GNG1103

Final Design Report

[Hydroponics System]

Submitted by

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University of Ottawa

Abstract

Throughout the course of the semester, we have worked to implement an easy to use, as well as easy to maintain hydroponics system that will give our client's community an abundance of natural food produce for 3 seasons out of the year. The goal of this project is to develop an efficient and self-sustaining hydroponics system that will be integrated with a greenhouse in order to produce food for the algonquins of Barriere Lake while working with the constraints of a limited access to running water and electricity.

While working with our client, we were able to determine various ideas that would help our system operate at a high level in their specific and unique environment. By doing so, we were then able to develop various designs, and build prototypes, while also trying to implement the feedback that we continued to receive. From thereon in, we focused on creating a final product that met all of our client's needs.

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List of Acronyms

Acronym	Definition
NFT	Nutrient Film Technique

1 Introduction

The main objective of this project is to design a greenhouse and hydroponics system for the Algonquins of Barriere Lake. Barriere Lake is an area that mainly consists of sand and bush, with no running water. Most of the drinking water is collected from springs. Growing food such as fruits and vegetables can be challenging at times. The GNG1103[D] Hydroponics Group 1 has taken on the task of designing a hydroponics system that will provide the people of Barriere Lake with fresh fruits and vegetables for three seasons of the year. The hydroponics system will then be placed in a greenhouse created by Construction Group 1. Due to the lack of running water, the greenhouse and hydroponics system must be entirely self-sufficient. The hydroponics system must be protected in their greenhouses in order to ensure that no children or rodents can harm the content or injure themselves. Hydroponics Group 1 decided to design a hydroponics system using the Nutrient Film Technique (NFT). A NFT system will allow for nutrient-filled water to pass through each pipe holding plants and provide nutrients to the roots of all plants. The design will hold layers of plants up in a vertical direction. The nutrient-filled water will be pumped, using a pump, to the top and then it will move down the angled pipes using gravity and water all plants on its way. A unique part of our design is that there will be a composting system attached to the nutrient tank. The nutrient tank will mix water with compost to make the nutrient solution. This would be an excellent way to save money and reduce the cost of buying nutrients. It would also increase community engagement. The designed hydroponics system is incredibly versatile, allowing the addition or reduction of rows, heights, run lengths, etc. The hydroponics system will be powered using solar panels provided by the university.

2 Need Identification and Product Specification Process

Problem Statement

The Algonquins of Barriere Lake require a three season greenhouse and hydroponics system that is entirely self-sufficient, easy to maintain, and durable enough to withstand all aspects of the surrounding environment.

Benchmarking Data

Table 1: Comparing Three Existing Hydroponics Systems

Specifications	Hydroponic Site Grow Kit Garden Vegetable Planting	Viagrow (Deep Water Culture)	AeroGarden Farm Plus Hydroponic Garden
Cost ($CAD)	$129	$281.59	$899.95
Weight (lbs)	7.7 kg	20.5 kg	21.6 kg
Size (m)	100 cm x 50 cm x 100 cm	30.5 x 30.5 x 38.1 (cm)	91.4 x 30.5 x 86.4 cm
Reservoir Size (liters)	15-20 L	144 L	N/A
Plant Slots	54	8	24
Style	Nutrient Film Technique	Deep water culture	Aeroponic
Modularity	Very portable	Very portable	Not portable

Target Specification Benchmarking

Table 2: Comparing and Ranking Each Hydroponics System

Specifications	**Importance**	**Hydroponic Site Grow Kit Garden Vegetable Planting System Kit (6-pipe 3-layer)**	**Viagrow (Deep Water Culture)**	**AeroGarden Farm Plus Hydroponic Garden**
Cost ($ CAD)	4	3	2	1
Weight (lbs)	2	3	1	3
Size (m)	2	1	3	1
Reservoir Size (liters)	5	3	1	
Plant Slots	5	3	1	2
Style	3	3	2	2
Modularity	4	3	3	1
Total		71	44	

Engineering Design Specifications

Table 3: Design Requirements

#	**Design Specifications**	**Relation**	**Value**	**Units**	**Verification Method**
	Functional Requirements				
1	Reservoir			Liters	Test
2	Water	>	20	Liters	Rainwater harvesting
3	Climate Control		0	C	Test

4	Power	>		Watts	Solar Panels
5	Submersible fountain pump	=	yes	N/A	Test
6	Channel for plants to grow	=	yes	N/A	Test
7	Starter cubes/small baskets to start seedlings	=	yes	N/A	Test
8	Return System	=	yes	N/A	Test
	Constraints				
1	Weight	>		lbs	Analysis
2	Cost	<	100	$	Budget
3	Size	=	6x6	m	Analysis
4	Weather	=	Year round	C	Analysis
5	Animals	=	Yes	N/A	Analysis
6	Electricity	=	No	Watts	Analysis
7	Clean water	=	No	Liters	Analysis
	Non-Functional Requirements				
1	Easy to use	=	yes	N/A	Analysis
2	Variety of plants	=	yes	N/A	Test
3	Product life	>	5	Years	Test
4	Safety: Minimum Pinch Points	=	yes	N/A	Test

3 Conceptual Designs

Each team member came up with 3 different design choices for the project as follows.

<u>Alana's Designs</u>

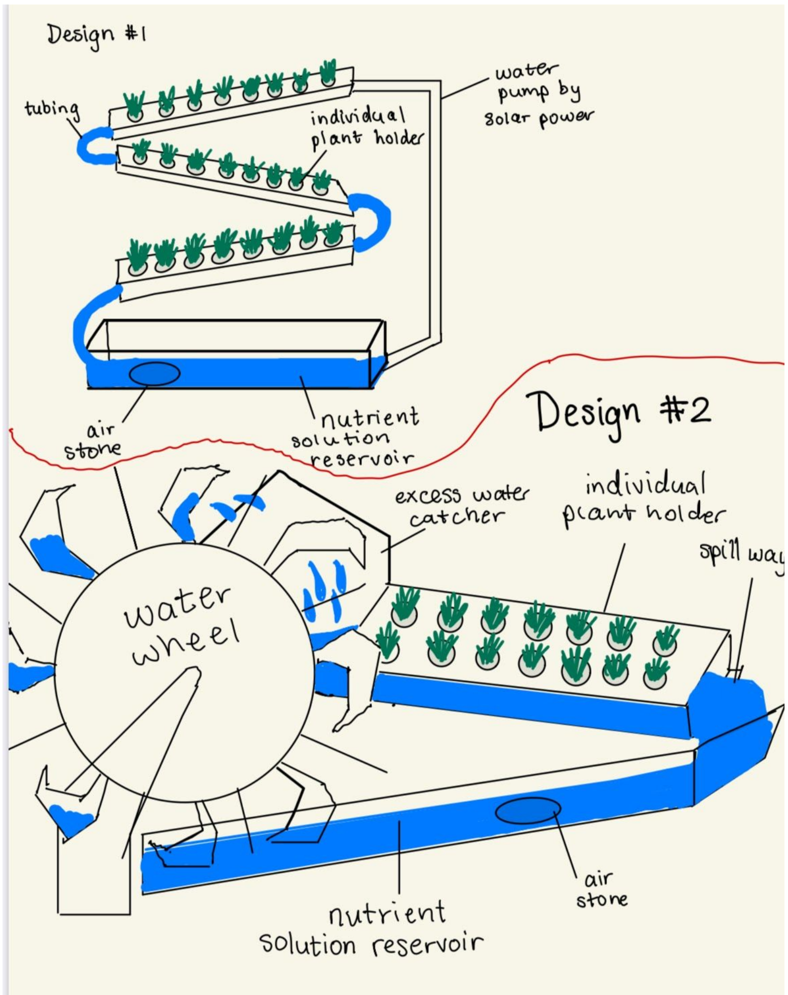

Figure 1: Alana's Design #1 and Design #2

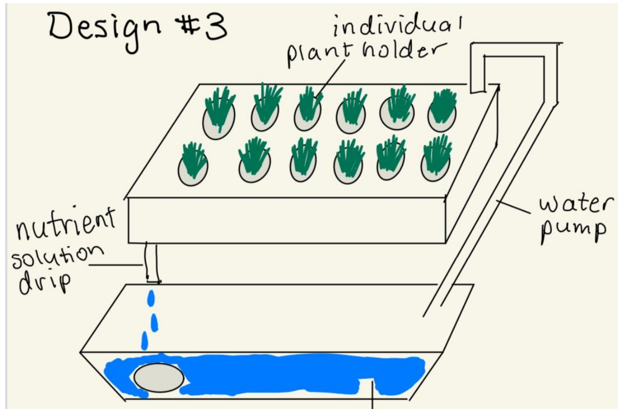

Figure 2: Alana's Design #3

<u>Weeda's Designs</u>

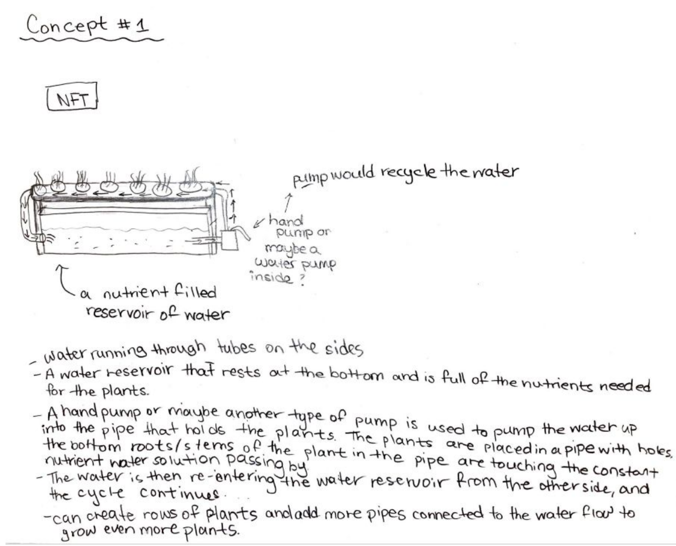

Figure 3: Weeda's Design #1

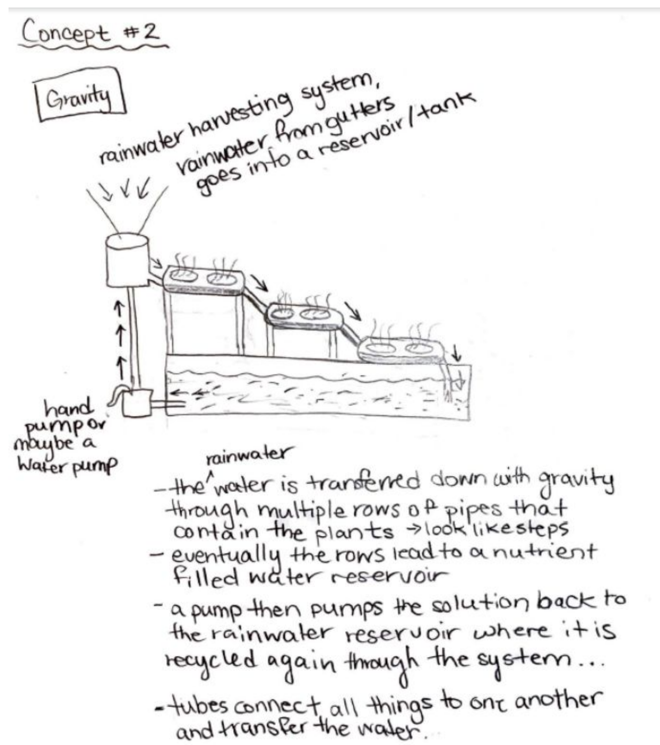

Figure 4: Weeda's Design #2

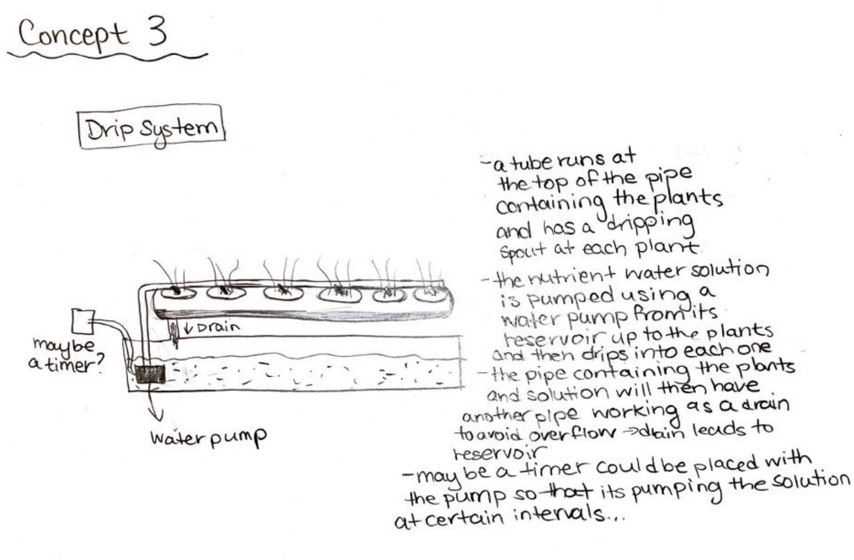

Figure 5: Weeda's Design #3

Lucas' Designs

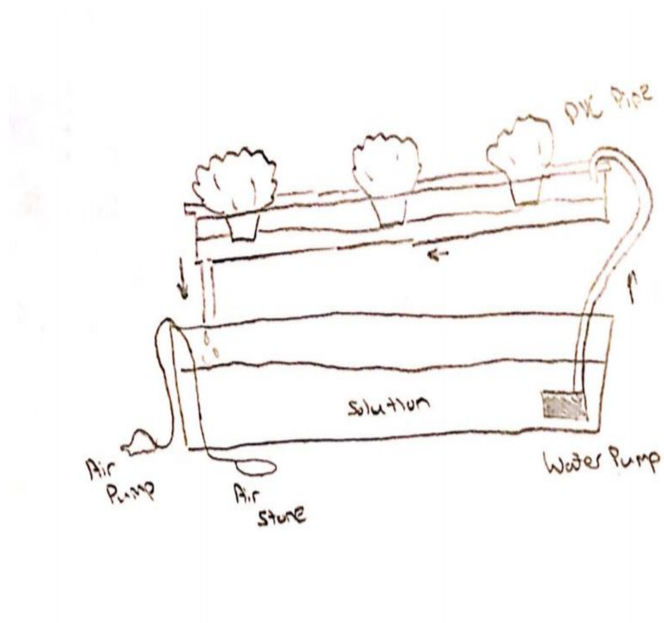

Figure 6: Lucas' Design #1

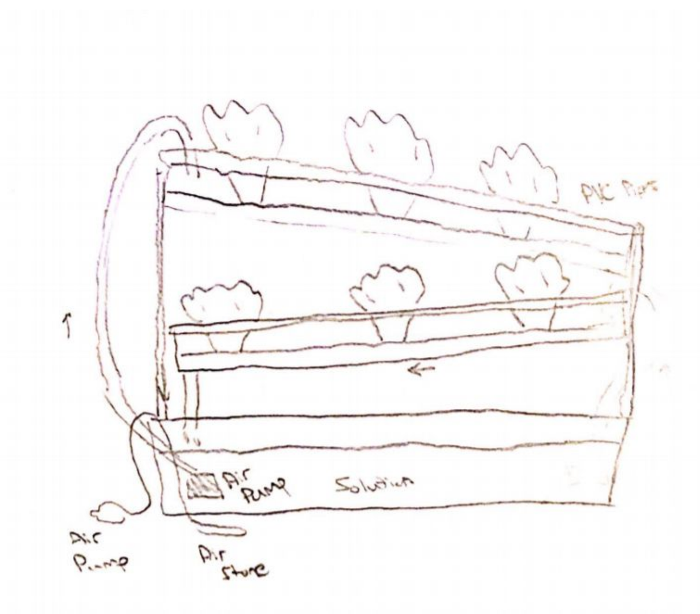

Figure 7: Lucas' Design #2

Joseph's Designs

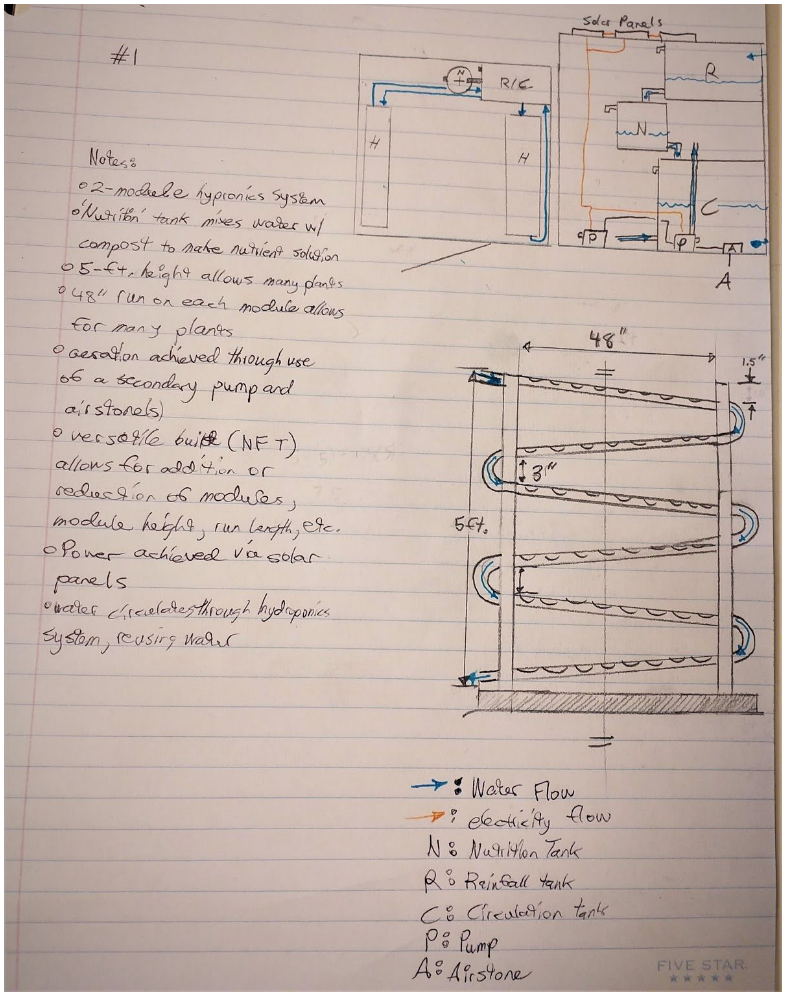

Figure 8: Joseph's Design #1

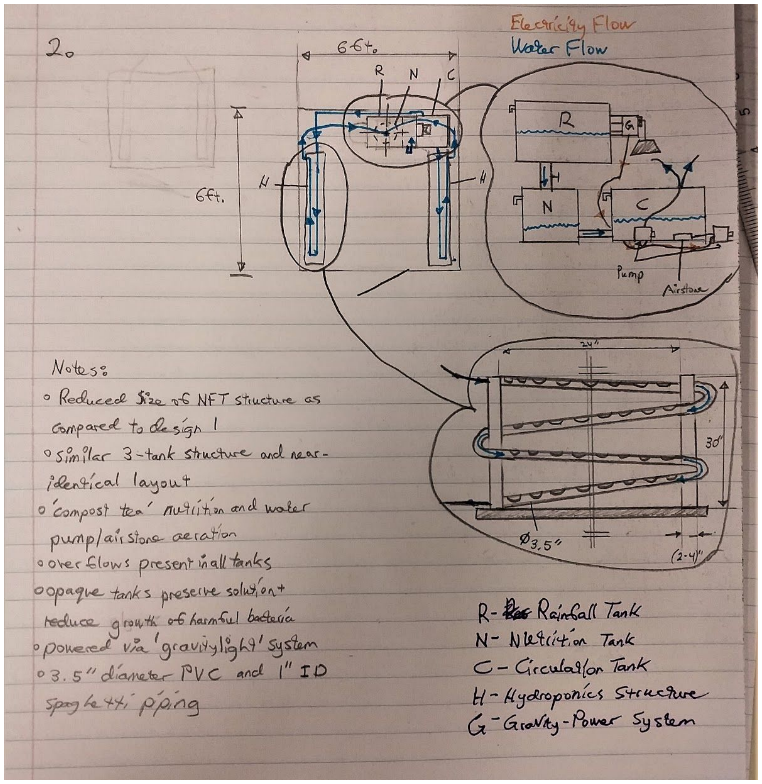

Figure 9: Joseph's Design #2

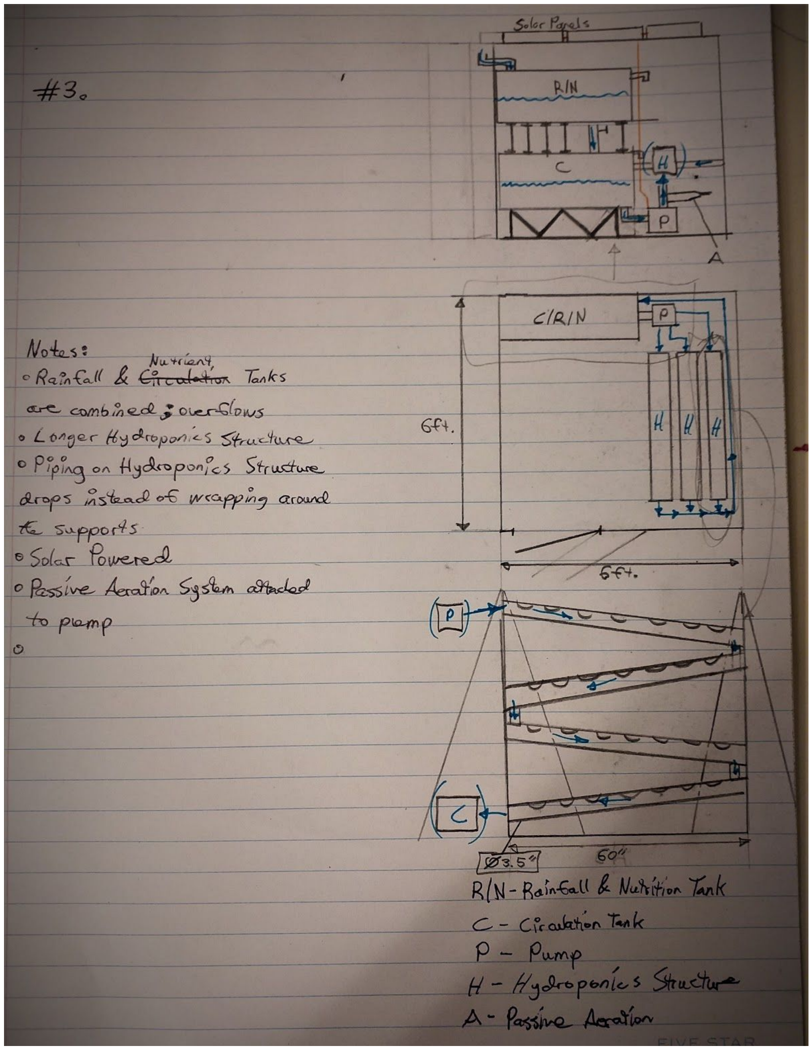

Figure 10: Joseph's Design #3

Gabe's Designs

This execution of the nutrient film technique (NFT) involves the use of 2 sawhorse-like structures, with PVC piping sloping down and around both sawhorses. The advantage of this system is the minimal use and ability to reuse all water. On the other hand, due to minimal spacing available for piping on the sawhorses, the number of plant slots is quite limited. A pump in the water tank pumps the nutrient enriched water up to the top opening, and the water then flows down the gently sloped pipes back into the tank.

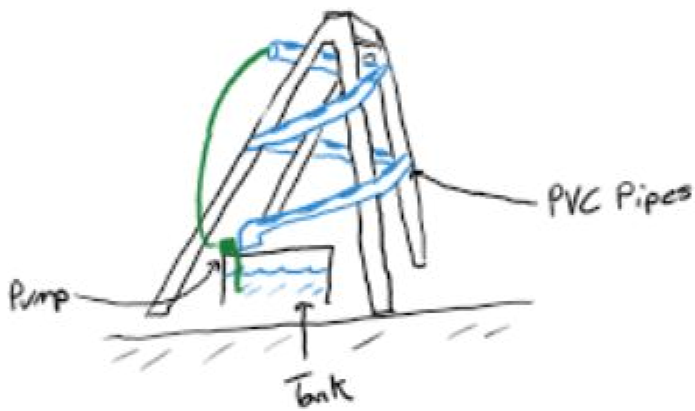

Figure 11: Gabe's Design #1

In this model of the NFT system, nutrient water is pumped from a tank up to a gently downward sloped PVC pipe which then flows into another pipe of similar nature. The pipes form a zig zag pattern as shown in the diagram. The advantages of this system include both minimal water use, and the ability to reuse all water. In addition to this, less lumber and PVC piping is needed, keeping costs lower. In turn, this model has very limited plant slots making it less ideal for our client.

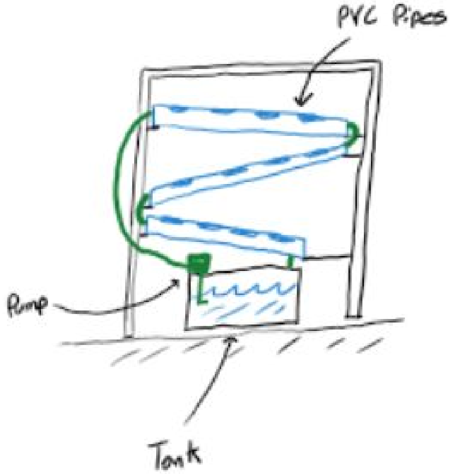

Figure 12: Gabe's Design #2

This third model of the NFT system is very similar to the previous model, but instead of one pipe per level, multiple pipes are fed nutrient water on each level. This is accomplished through one perpendicular pipe running along the ends of each pipe in the level. The advantages to this system include the ability for all water to be reused, and the ability for a very large amount of plants to be planted. One major disadvantage is the large amount of water that would need to be pumped to feed the entire array of pipes.

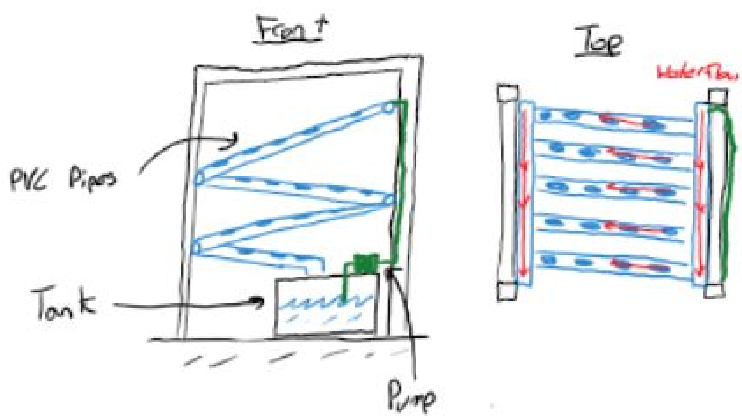

Figure 13: Gabe's Design #3

The final design chosen was Joseph's Design #1 in Figure 8.

Benchmarking:

Table 4: Design Matrix

Specifications	Joe's Design 1	Weeda's Gravity Design 2	Gabe's Design 2
Cost ($CAD)	≈ $126.90	$195.99	$330
Weight (lbs)	≈ 28 lbs	≈ 33 lbs	≈ 25
Size (m)	1.5 x 1.2 x 0.25	6 x 6 x 4	1 x 0.5 x 1.2
Reservoir Size (liters)	≈ 18 L	≈ 20 L	≈ 19
Plant Slots	48	24	36
Style	NFT	Gravity fed	NFT
Modularity	Portable	No	Portable

Table 5: Design Selection

Specifications	Importance	Joe's Design 1	Weeda's Gravity Design 2	Gabe's Design 2
Cost ($CAD)	4	3	2	1
Weight (lbs)	2	2	1	3
Size (m)	2	3	1	3
Reservoir Size (liters)	5	2	3	2
Plant Slots	5	3	1	2
Style	3	3	3	3
Modularity	4	3	1	3
Total		68	45	57

The global design we have chosen based on the selection matrices is Joe's Design #1. The design elements that are of most value are the uses of compost for nutrient solution, it being the least costly, having the capacity to carry more plants, and a capability to insert more plant tubes. In addition to this, the 3-tank structure allows for both the use of rainwater collection and the ability to re-use all nutrient enriched water. The system is powered by solar panels which are functional to two water pumps and an airstone.

4 Project Plan, Execution, Tracking & Bill of Materials

The project plan was constructed and tracked using Trello. The following figures are snapshots of the Gantt chart used to track all of the team's work and tasks for completing the prototypes.

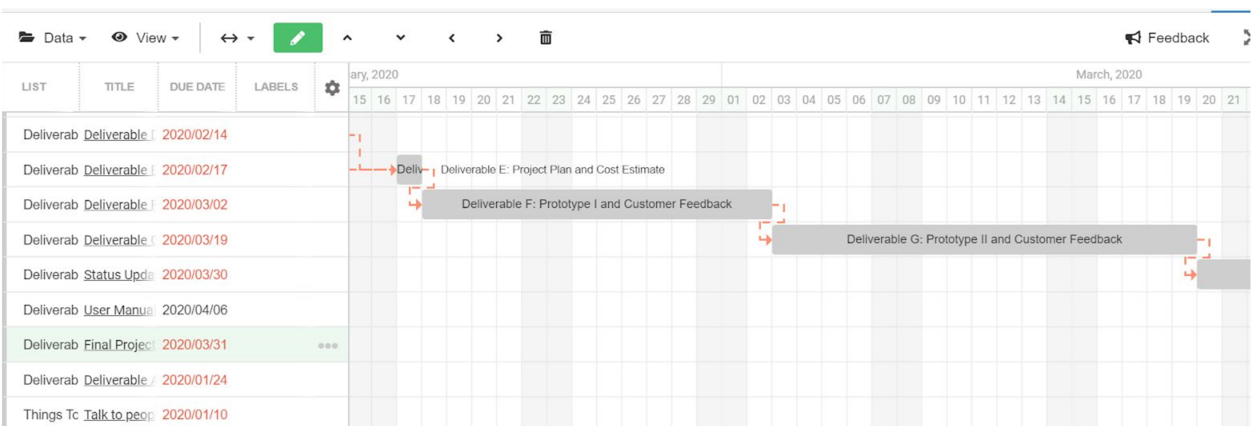

Figure 14: Gantt Chart Part 1

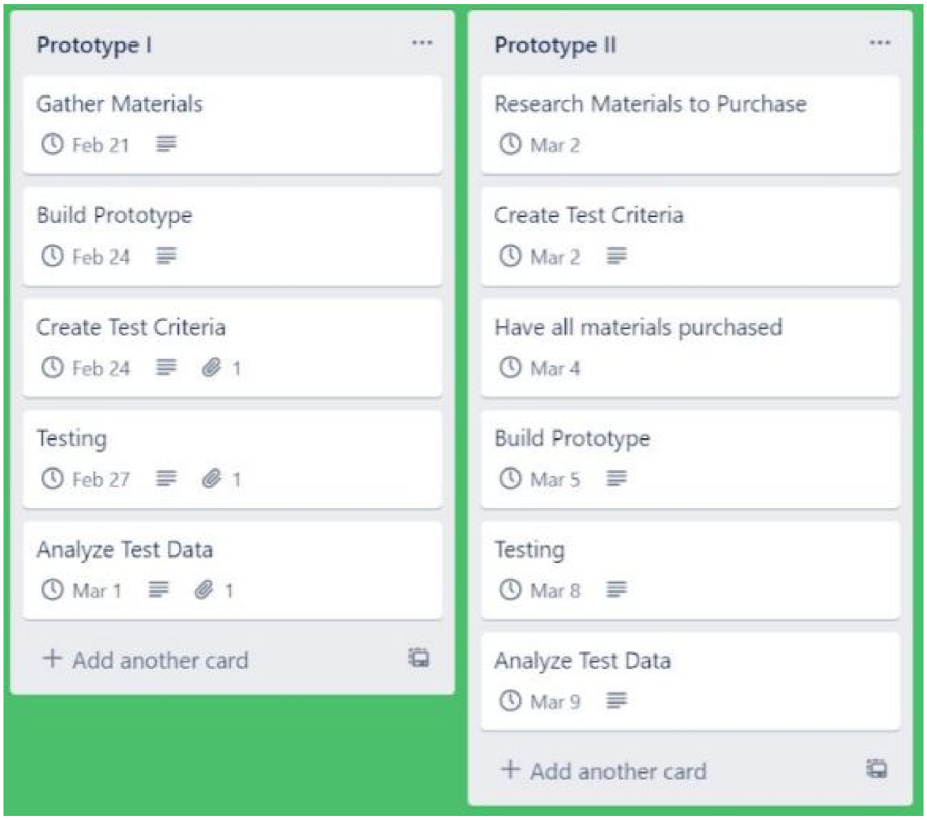

Figure 15: Trello Tasks for Prototypes

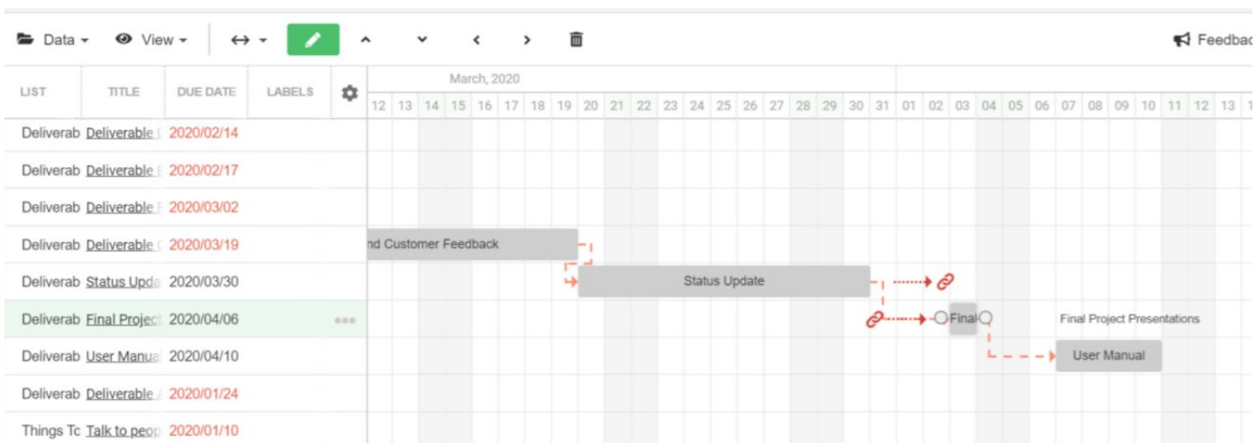

Figure 16: Gantt Chart Part 2

Unfortunately, the third prototype was not completed due to the COVID-19 pandemic, but the team tried their best to complete what they could. A final build was partially built by a team member in hopes of being able to display our vision. That final build will be explained in more depth in further sections of this report.

Before the pandemic, initial costs for prototype III were finalized and Table 6 helps summarize them all:

Table 6: Prototype III Materials Costs

Item	Cost ($)
Zip Ties (x100)	$8.30
Net Pots (x50)	$17.50
Peat Pellets (x36)	$4.00
Storage Bin	$12.67
Seeds/Plants	$5.00
8L Bucket (x2)	$12.00
Solar Panels	Funded by construction team
TOTAL	~$60

These numbers could have been subject to change after prototype III was built because there could have been new things needed or a few things missing. Therefore, this materials cost may not be the final cost for this design.

5 Analysis:

Calculations for the final design are as follows in Figure 17:

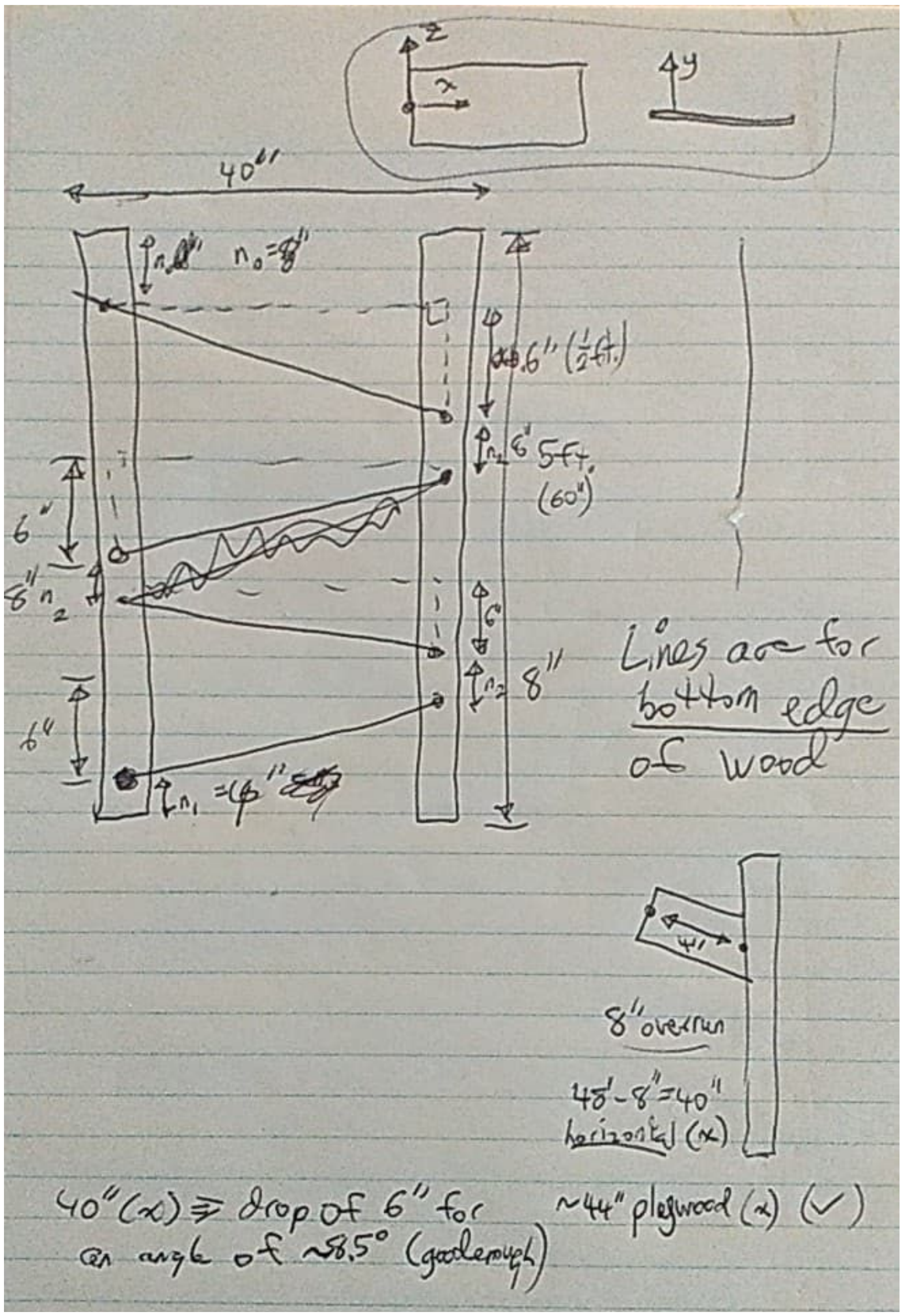

Figure 17: Calculations for Final Build

6 Prototyping, Testing and Customer Validation

<u>Results from Prototype I</u>

The client (Monique) was satisfied with our first prototype. She was intrigued by our composting and nutrient system. She also told us that she would communicate with local schools in order to see whether or not a compost system would work. If the compost system were to be feasible and applicable, the team agreed that a composting guide would need to be provided with the design.

Prototype I was constructed using cardboard and tape. It cost nothing and was an initial design for the next few prototypes. The following figures illustrate the steps to building the prototype.

Figure 18: Prototype I Part 1

Figure 19: Prototype I Part 2

Figure 20: Prototype I Part 3

Prototype II Digital Design

Prototype II was created using Solidworks. Figures 1, and 2 display the 3D model of our prototype II using Solidworks. Testing of the pumps obtained from the Makerspace lab were conducted in order to ensure that water can be pumped at a sufficient level. Based on the testing results, we could visually observe that the water pump was strong enough to pump water through the pipes and at a considerable height. Thus, we can confirm that our pump will have enough power to power our hydroponics system.

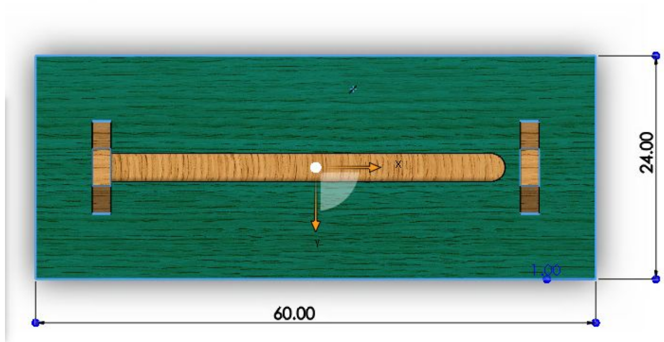

Figure 21: Top view of Prototype 2

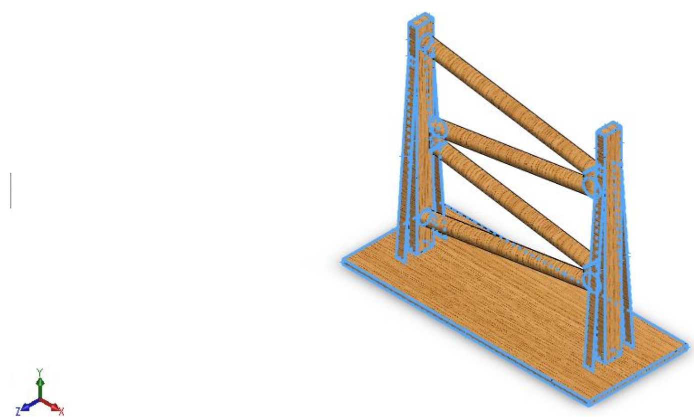

Figure 22: Side view of Prototype 2

7 Final Solution

The final build was a developed version of the second prototype, with modifications designed to add portability, durability, and increased capacitance to the original design. The final solution had two separate runs of PVC piping on either side of the supporting structure, held in place by gravity and friction, allowing for them to be assembled and removed without needing to use any fasteners. Piping in between each run must be added, holes drilled for the plant pots, and the structure connected first to the water supply system and then to the overall greenhouse. The wooden structure would be permanently fixed to the greenhouse in order to increase its stability. The original 3 reservoir system would be used; tests must still be made to verify this system's practical use.

Figure 23: Final Build

8 Conclusions and Recommendations for Future Work

Overall, our group was able to design a functioning hydroponics system that satisfied both the requirements and constraints laid out by the client in our initial meeting. Due to the Covid-19 pandemic, facilities shutdown, and the final prototype was not completed. Had the school's facilities remained open, we would have purchased all the necessary materials needed to complete the system (Plants, pipes, clay pellets, buckets, etc.) and built the final prototype using our materials. In addition to this, we would have taken the client's feedback from our third client meeting and implemented it into the final design, this mostly deciding the logistics and testing the three-reservoir composting system. Had these steps been able to take place, the final prototype would have been presented on design day, and eventually transported to the people of Barriere Lake.

9 Bibliography

1. "N.F.T. (Nutrient Film Technique) System." *Hydroponic N.F.T. Systems*, www.homehydrosystems.com/hydroponic-systems/nft_systems.html.
2. "Basic Hydroponic Systems and How They Work." https://www.simplyhydro.com/system/

APPENDICES

APPENDIX I: User Manual

The following section includes a list of parts, information on the features of the product, and instructions on how to construct it.

Hydroponic System Features

- ❏ 8 PVC pipes
    - ❏ 4 pipes on either side of the wood frame
    - ❏ 8 plant holes per pipe
- ❏ Wood frame
    - ❏ 4 wooden steps on either side of the wood frame for the placement of PVC pipes
- ❏ 3 containers
    - ❏ 1 container for water collection
    - ❏ 1 container for compost
    - ❏ 1 container for nutrient solution used in circulation
- ❏ Pump system
    - ❏ 120V pump
    - ❏ 12V to 110V step up converter
    - ❏ Solar panels
    - ❏ Connective tubing

Installation Instructions

1. Begin by ensuring that there are all of the items listed above. Continue placing the wood frame right side up. Ensure that there are four wooden blocks that attach to either side of the two wood pillars.
2. Place the 8 PVC pipes on the blocks at an angle. Refer to Figure 23. Connect the pipes with separate piping that must be cut to size and to ensure that there is no leakage. The skeleton of the system is constructed.
3. Connect the pipes at the bottom to tubing that attaches to the nutrient solution container. Place the pump in the same container and extend the tubing attached to the pump up to the top PVC pipes to expel into.
4. Allow the greenhouse gutters to lead water into the water collection container. The water collection container should be elevated above the nutrient solution container ensuring it is gravity fed. Attach the water collection container to the nutrient solution container with valved tubing so as to regulate the amount of liquid in the container.
5. Ensure that the compost container is situated above the nutrient solution container. Connect the two containers. Do not connect the water collection container and the compost container.
6. Attach the solar panel to the roof of the greenhouse and ensure that it is connected to the step up converter, which should be connected to the pump.
7. Once the power is connected. Place water into the nutrient solution container and test if the system is closed. Make adjustments where necessary to fix leakage. When the system is working with water, you may introduce the necessary solutions into the designated containers.

APPENDIX II: Design Files

Link to MakerRepo: https://makerepo.com/Joe5125/gng-1103-hydroponics-baddies