Water Team
Final Report

April, 2015

Prepared for:
Montaña De Luz Orphanage
Dr. Edgar Casale
ENGR 4692.01S

Prepared by:
Laura Lee
Elizabeth Clapp
AbdulRahman Alsuhaibani
1. Introduction

1.1 Background

Montaña de Luz (MdL) lacks the water infrastructure to produce potable (drinkable) water, and relies on purchased water for their drinking water. The staff of MdL has requested assistance with creating potable water at the facility to lower the facility’s operational costs. This has been an on-going request from MdL since 2009. Previous OSU teams have detected elevated levels of *E.coli* and arsenic in the tap water, and have also detected that qualities of the water are not at acceptable EPA standards, like alkalinity and hardness. After gaining knowledge of the current distribution system from previous documents and on-site inspection, the Water Team believes it is **not** in MdL’s best interest to attempt to produce potable water. The reasons for this conclusion are in the Sustainability Statement section of this report.

1.2 Team Members

Laura Lee  
Senior Food, Agricultural, and Biological Engineering Student  
Contact Information:  
Email: lee.4118@osu.edu  
Phone: (614) 205 - 5559

Beth Clapp  
Freshman Environmental Engineering Student  
Contact Information:  
Email: clapp.29@osu.edu  
Phone: (740) 550 - 3431

Abdulrahman Alsuhaibani  
Senior Chemical Engineering Student  
Contact Information:  
Email: Alsuhaibani.2@osu.edu  
Phone: (330) 835 - 7774
2. Table of Contents

3.0 Executive Summary ................................ 3
4.0 In-Country Work .................................... 3
  4.1 System Mapping ................................... 3
  4.2 Water Tests ....................................... 8
  4.3 Sediment Filters .................................. 12
  4.4 Slow Sand Filter .................................. 21
5.0 Scope of Work ...................................... 24
  5.1 Objectives ....................................... 24
  5.2 Deliverables ...................................... 24
6.0 Timeline ........................................... 25
7.0 Budget ............................................. 27
8.0 Sustainability Statement ........................... 29
9.0 Recommendations for Future Teams ............. 30
10.0 Appendix ......................................... 31
11.0 References ....................................... 39
3. Executive Summary

The water team successfully implemented the objectives outlined in the project proposal, although some tasks had to be modified upon discovery that conditions at Montaña de Luz (MdL) were not as expected and one objective was uncompleted due to time constraints. The tasks that needed to be modified were the tasks regarding the well. The well and the area surrounding it were dramatically different than what was expected, but the team was able to make adjustments accordingly. The objective that was uncompleted was the slow sand filter. Unfortunately, the team ran into lengthy troubleshooting with the sediment filters which imposed on the time allotted for slow sand filter construction. The team worked diligently to complete as much of the slow sand filter as was possible, and left instructions for finishing the filter with Chris Ratcliff. The team gained valuable insight on the layout of the water distribution system, the status of current contaminants, and constructed an efficient form of sediment removal. The time spent in Honduras was extremely rewarding in that meaningful work was done, and the children of MdL impacted each of the team member’s lives in an invaluable way.

4. In-Country Work

4.1 System Mapping

MdL lacked an updated map of the water distribution system layout. The most recent map was from 2009, and several changes had been made to the system since then. One objective of the water team was to create an accurate map of the water system while in Honduras, for MdL’s use as well as for future OSU water team’s use. Having an accurate and updated map will eliminate future obstacles surrounding a lack of knowledge of the system. Figure 1 shows a visual representation of the water distribution system. Water flows through the system components from left to right, and the dotted lines represent optional pathways. The subsequent text contains a detailed description about each component of the water system.

![Figure 1: Water Distribution System Components at MdL](image)

**Well**
First, water is pumped up from an underground well. There is a submersible lift pump, believed to be a Franklin Electric Submersible Motor, Model 2366019020. Originally, the team had made plans to execute several tasks that would protect the well from contaminated surface water and make it more sanitary. Upon seeing the well, several of the tasks were determined to be impossible. The well is
located next to a small brick house about 200’ downhill from MdL. The team had planned to slope the ground away from the wellhead, but this was unrealistic due to the severe slope of the hill and compacted soil. The wellhead, pictured in Figure 2, is molded into a concrete housing. Instead of the expected well cap on the wellhead, a metal T was directly attached. On the back end of the T, chlorine solution was injected, while the front end sent the chlorinated water uphill to MdL. Before the team arrived in Honduras, they were alerted that an opossum had been living inside the concrete housing. There were large holes in the front and back ends of the housing where the pipes entered, through which the opossum could have easily entered. There were also open holes around the well casing. The well casing surrounds the well pipe itself, and extends into the ground. The top of the casing was slightly covered by a piece of metal welded on (Figure 3), but was largely still uncovered. It is also important to note that the PVC piping running underground from the well uphill to MdL is 2.5” PVC, which is an older size of piping that is no longer made. If any adjustments are made to this piping, it is important to know that no 2.5” PVC will be available in Honduras.

After examining the well, the team decided the best plan of action should be to determine the depth, and seal the holes in the housing. The depth was determined by lowering rope with a weight on the end into the well casing. The team attached a small plastic syringe with the needle and plunger removed to the end of a length of rope, in Figure 4. The device was lowered into the well casing, and then pulled out once the syringe hit water. The team was able to lower and raise the syringe, and determined that the depth from the top of the wellhead to the water table is 214’. The syringe also functioned as a small collection vial, and the team was able to get a sample of water from the well for water testing. The water visibly had a large amount of sediment. The device was lowered into the well again to gather a larger amount of water for testing. Unfortunately, the device became lodged in the well and could not be pulled out. The team tried several times to dislodge the device, but it remained stuck. After this mishap, the team began closing the holes in the housing. The hole in the back of the housing was sealed with cement (Figure 25). The hole in the front of the housing was not cemented closed because the wiring for the submersible pump extended through this hole, and the team did not want to damage the wires.
Sediment Filters

Directly after water is pumped up from the well, it is sent through 3 sediment filters. The team installed these sediment filters this year, and they will be described in more detail in subsequent sections of this report. There is also a bypass around the sediment filters that can be switched over to manually by valves.

Chlorine

A blue, 55-gallon drum of Calcium Hypochlorite solution sits inside the small brick building by the well (Figure 5). MdL buys powdered Calcium Hypochlorite, which they pour into the 55-gallon drum and fill with water. There is a ½” PVC pipeline connecting the chlorine solution to the water line, joining just past the sediment filter valves. There is a small dosing pump above the drum, which periodically injects the solution into the water stream when the lift pump is turned on. The frequency of this injection is called the stroke rate, and it is currently set at 181 (0.181 liters/hr). If more chlorine is desired, the stroke rate can be increased. When the drum is empty, a valve above the drum can be turned, and the well water will instead flow into the drum and refill it. The chlorinated water then travels uphill from the well via underground piping to the holding tanks.

Holding Tanks

There are three large black polyethylene holding tanks sitting atop the pila building (Figure 6). They are “Trinidad Tough Tanks”, and have openings on top covered by a screw-on lid. There are
two 800-gallon tanks, and one 600-gallon tank, which all fill simultaneously when the lift pump is turned on. One 800-gallon tank (furthest from the well) has a floating sensor inside that signals when the level of water is about 1’ from the bottom, and turns the lift pump on. The circuit for the lift pump is located in the pila building. The sensor signals to turn the pump off at about ¾ of the way full. The tanks fill about 2 or 3 times per day. There is rebar ladder along the side of the pila building which leads to the tanks. Upon climbing up to the tanks, the team discovered that one of the lids was off. The tanks did not have any frogs or large amount of sediment as previous groups have reported, but they did have a strong fish-tank-like odor. The displaced lid could have caused a significant amount of contamination in the tanks. There were visible mice-droppings around the rim of the 600-gallon tank. The tanks also have open holes along the seal, which were probably originally intended for bolting the tanks together. These holes are large enough for pests and bugs to enter through. There are also oxygen inlet pipes that intersect with the water entering the tanks. On these oxygen inlets, there is an opening to the air that is covered by a mesh wire and secured with zip-ties. The PVC piping leading in to each separate holding tank is fairly mismatched, and ranges from ½” to ¾” to 1” piping. If any work is done to this piping in the future, it will be important to carefully note what size piping is where. At the base of the holding tanks, there is a cement box in the ground. Inside this box, there is a valve that can be manually switched to bypass the holding tanks to send water to the garden tanks instead.

Figure 6: Three holding tanks above the pila building, oxygen inlet pipes, floating sensor inside tank

Cistern

From the holding tanks, water is sent down to the cistern. The cistern is the under-the-floor section of the brick pump house that holds the distribution pump and the air pressure tank. The distribution pump was replaced in 2012, and is a Goulds J15S shallow well jet pump. The pump and air tank pressurize the water in the cistern, and distribute it to the MdL buildings. In times of power
outages, this section of the distribution system can be bypassed by switching valves inside the pump house. When this happens, only the holding tanks supply MdL’s buildings using the pressure difference from the height of the tanks. When the tanks run out, MdL can no longer flush toilets, shower, or use the sinks. The flow of water is also significantly reduced as the tanks begin to run out.

Figure 7: Cistern underneath pump house, houses distribution pump and air tank

**Arsenic & Fine Sediment Filters**

These filters are point-of-use filters located only in the children’s kitchen underneath the sink. They were installed by the OSU group in 2012 for the purpose of removing arsenic and fine sediment. These filters lead **only** to the smaller diameter faucet. The water team did not attend to these filters while in country because the cartridge’s exceeded the budget. The cartridges should be replaced every 3,000 gallons of use, and are overdue for replacement. The filters are made by Crystal Quest, and the sediment filter cartridge is product number CQE-RC-04015, and the arsenic filter cartridge is product number CQE-RC-04021. The cartridges will cost around $120.00 to replace.

Figure 8: Point-of-use arsenic and fine sediment filters underneath kitchen sink

Figure 9 summarizes the water distribution system layout, including the changes that were done by the team this year.
4.2 Water Tests

One of the objectives in this project was to determine the status of the water before and after the implementation of the filtration system (due to time constraints, the team was able to perform only the tests before installing the filters, while the other portion of the tests will be done by Chris Ratcliff). Four tests were performed to investigate the levels of arsenic, bacteria, pH, and nitrate/nitrite in the water. Three different locations were chosen to obtain the water samples from, the locations were the sediment filters, the holding tanks, and the comidor sink. These three locations were chosen to check whether there is a source of contamination within the distribution system. It should be noted that the tests might have been affected because the chlorinator was turned off between Monday 3/17 and Tuesday 3/18 in order to install the sediment filters. At the end of the trip, the team left the test kits at MdL to keep monitoring the status of the water.

**Arsenic Tests**

The inorganic arsenic occurs naturally in soil and in groundwater, the EPA standards for arsenic levels in drinking water to be less than 10 parts per billion (0.01 mg/L). Based on The Centers for Diseases Control and Prevention (CDC), drinking water that has high levels of arsenic in the long term causes several types of cancer and other diseases.

To test for arsenic level in the water, the team used QUANTOFIX Arsenic 50 test kit (Appendix A.1). The following table shows the dates and the results of arsenic tests for each location before the sediment filters were installed.
### Table 1: Arsenic tests results

<table>
<thead>
<tr>
<th>Location</th>
<th>Test Date</th>
<th>Results (mg/L)</th>
<th>Number of tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>Comidor Sink</td>
<td>3/14/2015</td>
<td>0.05-0.1</td>
<td>1</td>
</tr>
<tr>
<td>Holding Tanks</td>
<td>3/16/2015</td>
<td>0.05-0.1</td>
<td>1</td>
</tr>
<tr>
<td>Sediment Filters</td>
<td>3/16/2015</td>
<td>0.05-0.1</td>
<td>1</td>
</tr>
</tbody>
</table>

As can be seen in the table above, all the three locations had the same arsenic level (between 0.05-0.1 mg/L), which is by EPA, is considered unsafe to drink. On 4/22/2015, Chris Ratcliff conducted another arsenic tests at the comidor sink and the sediment filters. Both tests came out around 0.05-0.1 mg/L.

### Coliform Bacteria

The team used *LaMotte Coliform Test Kit* (Appendix A2) to test for the presence of bacteria in the water. The tests needed 48 hours to show the results. A total of 11 tests were done. The following table shows the tests dates and results for the three locations.

### Table 2: Coliform bacteria tests results

<table>
<thead>
<tr>
<th>Location</th>
<th>Test Date</th>
<th>Bacteria Presence</th>
<th>Number of tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>Comidor Sink</td>
<td>3/18/2015</td>
<td>Negative</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>3/19/2015</td>
<td>Positive</td>
<td>1</td>
</tr>
<tr>
<td>Holding Tanks</td>
<td>3/18/2015</td>
<td>Positive</td>
<td>5</td>
</tr>
<tr>
<td>Sediment Filters</td>
<td>3/19/2015</td>
<td>Positive</td>
<td>3</td>
</tr>
</tbody>
</table>

As can be seen from the table above, at the comidor sink two out of three tests turned out to be negative, while all the tests at the holding tanks and the sediment filters came out to be positive. It was obvious that the holding tanks and the sediment filters showed positive results for the presence of bacteria, because when the sediment filter was moved down to the new bypass, the filter was clogged with algae, Figure 10. However, more tests are needed to confirm the presence of bacteria in the comidor sink because one result was inconclusive. A positive test turned yellow and formed gas bubbles, while a negative test turned red and produced no gas. One of the comidor sink tests turned yellow, but did not form bubbles, Figure 11.
Figure 10: Sediment and algae clogging the sediment filter (100 mesh)

Figure 11: Two Coliform test tubes from the comidor sink. The left test tube shows negative for bacteria, while the right test tube may show positive for bacteria

**pH Tests**

pH is a scale that indicates the acidity (low pH) or alkalinity (high pH) of the liquid. Low pH values could cause health problems, by leaching the metals of the plumbing system. The team measured the pH using *Duotest®* (Appendix A.3), the following table shows the pH test results.
Table 3: pH tests results

<table>
<thead>
<tr>
<th>Location</th>
<th>Test Date</th>
<th>pH</th>
<th>Number of tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>Comidor Sink</td>
<td>3/14/2015</td>
<td>7.5</td>
<td>2</td>
</tr>
<tr>
<td>Holding Tanks</td>
<td>3/16/2015</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td>Sediment Filters</td>
<td>3/19/2015</td>
<td>6.5</td>
<td>2</td>
</tr>
</tbody>
</table>

From the table above, it can be seen that the pH increases as the water travels through the system. All the above levels of pH are acceptable (EPA standards for pH range is between 6.5-8.5). On 4/22/2015, Chris Ratcliff conducted pH tests, and the results came out to be almost the same, low pH at the sediment filters and higher at the comidor sink.

**Nitrate/Nitrite**

The CDC recommends performing nitrate tests on all wells. Nitrate is found in food, and could come from animal wastes, septic tanks, fertilizers and wastewater. The maximum level of nitrate by the EPA in drinking water is 10 part per million (10 mg/L), and the maximum level of nitrite in drinking water is 1 part per million (1 mg/L). The team used *QUANTOFIX® Nitrate / Nitrite test strips* (Appendix A.4). The following table shows the levels of nitrate/nitrite in the water.

Table 4: Nitrate/Nitrite tests results

<table>
<thead>
<tr>
<th>Location</th>
<th>Test Date</th>
<th>Nitrate (mg/L)</th>
<th>Nitrite (mg/L)</th>
<th>Number of tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>Comidor Sink</td>
<td>3/16/2015</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Holding Tanks</td>
<td>3/16/2015</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Sediment Filters</td>
<td>3/19/2015</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

As can be seen in Table 4, the level of both nitrate and nitrite is zero. However, when Chris Ratcliff did the test again on 4/22/2015 at two locations (the sediment filters and the faucet), “the nitrate/nitrate were also the same for both sets. Between 0 and 10 mg/L for nitrate and 1 mg/L for nitrite. Nitrite was clearly non-zero, at the 1 mg/L level, the nitrate was probably not white, but not all the way to the first level (10).” Chris said. One possible explanation for this change in the levels of nitrate/nitrite is that the dry season in Honduras ends in April, which means the beginning of the rainy season and higher precipitation, raising the chances of the rain dragging down the nitrate/nitrite to the groundwater. However, the levels of nitrate and nitrites are still within the EPA standards.
4.3 Installation of Sediment Filters

The table below summarizes the various mesh sizes offered by Rusco and the recommended use for each. A higher mesh size number corresponds to a higher level of filtration, or a lower micron level of filtration.

Table 5: Description of Rusco filter mesh sizes

<table>
<thead>
<tr>
<th>MATERIAL IN WATER</th>
<th>TO PROJECT</th>
<th>USE MESH NUMBER</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Shale, shell</td>
<td>General use</td>
<td>24</td>
</tr>
<tr>
<td>2. Debris</td>
<td>General use</td>
<td>24, 30, 40</td>
</tr>
<tr>
<td>3. Pipe scale, coarse sand</td>
<td>Sprinkler systems, Factory aerators, sand sensitive valves</td>
<td>40 to 60</td>
</tr>
<tr>
<td>4. Fine sand, grit from new wells</td>
<td>Drip irrigation systems, Factory aerators, sand sensitive valves</td>
<td>100 to 140</td>
</tr>
<tr>
<td></td>
<td>Poultry Growers</td>
<td>100 (.006&quot; opening)</td>
</tr>
<tr>
<td></td>
<td>Watering devices</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fogger Nozzles</td>
<td>140 (.004&quot; opening)</td>
</tr>
<tr>
<td>5. Very fine sand and grit</td>
<td>Pre-treatment</td>
<td>250 to 500</td>
</tr>
<tr>
<td></td>
<td>Pre-treatment</td>
<td>1000</td>
</tr>
<tr>
<td></td>
<td>Ultra water systems, R.O., etc.</td>
<td></td>
</tr>
<tr>
<td>6. Algae</td>
<td>Grows in presence of light under clear filter cover</td>
<td>Use Sun Shield™</td>
</tr>
</tbody>
</table>

The 2013 water team built a bypass connecting to the pipeline running up to the holding tanks and installed a 1 inch spin-down Rusco filter. This structure can be seen in the picture below. According to their documentation, they tried the filter with 100, 140, and 250 mesh, and selected the 250 mesh to be left in. That mesh size corresponds to 61 micron filtration.
After being told that the 2013 Rusco spin-down filter was causing problems by clogging frequently, the 2014 team decided to invest in a new filter, this time the 2 inch sediment trapper model. This filter used the 100 mesh, filtering out sediment 150 microns and up. Along the existing bypass, they replaced the 2013 filter with this new filter. However, the new filter continued to clog frequently and required a lot of maintenance, so the team removed the mesh element from the 2013 filter, leaving only the guides that wrap around the element to make the water spin, and they reinstalled this filter before the new filter as an extra barrier, a place for larger sediment to settle out before clogging the new filter. The updated structure as of 2014 can be seen below, with the bigger filter being the 2014 filter [1].

This year, the team was told that the 2013 filter without mesh really was not doing anything to filter sediment, and the 2014 filter again was sometimes an issue with clogging. The team wanted not only to lessen the maintenance hassle, but also to invest in something that would improve the
water quality. This led us to select both a filter to go before the 100 mesh filter, and one to go after. The before filter was a 30 mesh, 2 inch sediment trapper. That mesh size corresponds to 533 micron filtration, so it would remove debris before the 100 mesh filter to lessen clogging. To improve water quality though, the team wanted a filter capable of removing smaller particles after the 100 mesh. A 1000 mesh sediment trapper was selected for filtration down to 15 microns [2].

On site, the team conducted an experiment based on an idea from Chris and gained some interesting results. Laura climbed up to the holding tanks when the pump was on and noted the rate at which they were filling. This was with water running through the bypass and the clogged filters. Then, the team switched the valves so that the water would run not through the bypass and filters, but just straight up to the holding tanks. The flow rate of water filling the tanks increased greatly with head loss from the filters removed. Abdul and Chris took the mesh element out of the sediment filter, washed it off, and replaced it before switching the valves again to allow water flow through the bypass and filters. With the unclogged mesh, the rate at which the holding tanks were filling stayed about the same as with the bypass disengaged. This indicated that significant head loss was coming not from the filter and bypass alone, but from the filter being clogged, so if frequency of maintenance were to increase and our project putting in place multiple levels of sediment filtration to keep filters unclogged longer were to work, then that could mean less time to fill the tanks and much electricity used in pumping saved.

It is common practice in water treatment to add the disinfectant after sediment filtration. The 2014 team however had the chlorinator installed right at the well, possibly due to their desire to shock the entire system with chlorine in order to remove bacteria. Adding chlorine to water with high levels of Total Organic Carbon (TOC) though is ineffective and produces carcinogenic disinfection by-products, so a major step towards improving the water sanitation process at MDL was in correcting the system, moving the sediment filters before the chlorinator. This is why the team began the project by cutting away the existing bypass, closing those valves, and moving down to the well to build a new bypass with filters and to move the chlorinator pipe to after the new bypass. The pictures below show the cut away bypass, the distance from MDL to the well, the housings for the well and chlorinator, and the newly built bypass with filters.

Figure 14: Picture taken after removal of existing bypass.
Figure 15: Picture showing distance from MDL to well.

In the image below of the housing over the well, you can see the 1 inch white PVC pipe connected on the left. Water pumps out of the well and to the right up the hill, but that pipe on the left is the point of chlorine injection. It was cut and moved to after the newly built bypass.

Figure 16: Picture of well housing and main pipe, white piping now removed
After the bypass was built, it was tested when the pump turned on to fill the holding tanks. There were leaks, and at one point a pipe blew entirely, disconnecting from the tee, and were later repaired. The 1000 mesh filter clogged instantly with sediment, which flaked off when the system was taken off bypass. After watching the holding tanks fill, Laura reported that the water pressure was affected so much that water was not even reaching the third tank. For this reason, the 1000 mesh filter could not be used. Getting 15 micron filtration would have improved water quality greatly and would have made it possible to reduce contaminants after upping the chlorine dosage and replacing the Crystal Quest undersink arsenic filter, but placement of the filters so close to the well, which was not planned until the team got on site and saw the placement of the chlorinator, introduced head loss too soon and made it impossible for the pump to get water up the hill. It was a major design flaw. A better project design would have left the piping from the well alone and then would install fine sediment filters at the pipes that feed the holding tanks, maybe even extending those pipes up and then taking advantage of gravity. Then the chlorine would be added to the holding tanks, and they would act as clearwells, keeping the water clean until distribution. This would also resolve the issue with bacteria growing in the holding tanks as they did test positive for bacteria and Laura noted unsanitary conditions around them. Even though the well water at MDL is not used for drinking or cooking, it is invaluable for showering, washing dishes, and laundering clothing. To complete the project and restore the water system to working order, the team removed the 1000 mesh element and replaced it with the 100 mesh element from 2014. The middle filter which had contained that 100 mesh element was then filled with a 60 mesh element, another debris filter option that was sent along with the 30 mesh. This leaves the current sediment filtration system at a 30 mesh filter for 533 micron filtration, a 60 mesh filter for 250 micron filtration, and a 100 mesh filter for 150 micron filtration (Figure 18).
Figure 18: Schematic of current sediment filters

This is a good system for the purposes of lessening clogging and need for maintenance as each filter is only taking on sediment it is specced for, but it does not filter finer sediment. Pictures below document the process of building the bypass.

Figure 19: Water sits in the pipes when the pump is off. This is a picture of the water release when the main pipe was cut into and the water rushed down the piping up the hill to exit.
Figure 20: Mineral and bacteria buildup inside the metal pipe capping the well.

Figure 21: Jorge melting pipes to fit the 2 ½˝ pipe with the 2˝ pipe. 2 ½˝ is an outdated size of PVC that the team did not know was attached to the well, and no hardware store between Nueva Esperanza and Tegucigalpa carried. The pipe melting involves covering the pipe in PVC cement and lighting it on fire to be able to fit the pipes together.
Figure 22: Picture of bypass. Of the three lines branching off of the main, the first two are the in and the out of the bypass, and the third, the 1" line, is the new point of chlorine injection. Also note the placement of the bronze check valve, which is a backflow preventer to keep water from running back into the well after the pump turns off.

Figure 23: Another picture of the bypass, built along the outside of the building that hold the chlorinator.
Figure 24: Picture of installed sediment filters, with water flow through filters left to right, and neoprene sun shield covers to prevent growth of algae.

Figure 25: Picture of well and pump housing after moving chlorinator pipe and sealing opening.
Montana de Luz has a guaranteed source of clean, safe water in the bottled water they purchase. While the arsenic biosand filter (ABF) may work, there is no such guarantee of quality, so the orphanage may never want to drink the water it produces. The small town near MDL however, Nueva Esperanza, gets water from a well and uses it for drinking without any form of sanitation. According to Jorge and Chris, the people often get stomach illnesses from bacteria in the water. While boiling water kills the bacteria, it is a very time and energy consuming process, and it does nothing to remove arsenic or nutrient contaminants. For people in town, the ABF could improve quality of life very much. Another concern is that once the children of MDL grow up and leave, they will have difficulty finding sanitary sources of water, and may end up drinking dirty water like the town of Nueva Esperanza. Also, while Chris is currently at MDL working on implementing sustainable agriculture, food irrigated with arsenic rich water poses a great health risk.

As confirmed from years of testing, the well water at MDL contains arsenic. Arsenic is not often found in its elemental form, but as a component of a variety of minerals. It is harmless in this solid state, but once dissolved in water, the mobilized molecules become toxic. While inorganic arsenic is highly toxic, organic is not as much of a concern. Arsenic can naturally leach into ground
water from soil, or it can runoff into surface water and then ground water after coming from anthropogenic sources, such as pesticide application or waste incineration. The arsenic tested for by our team was arsenate and arsenite, As(III) and As(V) respectively, as the forms of inorganic arsenic most commonly found in ground water. While these of course are elemental forms of arsenic, they can be referred to as inorganic because their oxidation numbers predispose them to bond with things such as oxygen, sulfur, chlorine, and much else in the environment, whereas organic arsenic would be found with hydrogen and carbon.

The team did manage to complete the concrete housing for the filter by leveling some ground, mixing cement, building a concrete foundation, putting cinder blocks together with mortar, and running rebar through the holes in the cinder blocks. Sand on site was sieved using a .84 mm sieve and a 2 mm sieve. The plan was to sieve enough equal to or less than .84 mm sand, filtration sand, for 2 feet of depth. Then some of the between .84 and 2 mm sand, coarse sand, would go below the filtration sand, and 2 inches of tiny gravel and 2 inches of large drainage gravel would be hand picked to go below the layers of sand. The tube had a ¼ " inner diameter, making it a siphoning tube. It would be placed in the characteristic S with the bottom level against the bottom of the filter, and it would siphon out the filtered water. The importance of using siphoning rather than just attaching a spigot at the filter bottom is in maintaining the level of standing water above the biolayer, the top layer of the filter containing microorganisms that consume nutrients in the water and inactivate dangerous pathogens. The pathogens should be filtered out by the slow sand filtration, but a working biolayer adds to the effectiveness of the filter. In the way siphoning works, the end of the outlet tube is the level at which the water will stand when the filter is saturated. That level should be a controlled 2 inches. The biolayer needs oxygen, but it also needs to stay moist for optimum conditions. The 2 inches is the happy medium between letting oxygen diffuse and reach the biolayer and preventing the biolayer from being dry too long as the standing layer evaporates.

Sand must be washed before being placed in the filter. This is done by placing sand in a bucket, swirling it with water to dissolve dirt, and then pouring the dirty water off the top. If the sand is not washed enough, the flow rate through the filter will be incredibly slow and the water produced will always be turbid. If it is washed too much however, the flow rate may be too high and the biosand filter will not work because the water will not be getting adequate contact time with the biolayer. The maximum flow rate for a biosand filter is .4 L/min. After the sand and gravel has been washed, it is placed in the sun to dry, which kills any pathogens present. The filled filter is flushed with 5 % bleach solution to ensure elimination of pathogens. The figure below offers a visual on how clear the water should run before one is done washing.
Figure 27: Picture of jar test to determine if sand has been washed enough [4].

Figure 28: Picture of concrete housing constructed to hold the sand. The white PVC is a gutter separate from the filter, and the siphoning tube and the black diffuser basin can be seen off to the side.
Finally, the diffuser basin would sit atop the concrete housing, and it would be filled with 10 pounds of rusty iron nails. Iron oxide adsorbs dissolved arsenic in water.

The team built the concrete housing but did not finish washing the sand to fill the filter. From a recent report from Chris, the housing is leaky and must be sealed with more concrete. The biosand filter is a simple household water treatment tool that could have an immeasurable impact on the community in and around MDL. Although this year’s water team did not have time to complete the ABF after investing so much time in improving the quality of the household water, we hope that Chris will complete the filter and a team next year might focus on biosand filters as a full time project.

5.0 Scope of Work

5.1 Objective

The objective of this year’s water team was to increase the sustainability, efficiency, and knowledge of the water system at MdL by adding a better form of sediment removal, conducting water tests, and mapping the system.

5.2 Deliverables

1. An accurate and up-to-date schematic of the water distribution system
2. An efficient form of sediment removal before the chlorinator
3. Results of arsenic, pH, nitrate, and coliform bacteria tests at 3 points along the distribution system:
   a. Sediment filters
   b. Holding tanks
c. Comidor sink
4. A pilot slow sand filter as an alternative potable water source

6.0 Timeline

Project Timeline
Saturday 3/14 – Day 1
Morning
- Collect water sample from the kitchen sink to perform arsenic test
- Inspect the system
  o Identify the locations of the major components of the water systems
    (holding tanks, cistern, etc)
  o Measure the depth of the well

Afternoon
- Continue measuring the well depth
- Two team members went to the store to buy the PVC pipes.

Monday 3/16 – Day 2
Morning
- Inspect the system
  o Check the holding tanks
  o Collect water samples from the holding tanks
- Perform water tests
  o Arsenic tests on water samples from sediment filters and holding tanks
  o Nitrate/Nitrite tests on water samples from sediment filters, holding tanks
    and kitchen sink

Afternoon
- Cut off the old bypass, and clean the old sediment filter to use it in the new bypass
- Preparation to install the bypass
  o Go down to the well and take measurements
  o One team member went to the store to buy PVC primer

Tuesday 3/17 – Day 3
Morning
- Start working on the sand filter
- Bypass construction
  o Cut/ attach the PVC pipes to construct the bypass
  o Attach the bypass to the wall
- Turn off the pump and the chlorinator

Afternoon
- Start cutting into the main pipeline
  o Problem occurred: The main pipeline has a 2.5” diameter, while all the
    replacement parts were designed for 2”
  o Jorge started to make calls to the stores around Nueva Esperanza to look for
    2.5” parts, but no luck
  o Jorge and Chris went to Tegucigalpa to look for 2.5” parts
- While waiting on the parts to be available, the team worked on the sand filter
  o Mixing the cement
  o Pour the cement into the mold to construct the base of the sand filter
Evening
- The water level in the holding tanks was very low
  - The team should reconnect the main pipe and start filling the holding tanks, to avoid water outage
  - Chris and Jorge are finally back to MdL with most of the missing parts
    - No 2” to 2.5” connector
    - Jorge is going to heat the end of the PVC to make it fit without the connector
- It took 2 hours to connect the 2” end to the 2.5”
- The bypass is almost completed, the team will finish it by tomorrow
- Pump was turned on, and the holding tanks started to fill

Wednesday 3/18 – Day 4

Morning
- Check on the reconnected parts
  - Major leakage
  - Jorge cut off into the main pipeline again, added telescopic coupling to fix the leakage.
    - After one hour, the leakage was reduced significantly.
- Connect the bypass to the main pipeline, and start testing
  - After the running the water for the first time through the bypass, the third filter (1000 mesh) clogged within seconds, which resulted in a significant loss in the flow rate
  - The team replaced the 1000 mesh with a 60 mesh, so the new order became 30, 60, 100 mesh.
- Reconnect the chlorinator, to be injected into the main pipeline and after the bypass

Afternoon
- Build the housing for the slow sand filter
  - Use bricks and cover the inside of the housing of filter with cement to prevent leakages

Thursday 3/19 – Day 5

Morning
- Check on the bypass to make sure everything was working
- Turn on the chlorinator
- Cover the hole that was in the well housing with cement
- Continue working on the sand filter

Afternoon
- Conduct bacteria tests
- Build the housing for the slow sand filter
  - Use bricks and cover the inside of the housing of filter with cement to prevent leakages

Saturday 3/21 – Day 6

Morning & Afternoon
- Work on the slow sand filter
  - Separate the fine sand from coarse sand and gravel
  - Wash the sand thoroughly with bleach, until the water runs clear
7.0 Budget

The total amount spent was $708.95. The majority of purchases were done in the States, while several last minute pieces had to be purchased in Honduras. Figure # represents the budget allocation. The sediment filter section represents the majority of purchases, and includes the Rusco filters which were each about $145.00, the sun shields, and all PVC pieces and parts. The water quality tests include all test kits. The system mapping includes rope, while the slow sand filter includes cement.

![Water Team Budget Allocation](image)

Figure 29: Budget allocation
8.0 Sustainability Statement

The definition of a sustainable water system for MdL is a reliable system which provides water with low maintenance and low cost. Their current method of obtaining drinking water meets both these definitions, and is a great way to obtain safe drinking water. The most sustainable option for the future may be drilling an entirely new well, although that is outside of the scope of the current project. If well construction is an option for MdL in the future, the Water Team recommends having it professionally drilled to ensure that it is deep enough and properly lined and sealed.

The modifications in this report that were done helped to make MdL’s current distribution system for non-potable water more efficient, safe, and reliable. These modifications helped to increase the sustainability of MdL’s water system. For future OSU teams, it is important to remember that modifications that are expensive to maintain or require extensive labor to keep running will
probably go unused at MdL. It is of high importance to keep in mind the labor that will go into maintaining new modifications. If the water system is altered with these factors in mind, the system should continue to be beneficial and of use to MdL.

Reasons Against Drinking Water Production

It is important to explain why potable water production should not be pursued at MdL so that future teams will understand the reasoning behind this conclusion. First and foremost, OSU must keep the safety of MdL’s residents in mind. If an OSU team instructs MdL that it is okay to drink the water when the water is contaminated, people could become seriously ill, which could be fatal. Outbreaks of waterborne diseases like Cryptosporidium and Giardia have occurred in even the most secure water treatment plants, resulting in fatalities. The water team believes that this is too great a risk for a student group to take on, and that no future groups should advise MdL to drink the tap water.

MdL’s current means of obtaining drinking water is purchasing 5-gallon jugs which are delivered to MdL. They currently purchase forty 5-gallon jugs a week, and pay $1.00 USD per 5-gallon jug. The water delivered in jugs is produced by a water treatment plant. This method is guaranteed to be a safe supply, and is more reliable than on-site production of potable water.

If MdL still wished to produce water on site, several changes would need to be made to the system. The first changes would be to scale up the system to meet the additional demand previously supplied by the jugs. The increase in demand would be approximately 10,440 gallons/year, or 28.6 gallons/day. Calculations would need to be done to ensure that the pumps, well, and other components of the system could handle this increase. For example, the point-of-use arsenic and fine sediment filters under the sink require cartridge changes every 3,000 gallons. A large concern from the increase in demand would be the risk of running the well dry. If the well is depleted at a rate faster than it naturally replenishes, MdL will have to drill an entirely new well, which costs thousands of dollars. MdL relies on the well for showers, laundry, toilets, and all other uses besides cooking and drinking. If the well runs dry, MdL will not be able to do any of these things.

The second changes that would need to be made are to combat power outages. It is common for MdL to occasionally lose power due to the unreliability of the grid. The well lift pump and the distribution pump run on electricity. When power goes out, the system can be switched to a pathway where the water in the holding tanks supplies the sinks, toilets, and showers by gravity. However, once the holding tanks empty, MdL is without water. A system would need to be created to run the pumps during these outages. MdL currently has a generator, but it is used to power the kitchen appliances so food and medicine does not spoil.

The third change would be to repair the points along the distribution system that currently are problematic. For instance, the holding tanks have holes along the seal, which allow bacteria and pests to enter the water. The holes would need to be sealed to prevent any pathogens from entering the system. The entire system also would need to be shocked before regular consumption, to kill any persisting bacteria.

The fourth change would be to increase the amount of labor that goes into the water system. In order to ensure that the water is safe to drink, continual tests need to be done. Weekly tests should be done before first consuming the water, and then after that tests should be done bi-annually, or whenever a modification is made to the distribution system. The point-of-use filter cartridges would need to be changed for every 3,000 gallons, and the sediment filters need to be flushed clean every week. Every component of the system would need to be checked and occasionally replaced. For example, the holding tanks have a lifespan of 7 years.

The above changes that are necessary to implement a working water treatment system at MdL would require a hefty startup cost, as well as a large amount of labor. After the changes have
been made, the system still requires significant financial and man-power inputs to maintain potable water. The water team has decided that the initial start up costs and the costs of maintenance are not worth the investment, when MdL currently has a more sustainable method of drinking water procurement.

9.0 Recommendations for Future Teams

The most beneficial thing future teams could do to prepare for their projects is to seek out advice from other people. If possible, contact teams and trip advisors who have gone to MdL before and meet with them in person. From year to year, a lot of information has been lost in passing, and it is much easier to extract that information from a conversation rather than wading through past team’s documentation. It is also beneficial to seek out advice from professionals. They will have the best advice to give. If dealing with water/wastewater, Dr. Karen Mancl of the Food, Agricultural, and Biological Engineering department is an excellent contact, and was a direct influence on the team to avoid drinking water production at MdL. If pursuing any sort of agricultural project, the Ohio Extension Fact Sheets are helpful information tools, available at ohioline.osu.edu.

An area of need at MdL is a means of obtaining water when the power goes out. The power went out this year during the trip, and the water in the holding tanks lasted about 6 hours before running dry. After this happens, MdL cannot flush toilets, shower, or use the sinks. There is a second generator in need of repair at MdL. This generator could be fixed and connected to the pump controls in the pila building to supply water during power outages.

Another project that should be pursued is drafting a fire prevention plan. When the surrounding sugar cane fields are burnt, MdL is at high risk for fires. There is currently no form of fire prevention in place. As described by Leanna of the 2013 team, flames reached as high as the surrounding fences, and 3 men with backpacks filled with water came to put the fire out. Another project that should be pursued is shocking the system, which entails pouring a large amount of chlorine into the system, and letting it sit for 12-24 hours. Afterwards, the system should be flushed out and chlorine levels returned to normal. Shocking is a way to kill any residual bacteria that may be living in parts of the system.

Lastly, another good project to continue with MdL and the surrounding village is the slow sand filter. If the pilot version at MdL can be finished and operates successfully, it can be reproduced for individual homes in the village. If the leaks in the housing can be patched and the rest of the filter constructed, the water from this pilot can be tested for contaminant levels and flow rate. Future teams can use this information to construct slow sand filters for the village, using sand and gravel readily available in Honduras.
10.1 Appendix A: Test Kits

Figure A.1: Picture of a similar test kit that was used to test arsenic levels.

Figure A.2: Picture of a similar test kit that was used to test the presence of bacteria.
Figure A.3: Picture of the test kit that was used to measure the pH level.

Figure A.4: Picture of a similar test kit that was used to measure the nitrate/nitrite levels.
10.2 Appendix B: Manual For Cleaning The Filters

How to clean Rusco Sediment Trapper® Filters manual
1. Open valve#1 completely
2. Close valve#2 and valve#3
3. Drain the filters by opening the small red valve
4. Take off the sediment filters from the bypass by turning the sediment filter to left
5. Gently, pull the mesh.
6. Wash/clean the mesh from sediments. Run the water through the mesh (inside-out)
7. Return back the mesh to the bypass
8. Put on the filter housing, and tighten it (gently) by turning it to right
9. Close the red valve
10. Open valve#2 and valve#3
11. Close valve#1

Figure B.1: Picture of the numbered valves.
10.3 Appendix C: Miscellaneous Trip Photos

Figure C1: (left) Brand of bottled water MdL purchases, (right) one of two water coolers MdL relies on for drinking water

Figure C2: View of well house downhill from MdL, locked gate

Figure C3: Hole in front of wellbox housing that was left unsealed, wires for lift pump
Figure C4: Walchem chlorine metering pump

Figure C5: Proximity of holding tanks to cistern pump house

Figure C6: Well house downhill from MdL
Figure C7: 600 gallon holding tank, holding tanks above pila building

Figure C8: Nueva esperanza’s water supply. Team was told that this system is not connected to MdL’s

Figure C9: Example of test positive for coliform bacteria, all 5 samples from holding tank
Figure C10: Beginning construction of slow sand filter

Figure C11: Water Team 2015
10.4 Appendix D: AutoCAD drawings

Figure D1: Sediment filter piping, all 2” PVC

Figure D2: Piping immediately after wellhead
11.0 References

[1] https://eeicourses.engineering.osu.edu/mdl