Final Report

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1 Introduction

AguaClara is a student project team at Cornell University that designs sustainable water treatment systems. The team develops sustainable gravity-powered and electricity-free water treatment plants to serve communities in Honduras and India. AguaClara technology allows approximately 50,000 people in these countries to access reliable drinking water. The team is committed to provide such technology on an open-source basis to support economic, social, and environmental sustainability.

The design team produces AguaClara plant designs via an automated process. Mathcad code takes in user inputs for a proposed plant and produces the plant design by providing the calculated components dimensions in its outputs. A LabVIEW script takes these outputs from Mathcad and inputs them to the AutoCAD command line to draw a plant. Just by entering the plant flow rate needed, anyone online can use this program to access a detailed AutoCAD drawing, a construction materials list, and a report describing the plant designed to deliver this plant flow rate. Design team members work on challenges, which address existing problems and possible improvements to AguaClara plant designs. The design team also takes in findings from AguaClara research teams to implement their technology.

2 Backwash Recycling System for the San Matias Plant

The backwash recycling system will provide an additional water source if added to a plant. It will also prevent contaminated water from entering the neighboring environment of the plant. Currently, water used in backwash is discharged into a nearby river. The backwash recycling system will capture the flow in the filter siphon pipe at the drain channel and redirect the flow to a settling tank nearby. Water will then be pumped up to the entrance tank to go through the treatment process.

Cinthia Kims work in Spring 2016 produced some calculations for a proposed backwash lagoon. However, her final report explains that pumping rates were yet to be considered, and hence no dimensions of the lagoon could yet be defined. Thus, the Fall 2016 team had to first consider the backwash flow rate, volume per backwash, and pumping rate.

2.a Challenge Details

The team focused on a pilot study and design for the San Matias plant. The water plant in San Matias was chosen a pilot site due to two reasons: 1) San Matias has been suffering from water shortage during the dry season. 2) It has a low 14 L/s flow rate plant, which lowers the flow rate and power needed for pumping. The teams work focused on the pump, power source, tank, piping, and estimated costs.

2.a.1 Tank

After backwash, water passes through the filter siphon pipe to enter the drain channel. Yet, this water carries solid wastes that were washed from the filters. If water is simply pumped back to the entrance tank, these solids would go through the water filtration process again and would end up in plant components such as the flocculator, sedimentation tank, and filters. This would make backwashing useless. A settling tank was necessary to allow these contaminants to settle over time before re-entering the entrance tank. In order to lower cost, the rate of pumping water back to the entrance tank could not be as high as the 14 L/s backwash flow rate, since a high rate requires higher pump power and raises cost. Thus, the post-backwash settling tank was important in the design to temporarily store about 4000L from each backwash.

The team first considered building this new settling tank inside the drain channel. If the tank is built outside of the drain channel, erecting at least four side walls and a bottom would be needed to form a tank. By making use of the drain channel walls, the team would need to only add one wall to form a tank. This would greatly reduce the cost. Such design, however, was later ruled out due to construction constraints and operator access concerns. Construction inside the existing drain channel could affect the plants day to day operations. Plant operators frequently backwash the filter and discharge the sludge from other parts of the plant, such as the sedimentation tank. On the other hand, the limited space inside the drain channel also restricted this design. Plant operators need to regularly enter the drain channel to turn on valves that remove sludge from the sedimentation tank. Turning the drain channel into a tank could make the channel inaccessible.

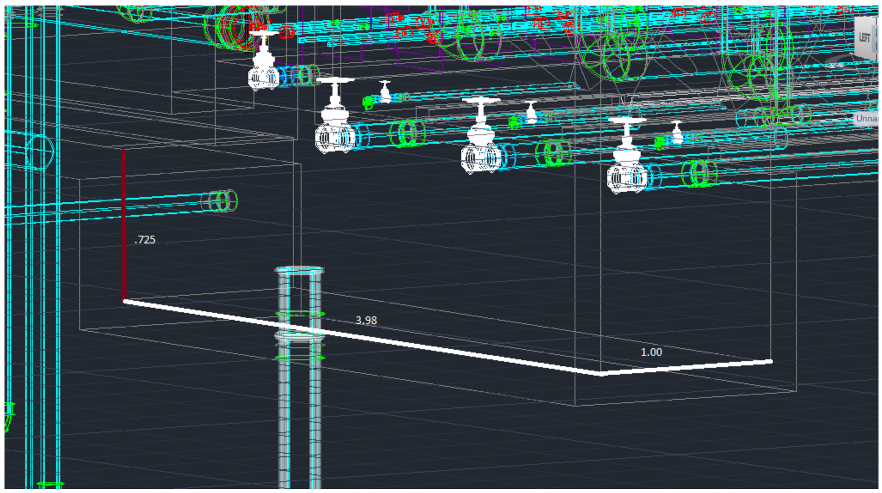

Figure 1: Dimensions of the Drain Channel

Taking these reasons into account, the team decided to build the settling tank outside the drain channel. The team still aimed to build it near the drain channel to reduce pumping distance, but noticed from photos that the plant is situated on a slope. The slope would have to be carefully considered when designing this tank. Necessary slope control may also increase costs. However, the team could not obtain plant construction drawings from Ethan. Thus, the team had to transfer its work to Ethan, who will follow up on the detailed design needed for implementing the recycling system.

Figure 2: The photos of the plant show that it is located on a steep slope. Final design and construction of the settling tank must consider this slope.

The team first considered building a cuboid settling tank, the simplest design in terms of construction. The designs main drawback was that the plant operators would need to go down to the tank bottom to shovel the accumulated contaminants.

Because of such slope, the team decided to build a sloped settling tank which could allow the contaminants to slide down the tank bottom. A valve that can be turned on by the operator would be placed at the lower end of the tank bottom. For ease of construction, the bottom of the tank could be sloped at the same gradation as the slope which the tank is to be placed on.

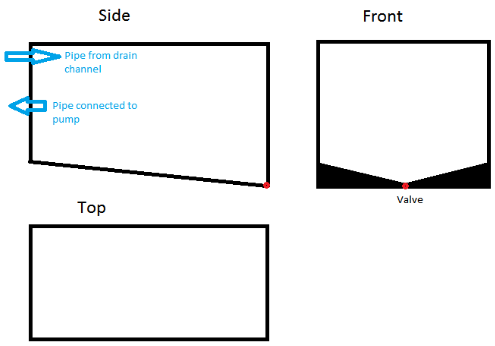

Figure 3: Design sketch for the settling tank. The red point marks out the location of the valve. The tank bottom could be inclined with the slope. The bottom of the tank would also be sloped towards the center to maximize contaminant removal.

The pipe connecting the tank to the pump would exit at the middle of the tanks height. This reduces contaminants that are transported to the pump, since contaminants settle at the bottom. The team wanted to reduce the amount of contaminants that go through the pump since they may reduce the lifetime of the pump.

The valves design would be critical in the tank. Located at the lowest point of the tank, the valve would experience high water pressure when the tank is filled with water. Hence, the team decided to use the same existing design of the valve used to remove sludge in the drain channel from the sedimentation tank.

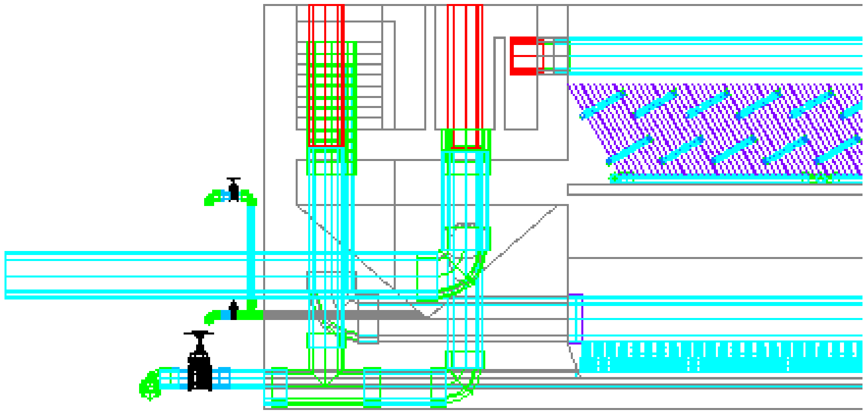

Figure 4: The design of the valve used in a 50LPS plant design from the design server. The valve control the bottom exit of the sedimentation tank for sludge removal. Using the same design for the settling tank will allow its sludge removal exit to withstand similarly high water pressures.

Plant operators would collect sludge from valves and dispose of the sludge. The valve design relieves the operators from the burden of shoveling contaminants out of the tank.

2.a.2 Pump

For recycling, backwash water had to be pumped to the entrance tank. Since AguaClara is committed to providing plants that do not rely on electrical power grids, accessing power for pumping in the local community has been a challenge. The requirements for the pump was determined to be 15 ft in head and 1.5 gpm for pump rate.

Site and Plant parameters San Matias **approximated** values used

$$Time_{Daylight} := 12hr$$

$$V_{Backwash} := 4000L$$

$$Height_{EntranceTank\_from\_DrainChannel} := 8m$$

$$Q_{RecyclePump} := \frac{V_{Backwash}}{Time_{Daylight}} = 1.5\,\frac{gal}{min}$$

Assumes that the full volume of water in the settling tank should be pumped within the span of one day

Figure 5: Calculation of the minimum flow rate required of the recycling pump.

The team decided that solar pumps are feasible in Honduras physical location and climate. The low latitude of Honduras means its daytime length stays fairly constant from 11.5 to 12.5 hours throughout the whole year. Also, when water conservation from backwash is more critical during dry season, there is less cloud cover. Thus, more solar power is available. Furthermore, in San Matias, there is a small elevation head difference between the entrance tank and drain channel of less than 4m. A much greater head of 30m has been achieved by solar pumping at an AguaClara plant by 1800W of solar panels in India, according to Maysoon.

The team considered using the Grundfos SQFlex solar pump, 11SQF-2, for the backwash recycling because AguaClara has experience working with Grundfos pumps in India. The SQFlex pump should be very suitable for the San Matias case due to the following reasons. Firstly, according to Grundos specifications, it is designed to operate in remote areas where water is scarce and the power supply is non-existent or unreliable; San Matias is such an area. Secondly, it can be easily installed and requires infrequent maintenance due to its built-in electronics and dry-running protection. Thirdly, the pump has more flexibility than other pumps on its power supply and performance, the SQFlex system can be combined and adapted to any need according to the conditions on the installation site. Finally, it is an electricity-free and environmentally-friendly water supply system that uses solar power. It is compatible with both AC or DC power supply at a wide range of voltages without requiring an external inverter, and a battery backup system can store surplus energy for pumping the next backwash or during cloudy weather. However, the pump costs 2050USD.

The team also found the Sun Pumps SDS-D-128 Submersible at USD 738. Though much cheaper, this pump requires a 30V power supply. Very few solar panels of 30V were found after extensive web research; most panels yield 12V. The team has been awaiting for the retailer The Solar Store to check on the suitability of this pump for our specifications.

Table 1. Pump Comparison

Pump	Cost (USD)	Req. Voltage (V)	Req. Power (W)	Head (m)	Rate (gpm)
Grundfos 11 SQF-2	2050	30-300	100	4.6	6.5
Sun Pumps SDS-D-128	738	30	62 (Peak)	7	1.75

Table 2. Solar Panel (12V) Costs by Power

Solar Panel (12V) Power (W)	Cost (USD)
40	149
60	199
100	299

2.a.3 Investment Payback Period

The team understood from Ethan that the final decision on its project would be made by the local community water board. The team calculated the payback period of the recycling project investment in San Matias, in order to determine the feasibility of such a recycle-pumping system. The payback period is time after project completion when the return on investment becomes positive, i.e. when costs are recovered from the value of benefits produced. To do so, the value of water produced by the plant per month, was calculated based on current water tariffs. Also, the volume of water saved was calculated from the estimated backwashes per month in the dry season. This is when backwashes occur less frequently, so the resulting estimate would be conservative. The obtained value per volume of water and volume of saved water were then used to calculate the monthly return on investment. The return was compared to project cost estimates. The most significant cost would be the pump or concrete; concrete cost estimates are described in the following paragraphs. Yet, the pump supplier had not replied on the final price it would offer. Hence, the team estimated a payback period of a couple years to as short as several months. Thus, the results yielded a good order of magnitude estimate of this financial cost-benefit ratio. The period was deemed very feasible by Ethan and Skyler.

This recycling project would yield a economic net benefit by the value of additional water produced after a short payback period; hence, it is economically feasible. Given this fact, the project is important and worthwhile for San Matias since the area has lacked water and had to conserve water significantly according to Monroe and Skyler. Thus, Byron the former San Matias plant operator was very enthusiastic about the project.

Cost of material for settling tank was roughly estimated with the US cost of concrete. At this cost estimation stage, a flat base was used for the rectangular settling tank. Attempts were made to calculate the wall thickness needed, based on the bending moment exerted by water on walls. The resulting thickness requirement was found to be approximately six times greater than the requirement needed for withstanding hydrostatic stress. Ultimately, the standard wall thickness of many plant components, 0.15m, was used to obtain a quick cost estimate for Ethan. To hold the water from one backwash, 2.1 cubic meters of concrete was needed, which would cost 250USD.

For a Rectangular Settling Tank with Height 1m, given V.Backwash:

$$V_{Backwash} := 4000L$$

$$T_{SetTank} := .15m$$

$$NH_{SetTank} := 1m$$

$$NL_{SetTank} := \left(\frac{V_{Backwash}}{NH_{SetTank}}\right)^{.5} = 2m$$

$$OL_{SetTank} := NL_{SetTank} + 2T_{SetTank}$$

$$V_{ConcreteandBricks} := OL_{SetTank}^{2} \cdot T_{SetTank} + 2OL_{SetTank} \cdot NH_{SetTank} \cdot T_{SetTank} + 2NL_{SetTank} \cdot NH_{SetTank} \cdot T_{SetTank} = 2.1 \cdot m^{3}$$

Assumes T.SetTankBase = T.SetTank

Figure 6: Cost of Concrete for Settling Tank.

In estimating the needed specification of the pump and pipe nominal diameter, the team accounted for factors which included the estimated flow rate required, major head loss from pumping 3.2m vertically, minor head loss from an estimated number of six elbows, and the roughness of PVC. About 18m of piping was needed, which would cost 15USD based on Ethans understanding. Given the pipe length, elbow number and vertical head loss, the team obtained a total head loss of 15 ft.

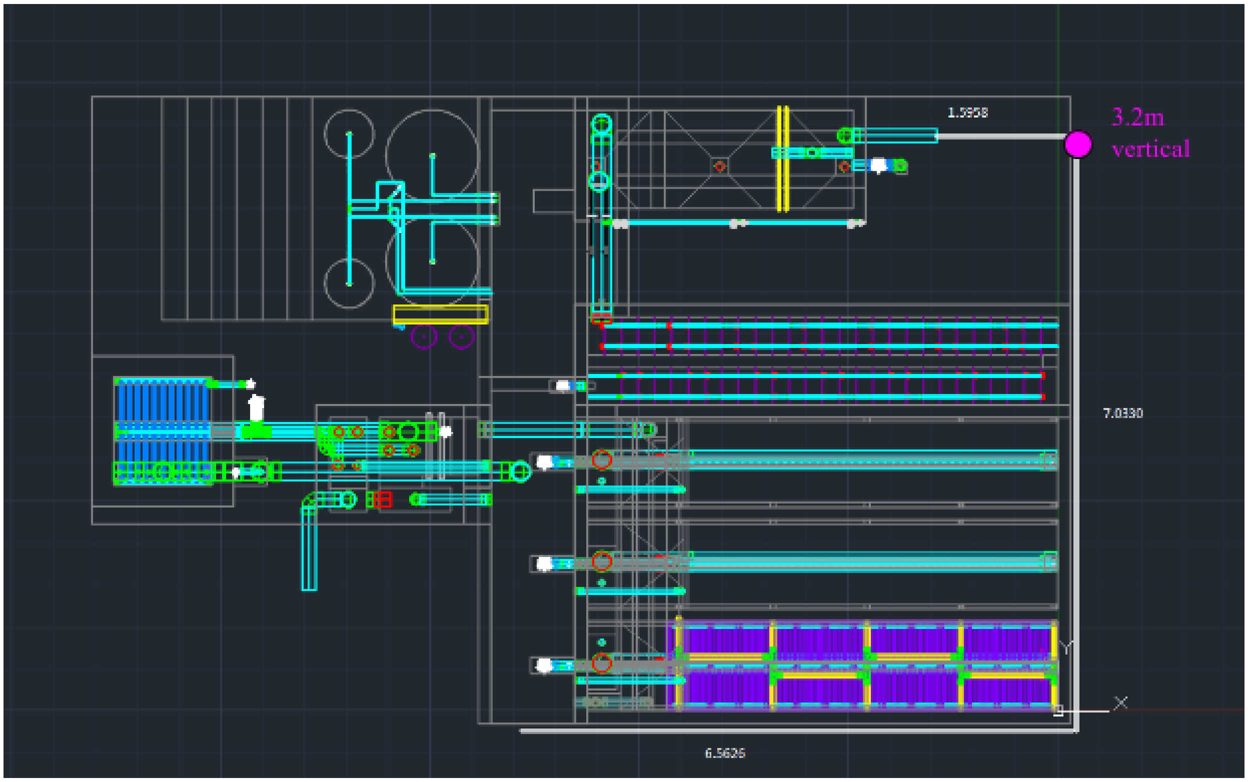

Figure 7: Pipe routing around the plant, lengths in meters. The team decided to build a pipe connecting the settling tank and entrance tank that routes around the plant, since the plant has already been constructed.

$$N_{Elbows} := 4$$

$$K_{Total} := N_{Elbows} \cdot K_{El90}$$

$$ND_{RecyclePipe} := ND_{PipeFlow}\left(2\frac{L}{s}, SDR_{26}, 3.2m, 12m, Nu_{Water}, E_{Pvc}, K_{Total}\right) = 1.5 \cdot in$$

Figure 8: Pipe diameter calculation. Given the information, the team calculated that a pipe with 1.5 inch nominal diameter is required for the backwash recycling system.

3 Future Work

The specific location of the tank needs to be further investigated. The team could not obtain the construction drawings for the San Matias plant, which makes it impossible to find an appropriate location for the tank. The team has decided with Ethan that he should decide later on the location based on conditions in San Matias. Alternatively, team members who will visit Honduras can conduct field research there to determine this.

The team consulted a few pump retailers and came up with some suggestions on the pump selection. The general idea is to use a solar-powered pump to bring water up from the settling tank to entrance tank. Further investigation, however, is still needed because retailers broke down in communication with the team when they received the specifications of the recycling system. The team suspects that many retailers may not want to sell pumps that are to be installed in Honduras. The decision on a pump should be made with a retailer who should know extensively about pump details that a novice needs time to learn about.

A possibility to work on is a general design of the backwash recycling system for all new plants produced from the AguaClara Automated Design Tool. Notably, the water wasted from backwash as a percentage of plant water output for each plant can be automatically calculated. A rough estimation of the payback period can also be automated for each plant, based on a rough range of prices of pumps which can provide 1) the head needed to elevate water from the filter siphon pipe to the entrance tank, and 2) the pump rate.

A fully automated general design may not be feasible due to the different nature of pump selection from automated plant design. The pump is the most costly component of the recycling system, yet the price of pumps vary greatly depending on specifications and brand (Table 1). Web research and a judgment made on it would have to be automated for full automation.

Settling tank designs can be refined by using geometries that research teams have experimented with; this can be done by scanning through a large amount of literature. The geometry modifications should ease the movement of solid contaminants through and out the bottom of the tank.

4 Task Map

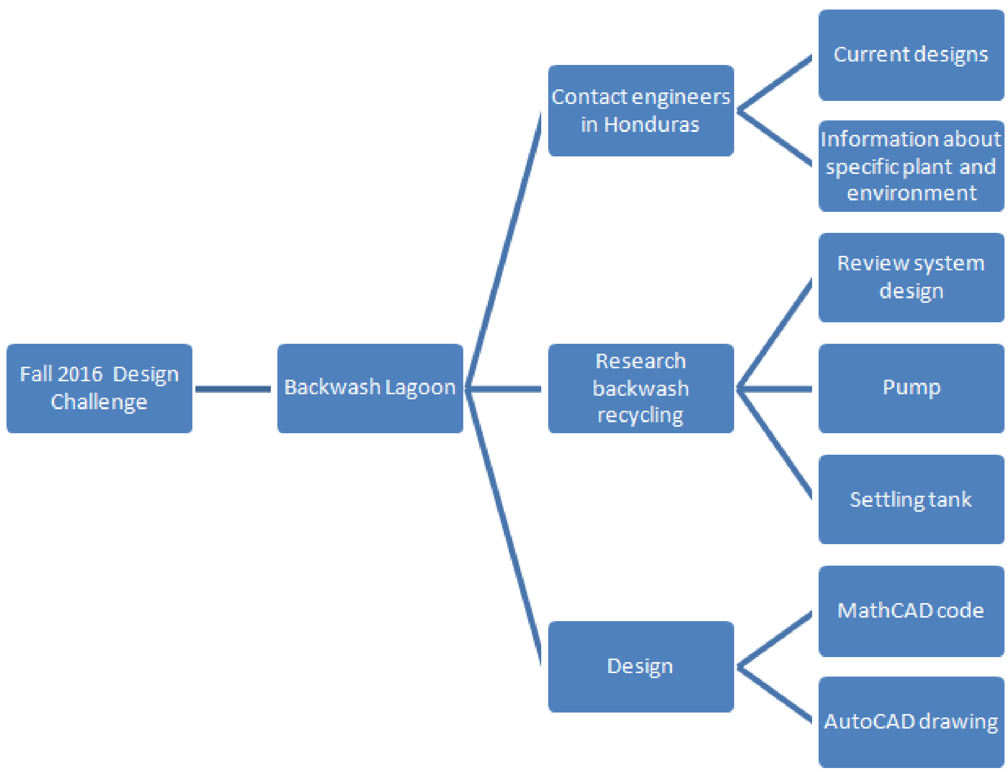

Figure 9: Task Map

4.a Task Map Details

- Backwash recycling
  - Contact engineers, Ethan and Skyler, from Honduras
    - Ask for current designs: evaluate which specific plant in Honduras would be a good start for developing a pilot backwash recycling system
      - San Matias plant is chosen

- * Information about Honduras which is required for the design
- – Research on pumps
  - * The team is looked at the possibility to use a sustainable pump to get the water to entrance tank from drain channel. Two kinds of pumps were considered: ram pump and solar pump. After investigation, the team decided to use a solar pump and also deemed the ram pump inappropriate for such use.
    - · Contact Maysoon from India and get some information about the solar pump that has been used in India
- – Research on settling tanks to temporarily store backwash water
  - * Consider whether to build a tank inside the drain channel or a separate tank outside.
  - * Calculate the volume of water used for one backwash, from which the team can design a tank of appropriate storage.
  - * Consider the pros and cons of different settling tank lining.
- – Design the backwash recycling system after finding appropriate pump and settling tank choices
  - * Create code using MathCAD
    - · Output commands into AutoCAD
  - * AutoCAD drawing