GNG 1103

Design Project User and Product Manual

Deep Water Culture Hydroponic System

Submitted by:

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Table 1. Acronyms

Acronym	Definition
DWC	Deep Water Culture - A type of Hydroponic plantation system
PVC	Polyvinyl Chloride - A material used for pipes
UPM	User and Product Manual

Table 2. Glossary

Term	Acronym	Definition
Deep Water Culture	DWC	A type of hydroponic plantation system.
Elbow Fitting	/	A piece of PVC that is shaped like an L. Is places on the ends of PVC pipes

		to redirect the fluid in a direction 90 degrees to the initial direction.
Hydroponic	/	A plantation system using sand, gravel, water, or clay pebbles.
Modular	/	A system that employs modules or sections as a base of its design.
Plug Plant	/	Seedlings that have begun the growing process in small plug-shaped trays. Allows for easy transplantation.
Polyethylene	/	The material that the plastic walls of the greenhouse are made of.
Polyvinyl Chloride	PVC	A material used for pipes.
Stopcock	/	The part of a PVC valve that is turned to either stop or allow fluid to flow through the valve.
Strapping	/	A thin strip of metal screwed into the walls of the greenhouse. Used to mount the PVC piping along the walls.

Styrofoam	/	The name of the brand that specializes in polystyrene materials, used synonymously with polystyrene itself.
Tee Fitting	/	A piece of PVC shaped like a T. Is placed on the ends of PVC pipes to split the flow of the fluid into two directions.

1 Introduction

This hydroponic system was developed while working with a client looking to acquire food sovereignty by the use of greenhouses that are user-friendly, low-cost and durable. The final design was the product seen here today, a two-reservoir Deep Water Culture system that allows for multiple methods to fill up the containers. The system is a low-height modular structure composed primarily of two plastic reservoirs with holes cut near the bottom to allow for a drainage system, a piping system to allow water to flow in from an external rainwater reservoir, and a solar powered air pump. This system is designed to be user-friendly and usable for ages 5+, however there are sections that may be sharp if damaged.

This User and Product Manual (UPM) provides the information necessary for anyone ages 5 and older to effectively use the Deep Water Culture (DWC) System and for prototype documentation.

2 Overview

There is a need for indigenous communities and farm acreages to acquire food sovereignty by the use of greenhouses that are user-friendly, low-cost and durable. The food produced should be organic and the utilization of the greenhouse should be sustainable.

The indigenous peoples need access to food even in times or climates that may not accommodate this need. This in turn creates a need for a system or structure that can integrate the option to plant a variety of foods and plantation shelter.

This DWC system is extremely simple to use. It was designed to allow for users from age 5 to operate it, and is completely modular as well to adapt to different environments. The solar power option is also a feature that can compensate for no-power regions or power outages. The drainage section of the system can also allow for nutrient solution recycling, as well as composting the waste and dead roots from the growing plants.

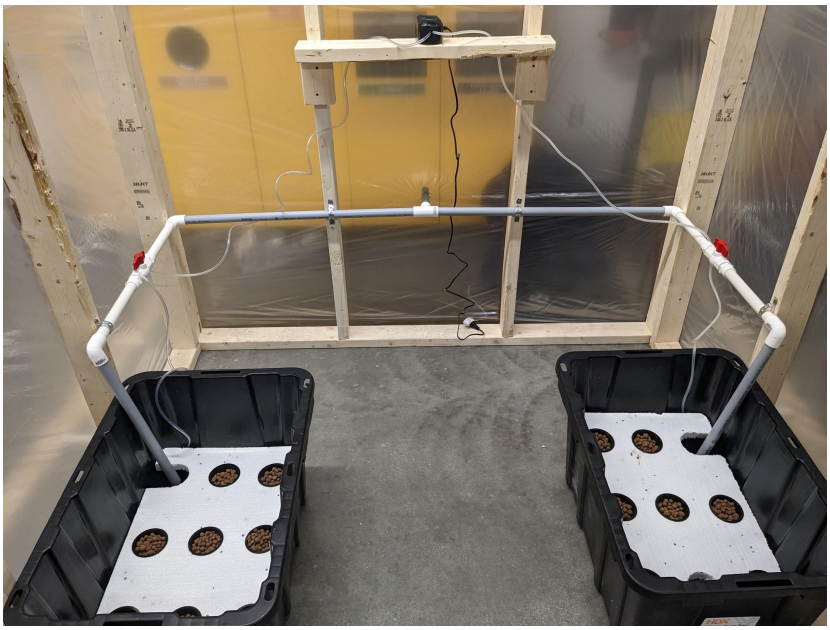

Figure 1: General view of hydroponic system.

Figure 2: View of hydroponic reservoir filled with water.

There are 3 key features with this system. The first is that the solar cell allows for the user to use any form or length of extension cord to connect it to the air pump which lets the user place the air pump anywhere convenient for them. The second is that the PVC valves are located low enough in the system that anyone can reach and use them, and once affixed properly, do not require a lot of effort to turn. The final key feature is that the inside of the reservoirs have a brightly painted strip that, when the foam board goes below a certain level, clearly indicates to the user that the reservoir needs to be refilled.

The hydroponics reservoirs and net pots are composed of dark plastic. Within each reservoir, there is an air stone connected to plastic tubing. The board that houses the net pots is composed of styrofoam. All piping in this product is composed of PVC.

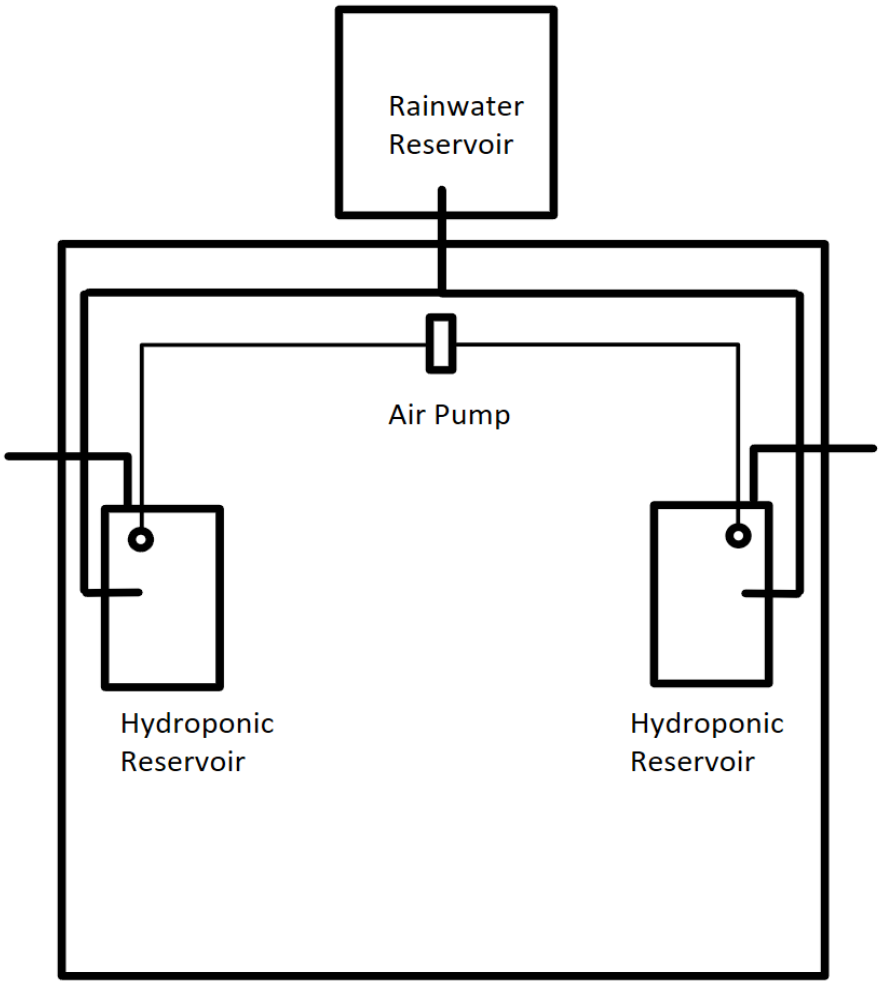

Figure 3: Diagram of hydroponic system.

2.1 Conventions

✶ The six-pointed red star indicates that the following sentence(s) is (are) important.

💡 The lightbulb indicates that the following sentence is a tip to make an action easier.

2.2 Cautions & Warnings

The air pump that has been used with this system stays on while it is plugged in. When you want to turn off the system completely, make sure to unplug the air pump as well.

Make sure to completely affix the PVC pipes before testing the valves, as the system is light enough that the pipes may twist

3 Getting started

3.1 Configuration Considerations

Once fully set up, the interior of the greenhouse will be spacious. There will be a walkway that extends to the back wall of the greenhouse. There will be some components situated directly on the ground. Other components will be mounted onto the walls of the greenhouse.

3.2 User Access Considerations

The two drainage pipes will be located at ground-level. This may cause difficulties for those who have trouble bending down.

The air pump is located on a wooden plank mounted on the wall. It is about three feet high, so some young users may have difficulty accessing it.

3.3 Accessing/setting up the System

Refer to figure 1 to see what the final setup should look like.

3.3.1 Installing the Drainage Pipes

Figure 4: Final assembly of drainage pipe.

Figure 5: View of the drainage pipe inside the greenhouse.

Obtain both hydroponic reservoirs and place them so that the pieces of PVC that extend out of the bottom of each reservoir are facing the back wall of the greenhouse.

Obtain two elbow fittings and the two smallest pieces of white PVC piping. Place the elbow fitting on the ends of each PVC piping that extends out of the reservoirs. Then, connect the small PVC pipings to the other end of the elbow fitting.

Obtain the two pieces of PVC piping that are labeled to go with the drainage piping and two PVC valves. Attach one piece of PVC piping to each valve, then connect the other end of each valve to the piping leading out of the hydroponic reservoirs. Simply slide the drainage piping under the polyethylene walls of the greenhouse; holes can be cut in the walls of the greenhouse after the water reception pipe has been installed.

3.3.2 Installing the water reception

Begin by placing the rainwater reservoir on the stool. Insert the PVC that extends out of the

bottom of the reservoir through the wall and into the greenhouse.

Next, place a PVC tee fitting on the end of the PVC that extends out of the rainwater reservoir.

Note from figure 1 that the sections of the water reception piping alternate between gray and white. Obtain the 2 long pieces of gray PVC and slide them through the strapping on the back wall and connect them to the tee fitting.

Add an elbow fitting to the ends of each of the gray PVC pipes.

Take the remaining four white pieces of PVC and organize them into pairs. Each pair should have one longer piece and one shorter piece.

To the remaining two PVC valves, place one shorter piece to one side of the valve and one longer piece to the other side of the valve.

First slide the longer side of each assembled rod through the strappings on the sides of the greenhouse. Then, connect the shorter pieces to the elbow fitting that was placed on the gray PVC pipes.

Place the final two elbow fittings onto the ends of the newly installed pipes.

Insert the final two gray pieces of PVC into the elbow fittings and pivot the piping into the hydroponic reservoirs.

3.3.3 Installing the Aeration System

Place the air pump on top of the wooden plank that is mounted on the back wall of the greenhouse.

Obtain the two lengths of tubing and the two air stones. Insert one end of each tubing into the two air outlets on the front of the air stone. Insert the air stones into the other ends of the tubing. Some force may be required to make these connections.

Feed the tubings around the airstone mount and pipings as shown in figure 1.

Plug the airstone into the power outlet that is being used.

3.3.4 Installing the Styrofoam Boards

On each styrofoam board, locate the hole that is pill-shaped and extends all the way out to the edge of the board. Place the water reception piping in that hole as shown in the following figure:

Figure 6: Demonstration of how the piping should fit into the designated hole in the styrofoam board.

Arrange the air tubings so that they fit comfortably in the recessed portion of the reservoir as shown in the following figure:

Figure 7: Demonstration of how the air tubing should be arranged when the foam board is placed in the reservoir.

Place seven net pots in one foam board and eight in the other.

3.4 System Organization & Navigation

The main component of the system are the hydroponic reservoirs. All other components are to allow the reservoirs to function properly. Other components such as water and air are connected to the reservoir with piping and tubing.

3.4.1 Features of the Piping

The pipes that are connected to the rainwater reservoir have valves that can stop or allow water to flow from the rainwater reservoir into the hydroponic reservoir. When the drainage pipe valves are open, water is easily removed from the reservoirs.

Since the fittings are not cemented into place, they can be easily disassembled at any time in case it is desired to move the hydroponics reservoir for maintenance.

3.4.2 Features of the Aeration System

There are various intensities of aeration that can be set by the air pump. This allows for fine tuning the oxygen output for the specific type of plant that is being grown.

The air pump is located above the water reservoirs. This greatly reduces the likelihood of water rising into the air tubing and reducing the effectiveness of the aeration system.

3.5 Exiting the System

When finished using the system, make sure that all four valves are in the closed position. Water should not be left flowing when the system is unattended; all of the water may be drained out, or the water may overflow onto the floor of the greenhouse.

Be sure to unplug the air pump before leaving the system. If the air pump is left on while unattended the water may become over oxygenated. This can stunt the growth of the plants.

4 Using the System

The following subsections provide detailed, step-by-step instructions on how to use the various functions or features of the hydroponics system.

4.1 Operating the PVC Valves

Turn the red stopcock in-line with the piping to allow the water to flow, and perpendicular to the piping to stop the flow of water.

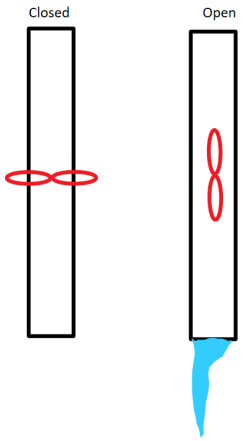

Figure 8: Closed state vs open state of valve.

When turning the stopcocks that control the flow of water from the rainwater reservoirs, there is enough support from the strappings to turn the stopcocks with one hand. However, when operating the stopcocks controlling the flow of drainage, place one hand on the piping and use the second hand to operate the stopcock. If only one hand is used, the caulking will receive a lot of stress and may tear.

Figure 9: Ideal grip when operating the stopcock on the drainage pipe.

4.2 Operating the Air Pump

The air pump has a circular dial on the back of it. Turning the dial will adjust the intensity of the bubbles. If the styrofoam board is hiding the bubbles, use the sound intensity of the air pump to gauge the intensity of air flow through the tubes.

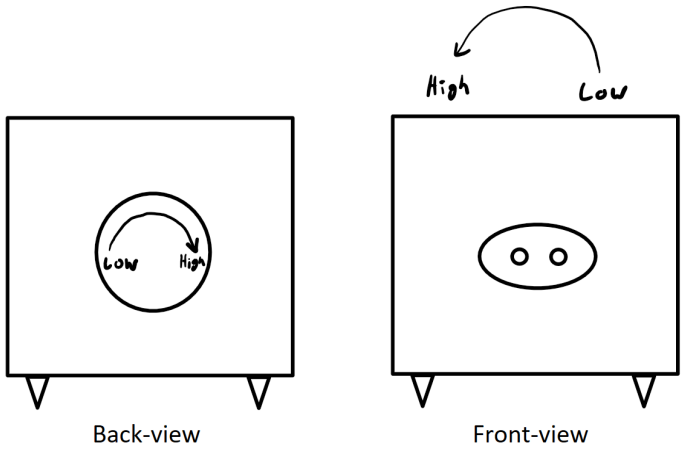

Figure 10: Direction of rotation for adjusting air pump intensity.

✶ The only way to turn off the air pump is by unplugging the pump from the outlet; turning the air pump all the way down will still leave air flowing through the tubes.

4.3 Freeing the Hydroponics Reservoir

For maintenance, it is required to remove the hydroponics reservoir from the piping. Before removing the reservoir, drain as much water as possible with the drainage pipe. This will make it so that only a small weight of water needs to be lifted and dumped.
After draining the water, detach the drainage pipe from the reservoir, remove the foam board, pivot the water reception pipe up and out of the reservoir, and slide the reservoir free from the piping.

Figure 11: Step-by-step images for freeing the hydroponics reservoir.

4.4 Adding Plants to the Net Pots

When adding plants to the net pots, it is recommended to purchase plug plants. Place a small amount of clay pebbles in the bottom of the net pot, insert the plug plant into the pot and surround the plug plant with enough clay pebbles to support it. Finally, place the pots back in the holes of the foam board.

Additional net pots may be purchased if needed. Each reservoir supports up to 8 net pots. If the plants grown require more root space, the surrounding net pots can be removed.

5 Troubleshooting & Support

5.1 Error Messages or Behaviors

If water appears outside of the reservoir, it is likely a leakage from the drainage pipe. Two suggestions for troubleshooting are epoxy and fiberglass tape. For fiberglass tape, ensure the area is damp but not wet, and apply the tape per the instruction on its packaging. If using epoxy, dry the area completely and apply per the instructions on its packaging.

5.2 Special Considerations

In case the drainage pipe is obstructed, it can be removed, allowing water to freely flow out. However, this must be done with caution. To do so, remove as much water as possible using a bucket or similar apparatus. Situate the reservoir in an area where water can flow without issue. Then, remove the drainage pipe (refer to section 4.3).

Ensure that when draining the reservoir, all electrical components are turned off and kept away from flowing water.e

WARNING: If the drainage pipe is removed while there is still water in the reservoir, the water will flow out uncontrollably. This should only be done as a last resort.

5.3 Maintenance

The reservoir should be cleaned once every one to two weeks to avoid debris buildup in the drainage pipe. This can be done by removing the air stone, emptying the reservoir (see 4.3) and wiping the bottom of the reservoir, clearing it of all dirt and debris.

5.4 Support

If there is a leakage, remove all electrical components and drain the reservoir. It is then recommended to contact your local hardware store for appropriate materials for troubleshooting.

6 Product Documentation

The final prototype was built based on specific considerations like water resistance and resistance to weather changes. For these reasons, our final product had to include materials that would respect our conditions.

- Mechanical components

PVC piping was selected over ABS piping as it is more resistant to UV exposure. ABS piping will warp under direct sunlight. However, it is possible to use ABS piping that has been painted with UV resistant chemicals.

For the water reservoirs, a black reservoir was preferred over a transparent reservoir, since it prevents/slows algae from forming. Since algae needs light to survive, a dark reservoir prevents this to be created inside the tank. Another alternative would be feasible if it could be kept in the dark, however, due to the placement of the greenhouse (outside). Also, since this plastic is non-biodegradable, this option is very durable, because it could last around 20 years, depending on the care given.

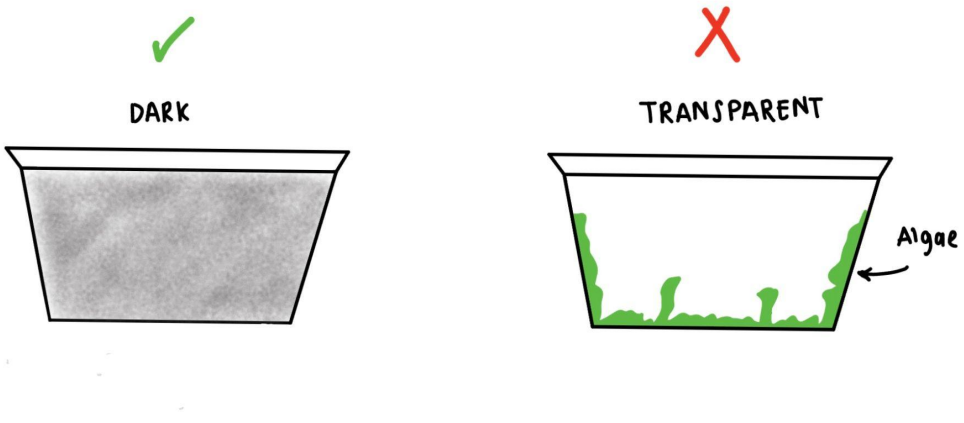

Figure 12: Difference between a dark and transparent reservoir.

For the lid, where the plants will be sitting, a styrofoam board was chosen instead of a plastic lid, because of its ability to float to adjust to different water levels. A plastic lid could also be used, but it wouldn't be able to adjust to the water level, possibly leaving the roots of the plants out of the water. One material that couldn't be used was a foam tray, that was too porous and would've sunk. Styrofoam is very durable, if taken good care of, because it does not decompose fast enough (almost 500 years).

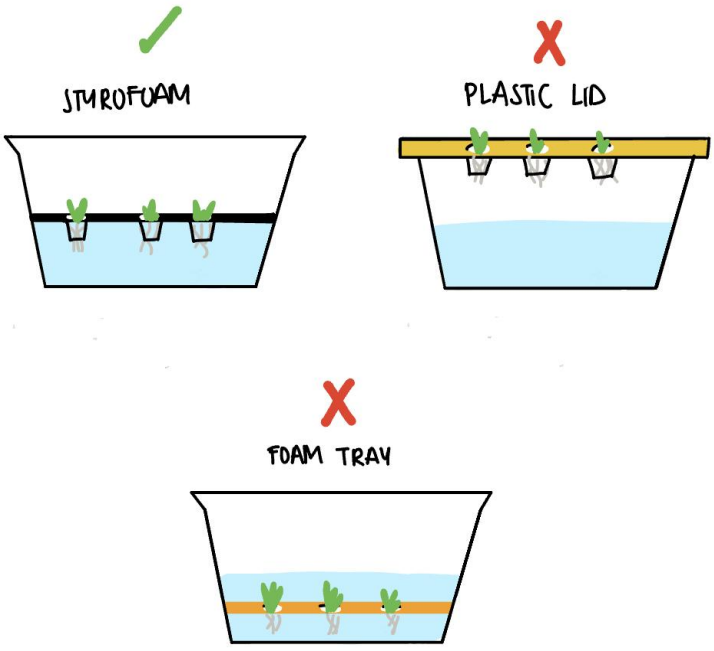

Figure 13: Difference between reservoir lids.

-Electrical components

To keep the water oxygenated, in order to keep the plants alive, a water pump is needed to move the water, for the plants' health and cleanliness. Because of our two systems, a water pump with two entries is needed to accommodate both systems. This option is more cost-efficient than buying two different air pumps, and also consumes less electricity. In a site where electricity is limited, and there is the need to use an alternative type of energy, having an electrical system that consumes less energy is favorable, so the solar panel or alternative energy has enough power to make both systems function.

6.1 Reservoir

6.1.1 BOM (Bill of Materials)

Item	Description	Unit Price	Units	Price
Reservoir bin	102L capacity	$15.00/bin	2	$30.00
Air pump	Pumps air into the reservoir to replenish oxygen used by the plants	$30.00/unit	1	$30.00
Net pots	Pots with rectangular holes in them which allow roots to grow out and into the water.	$15/15 pots	1	$15.00
Clay pellets	Inert material (does not affect pH) that is placed in net pots. Provide support for the plants.	$20.00/2.5L	1	$20.00
Foam Board	Polystyrene board that floats on the water with holes allowing the plants' roots to reach the water.	$15.00/8'x4'x1" board	1	$15.00
Vinyl Tubing	Tubing that connects the air pump to the air stone. 0.17" inside diameter, ¼" outside diameter.	$10/10'	1	$10.00
Total Price:				**$120.00**

6.1.2 Equipment list

To cut the holes and shape the foam boards, the following equipment was used:

- X-Acto knives
- Hot wire foam cutter
- Sharpie
- Measuring Tape
- Masking tape

To drill the holes in the reservoir, the following equipment was used:

- 1¼" hole saw
- Power drill

For the caulking of the points of PVC piping entry, the following equipment was used:

- Tube of silicone caulking
- Caulking gun
- Latex gloves (spreading caulking around hole)
- Glass of water (for making caulking more spreadable)
- Small piece of wood (to mount PVC when drying)
- Paper towels

6.1.3 Instructions

Cutting the styrofoam board:

1. On the styrofoam board, draw a box that is similar to the reservoir footprint but about an inch shorter in both dimensions.
2. Using an X-Acto knife or a hot wire foam cutter, cut out the drawn boxes
3. Divide each side length of the foam board into three sections and form a grid with the masking tape and drawn guidelines
4. In the center of each cell, trace a 3 inch circle.

   💡 It was found that the inner ring of the masking tape was the perfect diameter

5. Cut all 9 holes out of the foam board.
6. Make the following final cuts in the foam board for the water reception piping (red) and for a better fit into the hydroponic reservoirs (blue):

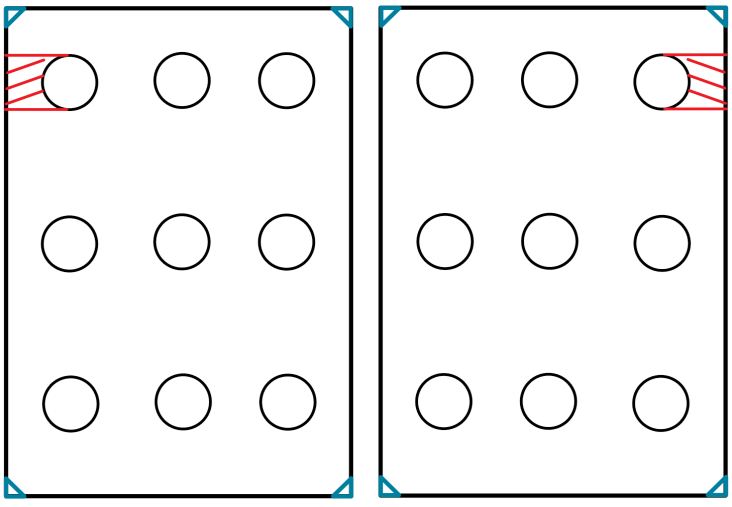

Figure 14: Final cuts to be made in the foam boards (highlighted in red and blue)

Installing the PVC piping entry:

1. With a 1¼” hole saw and power drill, create two holes in the center-bottom of each reservoir.

   💡 Select the height that you cut your hole based off of the height of the piece of wood that will be used to rest the PVC on. This will make the PVC perfectly flat when the caulking solidifies.

2. Insert the piece of PVC about one inch into the created hole.
3. Fill the glass of water, apply latex gloves and make sure that your caulking is flowing when the caulking gun is squeezed.
4. Apply a thick layer of caulking over the top of the hole. Then, wet your finger with latex gloves on and smear the caulking around the bottom of the hole.
5. Slide the small piece of wood under the PVC piping on the outside of the reservoir to maintain the position of the PVC piping.
6. Repeat this process on the inside of the hydroponic reservoir and the rainwater harvesting reservoir

6.2 Water Reception

6.2.1 BOM (Bill of Materials)

Item	Description	Unit Price	Units	Price
PVC piping ¾”	Piping 3/4 inches in diameter	$20.00/10’	2	$40.00
¾” valves	Check valves to stop backflow	$12.50/unit	4	$50.00
¾” PVC elbow fitting	90 degree PVC elbow fitting	$2.50/unit	6	$15.00
¾” PVC tee	Splits the flow of the fluid in the PVC into two directions	$5.00/unit	1	$5.00
¾” Male PVC adapter	For connecting pipes to valve	~$2.00/unit	8	$15.00
Total Price:				**$125.00**

6.2.2 Equipment list

- Miter Saw
- Sharpie
- Measuring tape
- Scissors

6.2.3 Instructions

Cutting the rainwater reception piping:

1. With the sharpie, measure out the distance between the center of the back wall to the edge of the back wall. Mark that distance twice on a length of PVC.
2. Measure the distance from the edge of the back wall to the first support beam on each side of the greenhouse. Mark that distance twice on a length of PVC.
3. Measure the distance from where the styrofoam board stops in the reservoir to where the PVC piping will bend towards the reservoir. Mark that distance on a length of PVC.
4. With the miter saw, cut the PVC piping at all sharpie markings.
5. Assemble as stated in section 3.3.2.

Installing the metal strapping:

1. Bend the metal strapping into the shape of the PVC piping.
2. Place PVC piping against the wooden beam with the strapping around it
3. With a screw, mark where the two screws will be drilled into the wall to secure the strapping in place.
4. Screw in each screw halfway, then slowly screw them in all the way

✶ If you drill in the screw too fast, the strapping will spin and deform.

Cuts for the drainage piping:

1. Mark 4 sections in a length of PVC that are about 4” long and two that are about 18” long.
2. Cut these pieces out with a miter saw.
3. Assemble as stated in section 3.3.1
4. To create the cut in the polyethylene wall, simply pinch the wall at the desired area of the cut and cut a straight line. Then pinch again to make a second cut forming a cross-shaped cut.

6.3 Solar Energy

6.2.1 BOM (Bill of Materials)

Item	Description	Unit Price	Units	Price
22W solar panel with charge controller	Primary power source	$135.00/panel	1	$135.00
Charge controller cable	Cable to connect controller to battery	$25.00/unit	1	$25.00
Battery	12 Volt, 20 Ah	$120.00/unit	1	$120.00
Power inverter	Converts DC input to AC input for air pump usage	$30.00/unit	1	$30.00
Inverter adapter	Adapter to connect battery to inverter	$20.00/unit	1	$20.00
Total Price:				**$330.00**

6.3.2 Equipment list

To attach cables to and from the battery, the following equipment is needed:

- Phillips Head screwdriver
- Battery bolts
- Heat gun
- Wire crimper
- Heat shrink connectors

6.3.3 Instructions

1. Attach the charge controller cables to the positive and negative terminals of the solar charge controller as per the instructions provided with the charge controller
    a. Typically, the cable is inserted in the terminal and a screwdriver is needed to keep the cable in place. However, if the instructions provided by the manufacturer differ, the manufacturer instructions take precedence.
2. Attach the other side of the charge controller cable (with the ring terminals) to the battery
    a. The instructions differ depending on the type of terminal the battery has, which should come with the battery. Typically, a battery bolt is needed.
    b. Attach the negative terminal first (black), then the positive (red).

3. Repeat the above step with the inverter adapter cable.
4. Plug the inverter into the inverter adapter cable
5. Attach the charge controller to the solar panel using the included cable
6. Move the solar panel into an area with direct sunlight
7. Appliances can then be plugged into the outlets on the power inverter

✶ Do not attach the charge controller to the solar panel before the battery as it will damage the charge controller!

✶ If the terminals are not compatible, a heat gun, heat shrink connectors and a wire crimper can be used to attach wires to an appropriate terminal before attaching to battery. The steps are as follows:
Place the exposed wire into the heat shrink connector and follow the manufacturer's instruction to choose the appropriate crimp strength. After crimping, use the heat gun to ensure that the connector is tightly stuck to the cable.

6.4 Testing & Validation

6.4.1 Testing That Took Place

The prototype was filled with water to test for any leakage around the PVC fittings and the caulking jobs. Water was also added to determine how the foam board will float on the water and how much water the drainage pipe will be able to remove from the hydroponics reservoir. Stress was also applied to the caulking jobs to see if they would tear.

6.4.2 Results from Testing

It was discovered that there was no leakage from the PVC fittings or the caulking jobs.

There was concern that the net pots would push out of the holes in the foam boards when the foam boards began floating, but this was not the case; the net pots stayed in position.

It was discovered that there was about one inch of water that could not be emptied by the drainage pipe. However, this was not a concern since the reservoir has to be removed and washed regularly anyways.
A significant amount of stress was put on the caulking of the drainage pipe during testing, however this did not tear the caulking.

7 Conclusions and Recommendations for Future Work

For a system that can be used year round, a heating subsystem can be added, given that electricity is available either through an external source or a solar energy subsystem.

As well, it is possible to implement a water “recycling” system where the water drained out of the reservoir can be filtered for dirt and debris, then routed back into the reservoir so that remaining nutrients can still be used. However, this involves the elevation of water and thus requires a pump that uses electricity.

It is important to keep in mind the energy consumption of the appliances so an appropriately sized battery and solar panel can be chosen.

8 Bibliography

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Grow Your Own Plug Plants. (n.d.). GrowVeg. Retrieved April 11, 2023, from https://www.growveg.com/guides/grow-your-own-plug-plants/#:~:text=Plug%20plants%20are%20seedlings%20which

9 APPENDIX I: Design Files

Table 3. Referenced Documents

Document Name	Document Location and/or URL	Issuance Date
Project Deliverable B: Needs Identification and Problem Statement	https://docs.google.com/document/d/13UChGSboGGyiKNQbfn6Tny2ob3SLX8OmwFoaDdi3T3s/edit	January 29, 2023
Project Deliverable F: Prototype 1 and Customer Feedback	https://docs.google.com/document/d/1DjIgzZ3PI9PqI0zI5VWlb9171G1qOUEsyBWBSEnqrvA/edit#	March 5th, 2023
Deliverable G: Prototype II and Customer Feedback	https://docs.google.com/document/d/17gsih5rKF7VzmJFqQ31kk55JtXkGis1dTKO4gWr4Kkg/edit#	March 12, 2023
Deliverable H: Prototype III and Customer Feedback	https://docs.google.com/document/d/1SXCVmZnMNZhwDZm_EPor8c-u2Z0mGWqJyNa60OPeH48/edit#	March 26, 2023
Reservoir Box.stl	Available in MakerRepo project	April 11, 2023
Styrofoam board.stl	Available in MakerRepo project	April 11, 2023

Final Bill of Materials - Hydrasol	https://docs.google.com/document/d/182kqDNM9EFjxF543FXboXQd_niKEciToaPOB4MLsn8I/edit# Also available in MakerRepo project	April 11, 2023

MakerRepo Link:

https://makerepo.com/nichop/1494.gng-1103-hydroponics-project