front, the decision was made to pursue a smaller rainwater catchment system. Rather than constructing enormous concrete tanks, the chapter would try to implement smaller plastic systems, and use as many existing roof structures as possible. To this end, the Organic Growers Club of OSU was contacted and gave permission for EWB-OSU to attempt construction of a pilot system. This served greatly as practice for the chapter in basic construction and the design problems that would be encountered with catchment system construction, since nearly every household system would be unique. A December implementation required that the communities select pilot design participants, which were chosen by the Water Committee just in time for the trip.

A last minute challenge came up in the form of design approval from WCTAC. The Technical Advisory Committee made some excellent suggestions, and withheld approval of the trip until some details were
resolved involving the tank foundation, wind loading, a first flush system, and overflow dispersion. More important were the strong suggestion that the pilot implementation be carried out on a community building rather than private homes, and that future designs reduce the total project cost. At 75+ households in the community, a system on each would be very costly.

This advice was heeded: the project changed directions and quickly obtained permission to construct the system on a school’s property. The school was deemed to have as high a need as any of the houses, and it was judged that a school improvement project had significant fundraising benefits. Thus, going into the trip, the EWB-OSU plan was to implement a rainwater catchment system on the El Naranjito School as a pilot construction for future cluster-based rainwater catchment systems throughout LM/EN.
Design

Pre-Design Activities and Considerations

The concept of rainwater collection was studied and developed by the design team in the months leading up to the implementation trip. After learning of the lack of community support for large concrete rainwater collection tanks as discussed above, the team shifted its approach to household-based systems with prefabricated plastic tanks. These tanks are readily available in Central America and are generally trusted by people as being safe and durable. These tanks can potentially allow more projects to be completed in one implementation trip and/or for community members to complete their own projects with the funding help of EWB. However, because of the financial implications of implementing on every house, the group chose to pilot test the concept on the El Naranjito school.

The EN school serves approximately 150 students. Water is used for drinking, cooking and cleaning. The school is located in a part of the community that is one of the furthest removed from a reliable water source. The group learned prior to travel that there is currently a rainwater collection tank adjacent to the school, however it is fairly small and runs out of water shortly after the beginning of the dry season. We decided that any amount of water storage we were able to provide to the school would be beneficial, but that to make a difference our tank needed to be at least double or triple the size of the existing system. On that basis, the design team chose to base designs calculations on the largest size pre-fabricated tanks readily available: 10 cubic meter high density polyethylene rotationally-molded tank, available in El Salvador from either Rotoplas or Cemix. Based on a comparison of tank specifications and pricing, the team chose to go with the Cemix Aquaplax tank.

Design activities included the following:

- Confirming that the tank volume would provide benefit to the school;
- Confirming the adequacy of the roof to provide sufficient water to fill the tank;
- Conceptualizing and designing a first flush system for the tank;
- Conceptualizing and designing a means of extracting water from the tank;
- Determining tie-down requirements for wind loading and conceptualizing a design to meet these requirements;
- Identifying maintenance requirements and tailoring designs to minimize maintenance and keep it within the capability of the community;

Some pre-design activities were completed well in advance; however some had not been known or were not considered prior to the trip and had to be done in the community.
Design Implementation

The rain harvesting system’s main components include the:

1. Foundation
2. Tank
3. Gutter
4. First Flush
5. Overflow
6. Collection Box
7. Tie downs

The system was installed to collect and store rain from the north half of the school’s roof. As rain falls on the roof it feeds into the gutter (3) that is sloped to drain into the PVC piping. The first two tubes are the first flush system (4) so the rain is first directed to go into this system. In rainwater harvesting, the first rain following a dry period is not desirable for capture and storage because it, contains dirt and debris that may have collected on the roof during the dry season. The first flush tubes are intended to capture this runoff and bleed it off slowly between storms. Once these two tubes fill up with the initial
runoff, the water is able to pass through the tubing to the tank (2). If the tank fills up to the top, the water backs up in the pipe and starts to overflow though the overflow pipe (5) which is angled higher so that the water does not overflow before the tank is full. The first flush pipes are equipped with removable caps at the bottom to allow debris to be removed periodically. The removable caps are designed to fit somewhat loosely such that water in the first flush pipes drains slowly following a storm and the capacity of the pipes is restored for the first flush from following storms.

Prior to the project, all runoff from the north half of the roof was conveyed to the site boundary in a shallow concrete gutter. The project included the addition of roof gutters, but will not increase the amount of water flowing in this channel. As a preemptive measure against erosion, the ground conveyance for stormwater runoff was improved and discharge points at the edge of the school site were armored. Armoring consisted of pieces of concrete and rock that were unearthed in the excavation of the tank foundation.

The cleanest water is neither from the very bottom (where the spigot is located) or very top. Literature suggests the cleanest water is located approximately one third of the way from top to the bottom of the water column. While it is not possible to ensure that water is always drawn from this location, a simple, yet effective strategy was used to position the intake in the water column: a rubber hose was tied to a float with a string approximately 15 inches long. This mechanism ensures that water is drawn from a location approximately 15 inches below the surface. Water at this location is expected to have relatively good characteristics throughout much of the operational cycle of the tank. Below is a picture of the inside of the tanks showing the tubing and float assembly.
It was desired that water only be accessible to teachers and students of the school during school hours. Additionally, the quantity of the tank and length of the dry season will require the school to have control over and limit the rate at which water is used. Therefore, it was necessary that the design provide controlled access to the water. The method chosen by the community and the design team to address this concern was the construction of a collection box below the grade of the tank that could be covered and locked. The collection box was constructed with cinderblocks and covered up with a door that had a locking system. A drainpipe was laid from the bottom of the box to the nearby slope to drain any water spilled in the box and drain the tank as necessary.
Implementation

1. Tools purchase:
   Evan Miles and Doug Van Bossuyt traveled to El Salvador one week before the rest of the team to begin our preparations of the work site and living arrangements. They ended up finding a very accommodating hardware store Ferreteria Vidales in Ahuachapán that was extremely helpful. This was the store that our Peace Corps Volunteer (PCV) Aaron Oppelt used to find the tank. They also ordered the tank at that time.

![Tools prior to transport to the communities](image)

2. Material procurement:
   While in Ahuachapán, Evan and Doug visited a rock and sand supplier (Stanley’s Materials.) They ordered \( \frac{3}{4} \) inch minus rock, Sand and Portland Cement. The purchase also included delivery to the work site. This delivery agreement would turn into a major hindrance for later steps.

   The biggest problem was that while Stanley spoke excellent English, the communication got misunderstood somewhere after Stanley. We ended up receiving \( \frac{3}{4} \) foot minus rocks. They were described as ‘Head sized’ but they were closer to 6-8” round river/pit rock.
Delivery was the biggest learning experience of our trip. Stanley tried 3 times to get our materials delivered to the site. Unfortunately, he did not realize the accessibility problems of our site, and sent large flatbed delivery trucks to make the delivery. The locals use 1980’s era Toyota pickups for all their delivery needs, and only the coffee Finca uses large delivery trucks to take down the coffee. Those trucks do not carry anything heavy to the top (like huge rocks, 1 cubic meter of sand and 8 bags of Portland cement.)

As a result, Stanley lost 2 trucks to breakdowns (est. repair cost of $600,) the sand and cement was delivered 2 days late, and the rocks were dumped at the side of the road where we had to arrange our own delivery to the site- 4 days late. The project was significantly slowed while the delivery issues were solved.

In addition to this material, we needed 2 more cubic meters of sand. This material was delivered by the very reliable Toyota trucks in 2 loads. The drivers were very good about not overloading their trucks- since this route is their primary work in the harvest season.

3. Water runoff mitigation:

When the Construction team arrived at the project site and realized that our basic materials were going to be delayed, we moved on to some of the less critical tasks. The first to be tackled was the potential for concentrated runoff from our gutter installation to cause erosion problems. The land slopes away from the school site at approximately 100 percent slope (1H:1V), and minor existing erosion was observed.

It ended up being that the majority of the school yard drains off the edge of the school site in the existing condition, so our tank would cause a minor increase in the amount of water
flowing off the cliff by diverting the water from the far end of the roof, instead of that water running onto the road.

Our design was to place rocks and discarded concrete chunks (from the foundation preparations- see next section) in a series of walls to slow down and protect the hillside below the school yard. There is a 5 foot drop from the school yard to the hillside, where previous rains had washed out part of the hillside. That area was extensively protected with concrete chunks to absorb the force of the falling water stream and slow down any water reaching that diversion.

We worked on several locations that were already worn into cliffs and washouts.

![Working on erosion control](image)

4. Foundation:

   Our first step was to prepare the area for our foundation. This involved placing the area of the tank, removing the surface cover and marking our hole. The surface cover was a mortar mix used to prevent the soil from being washed away by the rainfall. It was pried up and set aside to be used later.

   Digging the foundation hole was next. We started by digging down 8 inches to ensure we had a good under layer for our concrete. Once we realized that the rocks were not the correct size, we dug the hole deep enough to accommodate ‘head sized’ rocks with sand bedding.

   Our final foundation was described like this: a layer of compacted sand, sand supported rocks (packed as tightly as possible) and then watered to ensure the sand between the rocks was compacted. The next day, the tops of the rocks were uncovered to a uniform height of 2 cm. The sand visible between the rocks was then compacted by hand to ensure tightness. A layer of mortar was placed over the rocks in a layer approximately 2 inches thick, and was compacted into all the cracks of the rock. Mortar mixing and placement is described below.
5. **Anchor system:**

Once we had our foundation hole dug, we then placed our deadmen for the anchor points. These were an additional 4 inches deeper than the rock layer, and were formed in by using scrap sheet metal/laminate. We finalized our concrete mixture before pouring the deadmen.

The anchor points were constructed out of 3/8” rebar approximately 3 feet long. The rebar was first folded in half and then at about 18 inches from the cut ends, the legs were bent 90 deg. The final spread of the legs was matched to the forms of the deadmen, to give us about a 2 inch gap from the legs of the anchor to the form wall.

The anchors were placed such that they extended above the final concrete layer only slightly. Please see Appendix I for deadman and wind loading calculations.

The tank was tied to the anchors by wire rope (3/16 inch diameter.) We used 3 risers (each in a loop,) one for each anchor, joined onto a center loop on the top of the tank. All wire rope ends were connected with cable clamps.

Every riser section, from just below the tank’s corner to the center loop and the center loop were covered in plastic tubing to reduce the wear on the tank by the cables.
There was a miscommunication in the cutting of the riser loops, so there ended up not being enough wire rope to circle the tank and tie together all 3 risers. The risers were first connected to hold tension on the center loop. Then they were pulled as tight as we could to achieve tension. We also laterally connected 2 risers on the side of the prevalent winds (coast side) to hold them together. The third riser was directly in the path of opposing wind direction, so it was not necessary to provide additional support on that riser (see photos for a better understanding.)

Anchor system as seen from the west

6. Tap/Drain point:
One of the things we did not anticipate was the need to have the tap locked. The result was to build a cinder block lined hole with a door/lid. The dirt in the area gave us numerous problems because the make up was of 2 types. The first was a loam type of dirt, very crumbly and easy to dig. The other was a very compacted and clumpy mixture. It acted almost like it was concrete, but it broke once it was hit directly with force. The hardest part was the digging. What started out as a small hole soon became huge because those clumps of dirt kept popping free, usually in boulder sized chunks.

The cinder blocks were mortared together, using a ratio of 1 cement, 3 sand, and ½ lime. There was a floor of mortar poured, and a drain line installed to empty the hole. Our skills in mortaring could have been better, but we had the community help us at this point, which made things better.
7. Tap Locking system/ Lid:
The lid was made out of several planks, ripped to a width to form into a frame. To reduce weight for the children opening the tap for daily use, the lid is a combination of sheet metal and wood.

The locking system was a simple bar lock with a hook at one end and a loop at the other. The hoop is mortared into the cinderblocks and there is a hole cut into the lid for the hoop to pass through. The lock side of the pit has a lock loop drilled through the cinder block wall and mortared in place. The lid goes on first, it fits loosely on the hoop, and then the lock bar passes through the hoop. While the hook slides down the wall face on that side. The lock end then sits next to the lock loop in the wall. There was a lock and key set purchased and turned over to representatives of the water committee to provide to school staff.
8. Gutter:

The gutters were made of sheet metal, shaped into a square box U, and then riveted together. The sharp edge of the sheet metal was then folded over to provide structural stiffness to the walls of the gutter.

The supports of the gutter were rebar hooks bent into shape one at a time and then wired onto the existing structural elements. We really appreciated having a tall guy (Tristan) on our trip, because our ladder had to be returned before we were done.

9. Piping:

We started out by calculating the volume needed for our first flush collection and then came up with different designs based on what the hardware store might have. We ended up using two 6” diameter pipes for our first flush, with 4” piping for the rest. The first flush end caps were a bit of a challenge, because they were piping caps made to fit tightly, not the loose fit we needed for easy removal. We spent several hours filing and shaving the inside of each cap to ensure that the removal was easy. The last problem that we discovered is that in our days of staying busy, we dug the hole for the piping support in a less-than-ideal spot. That didn’t ruin our plan, but it required the use of a lateral extension from the vertical pipe and lateral braces. The piping support holds the weight of the piping, tested by us pulling on the support as we were done tying everything together.
10. Tank:
The tank was black plastic (PVC) designed to hold 10,000 Liters. It had a man-hole at the top with a cover, and a drain point on the bottom. We made a float for the supply of the drain point, to use to the maximum extent the top 2/3 of the water volume. The drain then goes into a 1” pipe that is capped by a ¾” garden hose ball valve.
11. Mortar/ Concrete mixing

The materials we used could be described like this:

- Sand: It was a mix of rocks and river sand. Not the common, finely crushed sand available in the USA. It was necessary to screen out the large rocks and organics first.
- Rocks: these were from our screened sand. At first we were unsure we would have enough rocks from the sand, but by the time we were done with our concreting, we had more rocks than we needed.
- Lime: We discovered that the lime used for the pit toilets was a necessary mortar item and was mixed in at a ratio of 1/2 volume of cement.
- Portland cement: 100 lb bags were very easy to use.

Our volumes were difficult to measure. Originally we used shovelfuls, but they can be a varied amount from person to person. It was very important to keep the same person measuring the material for each batch. We ended up switching over to a bucket later, because of the volume needed for our concrete.

Water was a very hard commodity to retrieve. It was a 20 min walk to the spring, and a 30 min hike back up the hill with 3 gal of water in our hands. The water used in the concrete mix was not measured in a fine amount. The coarseness and dryness of our sand made us use more water than we anticipated during the first few mixes. As a result, we splashed water in as needed to finalize our mixture instead of measuring out the amount. The bucket as a volume measuring device was helpful in maintaining a close approximation of concrete to water volume. The final ratio was almost 1 concrete to ¾ water. We observed water loss during the mixing process and then after the concrete/mortar had been placed, which is another reason why water to cement to ratios were higher than we expected.
Additional Projects Considered

The group spent a significant amount of time at the beginning of the December 2007 trip identifying and evaluating projects that may have been feasible to implement in addition to the EN school rainwater collection system. As it worked out, the team did not have enough time to implement another project, but the additional projects are discussed in this section as a preview of what the group may choose to implement on future trips.

1. El Naranjito gravity feed pipeline from privately-owned spring to community edge.
   - **Pro:** Community involvement is high for water projects in El Naranjito proper
     - Serves a large number of Houses (12 total)
     - Route is easy to use
     - Spring box is well above the highest point along the route.
   - **Con:** Need permission of owners to use the spring box’s (multiple owners to sift through)
     - Access to water is already somewhat easy for community, until spring goes dry late in season.

2. Las Mercedes School – solution for high turbidity in springwater during rainy season; likely involves protection of spring source from uphill runoff.
   - **Pro:** This would complete both schools’ water needs
     - Permission granted by School Board
     - Cistern in place, needs repairs
     - This would potentially fix water turbidity problems for houses adjacent to the school
   - **Con:** Community involvement is lower than other locations
     - Design of system might be extensive (low weight)

These options and others were evaluated by the group by formulating criteria and completing a decision matrix. Evaluation criteria included:

- Feasibility to construct the project on the current trip considering short time frame;
- Physical feasibility of project;
- Permission to construct the project;
- Existing access of the project area to water;
- Appropriateness of technology;
- Number of people who would benefit;
• Estimated cost and possible precedent formed by implementation;
• Maintenance requirements;

The group plans to evaluate these and other options in preparation for future implementation trips. Criteria will be different to account for different situational dependencies.
Surveying and Mapping

A second team spent the majority of the time surveying and mapping the community, its open spaces, collecting GPS data of its roads, springs, and households, as well as measuring and collecting information at the household level.

For the household mapping piece, measurements and drawings of each of the families’ houses, available space and possible available space for a water tank were taken. Of the sixty-two households that were mapped, twenty had an ADIC house. The ADIC houses are six by six meters, have cinderblock walls, concrete floor, steel rafters and corrugated fiberglass roofs, with drip lines that vary from 2.2 to 2.6 meters. For those families that had ADIC houses, there were usually one to three additions on the house. Those additions, as well as the households that had no ADIC houses, were mainly made of mud and stick with corrugated tin roofs and an average drip line of two meters. There were a few houses whose walls were also made of corrugated tin and fewer that had clay tiled roofs. If a house had a clay tiled roof, it was only part of the house, while the other parts had the usual corrugated tin roofs.

As a component of our community assessment project, major features relevant to the water project were mapped using a Trimble Geo XT GPS receiver and Terrasync software.

Features of main concern included houses, public buildings, water sources, and potential public building spaces. The locations of all houses and public buildings (as identified by the PCV) were recorded. Houses that weren’t visited for interviewing/survey purposes may have had their positions recorded remotely (offset from a road, for example). Major water sources such as spring boxes and streams (as determined by the team in-country) were visited and their positions were recorded. The locations of public building spaces (as documented in the community space surveys) were also recorded.

Features of less concern to the project include roads and trails. These features were recorded as convenient and will be useful in the creation of navigational maps.
All GPS data will be differentially corrected for accuracy and consolidated for ease of use.

The mapping and GPS data is planned to be compiled digitally using GIS. Consolidating the data in digital format will aid in designing plans for future trips, and for communicating with new members, travelers, and advisors of what has already been done. Having visible and digital information will strengthen the understanding of new members, allowing them to come up to speed with the project midstream.

A typical survey form
Health Assessment

The health component of the December 2007 trip included a health survey team tasked with gathering baseline data for the households in the communities of Las Mercedes (including Escobal), El Naranjito, and the ridgeline communities of La Cumbre to serve as the foundation for ongoing project evaluation. A household survey form was designed before the trip (see appendix) that was used to ask a member of each household about topics of household water, sanitation, and health conditions, a “Use and Satisfaction Survey” of the ongoing ceramic water filter distribution project, and identification of existing community health resources. The survey was reviewed by and received approval from the Oregon State University Institutional Review Board (IRB).

As the households are spread out along separated ridgelines, the following methods were used to gather data:

1. The night before (after families had returned from harvesting coffee) the survey team conducted a community meeting near a given cluster of homes where surveys would be conducted the following day. This community meeting served to 1) explain why we were there and what we would be doing 2) encourage a family member to be at home and available to answer questions, 3) conduct a focus group survey (see appendix) to determine health resources and health knowledge and 4) to generate discussion among community members as to what they thought would be a good solution to the drinking water problem for their particular area (e.g. community water cistern, individual cisterns, gravity fed system).

2. The following day the survey team went house to house in the cluster of homes designated and went through the survey with the Peace Corps Volunteer serving as translator. While household interviews were being conducted the mapping team completed the survey of the physical features of the house. Each household was asked and given the opportunity to participate, or not, in both the physical and health assessment surveys as per our approved IRB protocols.

3. Households that had a ceramic water filter were asked additional questions from the “Use and Satisfaction” survey. A water sample was also taken, using a random sample method which placed focus on getting samples from households that had young children in the homes, from the water filter using Whirlpaks.

4. At the end of the day the water samples were tested using a presence/absence test for E.coli, a strip test that tested for pH, total chlorine, free chlorine, hardness, and alkalinity, a separate strip test for nitrate and nitrite, and the colorometer was used to test for ammonia, and orthophosphate. (See below for water testing details)
Overall surveys and water samples were collected as indicated in the table below.

<table>
<thead>
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<th></th>
<th>Total # of surveys conducted w/ water filters</th>
<th>Total # of surveys w/out water filters</th>
<th>Total # of water tests completed</th>
<th>Total Surveys (Column B+C)</th>
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<td>Project Totals</td>
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<td>17</td>
<td>13</td>
<td>48</td>
</tr>
</tbody>
</table>

Analysis of survey data using SPSS is currently underway. Findings and lessons learned will be presented in a poster at the March 2008 International EWB conference in Seattle, Washington and in future reports to TAC.

Confidence in Water Testing Procedures and Materials:

The various water testing procedures and materials performed at various levels. The incubator brought along for the E.coli test did not have the correct electrical adapter, therefore was not functional. To replace this, a simple presence/absence test was done by covering the Scotch Petri Films with a sample and placed inside a black plastic bag to attract heat and sunlight throughout the day. To test the reliability of this test, other water samples from spring sources were tested. Generally, E.coli was found in some of the sources, yet not in the filter samples (see Results to come in appendix). Given this, we can assume that the incubation procedure used was encouraging E.coli growth where present.

The strip test for pH, total chlorine, free chlorine, hardness, and alkalinity was assumed to be non-functional, as all water samples revealed the same results. The expiration date on the bottle was assumed to be past, though it was not completely decipherable on the bottle. It is recommended that test kit materials are checked at minimum one month in advance of departure, as many of the supplies might need to be ordered.

The nitrate/nitrite test however performed well and was assumed to be working appropriately. The kit was current and the results varied for different water tests, both filter samples and source samples. The colorimeter was also assumed to be functioning appropriately for the orthophosphate and ammonia test.
Lessons Learned

During the trip, many unexpected and unplanned situations arose. The important lessons learned from our experiences are identified and discussed below:

1. We found that supplies were hard to procure. Buying them was not a problem; it was getting them transported to the work site that cost us a lot of time and caused work delays on the El Narnajito school rain catchment system. The road from Tacuba to La Cumbre seemed to be the main reason that vehicles had trouble delivering supplies. It is in very poor condition, often cutting into steep hillsides littered with large holes and rocks, which placed a lot of strain on the trucks that attempted to deliver supplies. Additionally there were a limited number of trucks, as well as appropriately sized trucks, available to deliver supplies. Again, this was in part due to trucks being dedicated to coffee bean harvest transport. To address these problems we identified as many local truck drivers as possible, and obtained their phone numbers so that we could multiple options available to us, should one truck fall through.

2. Material miscalculation challenges led us to be short on some supplies. This was not a major problem as we were able to get the extra supplies we needed without adding significant time to our work schedule, but nonetheless time was still lost. So in the future it will be important to calculate the supply needs more accurately.

3. Time was also lost while waiting for supplies to be delivered. On days when we were not constructing, we still required that some students be present at the construction site to await deliveries. Attempting to schedule deliveries more accurately and further in advance would allow all members of the team to use their time more efficiently. However, it seems that some delays are inevitable, so it is important to identify tasks that can be accomplished if things do not go as planned.

4. As discussed earlier in this report, materials were not always of the type and quality we expected. In addition, some tools and supplies could not be procured locally. Thus, it was critical to be able to work with the supplies and materials that were available. This required the ability and willingness to be creative and technical resources to confirm design modifications in the field. We found it valuable to have printouts of other similar case-studies and compact engineering reference books with us. It would also be valuable to have more people on the trip with contracting or handyman experience.

5. When we were at the construction site, there were a few days that community members did not show up to help, which cost us a lot of time as we were confronted with the dilemma of having to stop work until community members showed up to work. Much of their lack of involvement can be attributed to it being coffee harvesting season, which is their greatest source of income
for the year. It will be important to consider timing of future projects if community support is desired and/or required. It was mentioned to us that more people could be available if work parties were schedule a couple weeks in advance.

6. The project involved mixing concrete and mortar, as will future projects we expect. We had technical resources with us on concrete; however we still found that a lot of on-site testing had to be undertaken before we were confident in our mixes. As a result we recommend that a concrete and mortar workshop be held prior to the next trip or include future travelers that have some experience with masonry work.

7. Money logistics were problematic for the team. Cash is the method by which materials had to be purchased, however travelers had to go to Ahuachapán to find a bank and ATM. A trip to Ahuachapán consumed most of a day (1.5 hr. walk to Tacuba, 45 minute bus ride to Ahuachapan). The money withdrawn was usually in large amounts and was only carried by one person which posed a security risk. A better way to carry money and/or secure funds is imperative. Lessons were also learned during the administration of the health conditions surveys.

8. It appeared that a couple of the questions asked were not understood possibly due different cultural understandings or use of words which were translated to Spanish, but perhaps not to the word used locally. These lessons will be considered during our analysis and used to revise future survey tools.
Conclusion

Overall, this trip was very successful. The team was able to collect lots of pertinent health and physical site information as well as test out the design of the rain harvesting system at the La Cumbre School. In order to complete a project of this magnitude, it will be important to have an organized solution. To that end the OSU chapter’s next major task will be to develop a master plan. This will include a map with all the GPS points collected, access to the pictures taken at specific survey sites, organized quantitative health information, along with plausible solution designs for specific areas.

Possible projects for the Spring trip include construction of either a spring box for the Las Mercedes School to correct the turbid water problem or a gravity fed water system for the El Naranjito community.

Pending project funding support the next trips are planned for Spring, Summer, and Winter breaks of 2008. Once the master plan is put together, one system will be built during the Spring trip and two systems will be built during the Summer trip and two during the Winter. If the project team is able to stay on track getting these systems built, the project will hopefully be completed by the Spring of 2009.
Appendix I – Deadman Calculations

Assumptions (and Actual situation):

- Tank vertical surface is flat and catches all of the wind, like a sail. (The tank is a cylinder, with a very round top)
- Total wind force will be felt at the top of the tank. (The force of the wind will be concentrated at the middle of the height.)
- The weight of the tank is does not help hold the tank down in addition to the anchor lines. (The weight will be a minor help in holding down against the wind, also there will be a small amount of water that is not drained from the tank at the end of the wet season.)
- The Anchor cables are single strand. (The cables are looped to provide a little bit more assistance in resisting the force of the wind.)
- The initial equation is for there only being one Anchor for one direction. (There are 3 total, spread out in equal distance, Allowing all 3 anchors to help hold down the tank from any direction.)
- All Numbers are real (the numbers have been rounded up to the nearest 100# where ever possible.)

Wind Load

Load in Pounds = Surface Area * (Wind Speed)² * 0.00431

<table>
<thead>
<tr>
<th>Hurricane speed max (MPH)</th>
<th>Surface area (ft²)</th>
<th>Constant</th>
<th>Load (lbs)</th>
<th>Load (lbs) rounded up</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cat 1</td>
<td>95</td>
<td>66.84</td>
<td>0.00431</td>
<td>2599.93</td>
</tr>
<tr>
<td>Cat 2</td>
<td>110</td>
<td>66.84</td>
<td>0.00431</td>
<td>3485.77</td>
</tr>
<tr>
<td>Cat 3</td>
<td>130</td>
<td>66.84</td>
<td>0.00431</td>
<td>4868.56</td>
</tr>
<tr>
<td>Cat 4</td>
<td>155</td>
<td>66.84</td>
<td>0.00431</td>
<td>6921.13</td>
</tr>
</tbody>
</table>

Hold down force needed for one Anchor:

\[ \text{Moment} = (\text{- Wind load} \times \text{Height}) + (\text{Hold down force} \times \text{Length}) = 0 \]

<table>
<thead>
<tr>
<th>Load (lbs)</th>
<th>Height (ft)</th>
<th>Width (ft)</th>
<th>Hold Down Force (lbs)</th>
<th>Load (lbs) rounded up</th>
</tr>
</thead>
<tbody>
<tr>
<td>2600</td>
<td>8.86</td>
<td>7.55</td>
<td>3051.13</td>
<td>3100</td>
</tr>
<tr>
<td>3500</td>
<td>8.86</td>
<td>7.55</td>
<td>4107.28</td>
<td>4150</td>
</tr>
<tr>
<td>4900</td>
<td>8.86</td>
<td>7.55</td>
<td>5750.20</td>
<td>5800</td>
</tr>
<tr>
<td>7000</td>
<td>8.86</td>
<td>7.55</td>
<td>8214.57</td>
<td>8300</td>
</tr>
</tbody>
</table>

Total Hold down Force needed for 3 Anchors

\[ \text{Moment} = (\text{-Wind Load} \times \text{Height}) + (\text{Hold down force} \times \text{Length}) + (\text{Hold down force} \times 2 \times 1.9 \text{ ft}) = 0 \]

<table>
<thead>
<tr>
<th>Load (lbs)</th>
<th>Height (ft)</th>
<th>Width (ft)</th>
<th>Hold Down Force (lbs)</th>
<th>Load (lbs) rounded up</th>
<th>Load (lbs) per Anchor</th>
</tr>
</thead>
<tbody>
<tr>
<td>2600</td>
<td>8.86</td>
<td>7.55</td>
<td>802.93</td>
<td>805</td>
<td>268.33</td>
</tr>
</tbody>
</table>

Anchor Weight

| Tank Weight (lbs) | 500.00 |
| Weight of deadman (lbs) | 450.00 |
| Weight of slab (lbs) | 265.68 |
| Weight of Rocks (lbs) | 247.20 |
| Anchor weight (lbs) | 1462.88 |
| **Total weight (x3) (lbs)** | **4388.64** |

In conclusion, the anchors we have will hold up to a Category 1 hurricane, and will probably hold though a Category 2 hurricane.