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1 Problem Formulation

1.1 Objective Statement

Our objective, as a team, is to design and construct a simple and practical system for the New York WaterPod that is easily transported, user friendly, made with recycled materials, the over all cost as cheap as possible.

1.2 *Black Box Model*

Figure 1: Black Box Model.

2 Problem Analyses and Literature Review

2.1 Introduction

In order to find alternative solutions, we must first define and analyze the problem. Included below is a list of input and output variables with their own constraints. The literature review will help us further define and analyze such topics as hydroponics and aeroponics to what nutrients plants need to survive.

2.2 Problem Analysis

Input:

A design with plants that are growing unsuccessfully in their current settings.

Input Variables	**Input Constraints**
• Water supply	• The water supply will depend on the delivery system and how much the plants need.
• Plant growth	• The plant growth will depend on the nutrients given and how the plants will develop in the system.
• Sunlight exposure	• The sunlight exposure will depend on the weather in New York.
• Water delivery	• The water delivery will depend on the amount of water is used in the design and how the plants interact with the design.
• Water uptake	• The water uptake by the plants will depend on how they reach to the design.

• Educational value	• The design needs to show all ages how the system works and the plants grow.

Output

The design should successfully grow plants for the designated time period set by the WaterPod.

Output Variables	**Output Constraint**
• Plant growth	• Once plants are introduced into the system, growth should occur quickly and continue through growth.
• Educational value	• The design helps all ages understand hydroponic growing.
• Nutrient uptake	• The plants uptake the natural amount of nutrient solution for growth.
• Nutrient delivery	• The nutrient is delivered successfully and efficiently to the plants.

Solution

The possible areas the solution could vary are in design and functionality.

Solution Variables

- Method of construction
- Types of hydroponic system
- Type of plants
- Method of transport
- Size of project
- Size of crop
- Educational value

Solution Restrictions

- Different materials are available hydroponic grow systems.
- Built using mostly recycled materials.
- Deciding which solution best fits out criteria.
- The plants should be able to yield edible produce and thrive in the design solution.
- Shipped along with other classmates' projects in a crate, with limited dimensions.
- Must be able to fit in a greenhouse dome and be shipped to New York.
- The yield of the crop will depend on sunlight, water consumption, and how the plants interact with the design solution.
- The design needs to be able to be seen from the outside by visitors to the WaterPod.

Criteria	Constraints
• Cost • Size • Weight • Durability • Transportability • Ease of set up • Use of recycled materials • Design and construction time • Educational value • Level of energy efficiency	• Entire project must cost the team less than $300 dollars to construct. • Grow System must fit inside a 20 feet diameter dome that is 15 feet high. • Must weigh less than 200 pounds in order to ship to New York City. • Must sustain shipment to New York and daily use for 6 months. • Must be able to be shipped to New York and be moved around barge if needed. • Has to be easily reconstructed at the WaterPod in New York. • As much recycled material as possible. • The project must be designed and constructed in less than 4 months. • Needs to be designed well enough that viewers can understand the concept of the system. • The entire system should use the least amount of energy possible to still produce plants.

Usage

The solution must be able to be used for up to 6 months on the WaterPod barge.

Product Volume

The team will produce one prototype for growing plants with edible yields and educational value.

2.3 Literature Review

2.3.1 Introduction

The purpose of this literature review is to review topics regarding the design project.

2.3.2 Hydroponic System

There are five different types of hydroponics systems.   Hydroponic systems allow for two to ten times the amount yielded compared to regular soil growing (Brown 2009). There are wick systems, water cultures, drip systems, nutrient film techniques or Ebb and flow (Brown 2009).

There are many advantages of using hydroponics rather than typical soil based growing of plants. Hydroponic growing does not require fertilizer to be put into the plants. With this type of growing plants simply supplying the nutrients needed through the water. Hydroponics does not require cultivation, and requires a lot less effort to harvest. Hydroponic growing also does not require crop rotation, as there is no soil to lose fertility. Hydroponics has no chances to grow weeds with the different types of mediums it uses. Hydroponic systems tend to provide very uniform results without surprises. Without soil, hydroponics becomes a relatively very clean system of growing plants. The most important advantages of hydroponic designs are significantly larger yields, less labor required and better control over conditions of the plants and surroundings (Brown 2009).

Nutrient Film Technique

A nutrient film design provides nutrients to the plants via continuous flow of water underneath the root system. Plants are started in small rock cubes that are later introduced into the system for the rest of their life. The advantages to this technique are that it provides the plants with constant balance and optimum conditions for thriving plant growth. Nutrients can always be fed into the plants because of the constant flow. (Van Patten 2007). Disadvantages to this system are that if a malfunction in the pump occurs the plant can die very quickly due to the lack of nutrients (Brown 2009). It requires constant power, which can become a costly electrical bill. Requiring constant flow of the pumps can cause them to become clogged with nutrients and cleaning is required at times.

Ebb and Flow

The Ebb and flow system works by temporarily flooding the grow tray and draining back into the reservoir. The timer can go off multiple times depending on plant size. The nutrient reservoir pump is turned on and the nutrients flow into the trays and when turned off the solution flows back into a reservoir (Van Patten 2007). This system can be used with almost any type of medium. The advantages of this system are that no constant pumping or flowing of water in the system is required. Plants can still be maintained if a malfunction in the pump occurs. Disadvantages of this system are that pumps become clogged with the growing medium at times and must be cleaned (Brown 2009).

Wick System

A wick system consists of a bucket, a reservoir of nutrient solution, a wick, and a medium. The bucket is put onto top of the nutrient solution and the wicks hang down into the solution and nutrients are passed passively upwards towards the plants roots. This system can use perlite, vermiculite, or coconut mix as a growing medium (Brown 2009).

The advantages of a wick system are that water is passively transferred through the wick into the root area; this is a low energy demand system since no pumps are needed. The disadvantages of this system are that it requires a large amount of water and roots cannot always receive the right amount of nutrients through the wick (Brown 2009).

Drip System

Drip systems are the most used system in the world (Brown 2009). These systems work by a pump turning on and flowing a solution into multiple lines, which are small in diameter near the end so the solution drips onto the root system of each plant under a line.

There are non-recovery drip systems and recovery drip systems. Recovery drip systems have a run off route with a reserve tank that catches any runoff to be used again. Non-recovery systems don't try to catch the run off. Recovery systems are more efficient but can have a bigger shift in pH and nutrient levels than a non-recovery system (Brown 2009).

Water Culture/ Bubbler Aeroponics

A water culture system has the plant roots dipping into the nutrient solution. The solution is kept fresh with an aerator at the bottom. Lettuce grows very quickly in this system because lettuce is a water loving plants and therefore thrives in this system (Van Patten 2007).

An advantage of this system is that it can be easily made and designed with a low build cost. The roots have a chance to uptake nutrients at any time because of always having a supply to water. The main disadvantage of this system is root rot (Brown 2009).

In a bubbler aeroponic system the roots dangle in the nutrient solution, inside of the buckets or tubs. This system uses aerators to raise the oxygen concentration, which helps boost the plants growth. Aerators are used in fish tanks to keep the dissolved oxygen levels in the water high enough for fish to survive. Spray nozzles can be additionally set up along with the aerators for optimal the conditions.

2.3.3 Aeroponics

Aeroponics is a growing technique, which no mediums, such as soil, peat, rock wool, or perlite, are used to grow the plants. The plants are at the top of the system, in small wholes cut into the lid or top of pipe. The roots are suspended below inside of the tube or growing tub, depending on which type of design that is chosen. A device that mists the roots with water, allows the plants to get plenty of oxygen as they acquire the nutrients essential for their growth. In some cases, other watering techniques are incorporated into the system. This allows the roots to grow freely in a high oxygen environment (Carrol 2009).

The advantage to aeroponic growing is they use the least amount of water of any other system. Aeroponics can be incorporated along with any number of hydroponic systems as an addition of spray nozzles. There are a few problems that can occur while growing aeroponics. Major problems include root rot and pathogens. Pathogens can enter the plant through the solution, which can somehow become contaminated while the roots sit inside of the reservoir. Root rot can occur if the solution that the roots sit in is not aerated enough. Root rot is always lethal to the plant, if not caught early (Sweat).

True Aeroponics System

In a true aeroponics system plants are placed into holes cut into long pipes, with misters on the inside of a pipe. The pipe is at a slight angle allowing the excess nutrients to exit the tube in between each mist. This system allows the plant to only come in contact with the top of the system, which is supporting the plant, reducing the chances of the plants becoming diseased. A pump powers the mister, which is usually set on a timer that regulates how often the plants are watered, but can be left on at all times (Carrol 2009).

Deep Flow System

A deep flow system is very similar to the True Aeroponics System, with one exception. The tube does not allow all of the nutrients to flow out of the system between mists. Instead, there is a small reservoir allowing the tips of the roots to always be submerged in solution. This set-up can also double as a way to save the plants just in case of some malfunction in the system or a loss of energy. The only disadvantages to this system are an increased chance of root rot or of pathogens entering the plant through nutrient solution (Carrol 2009).

2.3.4 Water Consumption

Wick System

The water consumption of a wick system will depend on the system size. The wick system will use the most amount of water because the wick has to be submerged at least sixty percent of the way, some growers record that their six inch plants require a quart of water a day on a wick system (Brown 2009).

Nutrient Flow System

The nutrient flow system will require constant flow of nutrients under the roots but the solution will be drained and re-entered back into the system. The water in the nutrient film technique must be changed every couple days when first planted because the nutrient solution will become dirty with rinsing the medium. After the medium has been cleaned then the water replacement will be replaced less often (Brown 2009).

Ebb & Flow System

Ebb & flow systems have a tank nutrient reservoir which is used to flood the roots then the nutrients return to this system or just runoff to be disposed off. When the roots are flooded, the water consumption can be quite large but the solution drains back into the reservoir to maintain the water level (Wilson 2008). The solution must be changed about every week and replaced with a new nutrient solution.

Drip System

A drip system can be the most water efficient system if set up properly. A pump turns on in this system and which allows the nutrient solution to flow into drip lines, which do not use a large amount of water (Wilson 2008).

Water Culture/ Bubbler Aeroponics

Water culture systems sit on a large nutrient reservoir and the roots hang directly into the nutrient bath. An aerator is placed in the bottom of the nutrient reservoir so that the nutrients won't settle. The water must be replaced in a system like this every two weeks (Brown 2009).

True Aeroponics

The water consumption of a true aeroponics system will be by far the lowest of all the choices. The reason for this is because the misters set up around that plant all such a small amount of water to come out at a time. This system also does not have to run continuously, allow the amount of water waste to a minimal amount.

The Deep Flow Aeroponic System

The deep flow system will use more water than the true aeroponics system, but will still use considerable less than a regular hydroponics system. The yield may be slightly larger than, but comes with a higher chance of having problems. These problems include things such as root rot or plant harming pathogens, which can be transferred to the plants through the water that the roots sit in.

Compared to the water consumption of soil grown plants and those grown in a hydroponics system, the aeroponics system uses substantially less water (Van Patten 2007). In order to produce a kilogram of tomatoes using traditional land cultivation, 200-400 liters of water is required. Most hydroponic systems only require about 70 liters to produce a kilogram of tomatoes and an aeroponic system would use only about 20 liters for a kilogram of tomatoes (Synergy International Inc 2008).

2.3.5 Plant Yield

Aeroponics and Hydroponics both have a higher yield than soil growing methods. Aeroponics has a chance of producing a plant yield of 85 pounds per square meter for a year of growing (Trendgrinder 1994). Hydroponic systems have yielded 78 pounds per square meter (Parker 1994).   Tomatoes grown in just soil tend to have a yield closer to 56 pounds per square meter (Hemphill 2008).

2.3.6 Soilless Mediums

Perlite

The main use of perlite is as a soil additive to increase aeration and draining of the medium. Perlite is a mined material that looks like popcorn because as water vaporizes it makes many tiny bubbles in the mineral. Perlite is one of the best hydroponic growing mediums around because it can be used by itself or as a mixture with other mediums. Perlite is commonly used as one of the major ingredients of soilless mixes. (Brown 2009)

Perlite is relatively inexpensive and is easily combined in other soil mixtures. A disadvantage of using perlite is the fact that it does not retain water and dries the roots out quickly without water. The dust from perlite is bad for human health so wear a dust mask when handling it (Brown 2009).

Vermiculite

Vermiculite is a mined material. Vermiculite is most frequently used in conjunction with perlite as the two complement each other well. Vermiculite retains moisture up to two hundred percent by weight. A half and half mixture of vermiculite and perlite is a very popular medium for today's hydroponic systems (Brown 2009). Vermiculite is inexpensive to the consumer. The major drawback of vermiculite is that it retains too much water to be used alone. It can suffocate the roots of plants if used straight.

Coconut Fiber

Coconut fiber is rapidly becoming one of the most popular growing mediums in the world. It is the first totally organic growing medium. Coconut fiber is essentially a waste product of the coconut industry.

There are many advantages to using coconut fiber. It can hold large amounts of oxygen, is also rich in root stimulating hormones, and offers some protection against root diseases, including fungus infestation (Brown 2009). A disadvantage of coconut fiber is that some qualities can have a higher salt concentration then preferred.

Rock Wool Cubes

Advantages of rock wool cubes include retaining water, cleanliness and convenience. These cubes can hold an incredible amount of water, which can help support plants for a couple days even without watering. Rock wool cubes can hold at least eighteen percent air at all times, even when sitting directly in water. Rock wool cubes are also easy to handle and hold together very well. (Brown 2009).

A disadvantage to using rock wool is that it is very hard to dispose of because they are not environment friendly. The pH can vary quickly, which causes for more routine checks on the system. The dusts that rock wool cubes produce are bad for human lungs in a long duration. Rock wool cubes must be pre-soaked for at least a twenty-four hour period before they can be used where other mediums can be used immediately (Brown 2009).

Metal Nets

Metal nets are widely used due to the inexpensiveness. These nets are constructed so that the spacing between individual wires are large enough for individual roots to pass through, but for the root wad and plant to stay on the outside of the misting section (Jason 2005).

Cheesecloth's

Cheesecloth's are used in the same way as metal nets. Cheesecloth's are used instead of metal sometimes because the clothes have more stretch ability then metal. A downside of cheesecloth's is that they are more expensive then other mediums (Jason 2005).

Wires

Wires are the most basic way to suspend the plant. This system consists of wrapping a wire around the base of the stem, right above the root wad, and suspending the plant by securing the wire. This method is used because it is fast and cheap. This method is not as favored as other mediums because the wire can sometimes restrict the growth of the plant (Jason 2005).

Rocks

Rocks or a rock basket are used rarely as growing mediums. This medium consists of the plant in a basket and surrounding the roots with rock. The main advantages of these systems are it is aesthetically appealing, and surrounds the roots with nutrients. The down side to this is more water is required in order to penetrate the rocks to reach the roots (Jason 2005).

Root Wedges

Root wedges are cone shaped devices that have a slice that runs latitudinal to the center of it. These wedges usually are made out of soft rubber or organic materials. The stem of the plant is inserted into the slice on the side and coaxed towards the middle of the wedge. Once in the middle of the wedge the plant is tightly secured. This system is good because it blocks any nutrient water from escaping past the roots and going upwards. In contrast this system a disadvantage is restriction of airflow to roots and restricts growth of the stalk (Jason 2005).

2.3.7 Analysis of Materials

The members of the Water pod group have all stressed that they want to use recycled materials whenever possible. The Aeroponics and hydroponics systems would both be able to be constructed from mostly recycled materials. A common system contains two water pumps, a storage tub for nutrient rich water, spray nozzles for the nutrients, housing for the plants to receive the nutrients, supports for the housing, and the plants.

Pumps

Common pumps that are used for the system are aquarium pumps and two-gallon submersible pumps (Darrin 2007). These pumps are used first to suck the nutrient saturated water from the reservoir tank and then a secondary pump is used to pressurize the fluid through the spray nozzles. These pumps are likely to be found recycled by old aquariums, old ponds, or old grow operations.

Storage Containers

Storage tubs are large tubs that store the nutrient rich solution. These tubs have two purposes. The first purpose is to have the nutrient water be pumped out of them to the plants and the second is to gather the water that is not absorbed by the plants. Commonly used tubs for this are 20-gallon storage totes. The darker the storage container is better because light let into the container would cause algae growth in the solution (Jason 2005). If no light gets into the water then it will be harder for harmful bacteria to grow in the solutions.

Spray Nozzles

Spray nozzles are used to distribute the nutrient water to the roots of the plants. There are commercial spray nozzles that can be bought specifically for growing plants. In addition to commercial products, an option is to simply puncture holes in a PVC pipe that contains pressurized nutrient solution. A common problem that occurs with the spray nozzles is clogging. (Darrin 2007) This is caused by the nutrients coagulating on the openings and not letting any water through.

Housing

Housing for the plants consists of an enclosed structure that contains only the roots of the plants. This material needs to be very waterproof because this is where the nutrient solution is introduced to the roots and then drains back to the storage tub. Common material that is used for this is copper pipe and PVC pipe.

Support

The support for the system is a foundation to keep the system off the ground and also make transportation easier. There are many different types of foundations for the systems. A common support for the system is wood. Pressure treated wood is commonly used because of its resistance to water and heat.

2.3.8 Analysis of Nutrient Needs for Plants

All plants need basic nutrients to survive even in hydroponic and aeroponic systems. Hydroponic systems use a medium instead of soils and aeroponics usually uses nets or some other type of holding device. All of the nutrients need to be in the solution that is sprayed directly onto the roots or pumped over the medium. The common nutrients that are needed for a plant to thrive are described below (Resh 1978).

Nitrogen

Nitrogen is part of Amino acids, proteins, chlorophyll, nucleic acids, and coenzymes. All of these compounds are vital parts to plants life. Without these compounds the plant will have stunted growth, delayed maturity, and light green leaves (Hudwon 1981).

Phosphorous

Phosphorous is used in proteins, nucleoproteins, metabolic transfer process, ATP, ADP, photosynthesis, and respiration. Without phosphorus the plants leaves will turn purple and there will be a reduction in yield from the plant (Hudwon 1981).

Potassium

Potassium is used in the formation of sugars and starches, synthesis of proteins, catalysts for enzyme reactions, neutralizes organic acids, and promotes growth of stematic tissue. Lack of potassium will result in reduced yields, spotted and curled leaves, week root systems, and marginal burning of the leaves (Hudwon 1981).

Calcium

Calcium is used in the cell walls of the plant, cell growth, cell division, and cofactor for some enzymes. Without calcium present the terminal leaves would become deformed, have reduced root growth, and dead spots would appear on the leaves (Hudwon 1981).

Magnesium

Magnesium is essential in chlorophyll, formation of amino acids and vitamins, and neutralizes organic acids. With lack of magnesium leaves may turn yellow and even be shed (Hudwon 1981).

Sulfur

Sulfur is essential in amino acids, vitamins, and flavor cruciferous in plants and onions. With a lack of sulfur, a plant may have light green leaves, reduced growth, weak stems, and yellowing leaves (Hudwon 1981).

Boron

Boron in plants affects flowering, pollen germination, fruiting, cell division, nitrogen metabolism, water relations, and hormone movement. A lack of boron in plants and their buds will die, lateral branches will begin to grow and the plants overall become brittle (Hudwon 1981).

Copper

Copper in plants is a constituent in enzymes, chlorophyll synthesis, catalyst for respiration, and assists in carbohydrate and protein metabolism. Without the proper amount of copper in the plants terminal leafs, buds begin to die, stunted growth results, and eventully terminal leaves die (Hudwon 1981).

Chlorine

Chlorine in plants aids in root and shoot growth. With lack of Chlorine in plant wilting occurs and leaves bronze (Hudwon 1981).

Iron

Iron in plants acts as a catalyst in the synthesis of the plants chlorophyll. Chlorophyll is involved in formation of compounds and many enzymes. With lack of Iron the leaves begin to yellow and chlorosis of veins begin (Hudwon 1981).

Manganese

Manganese in plants assists with chlorophyll synthesis and acts as a coenzyme. If a lack of manganese in a plants leaves occurs the plants leaves turn white and growth will be stunted (Hudwon 1981).

Molybdenum

Molybdenum is essential in some enzyme systems that reduce nitrogen and also is involved in protein synthesis. A lack of molybdenum in a plants system and it will become nitrogen deficient and leaves will become narrow (Hudwon 1981).

Zinc

Zinc is used in formation of auxins, chloroplast, and starches. Lacking zinc in a plant will cause abnormal root growth and mottled leaves will occur. These are the necessary nutrients that are needed for a plant to thrive. Most of these nutrients and minerals are all commonly found in many fertilizers (Hudwon 1981).

2.3.9 Analysis of Growing Climate in New York

The WaterPod project is scheduled to depart on May 1, 2009, the beginning of summer. The barge is scheduled to roam the waterways for six months then be terminated. The weather in New York can play a defining role in the effectiveness of our project.

The weather in New York during May consists of an average of 53-68 degrees Fahrenheit. The precipitation average during the month of May is 4.5 inches. This continues till July when it peaks at 68- 83 degrees Fahrenheit and has an average of 4.2 inches of rain. From July to October the temperature decreases with a minimum of 47 Fahrenheit. From the July to October the rainfall is continues with a deviation of about one inch. In the months of September and October arrive the temperature will fall below the recommended temperature for sustaining plants of 50 degrees Fahrenheit (Hartman 2009). All this can be seen in a chart form in Figure 1.

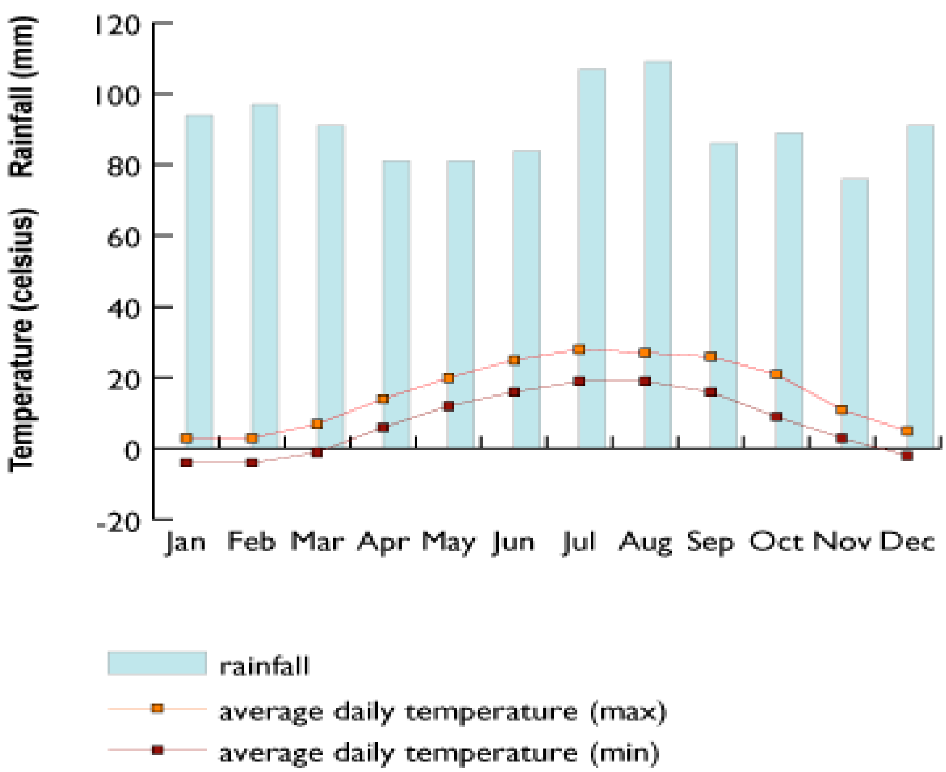


Figure 2: An annual chart of temperature and rainfall.

3 Alternative Design Solutions

3.1 Introduction

During this section the team brainstormed different needs for our project. Using these different needs we were able to compile a total of eight possible designs for our project. The following includes a discussion of the brainstorming sessions and list of alternative solutions, as well as explanations and figures explaining how these systems work.

3.2 Brainstorming

The team held two brainstorming sessions. The first of the two was a less formal session held in the campus library. It was a more informal brainstorming session in which each of us presented our ideas, and they were drawn on a whiteboard. We then split up, and brainstormed on our own time. Our second meeting was a compilation of all the information we had produced while apart. We shared our information with one another, and shared our own comments and criticisms. See Appendix A for brainstorming notes.

3.3 Alternative Solutions

3.3.1 The Continuous Flood and Drain

The continuous flood and drain hydroponic system, as seen in Figure 3, can be used to grow different plants with little human interaction. The continuous flood and drain system uses continuous water that flows along the roots of the plants to deliver nutrients. This design is composed of four or five boxes for growing in. These boxes is where to plants will be held and also were the nutrient solution will flow along the roots of the plants.

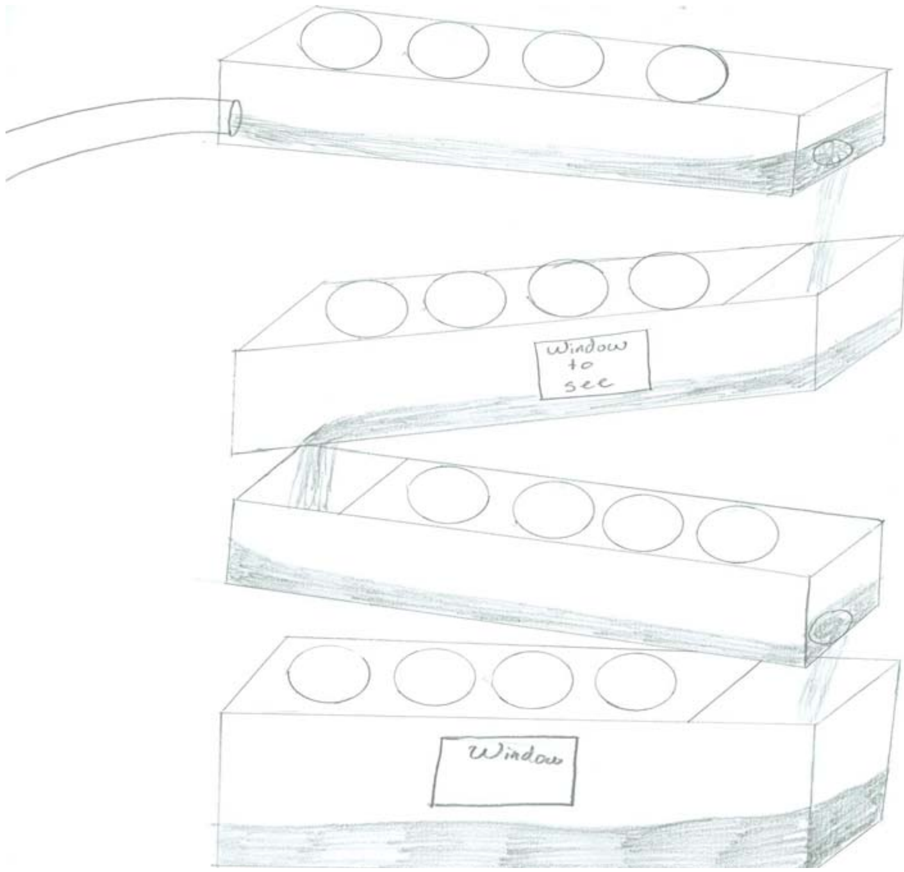


Figure 3: A continuous flood and drain hydroponic system.

A nutrient reservoir is used to provide the system with water and nutrients. This Nutrient reservoir accomplishes this by having a pump submerged in it. This pump will then create a constant flow of nutrients along the roots of the plants. The lowest box will be parallel with the ground and act as the drain part of the system. The above boxes will be slanted so the water will be gravity feed through the system. This system can be designed to reuse the nutrients or to just use them one time and then dispose of it. The windows main purpose is to act as a educational tool for people to see what is occurring inside of these boxes.

The continuous flood and drain system will be moderate in expensiveness to build and use a high amount of energy. This system is capable of using little amounts of water due to the fact that it can recycle the water for more runs. The yield for a continuous flood and drain is good because of the plants being able to get nutrients continuously. The nutrient solution that is needed for a system like this is identical to that of all other aeroponic and hydroponic system. Nutrient solutions that are commonly used for hydroponic and aeroponic system are usually any soluble fertilizer. The overall reliability of this project is good due to only having one pump and very little moving parts.

3.3.2 The Umbrella Aeroponics

The umbrella aeroponics design incorporates an umbrella shaped grow structure to hold the plants in. Nutrients are supplied to the plants through one or two spray nozzles. The structure and overall placement of this design can be seen in Figure 4. The nozzles will spray one to two times a day. This system uses a very small amount of water, due to the fact that water is not continuously being put on the plants roots.

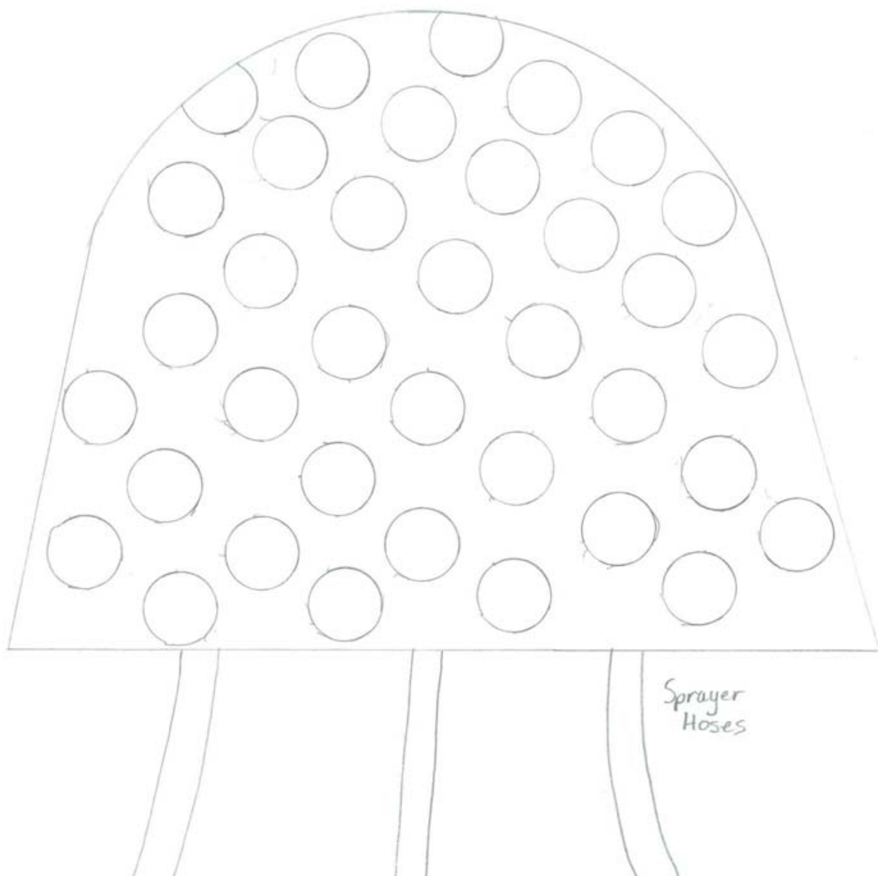


Figure 4: A frontal view of the umbrella aeroponics.

A solution reservoir is mounted next to the Bubble System. Inside this solution reservoir will be a water cooler, which keeps the solution at a constant temperature and a bubble rock to keep the nutrient solution mixed well and consistently. A high-pressure pump is attached to the bottom of the tank, removing and pressurizing, solution from the storage tank as needed. All of the devices will be able to be set on timers, allowing the system to run itself and the need to be tended to at a minimal. There is a window located on the side of this system that will allow people to see what is occurring on the interior of the design.

Umbrella Aeroponics will be moderate on electrical usage because of not having the pump continuously running. The yield from the plants will be also moderate from not having a constant flow of nutrients. Umbrella Aeroponics is expensive due to the fact that a high pressure pump is needed. In addition this system is not very reliable due to the fact that each hole has three sprayers and sprayers are able to clog. This will result in the system having to be shut down and cleaned.

3.3.3 Tree Hydroponic System

The tree system is identical to the octagon system in the way that nutrient is delivered. The difference is that instead of being built vertically it is built horizontal. This system resembles that of a three-step pyramid. On the highest step an octagon section would be position around the tree with a break in the PVC pipe so that the solution can enter and exit the system. On the next step down would be a slightly larger octagon row than the one before that would also fully surround the tree. Finally there would be one final row around the base of the tree. In essence this would be a three-staged pyramid that is built around the base of the tree. The tree is planned by the client to be planted in the middle of the green house. The workings of the design can be seen in Figure 9.

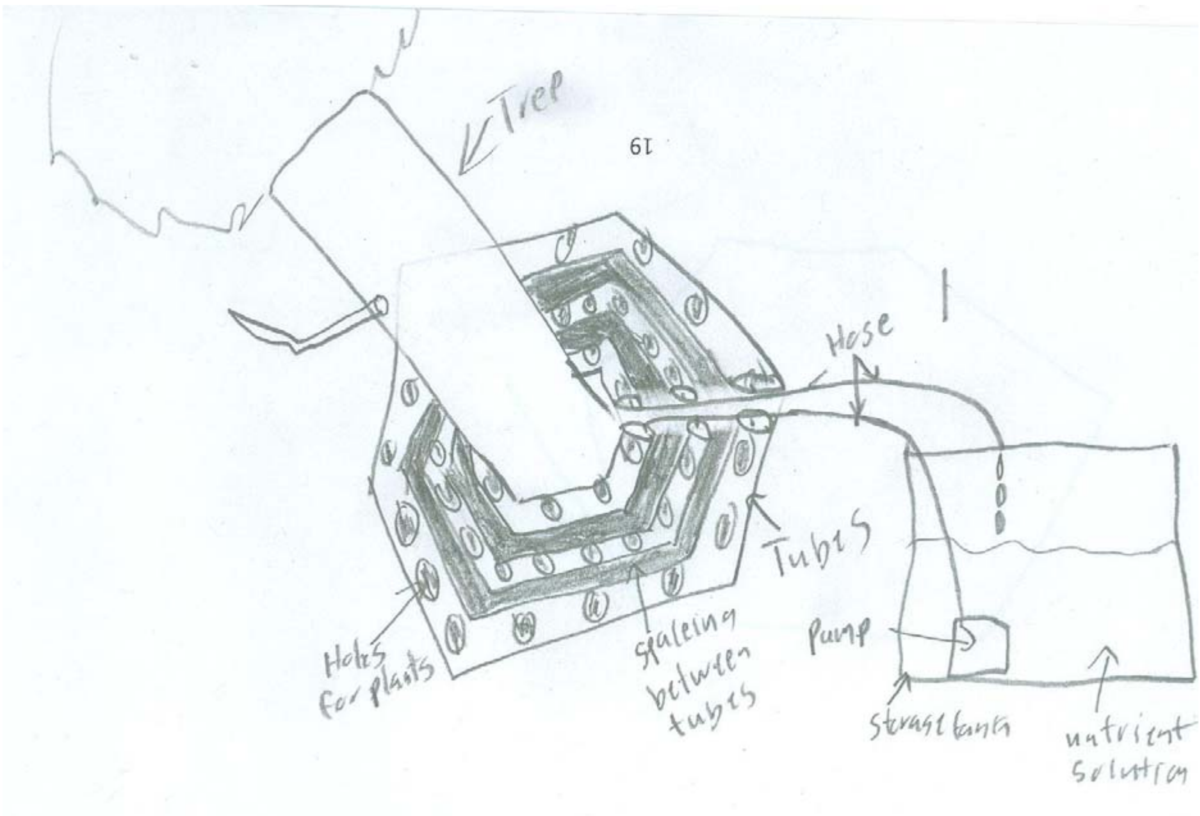


Figure 5: A birds-eye view of the tree hydroponic system.

A pump will be submerged in the nutrient solution that is stored inside of the tub. This pump will then siphon nutrient solution from the tub and pump nutrient solution up to the three separate rows through hoses. The nutrient solution flows up hoses and enter these PVC rows by watertight holes that are drilled in the caps on the ends of each row. All three rows are slightly tilted towards the right side so the solution will flow, due to gravity, to the drainage side as seen in Figure 5.

Once the solution enters each row it flows around the entire octagon shape, passing by each root and watering them. Once the nutrient solution has completed to octagon cycle, due to gravity it comes to the drainage side of the system. The solution is then drained back out of the system and into the nutrient solution tub, through hoses, to be reused. This entire process, other than the pumping, is due to gravity.

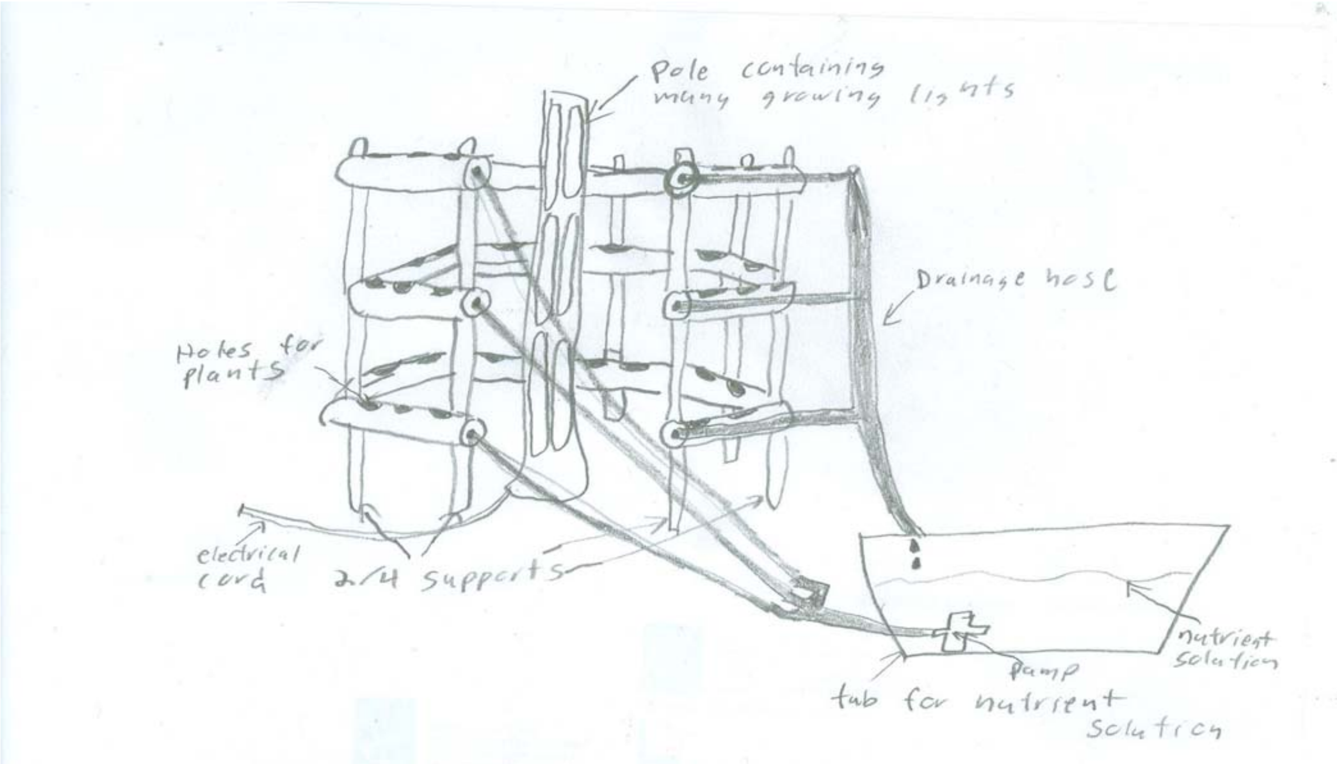
This system can also have a timer that will regulate the intervals on witch that the pump turns on. This supplies the plants with the right amount of nutrients per day. This system uses low amounts of electricity due to the fact that the pump does not need to be run continuously. The cost of the Tree System is low because there is little amount of material needed and a high-pressure pump is not needed.

3.3.4 The Octagon Hydroponic System

The Octagon Hydroponic System is comparable to the Tree Hydroponic system in the fact that is a hydroponic system in circular tubes. This system also contains a solution reservoir.   The solution container should be dark in order to reduce the amount of bacteria that could grow in it.   A pump will be submerged in the nutrient solution that is stored inside of the tub. This pump then siphons nutrient solution from the tub and pump nutrient solution up to the three separate rows through hoses.

The nutrient solution flows up hoses and enter these PVC rows by watertight holes that were drilled in the caps on the ends of each row. All three rows are slightly tilted to the right side. This tilt is put in place so the solution flows, due to gravity, to the drainage hole on the end. This design is shown in figure 6.

Figure 6: A side view of octagon design.



Once the solution enters the row it will flow around the entire octagon shape, watering each root, until it comes to the drainage side were the solution is drained back into the nutrient solution tub through hoses to be reused. This entire process, other than the pumping, is due to gravity.

The light pole in the middle of the system is used in order to supply the plants with ample amounts of light. The plants need the extra light do to the fact that they are stacked on top of each other.   By having the light in the middle each plant can get artificial light from its center and natural light from its outside.

The Octagon System uses more electricity than the Tree hydroponic system because the need for the solution to be pumped to a higher elevation. This results in the pump having to work harder resulting in more energy use. In addition the building cost of this system are high due to the huge amount of materials that are needed. The water usage should be moderate because the system is capable of recycling the water and using it for more that just one cycle.

3.3.5 The Bucket Aeroponic System

The bucket aeroponic system is meant to have a plant roots submerged in an ordinary 5-gallon bucket. Inside of this bucket a hose will be coiled around the roots and supply water to them. The Bucket system begins with a dark colored tub that is filled with a nutrient solution. Submerged in the solution is an electric pump. The pumps cord protrudes out the top of the container and plugs into an energy source. The pump siphons in nutrient solution and pumps the solution into a hose. This water would be ideally kept around 65 degrees. A general idea of the system can be seen in figure 7.

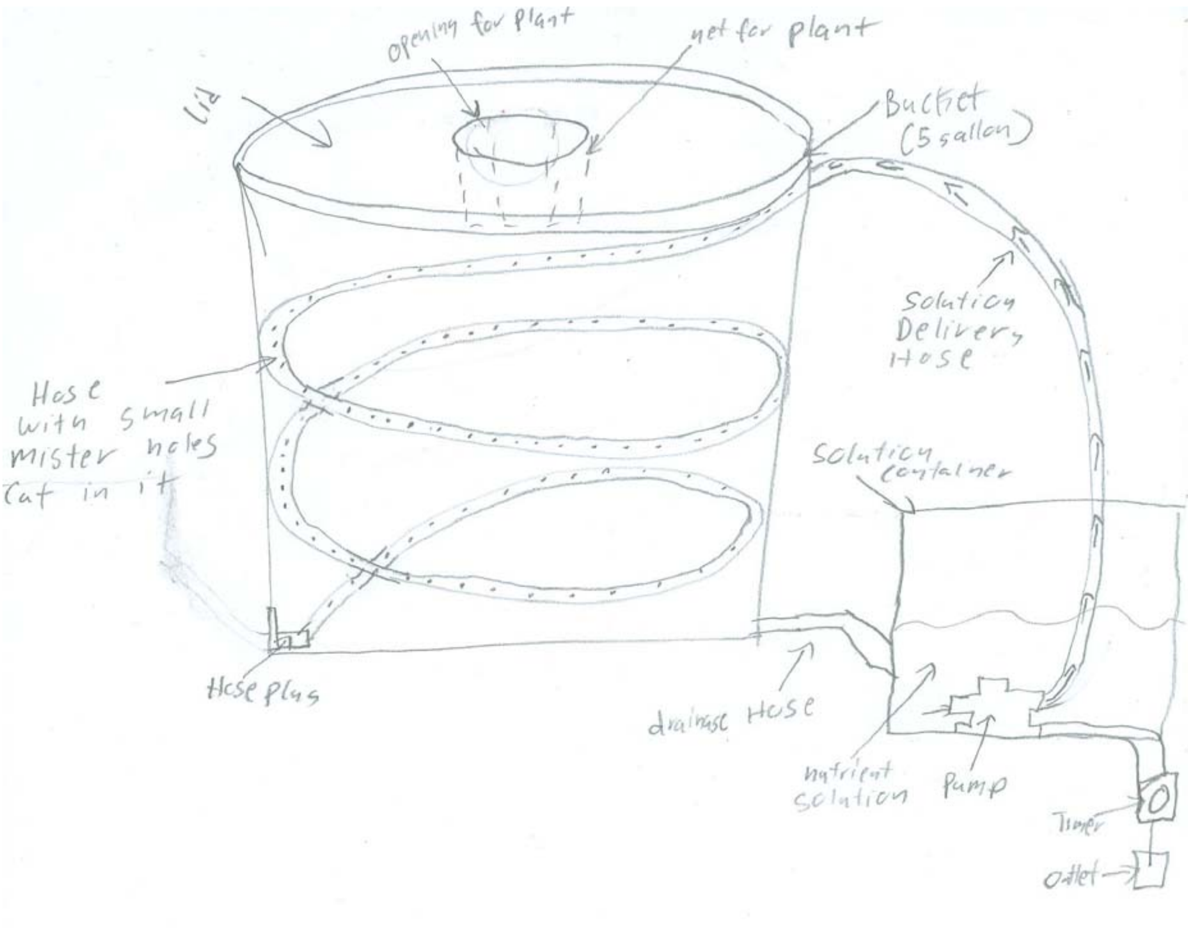


Figure 7: The front view of the bubble aeroponic design.

The hose enters the bucket through a hole drilled in the lid of the bucket. The tube does not just get pinched under the lid because the point is to try and keep as much light out of the bucket as possible. After entering the bucket the hose spirals down the sides until it hits the bottom where it is plugged to keep the pressure in the hose.

The roots of the plant will be in the middle of this spiral of hose that is shown in Figure 7. By having the end of the hose plugged, the pressure builds up inside. This nutrient solution that is under pressure will then be released through small holes that are drilled in the hose. These small holes create a fine mist that is projected out ward. By having the holes aimed towards the middle of the bucket the roots receive all the water and nutrients necessary.

Any excess water will be drained out of the bucket by a small hose on the bottom. This excess solution is then be gravity fed into the nutrient solution tub. The top of the system will have a lid that is securely fitted to the top of the bucket. In the middle of this lid will be a 3-4 inch hole with a net for the plant to sit in. This system could be used with multiple buckets, to grow a larger garden and still be power by a single pump. A timer is an option in order to keep water consumption at a minimum.

3.3.6 The Hexagonal Aeroponics System

This design takes advantage of being hexagonally shaped resulting in more surface area for more plants to be grown. Other designs, such as wall designs, or staircase designs are flawed in that they typically only have one surface through which the plants can grow. By using a hexagonal design the space used is optimized.

The hexagonal design will grow plants on four of the six sides. The other two sides are missing, allowing easy access to tend to the plants and to allow room for the piping from the nutrient solution to system. The basic design can be seen in Figure 8.

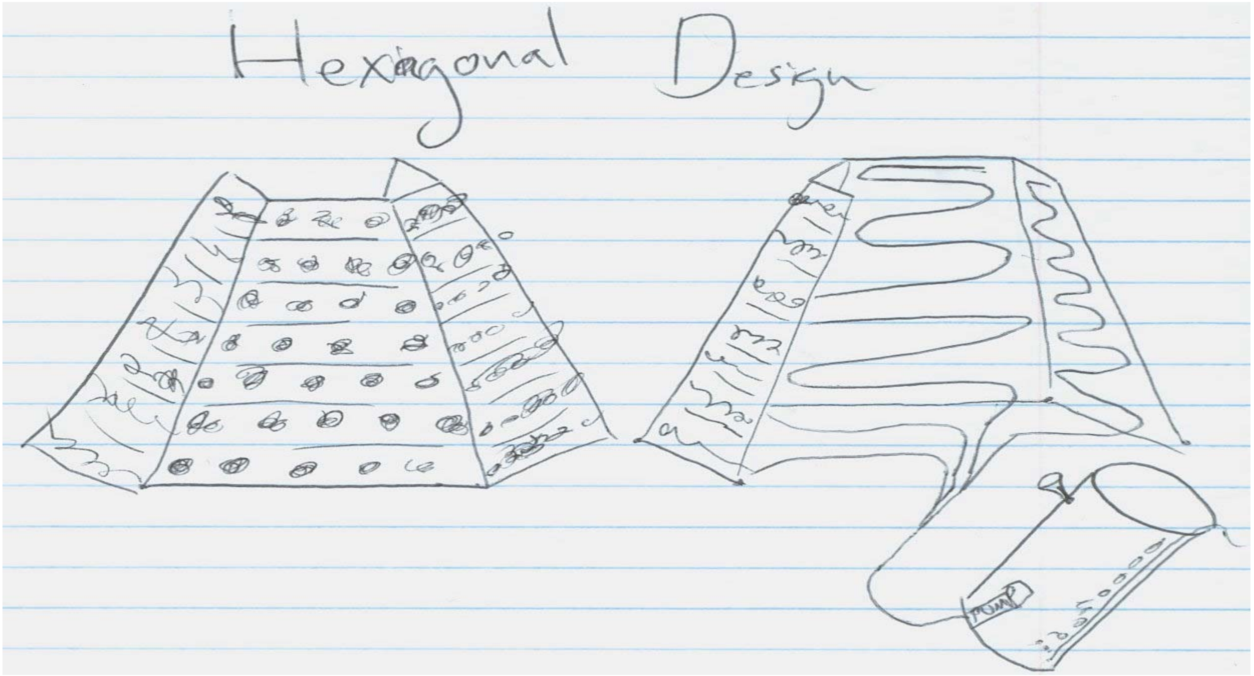


Figure 8: A front and rear view of the hexagonal design.

The nutrient solution starts in a dark colored 55-gallon barrel, which is placed above the system on a rack. Inside of this 55-gallon drum, there are a few different components. The components regulate the nutrient solutions temperature, consistency, and oxygen content. The first component is the interior workings of an old water cooler. The old water cooler's cooling mechanism helps keep the water at a constant temperature of about 65 degrees, which allows more dissolved oxygen to present in the water, then at higher temperatures. Another component located inside of the nutrient storage barrel is a bubble rock.

An aerator is used to make sure that the levels of dissolved oxygen are high enough for the plants and to keep the solution well mixed. The high-pressure pump is attached to the bottom of the tank, removing solution from the storage tank as needed. All of the devices will be able to be set on timers, allowing the system to run by itself and therefore only need to be tended to occasionally. The pump siphons the water out of the barrel, and pump the solution into tubes, which runs through PVC piping, represented as squiggly lines in Figure 8. Out of PVC piping the plants will grow and the roots will be sprayed with nutrient solution, through small holes or spray heads. The materials required for this design will be the nutrient drum, with all of its components, hoses, PVC piping, as well as a wooden frame to hold the structure together.

3.3.7 The Wall Hydroponic System

The Wall Hydroponic design takes advantage of the plants being able to be stacked vertically, without blocking out sunlight from each other. This system involves a wide ladder-like design that on which the plants sit on the rungs as scene in Figure 9.   This system is a drip system, which means a small hose will run along each plant, up and down the rungs.

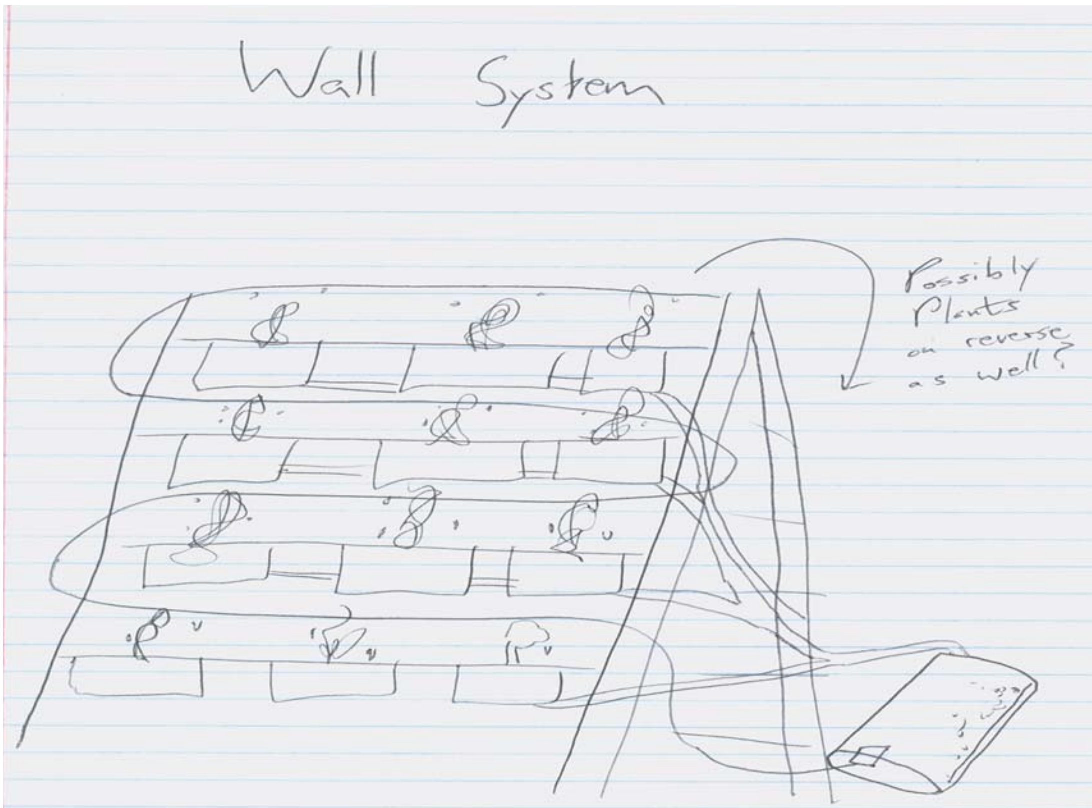


Figure 9: The early design of the wall system.

Depending on whether or not the system is one or two sided; one or two hoses may be required, respectively. The biggest issue with plants being on either side is that the system requires being in the middle of a room, rather than sitting against a wall. In order to tend to the plants, someone will need to be able to fit on the reverse of the wall. Also, the plants on the reverse of the system could find it harder to get sunlight than the plants on the front.

Advantages to this system are that, for a hydroponics system, high yield, it is aesthetically pleasing design, and are easy to manage. Some important issues that can come arise with this design is the fact that its large size will require a lot of potentially expensive materials. The Wall System is difficult to ship, and although it has high yield for a hydroponics system, relative to an aeroponics system, it may have lower yield than other choices.

Materials required for this project are large pieces of dimensional lumber, pots in which the plants can grow, hoses for the dripping system, and a pumping, bubbling, nutrient system similar to those in other concepts for aeroponics. The pump is able to be at a significantly lower pressure pump because it only needs to create dripping instead of spraying. The wall system can also have piping coming from all of the plants catching excess water for reuse. Recirculation of water makes the project more sustainable for the environment, and potentially less costly. Unfortunately, this creates the risks of lower than ideal pH levels, though this can be monitored and corrected.

A pump siphons a water nutrient solution out of the bubbler, and through PVC piping which drips nutrient solution through holes onto the plants. A catchment system lies under the plants, and water that is caught by this system is being returned to the nutrient solution reservoir.

3.3.8 True Aeroponics System

The true aeroponic system is meant to gather nutrients from a storage container and deliver it to the plants through pressurized mists. In this system the nutrient solution starts in a dark colored 55-gallon barrel, which is mounted above the system. Inside of this 55-gallon drum, there are a few different components. These components work to ensure that the plants receive the right mixture of solution, temperature, nutrient solution, and dissolved oxygen in the nutrient solution. One component is the interior mechanics of an old water cooler. Using the cooling system located inside of the water cooler helps keep the water at a constant of about 65 degrees, which allows more dissolved oxygen to present in the water then at higher temperatures. Another thing inside of the nutrient storage is a bubble rock. This is used to make sure that the levels of dissolved oxygen are high enough for the plants and to keep the solution well mixed. Then the high-pressure pump will be attached to the bottom of the tank, removing solution from the storage tank as needed. All of the devices can be set on timers, allowing the system to run itself and the need to be tended to at a minimal.

Using the pump, the nutrient solution will be pressurized through CPVC tubing, to the five-way splitter. After the five-way splitter, the water flows into the five different growing tubes. These tubes will be made of CVPC tubing with a 6-10 inch diameter. Inside of each tube, there are be five holes where the roots of the plants growing are be suspended. Either a spray head or a small hole drilled into the watering pipe will be located at each plant. This waters the plant's roots with a fine mist of nutrient solution, giving the plant all of the vital nutrients needed to flourish.

Each of the five growing tubes will be located on a different step. They tube slightly elevated on one end, which allows any excess solution that drips from the plants roots to flow to the end of the tube. There it drains into the next level of the system and continues its way to the very bottom. At the bottom it is caught in small container.   As the container fills, someone will have to recycle this water back into the nutrient reservoir.

Overall the system will be approximately 5 x 5 x 5 feet, depending on restrictions given. It will have the overall layout of a set of stairs, but with one exception. There is a tube with five plants growing out of it, on each step. Also a smaller pipe will be coming down and enter each of the five larger pipes. The very bottom pipe will have a small section that is see-through, for educational purposes, but can be covered when not being used for that purpose. The design is shown in figure 10.

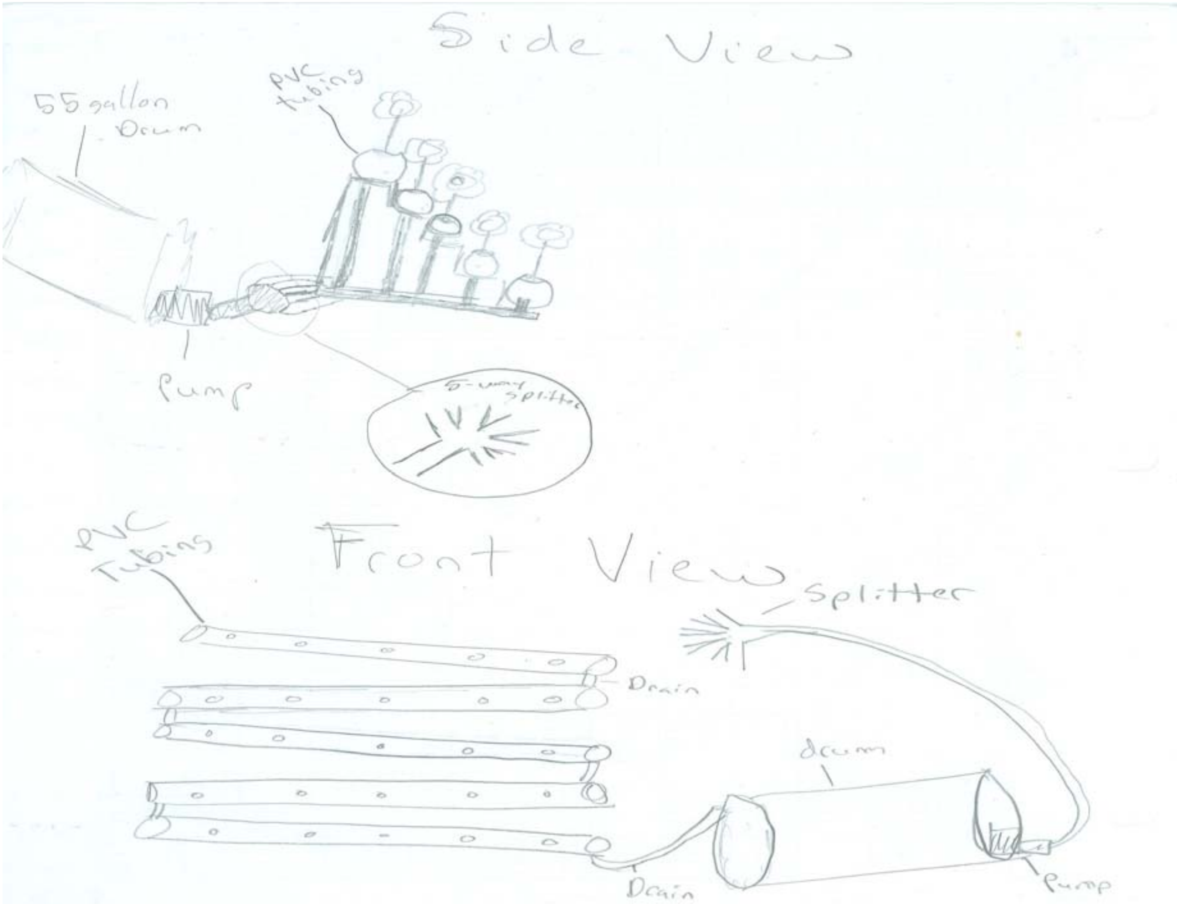


Figure 10: A true aeroponics system design is displayed with two views.

3.3.9 Bubbleponics Supertray

The bubbleponics supertray uses many aerators at the bottom of a reservoir to splash water on the roots of plants suspended in the lid of this reservoir. In bubbleponics system, there is no need for an external nutrient reservoir. Instead located at the bottom of the system is a large tray. The nutrient depth above this tray is between one foot and two feet. The depth of the water depends on the length of the roots. As the roots begin to dip into the reservoir due to growing, the water level will have to be lowered. The desired height of this nutrient is 1 inch below the longest root. Inside of the nutrient tray, there is a row of bubble rocks. These bubble rocks have to be on the more powerful than conventional aquarium stones, so that as the bubbles erupt from the top of the water, they will splash droplets of water onto plant’s roots. This design can be seen in Figure 11.

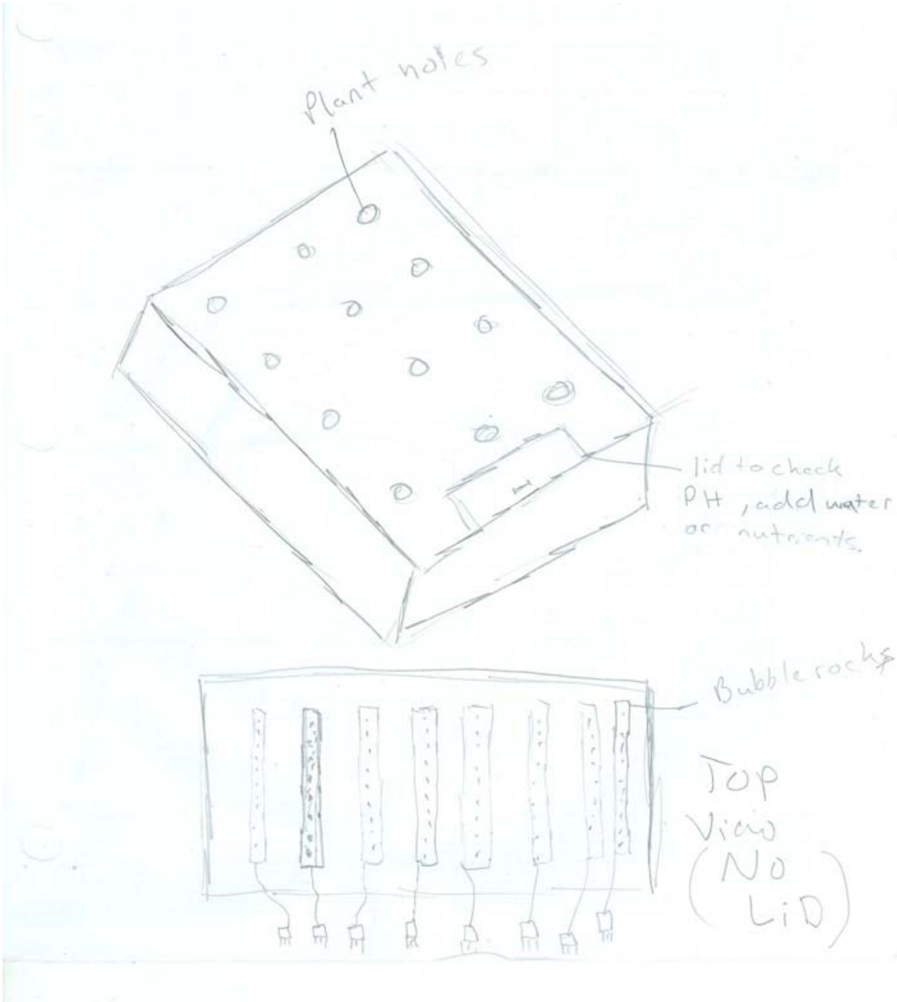


Figure 11: Complete views with the lid on and off the bubbleponics supertray.

The tray that the nutrient solution will be sitting in has a 3-foot depth and a 6x6 foot surface area. It is lined with four to eight bubble rocks to promote oxygen in the water and too keep the plants well watered.

The lid to the nutrient tray is also where the plants are holstered. A growing medium will be used to hold the plants upright and the roots will hang under the lid of the nutrient tray.

This system is hard to demonstrate which could negate the educational value of it. The nutrient tray is dark color in order to keep light out. The only access to this tray is through a small flap that can be flipped up to check the ph levels of the nutrient solution. The design below, Figure 12, has the top cut off and a diagram of the 55-gallon drum.

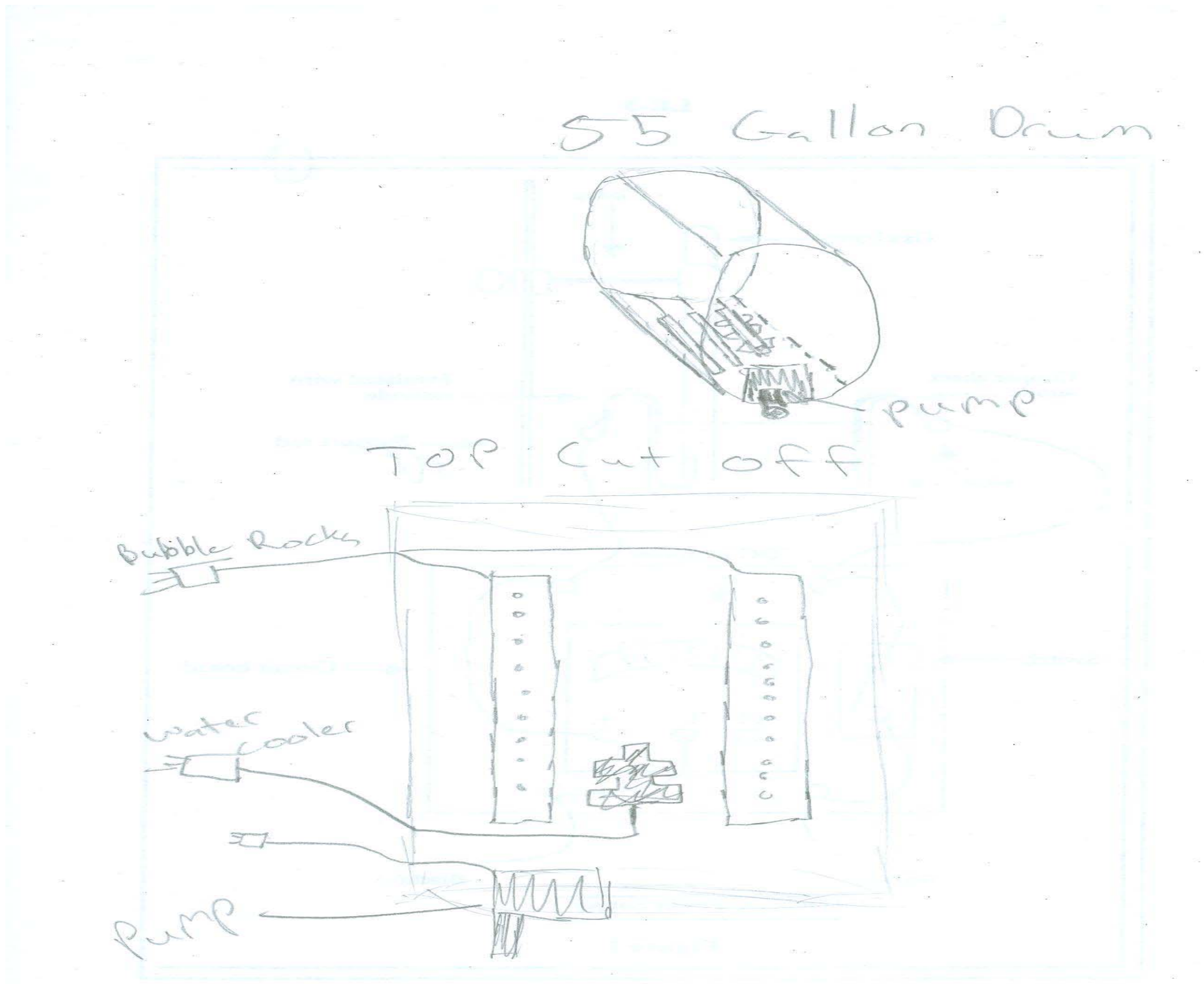


Figure 12: The bubbleponics system with the top cut off.

4 Decision Phase

4.1 Introduction

This section describes the process in which the final solution was decided on, from the list of possible solutions in the previous section. Criteria were a big part of deciding on which option would be implemented. In order to take criteria into account, the Delphi method was used to determine how each solution met the criteria.

4.2 Criteria Definition

Section II listed off the criteria that must be met while designing and building this project. In this section, the criteria will be explained in more detail**.**

Cost

The cost for this projects design and construction should be under $300. This criterion helped choose a solution that was feasible for the budget. More than $300 could be spent, with permission from the client.

Size

The size was an important constraint, as for this project must be able to fit in the space available on the barge. The WaterPod have very limited space on their barge and it is being dispersed very sparingly.

Weight

The weight of this project should be as light as possible; as for it needs to be shipped from California to the client in New York.

Transportability

Transportability goes along with weight. Since this project is being shipped, it should be able to be taken apart and made into smaller sections. This will keep shipping cost as low as possible.

Durability

This project must be durable enough to last for at least six months, with little or no maintenance. Six months will be long enough; as for it is the duration of time that the WaterPod team will be living on the barge.

Ease of Setup

How easy it is to take apart and put back together needed to be taken into consideration. The WaterPod people will have to reconstruct the project, when it arrives in New York, and it should be as easy as possible to avoid and complications.

Use of Recycled Materials

The use of recycled materials is not only good for our environment, but is also good to keep our cost down. Constructing as much of the project as possible out of recycled materials will be key to keeping in the range of the budget given.

Design and Construction Time

Less than four months of time was allowed to completely design and construct this project. Having such little time added more constraints, limiting the design and building time.

Educational Value

Many people will come onto the barge and check out the different designs being implemented. People need to be able to see all aspects of the project, so they can get an understanding of what the system does.

Energy Efficiency

The goal was to have the project use little or no energy. The WaterPod team will be producing electricity on the barge and there will not be a substantial amount of excess electricity after the essentials.

Solutions

There are 9 possible solutions that we had to be chosen from. The explanation and diagram of each of these solution possibilities was described in Section III.

These Solutions are:

- Continuous Flood and Drain
- Umbrella Aeroponic
- Tree Hydroponic
- Octagon Hydroponics
- Bucket Aeroponics
- Hexagonal Hydroponics

- Drip Hydroponic

4.4 Decision Process

A Delphi Method was incorporated to make a decision on which project would be used as a final solution. The Delphi Method is a way to weigh the criteria against each of the different solution options. The criteria were set on a scale from 1-10, ten being the most important and one being the least. The criteria's scores can be seen in Table 1 below.

Criteria	Scale (1-10)
Cost	8
Size	6
Weight	8
Durability	8
Transportability	7
Ease of set up	9
Use of recycled materials	9
Design and construction time	10
Educational value	8
Level of energy efficiency	6

Table 1: The criteria set by the team.

To start the process we looked over each of the alternative solutions, seeing how well each solution met the criteria. A scale from 1-10 was used to determine this for each of the criteria. After all the solutions had been weighed against the criteria, a decision was made based on the score each solution had received. The results from each of the solutions can be seen in Table 1.

Scale out of 50 (highest)

Criteria	weight	Cont. Fld. and Drn	Umbrella Aero.	Tree hydro.	Octagon hydro.	Bucket Aeropo.	Hex Aero.	Wall
Cost	10	35 / 350	40 / 400	20 / 200	5 / 50	42 / 420	20 / 200	40
Aesthetics	6	40 / 240	45 / 270	50 / 300	45 / 270	15 / 90	45 / 270	40
Safety	9	40 / 360	35 / 315	30 / 270	25 / 225	12 / 108	27 / 243	35
Reliability	10	35 / 350	25 / 250	15 / 150	21 / 210	45 / 450	35 / 350	36
Yield	7	30 / 210	40 / 280	26 / 182	35 / 245	40 / 280	42 / 294	32
Space utilization	7	45 / 315	48 / 336	46 / 322	36 / 252	45 / 315	38 / 266	29
Water efficiency	8	12 / 96	41 / 328	13 / 104	17 / 136	40 / 320	38 / 304	15
Electrical Efficiency	6	11 / 66	38 / 228	11 / 66	11 / 66	40 / 240	37 / 222	11
Total		1987	2407	1594	1454	2223	2149	

Table 2: The Delphi Matrix.

To come to a final decision on what the final design should be, the top three solutions were all looked at. The umbrella hydroponics, true aeroponics, and bubbleponics supertray designs scored the highest as seen above in Table 2. Instead of just choosing one of the designs, all three of them were incorporated into the final solution that was decided on.

5 Specification of Solution

5.1 Introduction

The purpose of this section is to discuss and explain the various aspects of the final solution that our team has selected, which can be seen in more detail in section 4. This includes a detailed description of the hydroponic system design, the costs of the project, instructions for implementation and use of our model, and results of the project. The detailed description will include a CAD drawing and a detailed description of our project. The cost section will explain our costs for the design, implementation, and maintenance needed for our design. The implementation section will explain how to use and maintain The Drip Hydroponics System. This section will describe the results that have been concluded from current testing, and the overall functionality of the model.

5.2 Design Description

In section 4 we used team logic and the Delphi method to select a final design. Originally after the discussion PWW chose to build an aeroponic system, but after further research realized that the aeroponic system did not meet the criteria of our client. An aeroponic system would be to unreliable and require more energy than desired. The final decision for a hydroponic system was based on the on the system will be reliable, use very little electricity, and use a moderate amount of water.

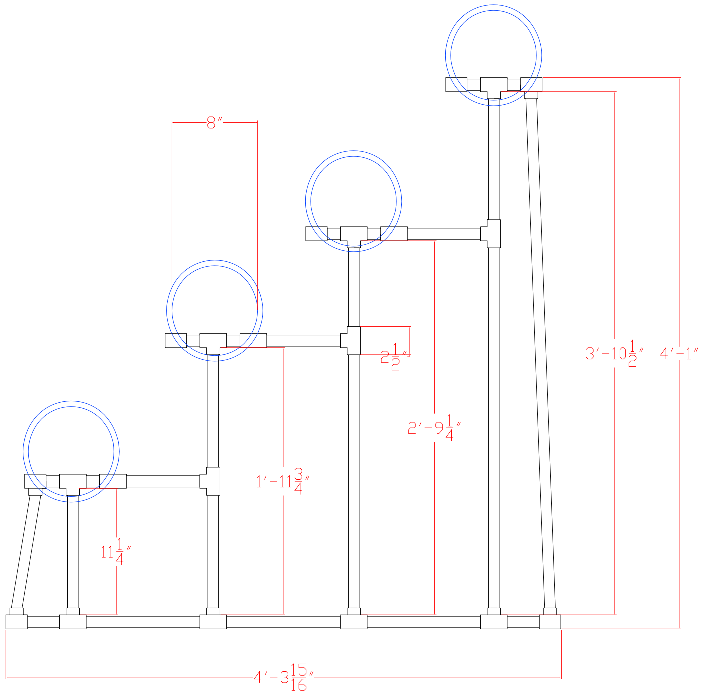


Figure 13, AutoCAD Side view of Drip Hydroponic System

Our final solution scene in figure 13, is named, "The Drip Hydroponic System."   This system's design that will use the least amount of resources in order to produces the largest amount of vegetables or fruits. The Drip Hydroponic System is a fully functional way to grow vegetables and fruits without soil and with minimal human interaction. The hydroponic system contains a pump, nutrient solution, solution storage barrel, nutrient delivery hoses, nutrient catchment system, solution delivery rings, 8 inch PVC pipe, ½ inch PVC pipe, a 1 inch PVC pipe support structure, and nets to hold the plants in place. We chose to use PVC pipe for most of the structure do to the fact that it is much lighter and therefore easier to ship to New York, yet still is durable.   In addition the PVC will be able to withstand the corrosive chemicals that are found in most common fertilizers.

Figure 14: A front view of solution tank draining to plants.

As scene in Figure 14, the entire support structure for our system is completely constructed out of 1 inch PVC pipe, hemp rope, and connecting PVC pieces. The project's entire support structure is spray painted in order to make all the mismatching colored pieces of PVC pipe look uniform, as seen in Figure 15.   Sitting on top of the support structure is the eight-inch diameter PVC pipes that have a total of sixteen holes cut in the top for the plants to sit in. The plant's roots sit inside of a perlite and marble mixture inside of each basket.

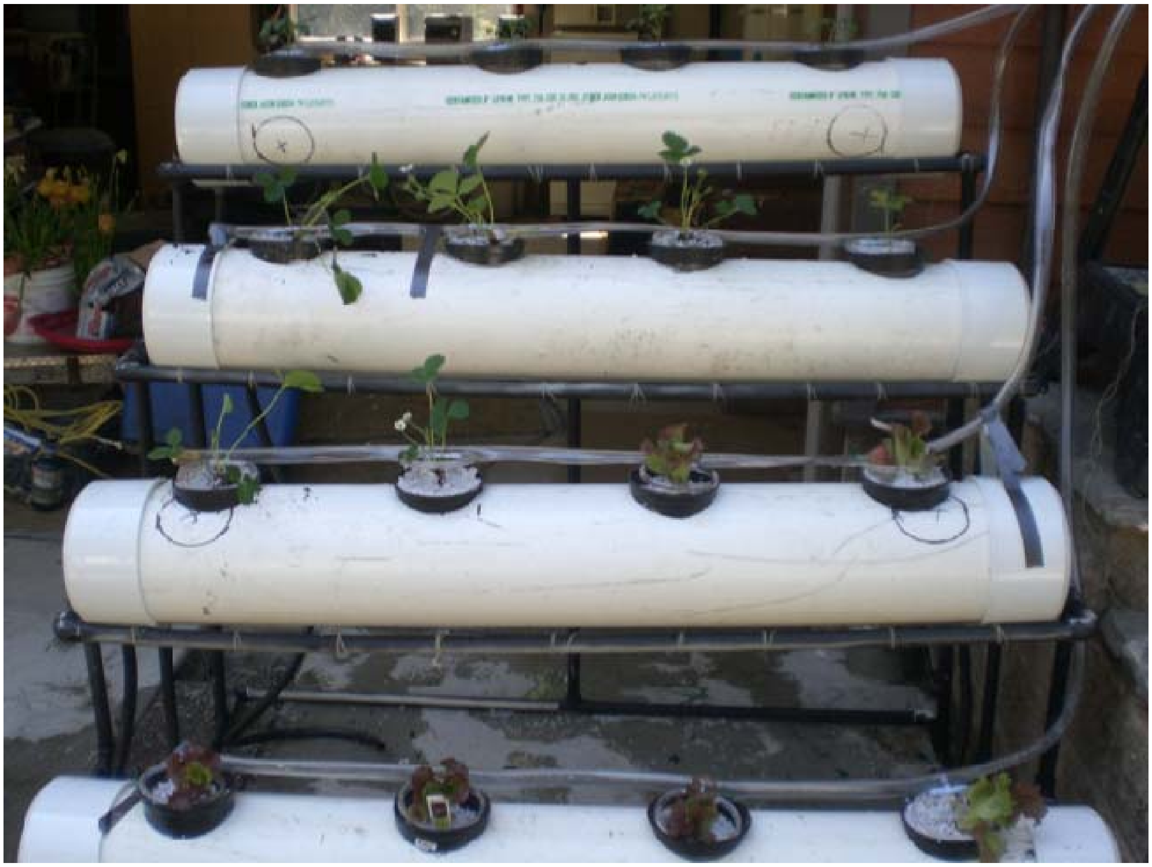


Figure 15: View showing 1” PVC structure and 8” plant housing.

5.3 Design’s Function

As scene in Figure 14, the entire system starts in the solution barrel that is planned to be mounted 15 feet above the project. The barrel contains the nutrient solution and an aerator. The aerator is a bubbling mechanism that supplies the nutrient solution with enough dissolved oxygen for the plants to live. Once the solution is aerated the release valve, Figure 16, is opened at the bottom of the barrel. Connected to the release valve of the tank is a four-way splitter, Figure 17. This splitter makes it possible for each individual row to receive nutrient without affecting the other rows. After the four-way splitter there is a short section of clear tubing attached to it. After a six inch section of tubing each hose has another valve so each row will have an individually controlled flow. Once the solution flows down the 15 feet of tubing and fills up the clear hose, Figure 15, the hose will become pressurized. Once the hose becomes pressurized the solution will fill up the “halos” that are placed around each plant. Once the halos fill up there is three holes drilled in the bottom of each halo, which will let water drip into the baskets as shown in Figure 18. Once the perlite is sufficiently saturated the excess nutrient solution will flow into the 8" PVC pipe. Once inside of each tube, due to a slate grade, the solution will drain to one side of the tube. Once on the left or right side of the tubes the solution will drain through drains that are on the bottom of each 8" pipe. The excess water collected is drained into a separate barrel located at the bottom of the system were the solution can be pumped up to the top barrel to be reused again.

*For details on how to set up the system see Appendix B.

Figure 16: Release valve.

Figure 17: Four-way hose splitter attached to 55-gallon drum.

Figure 18: Halo ring surrounding a lettuce plant.

5.4 Cost Analysis

Design Cost Hours

The design costs for our project consist of the total amount of hours that have been put into our project since the beginning. The total amount of hours that PWW has put into the project is 165 hours.

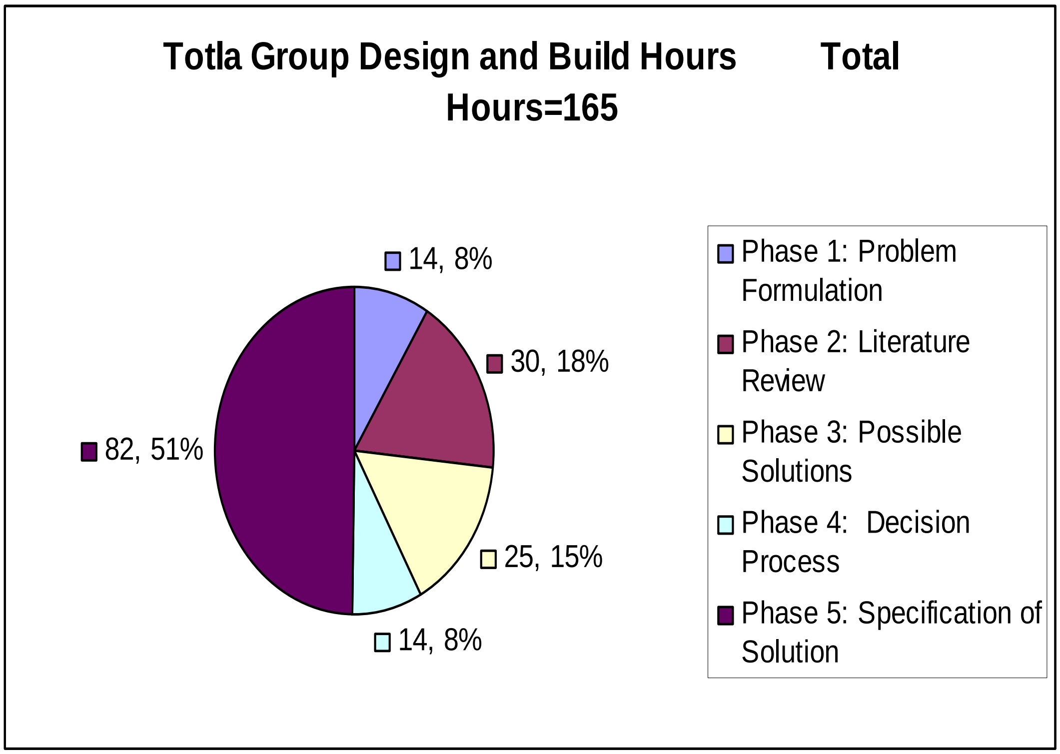


Figure 19: Chart of total hours.

Implementation

The implementation costs is a cost summary of all the materials, listed in Table 3, that were gathered to build our project.

Table 3: Implementation Costs

Materials	Amount	Location	Team Cost	Potential Cost

Support Structure				
1” PVC Pipe	20 feet	Arcata Salvage	$16.00	$40.00
1”PVC Pipe	20 feet	Pat’s House	$0.00	$40.00
PVC T joints	32 pieces	Ace Hardware	$16.12	$16.12
PVC Elbow Joints	28 pieces	Ace Hardware	$20.00	$20.00
Spray Paint	4 cans	Ace Hardware	$20.00	$20.00
Hemp Rope	20 feet	Ben’s Dorm	$0.00	$10.00
PVC Pipe Glue	1 jar	Ace Hardware	$2.75	$2.75
Solution System				
55 gallon barrel	1 barrel	Resale Lumber	$35.00	$65.00
Pump	1	Let it Grow	$55.00	$62.00
Solution Delivery Hose	20 feet	Ace Hardware	$20.00	$20.00
Solution Retrieve Hose	10 feet	Let It grow	$10.00	$10.00
Teflon Tape	1 role	Ace Hardware	$.75	$.75
Release Valve	1	West Coast Plumbing	$2.35	$3.75
Five way Splitter set up	1	West Coast Plumbing	$9.25	$11.50
Bung Hole For Barrel	1	West Coast Plumbing	$3.50	$5.00
Spray System				

1/8” hose	10	Ace Hardware	$15.00	$20.00
1/8” T connector	16	Ace Hardware	$5.00	$6.00
Metal Fence Nails	16	Pat’s House	$0.00	$1.00
Corks	4	Pat’s House	$0.00	$1.00
Plant Containment System				
8” PVC Pipe	20 feet	Resale Lumber	$32.15	$120.00
8” PVC Caps	8	West Coast Plumbing	$116.00	$180.00
Plant Baskets	16	Let It Grow	$26.00	$40.00
Perlite	5lb bag	Let It Grow	$8.00	$8.00
Marbles	½ lb bag	Pat’s House	$0.00	$3.50
Total			$406.87	$711.37

Implementation and Maintenance Costs

This system was designed to withstand use for a total of six continuous months. The project was designed to be physically sound, but does need maintenance. The maintenance and implementation costs are the same because the implementation costs for starting the project, throughout the project all of these project necessities will have to be bought again. These maintenance and implementation costs include electricity, nutrient solution, and water. The rest of the materials were designed to last throughout the six months.

Table 4: Maintenance Costs

Supply	Amount	Costs	Location
Electricity	1 pump cycle	$0.00	generator
Water	12 gallons per day	$0.00	rainwater collection
Nutrient Solution	2bags	$100.00	New York store

5.5 Instructions for Implementation and Use of Model

Hydroponic Assembly

The system will be shipped to the client disassembled to lower shipping costs. Each section of the PVC support structure will have a color-coded male end that fits into the corresponding female end. By following these color codes in combination with Table 2, the structure will be easy to construct. Instead of just inserting the two ends together, place PVC cement on each adjoining side then connect them. After joining the sides makes sure that each section stands straight and is square. The 8” PVC plant holders along with the ½” spray section will be shipped already assembled. Each of the four sections needs to be placed on one of the color coded tiers. The plant holding section will be color coded to what tier it should be placed on. After placing the section on the tier, secure it with the straps provided. Once the initial structure and plant housing is secure attach the numbered houses, that come out of the pump, to the numbered nipples on the left side of the plant housing. Next connect the drainage tube to the right side of the bottom 8” plant housing and place the other end in the nutrient solution reservoir.

Implementation and Use of Design

The hydroponic system should be set up in an area that has regular temperatures that hover between 55-70 degrees Fahrenheit. Nutrient solution will have to be bought and then mixed with the correct ratio of water to fill the fifty-five gallon drum. Once the pump has been fully submerged into the solution container it will sit on the bottom. Then place the desired plants in the sixteen holes on the 8” plant housing. Once the plants have been placed and pump has been plugged in with the timer, turn the pump on and watch the plants grow.

The solution will have to be changed out, on average, every 7 days and a new solution batch mixed up for the plants. The solution may be need to be changed either more or less frequent due to different outside variables that can affect how fast the plants use the nutrient Solution. These variables include humidity, temperature, and size of plants. The only part of the project that needs to be watched is the nutrient solution drum. The Ph and Temperature inside of the drum should be checked regularly in order for the plants growth not to be stunted.

5.6 Results

The Drip Hydroponic System, after some alterations, works perfectly. During tests runs the system grew tomatoes, strawberries, and lettuces for a week. Growth was noticed and no leeks were discovered. All together the system is functional and meets the client criteria. The Drip Hydroponic System uses very little water, uses very low electricity, and is shippable.

6 Appendix

Appendix A: Brainstorming Notes

Brain storming

Materials

Sprayers - Buying, drilling holes in PVC pipe

Nutrient solution — They will buy the solution in NY, but we will do research to tell them

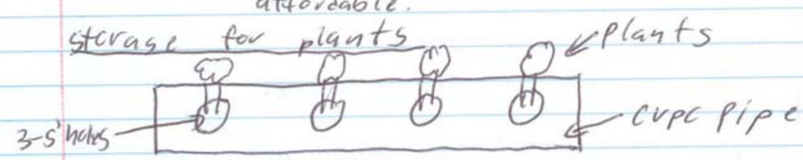
Pumps

- Aquarium pumps
- Sump pump is for low pressure
  - used mostly in Hydroponics
- Jet pump
  - used for Aeroponics at higher pressure
- CVPC pipe of various dimensions
  - use pipes to hold plants and also to deliver misters.

Storage tanks for solution

- Barrels
  - good because hold a lot of Nutrient solutions
- Tote containers
  - good because cheap and affordable.

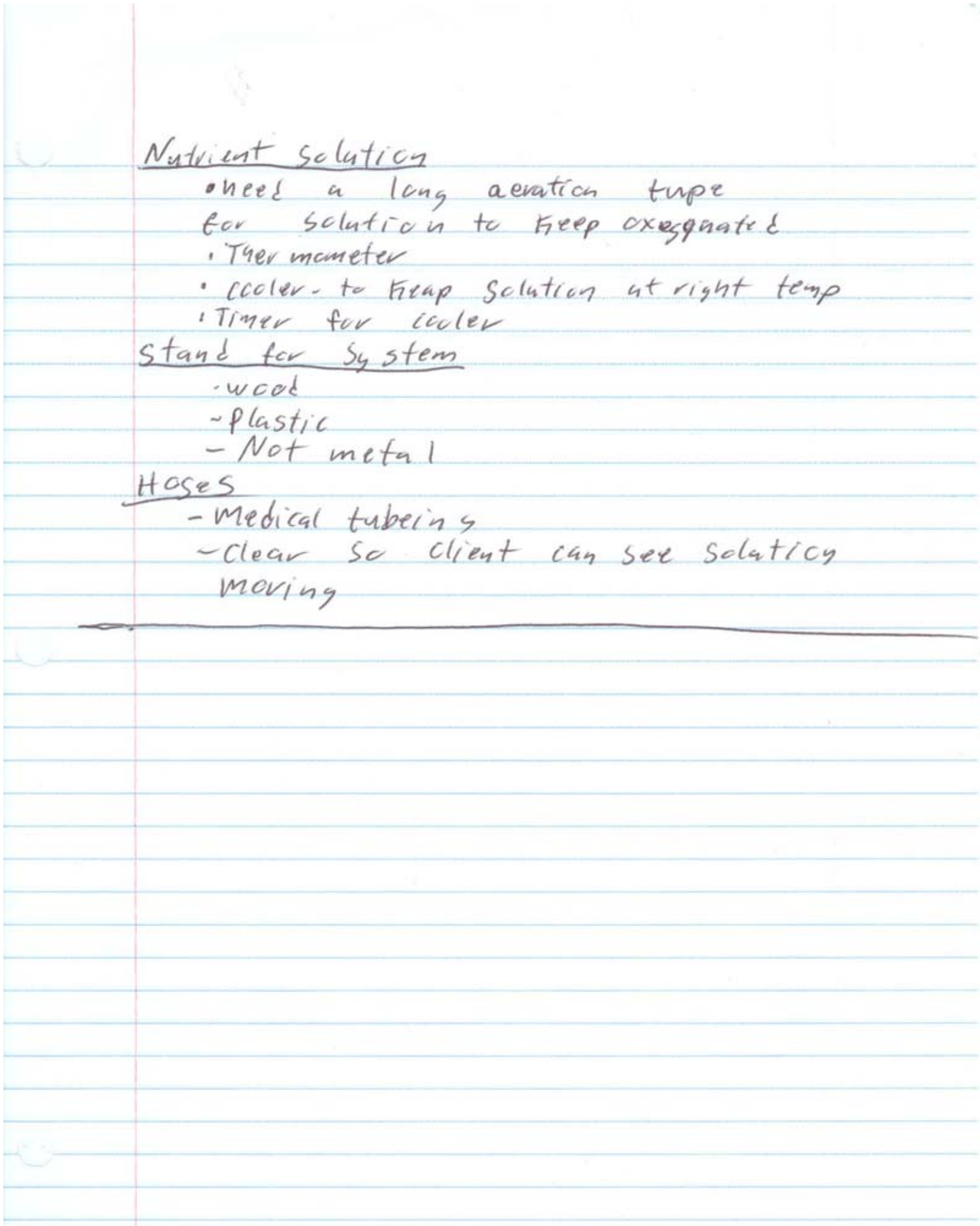
Storage for plants



CVC pipe with 3-5' holes cut on top for plants to sit in.

- Mesh nets
- Wire nets

Figure 20



Nutrient solution
- need a long aeration tupe for solution to keep oxegnated
- Ther mometer
- cooler - to keap solution at right temp
- Timer for cooler

Stand for System
- wood
- plastic
- Not metal

Hoses
- Medical tubeing
- Clear so client can see solaticn moving

Figure 21

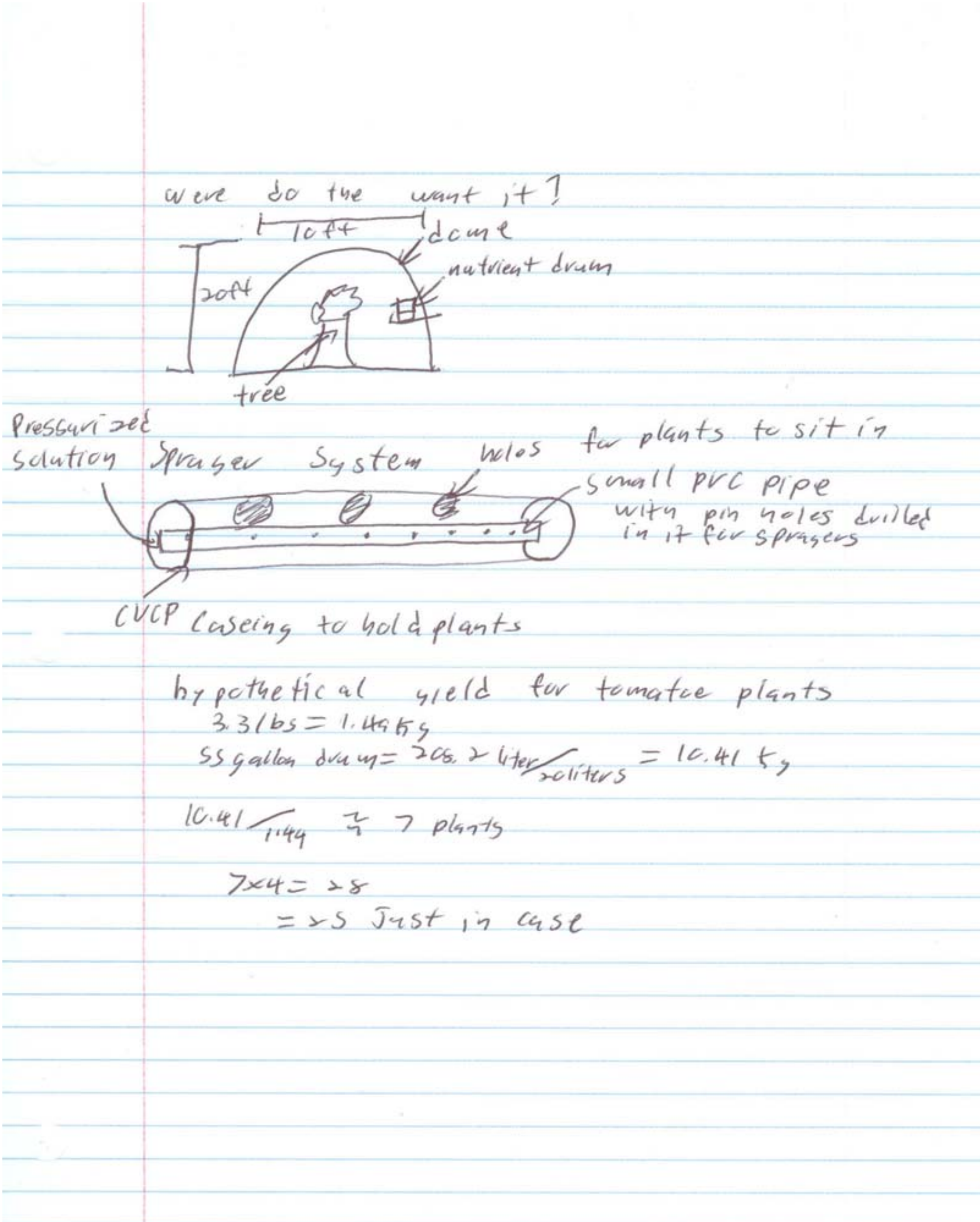

were do the want it ?
10ft
dome
nutrient drum
20ft
tree
Pressurized solution
Sprayer System
holes for plants to sit in
small pvc pipe with pin holes drilled in it for sprayers
CVCP Caseing to hold plants
hypothetical yield for tomatoe plants
3.3 lbs = 1.49 kg
55 gallon drum = 208.2 liter / 20 liters = 10.41 kg
10.41 / 1.49 ≈ 7 plants
7x4 = 28
= 25 Just in case

Figure 22

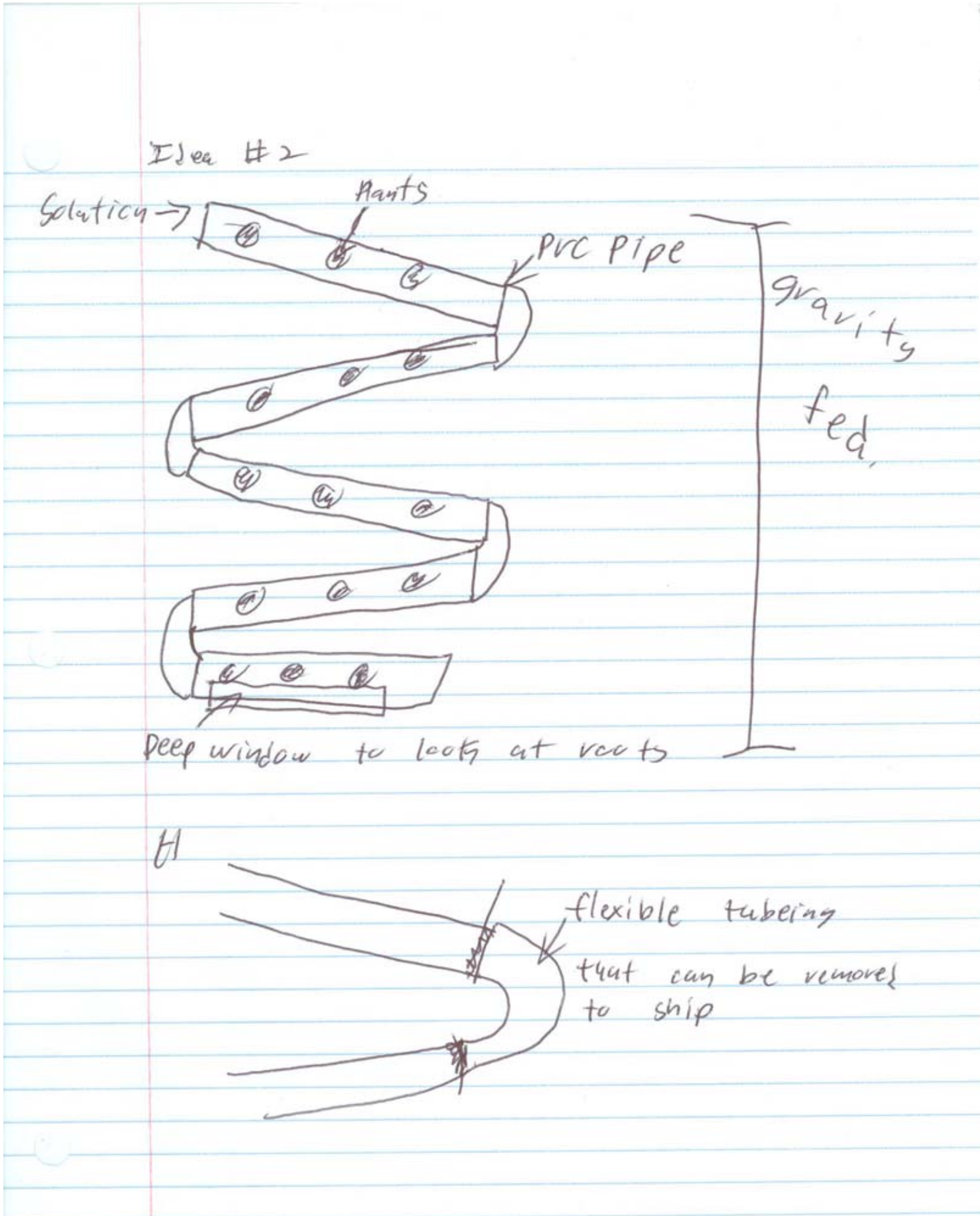

Idea #2
Solution →
Plants
PVC Pipe
gravity fed.
Deep window to look at roots
flexible tubeing
that can be removed
to ship

Figure 23

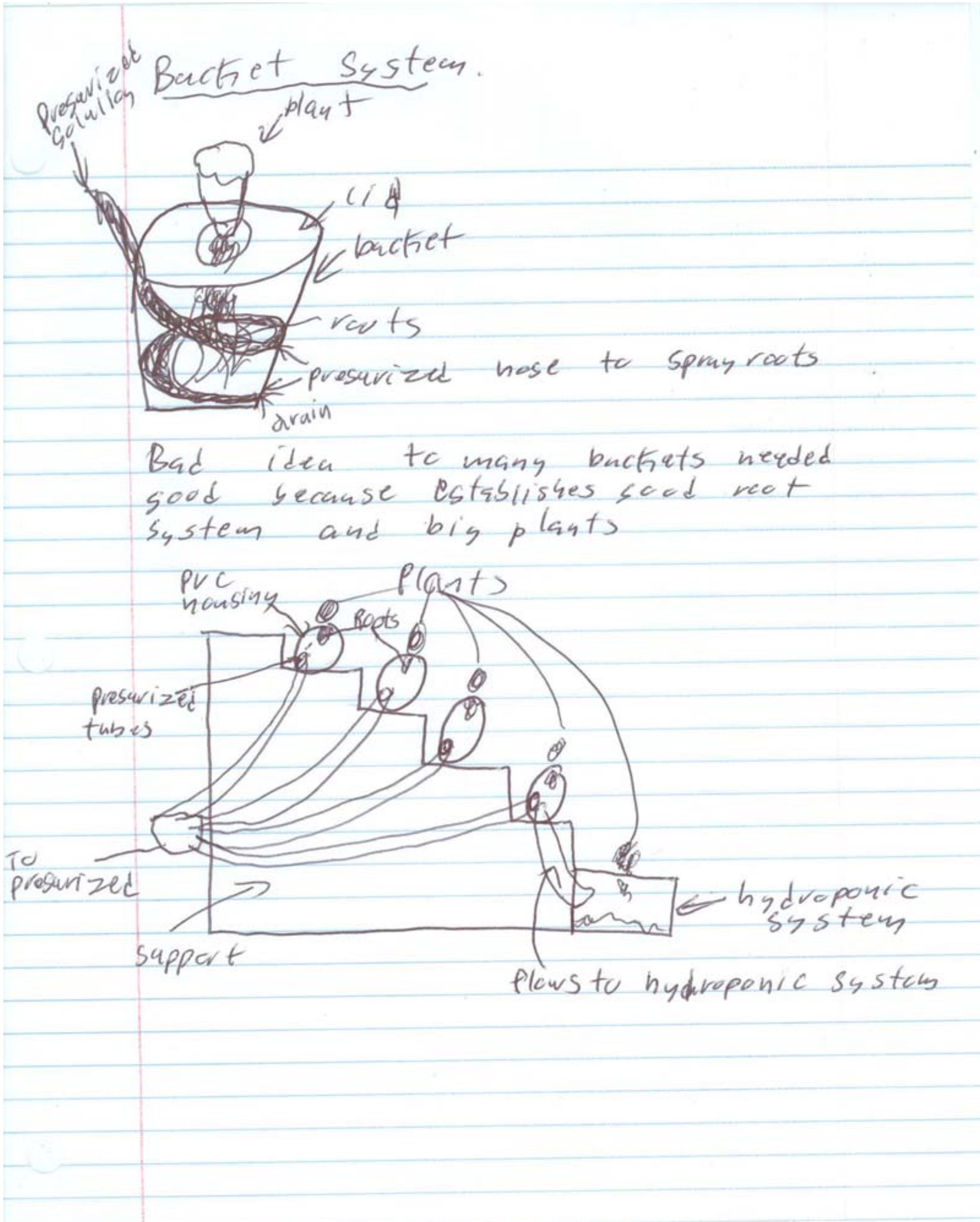

Bucket System.
Presurized Solution
plant
lid
bucket
roots
presurized hose to spray roots
drain
Bad idea to many buckets needed
good because establishes good root system and big plants
PVC housing
Plants
Roots
presurized tubes
To presurized
support
hydroponic system
flows to hydroponic system

Figure 24

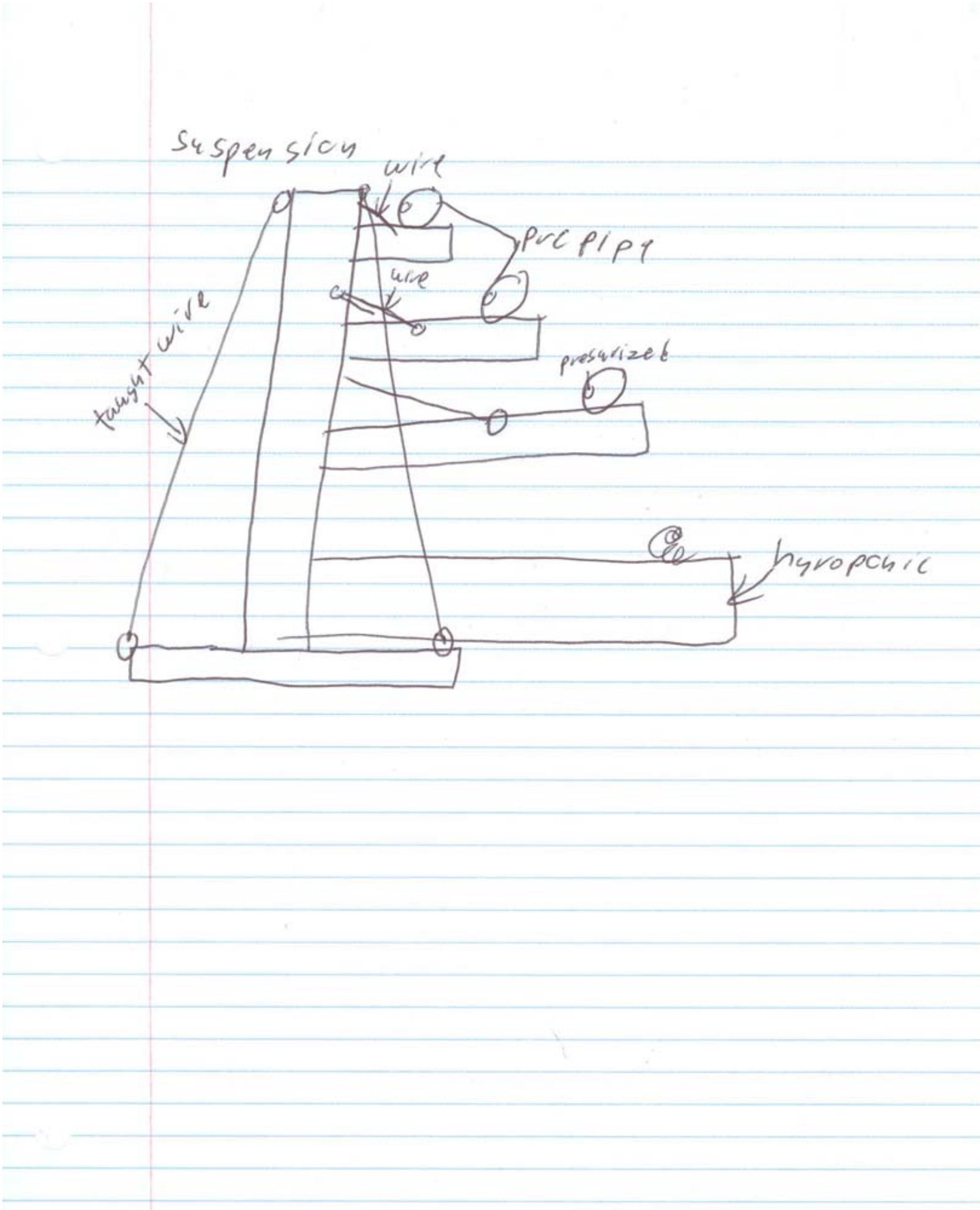


Figure 25

Appendix B

6.1 Assembly Instructions

These instructions are going to be based on the numbers and names that are located on the different sections of pipeing and materials. Directions will be given on a coordinate system of North, East, South, and West. For example West refers to the right of a given point.

Step 1. Gather pipe sections 1,2,3,4. Lay the pipe sections out with pipe section 1 south, pipe section 2 north, pipe section 3 east, and pipe section 4 west, see Figure 26.

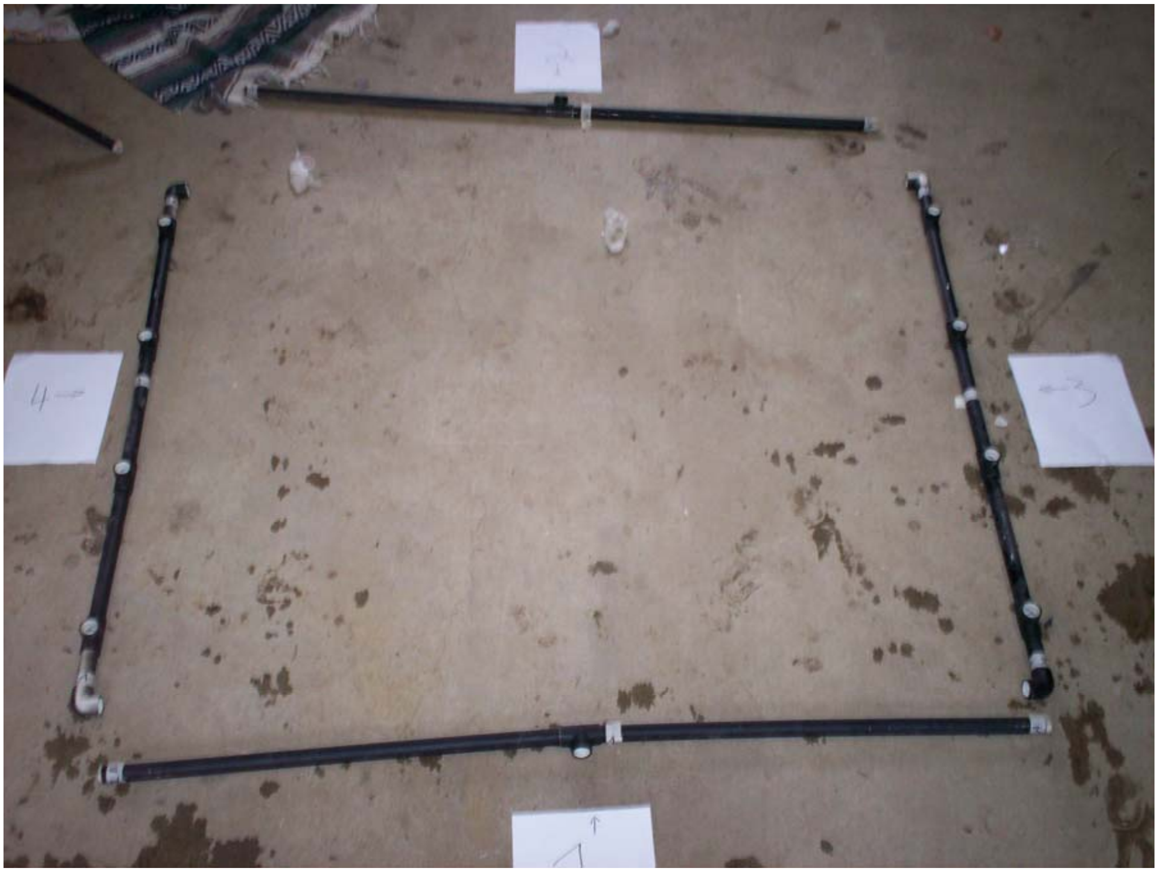


Figure 26: Initial base layout of Hydroponic system.

Step 2. Join each male end to the corresponding female end. For example male end 1A to female end B1, see Figure 27.

Figure 27: Joining base.

Figure 28: Joined Base.

Step 3. Gather short pipe sections labeled 5,6,7 and put male ends into labeled female ends. Pipe section goes in the middle, 6 in the hole west of 5, and 7 goes in the hole east of 5, see Figure 29.

Figure 29: Pipe sections 5,6,7 in place.

Step 4. Put tier labeled “Tier 1” onto three posts, see Figure 12.

Figure 30: Tier 1 in place.

Step 5. Gather short pipe sections 8 and 9. Put pipe section 8 on back hole of the tier on the west side and 9 on the east side, see Figure 31.

Figure 31: Pipes 8 and 9 in place.

Step 6. Gather longer pipes 10 and 11. Insert pipe 10 on the west side of the project connecting it to Tier 1. Repeat with pipe 11, but on the east side of the project. Use pipe sections 8 and 9 to join these sections to Tier 1, see Figure 32.

Figure 32: Pipe sections 10 and 11 assembled.

Step 7. Put Tier 2 on top of pipe sections 10 and 11. Make sure that the side of the tier with openings facing towards the back of the project, as seen in Figure 33.

Figure 33, Tier 2 assembled

Step 8. Gather pipe sections 12 and 13. Place pipe sections 12 on the backside of the west side of Tier 2. Place pipe section 13 in the same manner, but on the back east side of Tier #2, see Figure 34.

Figure 34: Pipe sections 12 and 13 assembled

Step 9. Gather pipe sections 14 and 15. Insert pipe 14, following directional arrows on pipe, onto the west side of the project. Pipe 15 should be inserted in same manner, but on the east side of the project, see Figure 35.

Figure 35: Pipe sections 12,13,14, and 15 assembled (Note Directional Arrows)

Step 10. Place Tier 3 on top of pole sections 14 and 15, once again having the side of the tire with the openings face the back of the project, see Figure 36.

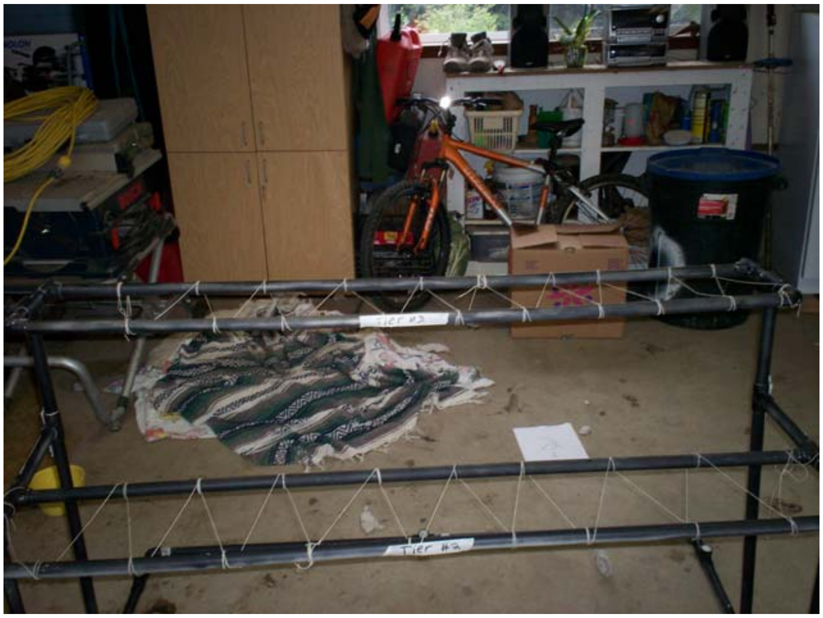


Figure 36: Tier 3 assembled

Step 11. Gather pipe sections 16 and 17. Once gain place 16 on the back west side of Tier #3 and pipe sections 17 on the back east side of Tier#3, see Figure 37.

Figure 37: pipe sections 16 and 17 assembled.

Step 12. Gather pipe sections 18 and 19. Insert pipe 18, following directional arrows on pipe, onto the west side of the project. Pipe 19 should be inserted in same manner, but on the east side of the project. Once Pipe sections 18 and 19 are assembled place Tier 4 on tope, see Figure 38.

Figure 38: Pipe section 18 on left and 19 on right. Tier #4 placed on top.

Step #13. Gather Long Pipe section 20. Place in the remaining holes on the back side of the project, see Figure 39.

Figure 39: Pipe section 20 is supporting Tier 4.

Step 14. Place corresponding troughs with corresponding Tiers. For Example trough 1 goes with Tier 1. In addition place the corresponding labeled hose sections with Troughs. Once again Hose #1 corresponds with Trough # 1, see Figure 40.

Figure 40: Troughs and hoses in place.

Step 15. Place 16 supplied plant containers snuggly in the holes in the four troughs. Make sure the baskets fit snug in order for no light to reach the roots. Fasten each Halo ring around the plant using supplied metal U’s, see Figure 41.

Figure 41: Halo ring surrounded around lettuce.

Figure 42: Plant basket containing perlite firmly secured in the trough

Figure 43: All four troughs fully set up.

Step 16. Connect ends of 4 delivery hoses to nutrient barrel, release valve and watch nutrients be delivered, see Figure 43.

Appendix figure 24, Barrel-supplying plants with Nutrients.

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