Project Report:

Gravity Filter Hydroponics System

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University of Ottawa: Faculty of Engineering

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Gravity Filter Hydroponics System

This report analyses the steps we took in designing our gravity filter hydroponics system to be used by Syrian refugees.

April 10, 2017

Declaration of Sole Ownership

We Benjamin Cooper, Spencer Manoryk, Jonathan Prance, Graham Sanford, Caleb Schmidt, confirm that this work submitted for assessment is our own and is expressed in our own words. Any uses made within it of the works of any other author, in any form (ideas, equations, figures, texts, tables, programs), are properly acknowledged at the point of use. A list of the references used is included.

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1.0 Introduction

This report examines a hydroponics system developed by five University of Ottawa Engineering students. The purpose of this report is to describe the process of design, development, and testing of a hydroponics system to be used by Syrian refugees.

Refugees are currently incapable of growing crops due to the poor soil conditions, and drastic climate changes of the Jordanian deserts. Temperatures range from just above freezing at night, to over 40 degrees Celsius during the day^[1]. These temperature fluctuations limit the variety of crops that can be grown, and the sandy surface inhibits any natural growth of edible crops. For these reasons there is a need for hydroponics system in these refugee camps to provide these Syrian refugees with the capability of cultivating fresh crops.

The hydroponics system must be able to effectively grow crops to provide a family with an adequate quantity of vegetables despite the harsh environmental conditions the camps reside in. The system must have the ability to sustain drastic temperature changes and severe wind conditions ^[3], without compromising its structural integrity. Due to these temperature extremes, the design must minimize the quantity of evaporation this system is susceptible to. The system must be capable of regular maintenance such as water refilling, and system cleaning to prevent the growth of potentially harmful bacteria/mold/pathogens. As a refugee family's living space is limited, this hydroponics solution must reasonably fit within the households dimensions.

This project is being carried out under the following assumptions:

- There is access to water (clean or dirty)
- There is access to sunlight to to enable the plants photosynthesizing mechanisms
- There is access to sand and gravel/rocks
- Resources necessary will be within the budget of the funding NGO

The body of this report contains six main sections: benchmarking, concept designs, project plan, methodology, testing results, and conclusions. The benchmarking section outlines existing hydroponic systems, and how elements of these systems may be implemented in our own design . The second section, design, pertains to how the project team carried out the development of the system. The third section outlines the implementation of a project plan to ensure the design was feasible. The fourth section, methodology, contains information regarding how the project team carried out the development of the system. The testing results contains information about how the testing was performed and the critical analysis that was gathered through it. The final section will make conclusions based off the testing results, as well as outline the challenges faced and

final recommendations.

This report is written for Professor David Knox, along with the faculty of engineering at the University of Ottawa. The stakeholders for this project are Syrian refugees, University of Ottawa, and the project team consisting of Benjamin Cooper, Spencer Manoryk, Jonathan Prance, Graham Sanford, and Caleb Schmidt.

2.0 Benchmarking

This section will focus on outlining the different existing hydroponics systems that we investigated to develop our own design. We will quantify the design specifications in order for our design to compete in the current market. To develop our solution and gather design criteria, we benchmarked 3 existing hydroponics systems available today. The systems that we benchmarked include:

- Desert farming solution
- Drip System
- Flood and drain system

2.1.1 Desert Farming Solution



Figure 2.1: Desert farming solution

A benchmarked solution that we have identified as being related to our own problem is a design created for mass produced desert growing. The purpose for this design is to allow farmers to grow valuable produce in the desert for financial gain^[1]. This project has not yet been fully implemented but three pilot projects are currently being executed and the design is very interesting to our team. The desert growing design is a low power use greenhouse that uses salt water to provide hydration to the plants, see figure 2.1^[6]. The greenhouse

structure in the design is large and should be implemented for large scale growing projects. The system works by piping in salt water from the sea, be it by gravity or mechanical means, to the

greenhouse facility^[6]. Just as humans cannot consume salt water for hydration, plants too need fresh water to grow. This design utilizes the strength of the sun in desert climates to provide the energy for the conversion process between saltwater and freshwater. The salt water is piped into thin honeycomb structures at the top of the greenhouse were the sun is the most direct. The salt water evaporates leaving all of the salt behind then condensed back into liquid form^[6]. Once condensed, the once salt water is now fresh water and can be stored for use in the greenhouse irrigation system^[6]. A positive side effect of this water treatment process is the humid climate inside the greenhouse that results from the evaporated salt water^[6].

The scope of this design is very different from scope of what we are attempting to develop, however, aspects of the design do fulfill some of our projects identified needs. The first need that this solution meets is low water usage. This solution does not utilize any fresh water in the irrigation process and only uses salt water that is useless for human consumption. The second identified need that the desert farming design meets is low energy usage. By utilizing the sun for the distalization process and providing plant light, this system can operate with only a few pumps for water transportation^[6]. A third need that is satisfied by this design is the production of quality produce. The greenhouse design is enclosed and protects the crop from both bad weather and pests that would otherwise adversely affect the quality of harvest. The fourth and final need this design addresses is that the growing solution does not depend on the soil quality of the area. On the inside of the greenhouse is a raised section that allows the farmer to use any quality of soil he or she wishes. This solution does not meet the following needs for various reasons: low cost, low maintenance, temperature control, ease of use, and size/portability.

2.1.2 Drip System

Building a small and affordable hydroponics system can be relatively simple. The drip system is a cheap and effective way to build a hydroponics system. For around 100 dollars the following list of materials can be purchased to create this small scale hydroponics system: four five gallon buckets to hold the plants in, four bulkhead fittings, black vinyl tubing for the drain and fill lines, a pump for the water, a storage container for the water between 18 and 30 gallons, a hydroponics growing medium, a furnace filter to prevent the medium from getting into the lines, t connectors for the vinyl tubing, and dark coloured paint to light proof the bucket reservoirs. Using these materials a hydroponic system can be created to support the growth of four plants. Specially designed hydroponic nutrients could also be added to encourage the growth of crops in the system. The aspects of this system that satisfy our design criteria are its low cost, ease of assembly/maintenance, production of quality vegetables, and capability to sustain a small family. The negative aspects of this system are its heavy demand on water, its inability to use grey water,

and its dependence on special nutrients to strengthen the soil.[4]

2.1.3 Flood and Drain System

Another variation of the hydroponics growing system is a flood and drain system. This system requires the plants to be orientated in a series formation^[5].

series formation[5].









This orientation is rather straight forward, and can be set up both indoors and outdoors. The plants are held in the main part of the system (far right on above diagram). A timer is set on the pump to control when the water flows through the vinyl pipes. The water continues to fill the main system until the plants roots are soaked. This is a preset volume of water that can be actively altered depending on user's desire. The waters elevation is altered through the use of an over flow tube (Figure 2.3); a tube which sets the height of the water and ensures that the water does not overflow while the pump is running. When the water reaches the overflow tube, the pump shuts off and the water is siphoned back into the reservoir where it can be reused for the next periodic cycle.

This system has many aspects which would be beneficial to a hydroponics system being used in a refugee camp. This system is easy to use/maintain, it can be easily moved and does not require lots of space, it constantly reuses water, it produces quality crops, and the materials used in its design are cheap. The negative aspects of this system are its dependence on freshwater and electricity for the pumping mechanism.

3.0 Proposed Concept Designs

This section examines multiple plant growing solutions with the potential to provide farming opportunities quality. Members of the group initially created conceptual ideas on their own; from here, concepts were combined to create three potential conceptual designs to be used in the creation of our final system. Only the 3 main concepts will be analysed in this section; the concepts that members of the group came up with individually will be included in Appendix A.

3.1 Overview of Potential Solutions and Criteria for Review

Criteria for concept review: refer to Appendix A for design criteria table

- Low maintenance: While several of the refugees are described to be adequately skilled in basic mechanical maintenance, burdening the members of the camp with ongoing maintenance is unsatisfactory. In addition, the refugee camp lacks access to a wide range of building materials, and as such any maintenance required should be able to be completed using materials local to the Jordan camp.
- Low Cost: The ideal hydroponics system will have the lowest cost possible. A design criteria of less than \$100 was set for the project. The cost of the project must be kept below \$100 in order to be considered successful because a budget of \$100 was set, and any minimization of cost makes it more affordable for NGOs to implement our hydroponics system in the camp.
- Minimized size: The ideal system would be as small as possible. As the camp has a constantly increasing population, preserving space would be ideal, thus the smallest effective solution possible should be implemented. By our design criteria, the system should occupy less than 2m^2 in order to be considered successful; however, this design criteria does not have to be adhered to strictly because of the relatively low importance of space efficiency when compared to water, and electricity efficiency.
- Minimized weight: The ideal system would have a weight that allows it to be easily moved , but also to not blow away in high winds. Our design criteria for weight was set to be the carrying capacity of two people. This criteria allows for the system to be easily moved in any situation as long as a 2 person team is available to move it, and we believe

this weight will also be sufficient to prevent the system from blowing away in high winds.

- Low Power Usage: The hydroponic system would also have the lowest power requirements possible due to the lack of access to electricity by the user(s). A successful concept that uses electricity would operate on 12v and less than 50 amps.
- Low Water Usage: The ideal hydroponic system would use the smallest amount of the water possible, as fresh water delivered to each family is extremely limited. This can either refer to the smallest amount of freshwater possible, specified at a value of 2L for maximum freshwater consumption, or an unlimited amount of filtered water.
- Ease of Use: The final design should be easy to use, requiring little to no previous experience with crop production. Any instructions should be clear and concise, with as little ambiguity and complexity as possible.

3.2 Solution One

The first conceptual design is an outdoor system that uses grey water to supply the system. Grey water would be poured into a hole in the top of the water storage container and becomes cleaned enough to be used for agricultural purposes (via a carbon filter). Water is then transferred from the container to the metal growing trough via a water control valve and hose. The trough fills with enough water until the roots of the plants are submerged. The plants are grown in a medium of dirt and sand found in the area surrounding the camp. Nutrients are added to the water trough through the use of an "iv drip" from a separate nutrient container. The structure of the system would be constructed of lumber, and a wooden lattice. A thermal blanket would be used in order to protect the plants in the system from harsh overnight conditions.



Figure 3.1: Sketch for conceptual design #1

3.2.1 Cost

When analysing this system for cost, it was decided that it would be too expensive to implement. This system uses a carbon filter which would need to be changed periodically in order to operate this system. We decided not to use the carbon filter from this design due to these financial constraints. This system was considered a failure by our design criteria for cost.

3.2.2 Maintenance

When analysing this system for maintainability, it was determined that it would be a failure. The system uses an activated carbon filter that needs replacing, and may not be available for affordable purchase in Jordan.

3.2.3 Size

When analysing this system for size we determined that it would be successful. This system could be built in the space of $2m^2$, which was set as our criteria for size.

3.2.4 Weight

When analysing this system for weight, we decided that it would be successful. This system uses

materials that would allow it to be partially disassembled and carried by two people as per our criteria.

3.2.5 Power usage

This system would require no power, as it is powered only by gravity. This system was considered successful based on our power criteria.

3.2.6 Water usage

Analysing this system for water usage revealed that it may not be ideal for use in the climate of the camp. The system is fairly open to the elements and sun causing unnecessary evaporation was a concern.

3.2.7 Ease of use

Detailed analysis was not done as to whether or not this system would be a success in terms of ease of use. While we did not create any instructions for this system, we believe that if we did take the time to create instructions, it would be easy enough to use.

3.3 Solution Two

The second conceptual design employs an elevated gravitational filter containing rocks, pebbles, and sand to purify greywater and stores the greywater in a plastic container. The plastic container is attached to a valve, which operates as a drip feed controlled by Arduino software. The drip feed is calibrated to maintain the water level in a metal hydroponic trough, accounting for water loss through plant consumption and evaporation. Water is transferred from the water trough to the growth medium by use of wicks, with nutrients added by a drip feed to each individual plant. To ensure proper nutrient saturation, the nutrients will be dyed blue, and illuminated by a light, whereas the waters optics colour will determine if the proper level of saturation has occurred. This device is to be used indoors, and relies on large battery to power the LED light for photosynthesis purposes, and provide power for an arduino device.



Figure 3.2: Sketch for conceptual design #2

3.3.1 Cost

The second design is expensive when compared to our cost metric of \$100, due to its excessive electrical components, such as the arduino board and LED lighting, as well as the metal trough. Therefore, in terms of cost this design did not meet the design criteria.

3.3.2 Maintenance

The maintenance component of the second design was also considered to not meet the design criteria, due to the amount of materials that would be difficult to maintain and replace. The programming board, LED lights, and battery are all scarce materials in the refugee camp of Jordan, and would be extremely difficult to replace if damaged.

3.3.3 Size

The size of the prototype would be able to meet our requirement for occupying less than 2 m 2 of space.

3.3.4 Weight

The weight of the prototype meets both qualitative measurements, as it is transportable by a two person team as well as possessing significant weight to not blow over by medium to high velocity winds.

3.3.5 Power usage

The design using an arduino system uses an excessive amount of power, dedicated the arduino drip control system, external LED light source, and optical illumination for nutrient saturation. These combined systems surpass the constraints of 12V and 50 amps, and thus the design fails the power usage criterion.

3.3.6 Water usage

This design meets the water requirements of 2L, as the water consumed by the system is filtered greywater. Due to the nature of the water used, there is no limits on the amount of water consumed, as it is recycled use.

3.3.7 Ease of use

The design succeeds in meeting the ease of use requirements, as the production of crops from this system can be obtained by simple instructions. In addition, the pre-programmed arduino nutrition drip feed removes any additional calculations needed to be conducted by the user. The design is ideal in terms of its ease of use.

3.4 Solution Three

The third solution employ a evaporated filtration method, which boils water and then transfers the water vapour into an elevated plastic container. The water then condenses, and is passed through a nutrition patch via a valve. The water then flows into a PVC pipe, wherein the water level is able to submerge the roots. Holes are drilled periodically into the PVC pipe, wide enough to implant a growth medium for the plants as wella s the plants themselves. The growth medium must be penetrable by the roots in order for the roots to gain access to water.



Figure 3.3: Sketch for conceptual design #3

3.4.1 Cost

No detailed cost analysis was done for this system; however, it uses parts similar to our final system which was under budget, which makes it reasonable to believe that this system could be produced under budget.

3.4.2 Maintenance

The system was determined to be a failure in terms of our maintenance criteria. The system could become difficult to maintain due to the complexity of the boiler system

3.4.3 Size

The size of this system was determined to be not successful when analysed against our criteria for $2m^2$. Having a separate unit for water boiling caused the system to occupy too much space and not meet our criteria.

3.4.4 Weight

The weight of this system was determined to be unsuccessful by our criteria for being able to be carried by two people. We believe that this system would take at least three people to move because of its three distinct parts (boiler, tank, growing tray). While it did not meet our criteria, ity could still be a successful solution as this size criteria is of fairly low importance.

3.4.5 Power usage

The system was determined to be a success in terms of power consumption. The system uses no electricity and is therefore successful by our criteria. This system does however use fuel found around the camp in order to boil water. The efficiency of this process was not evaluated and the system could potentially require a lot of fuel to run.

3.4.6 Water usage

The system was determined to be a success in terms of water consumption. The unit is sealed almost entirely which prevents water from escaping the system; furthermore, the system uses recycled water, and water consumption would not be a problem because of this.

3.4.7 Ease of use

The system was determined to be a success in terms of our ease of use criteria. Simple instructions could be written for the user of the system. One thing to note is that the gathering of fuel for the system could be more work depending on how much fuel is consumed; because of this, the system could potentially be considered a failure.

Criteria	Importance (Weight)	Conceptual Design #1	Conceptual Design #2	Conceptual Design #3
Cost	5	3	1	2
Maintenance	3	3	1	2
Size	1	3	2	1
Weight	2	3	2	1
Power usage	5	3	1	2
Water consumption	5	1	2	3
Ease of use	3	2	3	1
Total		59	34	47

Concept Analysis

Table 3.4 Best spec evaluation, weighted on a 1-3 scale

3.5 Finalized Conceptual Design

The final design incorporated the most positive aspects of the three previous designs to synthesize the best possible design in terms of quality and performance. Table 3.4 shows the best aspects of each conceptual design. The design consists of the small rock and sand gravity filter proposed in design one, with a plastic abs storage container for the filtered water. A valve then connects the container to a PVC pipe, as proposed in design three. The pipe was several insertion points for each individual plant, where a growth median will stabilize the plant from any external conditions.



Figure 3.5: Sketch for final conceptual design

3.5.1 Cost

The cost effectiveness of this design is extremely high, due to the aspects of the design such as the PVC pipe, gravity filter, and water storage container. All of the materials are commonly available at hardware stores and from many suppliers. This design allows for the use of a wide

range of parts, which allows it to have a low cost of approximately \$60.

3.5.2 Maintenance

Maintenance of this system can be easily explained with basic instructions. No technical knowledge is required to operate and maintain the system and the residents of the camp would be able to use it with relative ease.

3.5.3 Size

The size of this system is within our criteria for taking up less than 2 m^2 of space. The system is also scalable if the demand for crops increased; the system has essentially no fixed size, and its configuration is easily modifiable.

3.5.4 Weight

The weight of this system is low enough that it can be carried by a 2 person team. One person carries the water reservoir and filter unit, and the other person carries the PVC growing pipe and plant cups. All elements of the system are weighed down by water during operation in order to combat the high wind speeds found in the camp.

3.5.5 Power usage

This design uses no electricity at all, and is therefore a success by our criteria. Water flow through the system is accomplished completely with gravity and requires no additional power. Lighting for the system is to be provided by the sun so that no electrical lighting will be required.

3.5.6 Water usage

By operating on recycled grey water, this design is able to meet our criteria for water consumption. The design is also water efficient due to its sealed design; water is stored in a abs plastic bucket with a lid on it, and when water is in the system it is contained by a PVc pipe that only has openings for the plant growing cups.

3.5.7 Ease of use

This design meets our criteria for ease of use by being simple enough to have easy to understand instructions written for it. The system also requires no technical knowledge to operate.

Between the three designs, the gravity filter using rocks and sand was selected due to its extreme cost effectiveness comparatively to the other filter systems. The water would then be stored in an elevated abs plastic tank, as it is lightweight and durable, limiting the need for maintenance. A PVC pipe was chosen as the growth tank once again to its low cost, as well as its low weight, allowing the product to be easily transportable. Natural electrical elements were eliminated from the design, as the constraint of electricity on the camp was determined to be too high to implement an electrical systems with enough merit to be used.

4.0 Project Plan

Project plans are created to provide individuals/teams with an estimate of the necessary steps required to effectively complete the project. Creating a project plan was an essential aspect to the group's success as it was always understood what a task entailed, who was in charge of it, and when the task should be completed by. In general, creating a project plan provided our group with the confidence that all elements of the project could be completed if a formal schedule was followed.

4.1 Project Schedule for Entire Project

During the prototyping and testing phase, an in depth project plan was created to ensure adequate time was allocated to each segment of the project. It was understood that the project plan may not be followed precisely; however, it allowed our group to have an excellent sense of time management. By referring to the project plan, we were able to determine when elements of the project should be completed by, and which member was in charge of each section. This allowed our team to actively track the progress of our project, and determine if we were on schedule. This project plan was formatted into a Microsoft Projects Gantt chart, as can be seen in the figure below.

								1	2017 1	March					2017	April				
	Task Name 👻	Duration 👻	Start 👻	Finish 👻	Resource Names 👻	16	21	26	03	08	13	18	23	28	02	07	12	17	22	27
1	 Prototype 1 (Water Filter) and customer feedback 	11 days	Mon 17-02-20	Sun 17-03-05	Ben Cooper				-											
15	 Prototype 2 (Plant Tray) and customer feedback 	6 days	Mon 17-03-06	Sun 17- <mark>03-1</mark> 2	Caleb Schmidt				E		1									
29	 Prototype 3 (whole system) and customer feedback 	11 days	Mon 17-03-13	Sun 17-03-26	Spencer Manoryk								-							
39	Final Project Presentation	0 days	Mon 17-03-27	Mon 17-03-27	Jonathan Prance									03	-27					
40	Final Project Report	10 days	Mon 17-03-2	7 Fri 17-04-07	Graham Sanford											G	raha	m Sa	anfo	rd

Figure 4.1 General Project Schedule

4.2 Project Schedule for Prototypes

The prototyping phase is a time consuming, yet crucial phase of the project's completion. Due to the importance of this phase, we designed a project plant to ensure time and personnel were allocated to specific tasks. All three prototype test plans were created using Gantt charts (Appendix A), and follow a similar format. Each prototypes creating consisted of three phases: define, design, and build. The defining segment consisted of members outlining the purpose of the prototype as well as a testing procedure. The next segment focused on the designing of the intricate elements of the prototype. A rough idea was understood at this point as to what the prototype must contain; however, the design process translated these conceptual ideas into tangible designs. The third segment focussed on the actual construction of these designs to create a functioning prototype.

4.3 Project Cost Estimate

As our group was expected to create all three prototypes within a budget of 100 dollars (CAD), it was important to estimate the total costs of our system to ensure we remained in budget. To accomplish this task, extensive research was conducted to ensure we were purchasing only essential products and at the cheapest price point available. After the necessary items were determined and priced out, a Microsoft excel spreadsheet was used to organize and total our project costs.

Item	Source	Quantity	Cost (\$)
4 in. x 2 ft pipe	Home Depot	1	8.97
1/2 in. x 10 ft end pipe	Home Depot	1	2.94
1/2 in. PVC DWV Hub x SJ Trap Adapter	Home Depot	1	1.36
1/2 in. PVC DWV Trap Adapter	Home Depot	1	1.76
1/2 in. PVC DWV Coupling	Home Depot	1	0.78
HDX 5/8 in. Dia x 15 ft. Garden Hose	Home Depot	1	7.97
3/4 in. Brass FPTxMHT No-Kink Hose Bibb	Home Depot	2	7.88
5/8 in. Metal Female Mender	Home Depot	1	3.47
15 Gallon Plastic Drum	Uline	1	52
PVC cement	Home Depot	1	3.49
Plumber's putty	Home Depot	1	3.99
1L container	Scrap	1	0
Plant Containers	3D Printer	5	0
Mylar thermal foil	ebay	1	5
TOTAL			99.61

Figure 4.1.5 Table of Estimated Cost

5.0 Methodology

The methodology section describes the processes taken to build the prototype, and the main objectives that were focused on while testing. This section is broken into three parts: the testing of prototype one, the testing of prototype two, and the testing of prototype three.

5.1.1 Prototype One: Building and Testing Objectives

For the construction of our first prototype, we focused on the following building procedure:

- 1. Construct a filter tube with a pvc pipe
- 2. Attach the filter through a hole in the lid of a bucket that will also function as a water supply tank
 - a. seal the hole around the area where the pipe enters
- 3. attach a rubber hose to the bottom of the water bucket
- 4. attach a valve somewhere in the water hose
- 5. at the opposite end of the water hose, attach to the pvc growing pipe
- 6. ensure both ends of the pvc growing tube are sealed with end caps and silicone
- 7. put holes of size large enough to hold your growing cups along the length of the pvc growing pipe

After building our first prototype, we focused on testing the following aspects of the prototype :

- 1. The capability of having a filter system that easily attaches to the water supply tank. The filter is heavy and the tank needs to have the ability to hold the weight of the filter.
- 2. The ability to implement a user controllable water flow control system to supply the growing pipes with water.
- 3. The ability to contain the plants/vegetables in growing cups that also contain the growing medium.

5.1.2 Prototype Two: Building and Testing Objectives

For our second prototype, we followed the following building procedure:

- 1. Attach a piece of cloth at the end of the filter in order to block sand from entering the bucket
- 2. Apply silicone at any area that shows signs of leaking

After implementing our design ideas for prototype two, we focused on testing the following aspects of our design:

- 1. Ensure a watertight seal at entry and exit points of the growing pipe when the system is filled with water.
- 2. Test flow controllability from the bucket to the pipe, and for no problem draining the pipe.
- 3. Ensure that the filter is able to remove most of the soap from a solution of shampoo and water.
- 4. Ensure that the water filter is able to clean water at a reasonably fast rate.
- 5. Ensure that filter does not allow particulate to enter the water bucket.
- 6. Bucket is able to support the filter system.

5.1.3 Prototype Three: Building and Testing Objectives

For the third and final prototype (Figure 5.1 Appendix A), we followed the following building procedure:

- 1. Cut notches into the bucket, for the metal rods that support the filter
- 2. Using nuts and bolts, tighten the metal rods to support the filter horizontally.
- 3. Incorporate sponges into the cups, to provide an adequate growing medium for the plants
- 4. The ability to fill the growing pipe with water so that the plants' roots have access to it

After building our final design, we focused on testing the following aspects of our system:

- 1. Ensuring that the horizontal and vertical components of the filter are well-supported by the metal rods
- 2. Secure the PVC growing pipe, so rotational motion is restricted to a minimal.
- 3. confirming that leakage from the water level indicator is non-existent

6.0 Results and Analysis

The results and analysis section includes a complete set of all observations and results obtained from carrying out the testing procedure. At the end of this section we will also present the project team's opinions on where the testing has been successful and any downfalls that have been noticed.

6.1 Testing Results

This section includes our testing results from each prototype. The results in this section are obtained from following the objectives laid out in the above testing procedure

6.1.1 Prototype One

For the testing of prototype one, we focused on implementing the crucial aspects that are outlined above. The first aspect tested was, the strength capability of the lid on the bucket. we tested the ability of the lid to be able support the heavy filter with just silicon. To do this, the filter was taken to the rideau canal on a windy day to mimic the conditions that would arise in the Jordan refugee camps. After the test, we realized the silicon was not strong enough to support the lid, so we implemented a new design to be tested in the next prototype. Next, we flushed water through the system to observe the functionality of the valve, and observed it was a suffice solution to our design criteria. The final aspect that we tested, was the ability of the cups to embody the plants effectively. To do this, holes were cut in the bottom of dixie cups, so the plants could still be supported and roots could reach the water. This aspect was an adequate support for the plants, but a new a better growing medium still had to be implemented in later prototypes.

6.1.2 Prototype Two

For the testing of prototype two, the first thing that was done was, one gallon of water was flushed through the system to check for any leaks. We noticed, after timing the water flow, it took the one gallon of water 15 seconds to flow into the PVC pipe holding the plants, from the bucket. After the this test, we noticed that there was a leak in the tubing. The leak was fixed by tightening the hose clamp on the tubes. We ran the water through the system again, after adjusting the hose clamp, and found that there were not any more leaks in the system. For the next test, we gathered some sand and some rocks to test the filter. To represent the grey water that the refugees would be using, we mixed some shampoo into the water and drained it through the filter. After doing this, the water that was drained into the bucket through the filter, and was tasted by Graham, who says that the water did not taste soapy. Also, it appeared clean, and did not feel like there was not any sand or rocks in the filtered water. After testing, the filter that was being held onto the bucket by silicone, broke off again, so for our next prototype we decided again to implement a new design to fix the support of the filter.

6.1.3 Prototype Three

For our final prototype, testing the horizontal support of the filter was our first priority. To test this, we applied a constant force to all sides of the filter and observed if there was any considerable horizontal displacement on the filter that could be considered a concern. After testing, we were able to conclude that the filter support system was capable of withstanding 40N of force applied by hand on all sides of the filter. Next, we observed the strength and support that our latest design provided for the vertical component of our filter. To ensure the vertical support was adequate, we filled the filter three-quarters full of sand and rocks to observe how effectively the steel rods supported the filter. While doing this, we observed that the steel rods did not deform, or bend and were able to successfully support the filter. The measured force that was supported by our filter was 100N. Furthermore, we tested the PVC containing the plants, to ensure there was not any rotational movement that could potentially damage the plants. To properly test this, we attached the wooden blocks to the PVC pipe and applied horizontal pressure to the ends of the PVC and perpendicular pressure to them to observe the effect. After,

we observed that the wooden supports supplied adequate support for the PVC allowing no rotational or translational motion. For the final testing of our prototype, we observed how effective the water level indicator was. In doing this, we were able to conclude that the water level indicator was an effective and useful component to implement into our design, to observe the water level in the PVC.

7.0 Conclusions and Recommendations

This section will provide closing remarks drawn from the data collected in the above testing section. This section has three main components: Summary of Testing Conclusions, Challenges, and Final Recommendations.

7.1 Summary of Testing Conclusions

This section outlines the team's predictions at the start of the testing procedure and compares them to the actual conclusions we were able to make after the testing was completed.

7.1.1 Pre Testing Predictions

Our original predictions for testing our hydroponics system included multiple aspects from each prototype . The first design flaw that we predicted for prototype one, was that the filter, being held on to the lid by silicone, would break off of the lid due to the extensive force that would be supplied around the filter from wind. for prototype two, we pondered if the system would be able to withstand the water pressure, and prevent any leaks. After the designing of prototype three, we envisioned that the vertical and horizontal component of the filter could potentially remain an issue in our system, even after implementing a supposed solution to the problem.

7.1.2 Post Testing Conclusions

After testing the different aspects of each prototype that we thought might invoke an issue in our system, we were able to eliminate any concerns that still remained. Our original prediction of the filter not having enough support was correct, as during the testing it broke off the lid. During the testing of prototype two, we noticed one leak, that was easily fixed , in the system, so after testing it again we were able to safely presume no more leaks would occur. For the filter support, in prototype three, we were able to successfully confirm that our new method of providing horizontal and vertical support proved to be an adequate solution to the issue.

7.2 Challenges

During the development of our design, the group came across many challenges. Challenges faced include design, construction, testing, and management challenges.

7.2.1 Design Challenges

Throughout the ideation phase, problems arose about the combination of our ideas. This can be attributed to a lack of organization, as many of the ideas had to first be transcribed into an excel spreadsheet to properly compare ideas. These were compiled from hand written notes, but each individual member had their own set of notes and own omittance of important information, and thus describing the most promising ideas was impossible until examining all the ideas in one table. In retrospect, writing all notes in a digital form initially would have been productive and efficient way to conduct the ideation process.

7.2.2 Device Construction Challenges

The construction of each version of the prototype had its own set of unforeseen problems that were addressed while iterating on previous feedback in pursuit of the ideal design. The construction of the first prototype was relatively unencumbered by construction problems, as without client feedback it's comprehensive design matched our final design sketch. The only construction issue noted was the attachment of the the water storage container to the valve and tube, as the use of silicon needed to be approximated. This approximation led to a fragility to our design, as the silicon was exposed to external elements and was vulnerable to damage when transporting the prototype, as well as when conducting prototype tests.

Prototype two's construction elements were extremely limited, and as such no design challenges were incurred.

Prototype three presented a series of design challenges, specifically related to the addition of vertical and horizontal supports. The vertical support had no construction issues, however the horizontal supports presented a series of problems related to stabilization. The initial implementation of two threaded rods, providing compression to the filter itself, did not provide adequate support, as the abs bucket deformed when subjected to significant pressure. Thus the

filter was prone to prying the threaded rod out of a strictly vertical orientation, reducing its effectiveness on stability. eventually leading to a tilted filter. This problem was addressed by the implementation of two carved wooden block supports, that would be placed in between the rod and the filter, increases the pressurized surface area and reducing the force applied to the threaded bolt, and thus the bucket. Placing these wooden blocks at the correct angle with compression provided by the threaded rods was extremely difficult to obtain. Although the idea was thought to be ideal theoretically, the implementation of the idea into the third prototype proved to be a challenge.

7.2.3 Device Testing Challenges

A device testing of all three prototypes faced no significant challenges. Although prototypes one and two failed tests including leakage and stability, failure of some of the aspects of testing were expected. Therefore, the only challenges faced were time challenges, discussed belong in section 7.2.4: Project Management Challenges .

7.2.4 Project Management Challenges

Project management challenges faced throughout the duration of the project were connected heavily to organization. The ability to designate tasks to specific individuals was quite successful, but the time to complete these tasks was universally underestimated. This was especially true during the prototyping phase, as several unexpected adjustments were made, doubling the allotted time. While this adjustment was able to be accommodated, if the continuation of the prototyping phase could not be completed significant problems could be occurred. Designating an increase time period for many of the deliverables and most notably the testing phase of prototyping is warranted for any future design projects.

7.3 Final Recommendations

After the completion of this project we created a project summary to outline the valuable skills we acquired, as well as any recommendations for further improvement.

7.3.1 Project Summary

Upon completion of this design project our team produced a working prototype and also gained valuable skills that we will carry throughout our engineering careers. We have fulfilled the needs set out at the conception phase of this project by adapting the design thinking methodology as set

out in course theory content. Throughout the project we have realized the importance and benefit of putting design focus on the user of the product and developed our empathy skills in order to achieve this. A key takeaway from this project was the importance and difficulty of creating cheap and useful prototypes that accurately represent our design. In taking the time to design our prototypes we were able to successfully test specific aspects of our design and gain valuable information.

7.3.2 Recommendations for Improvement

There are a few recommendations for improvement that our group outlined to make the Gravity Filter Hydroponics System more efficient. The first recommendation for improvement is the implementation of a filtration system for pathogens. The removal of pathogens would be a positive addition to our system in order to insure the safety of produced crops and also reduce the need for cleaning of the hydroponics system. The current filter we have implemented on our system is a simplified version of a pathogen filter. With a few improvements to the filter structure and also an increase of filtering capacity, pathogens would be able to be successfully removed from any water source.

The second recommendation for system improvement is the implementation of a method to solve the issue of water stagnation. Plants require oxygen in the root systems even when submerged in water. Currently the system's water is only oxygenized upon entry of the PVC plant tray; this means the tank has to be completely refreshed to maintain O_2 levels. An improved system would have a solution that agitated the water enough to absorb O_2 maintaining the oxygen content in the water at approximately 9 PPM^[2].

The final recommendation for improvement is the implementation of automated nutrients dispensing into the system. For an optimized growth cycle plants would receive the same nutrients level throughout the day. Our current system will over saturate the plants in the morning and then leave a deficit of nutrients in the afternoon. To have a constant level of nutrients throughout the day, our team's recommendation is the development of a mechanical drip system.

Glossary

- a) **Hydroponics**: The process of growing plants in sand, gravel, water or any other medium other than soil.
- b) **PPM:** Parts per million
- c) **PVC:** A material called polyvinyl chloride which is commonly used in the construction of pipes.

References

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Appendix A

Design Spec	Relation (<,>,=)	Value	Units	Verification Method				
Functional Requirements								
1. Cost	<=	100	\$					
2. Size	<	2	m^2	Measure				
3. Temperature	<	30	С°	Test				
4. pH	~	5.5-6.5	рН	Test				
5. Power	<	12, 50	Volts, Amps	Measure				
6. Water	<	500	Litres	Measure				
Non-Functional Requirements								
7. Weight	<=	1	Carrying capacity of 2 avg human	Test				
8. Yield	=>	15000	Calories	Measure				
9. Safety	<	500	РРМ	Measure				
Constraints								
5. Cost	<=	\$100	Canadian Dollar	Measure				

Table 3.1.0 Design criteria

						2017 March
	Task Name 👻	Duration	👻 Start 👻	Finish 👻	Resource Names 👻	20 22 24 26 28 02 04 06 08 10 12 14 16 18
1	 Prototype 1 (Water Filter) and customer feedback 	11 days	Mon 17-02-20	Sun 17-03-05	Ben Cooper i	
2	⁴ Define Prototype 1	4 days	Mon 17-02-2	Thu 17-02-23	1	
3	Define Prototype Purpose	2 days	Mon 17-02-20	Tue 17-02-21	Graham Sanford, Jonathan Prance	Graham Sanford, Jonathan Prance
4	Outline Testing Procedure	3 days	Mon 17-02-20	Wed 17-02-22	Caleb Schmidt, BenCooper,Spence	Caleb Schmidt,BenCooper,Spencer Manoryk
5	⁴ Design Prototype 1	3 days	Fri 17-02-24	Tue 17-02-28		
6	Design Resivoir	2 days	Fri 17-02-24	Mon 17-02-27	Graham Sanford,Jc	Graham Sanford, Jonathan Prance
7	Design Filter Structure	2 days	Fri 17-02-24	Mon 17-02-27	Caleb Schmidt	Caleb Schmidt
8	Design Filter Contents	2 days	Fri 17-02-24	Mon 17-02-27	Ben Cooper, Spencer Manoryk	Ben Cooper,Spencer Manoryk
9	Group Design Meeting	0 days	Tue 17-02-28	Tue 17-02-28		♦ 02-28
10		5 days	Tue 17-02-28	Sun 17-03-05		
11	Contruct Tank and conections	4 days	Tue 17-02-28	Fri 17-03-03	Graham Sanford, Jonathan Prance	Graham Sanford, Jonathan Prance
12	Contruct filter structure	2 days	Tue 17-02-28	Wed 17-03-01	Caleb Schmidt	Caleb Schmidt
13	Construct Filter Contence	2 days	Thu 17-03-02	Fri 17-03-03	BenCooper, Spencer Manoryk	BenCooper,Spencer Manoryk
14	Combine Parts	0 days	Sat 17-03-04	Sat 17-03-04		♦ 03-04

Figure 4.2 - Prototype 1 Project Schedule

	Task Name 👻	Duration		Finish 👻	Resource Names 👻	06 08 10 12 14 16 18 20 22 24 26 2
15	 Prototype 2 (Plant Tray) and customer feedback 	6 days	Mon 17-03-06	Sun 17-03-12	Caleb Schmidt	
16	4 Define Prototype 2	1 day	Mon 17-03-06	Mon 17-03-0	E	
17	Define Prototype Purpose	1 day	Mon 17-03-06	Mon 17-03-06	Ben Cooper, Caleb Schmidt	Ben Cooper,Caleb Schmidt
18	Outline Testing Procedure	1 day	Mon 17-03-06	Mon 17-03-06	Spencer Manoryk, Graham Sanford,Jo	Spencer Manoryk,Graham Sanford,Jonathan Pranc
19	⁴ Design Prototype 2	1 day	Tue 17-03-07	Tue 17-03-07		
20	Design PVC system	1 day	Tue 17-03-07	Tue 17-03-07	Ben Cooper, Caleb Schmidt	📕 Ben Cooper, Caleb Schmidt
21	Design plant holes	1 day	Tue 17-03-07	Tue 17-03-07	Jonathan Prance	🗾 Jonathan Prance
22	Design plant cups	1 day	Tue 17-03-07	Tue 17-03-07	Spencer Manoryk,	Spencer Manoryk, Graham Sanford
23	Design Meeting	0 days	Tue 17-03-07	Tue 17-03-07		♦ 03-07
24	▲ Build Prototype 2	4 days	Wed 17-03-08	Sat 17-03-11		
25	Build PVC system	3 days	Wed 17-03-08	Fri 17-03-10	Ben Cooper, Caleb Schmidt	Ben Cooper,Caleb Schmidt
26	3D print palant cups	3 days	Wed 17-03-08	Fri 17-03-10	Jonathan Prance	Jonathan Prance
27	Cut plant holes	3 days	Wed 17-03-08	Fri 17-03-10	Spencer Manoryk, Graham Sanford	Spencer Manoryk,Graham Sanford
28	Combine Parts	1 day	Sat 17-03-11	Sat 17-03-11		

Figure 4.3 - Prototype 2 Project Schedule

													2017 A	pril							
	Task Name 👻	Duration	👻 Start 🔍	Finish 👻	Resource Names 👻	12 14	16 18	3 20	22	24 2	6 28	30	01	03 0	5 07	09	11	13	15	17	19
29	 Prototype 3 (whole system) and customer feedback 	11 days	Mon 17-03-13	Sun 17-03-26	Spencer Manoryk						I										
30	Define Prototype 3	2 days	Mon 17-03-1	Tue 17-03-14																	
31	Define Prototype Purpose	2 days	Mon 17-03-13	Tue 17-03-14	Caleb Schmidt, Graham Sanford	-	Caleb Sc	hmidt,	Graha	m Sar	ford										
32	Outline Testing Pro	2 days	Mon 17-03-1	Tue 17-03-14	Jonathan Prance,S		Jonathar	n Pranc	e,Spe	ncer N	lanory	k,Ben	Coop	er							
33	4 Design Prototype 3	3 days	Tue 17-03-14	Thu 17-03-16																	
34	design plant support system and growth medium	2 days	Tue 17-03-14	Wed 17-03-15	Ben Cooper, Caleb Schmidt, Graham Sanford, Jonathan Prance,S		Ben Co	ooper, o	Caleb	Schmi	dt, Gral	ham S	anfo	rd, Jon	athan	Pran	ce,Sp	encer	Man	oryk	
35	Design meeting	0 days	Thu 17-03-16	Thu 17-03-16			03-16														
36	Build Prototype 3	4 days	Fri 17-03-17	Wed 17-03-2	2			_													
37	Put together grow system	4 days	Fri 17-03-17	Wed 17-03-22	Caleb Schmidt, Graham Sanford,Jc				Ca	leb So	hmidt	,Graha	am Sa	anford	,Jona	than I	Pranc	e,Spe	ncer	Mano	ryk
38	Intagrate Prototype 1 and 2	3 days	Thu 17-03-23	Sat 17-03-25	Ben Cooper, Caleb Schmidt				1	enne E	Sen Coo	oper,C	aleb	Schmi	dt						

Figure 4.4 - Prototype 3 Project Schedule



Figure 5.1 - Prototype 3 Design