Subsystems Report

Jonathan Sumner Evans

Section U

November 3, 2016

Contents

1 Introduction

A food desert is an area where access to fruits and vegetables is limited, too expensive, or nonexistent due to a lack of grocery stores and farmers markets within a convenient walking distance [1]. People living in food deserts often rely on fringe food retailers and discount stores, such as gas stations and dollar stores, for food. These retailers tend to sell high-fat and processed foods which contributes to higher rates of obesity and diabetes in those food desert areas. According to the US Department of Agriculture, there is a food desert in the Wheat Ridge area located between Wadsworth, 32nd Avenue, and 38th Avenue [2].

The team's goal is to empower English and Spanish speaking Wheat Ridge residents over 65 years in age who live in a food desert and rely on food stamps to utilize a self-sustaining plant growing system. Most of the system will come prepackaged for safe installation and use. It will also partially use materials that can be sourced in the Wheat Ridge neighborhood. The net cost will be neutral or better after two years of plant harvest and will include features that consider the potential physical limitations of the stakeholders.

2 Solution Description

The team's design addresses the problem with a system composed of five distinct and interconnected subsystems. The structural subsystem is a three-tiered structure that is compact, lightweight, and cost-effective so that the stakeholder can easily install and maintain it. With it's 12 hole design and the reservoir at it's base, the structure is the key connection between the hydroponic soda bottle system and the watering system.

The watering system consists of two symbiotic subsystems: the reservoir and the cascading water system. The reservoir system uses four separate water tanks each of which correspond a growing stage in the plant cycle. The water is delivered to each plant by pumping water to the bottles in the top tier of the structure; the water then cascades down to the next two rows through tubing that connects the bottles together. Water drains from the lowest bottle back into the reservoir. This system only requires the stakeholder to refill the reservoirs one time per week.

The nutrient subsystem is housed partially within the reservoir. Along with the structure and watering system, the stakeholder will receive packages of pre-measured nutrients that correspond to the growing cycle of the plants. By using a color-coding system, the nutrient system will be easy to understand regardless of the stakeholder's native language. The stakeholder simply has to fill the reservoirs with the nutrients and water which will then be delivered to the plants via the water delivery system.

Finally, the hydroponic (soilless) soda bottle system is composed of re-purposed 2-liter soda bottles and materials that can easily be sourced in the Wheat Ridge food desert. We chose a hydroponics system because they use up to 90% less water, so they can be watered less often and are typified by less insects, a more controlled environment, and a steady harvest [3]. The soda bottles are the foundation for the snow peas, lettuce, and spinach to grow. The water-nutrient mixture is pumped into the bottles and is carried to the plant via a wick. This design prevents the stakeholder from overwatering and underwatering the plants and lowers the cost of the entire system by using easily-sourced substrate instead of soil. The final solution also includes a tool which will allow the stakeholders to easily construct the bottle systems themselves despite their physical limitations. These five interconnected subsystems comprise the team's final solution (shown in Figure 1): an elegant, easy-to-maintain food growing system designed with the stakeholders' needs in mind.

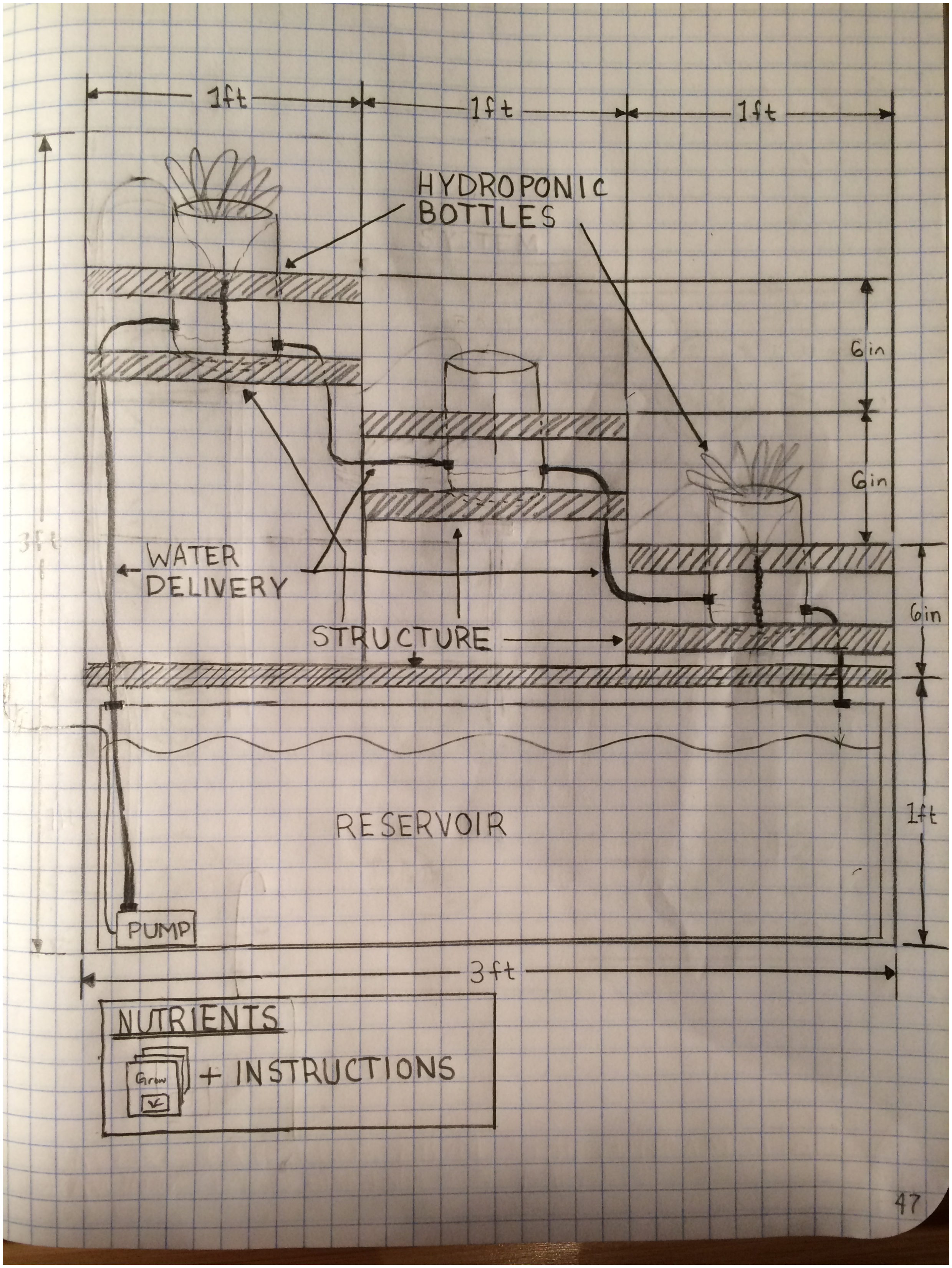

Figure 1: System Sketch Showing Each Subsystem

3 Subsystem Description

The water delivery subsystem is the sole mechanism for transporting nutrients and water from the reservoir to the soda bottles. This subsystem is critical to the overall system because if water and nutrients are not delivered to the bottles, the plants cannot grow and no food can be produced. The water delivery subsystem is comprised of four separate water circulation systems, one for each nutrient stage. This helps facilitate the system's modular design. Each circulation system corresponds to a single column of bottles and distributes water to each bottle in the column (see Figure 1).

Since we are using a wicking mechanism to transport water and nutrients from the bottom of the bottle to the plant, the circulation system does not have to run continuously, it merely needs to maintain the water level in each bottle. Because of this, the design requires the pumps to be on a timer which allows the water to run for a few minutes every hour. This solution decreases the environmental footprint of the system and also reduces operating costs for the stakeholder. Additionally, if there is a power outage and the pumps stop operating for a period of time, the system will remain stable until the water in the individual bottles runs out.

Because many of the water delivery system's components are interfaces with other subsystems, the only component of the design specific to the water deliver system is the tubing. The tubing carries water and nutrients from each of the four reservoirs to the uppermost bottle. The tubing also carries water from one bottle to the next in each column until the water drains out of the lowest bottle in the column and back into the reservoir through another tube. In the final design, 1/2" tubing will be used. This diameter was chosen for two reasons:

1. The fittings on the pumps that the team is considering are 1/2″ fittings.
2. There are many options for 1/2″ bulkheads on the market. From my online searches, 1/4" bulkheads are less common. These bulkheads are the primary interface point between the water delivery system and the hydroponic bottles (see Subsystem Interfaces for more details).

The tubing in the final product will be black to reduce the water's exposure to light. Exposure to light causes algae growth [4] and since one of the system's requirements is that algae growth is prevented, this precaution is necessary.

As shown in Figure 2, there is a total of 3′ of tubing between the pump and the uppermost bottle. 7 3/4″ of the tubing is inside the reservoir and 2′ 4 1/4″ is outside the reservoir. Figure 3 shows that there is a total of 1 $1/2'$ of tubing between each bottle: $1/2'$ horizontally and $1'$ vertically.

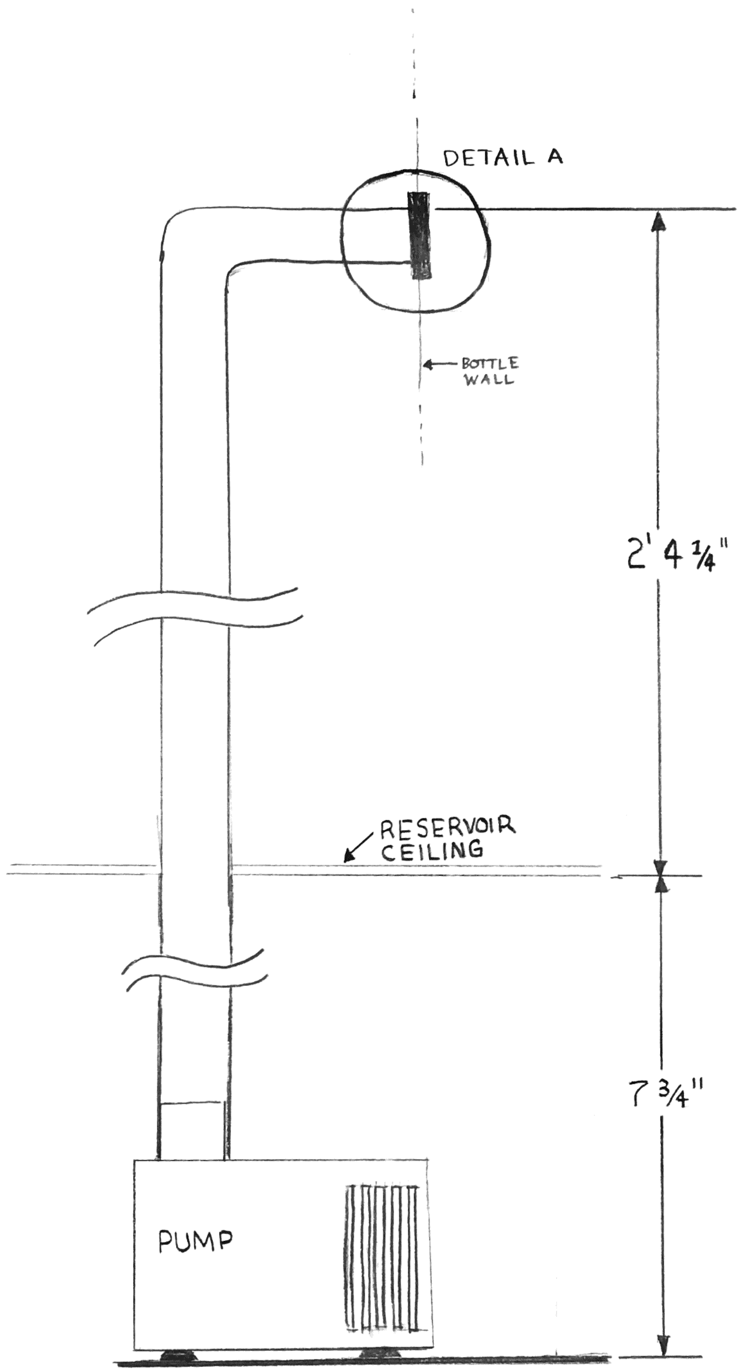

Figure 2: Dimensions of Tubing from Pump to Bottle

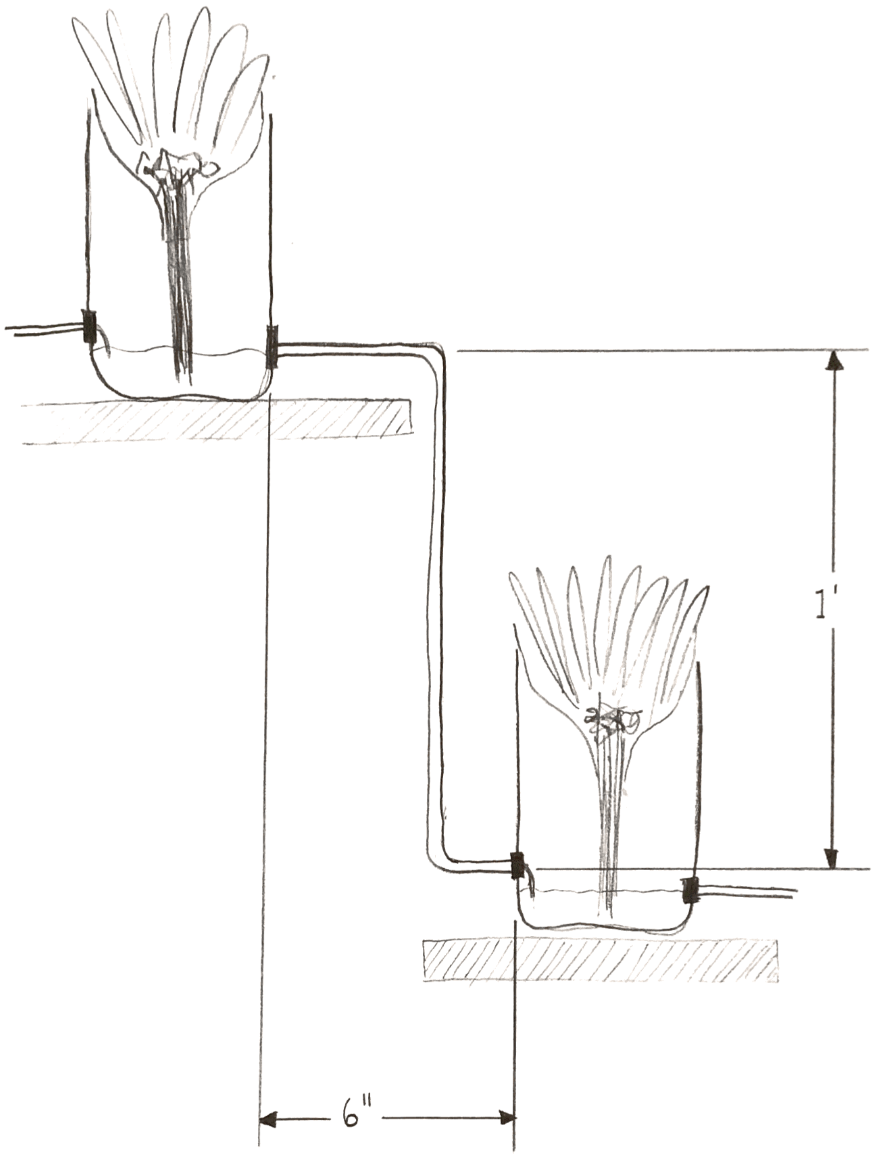

Figure 3: Dimensions of Tubing from Bottle to Bottle to Bottle

4 Subsystem Interfaces

There are two interfaces between the water delivery system and the other subsystems:

1. The connections to the four reservoirs in the reservoir system.
2. The connections to and from the twelve hydroponic bottles.

The interface with the reservoir is twofold. First, the tubing of the water delivery subsystem attaches to the pump in the reservoir. The tubing also passes through a hole cut in the ceiling of the reservoir. To ensure that the pump and tubing are compatible with one another, $1/2''$ tubing is being used. Additionally, the ceiling of the reservoir will have a $1/2''$ hole allowing the tube to pass through. This arrangement will allow the stakeholder to lift lid of the reservoir without having to disconnect any tubing.

The interface with the bottle consists of a bulkhead fitting, the $1/2''$ tubing and the bottle itself. Figure 4 shows this interface. The bulkhead fitting has two parts: the bulkhead body and the bulkhead locknut. The bulkhead body and the threads are one piece and fit through a hole in the soda bottle created using the bottle creation tool designed for the hydroponic bottle system. The bulkhead locknut is threaded and, once tightened, seals the gap between the bulkhead body and the soda bottle [5]. The threads of the bulkhead body also hold the tubing in place.

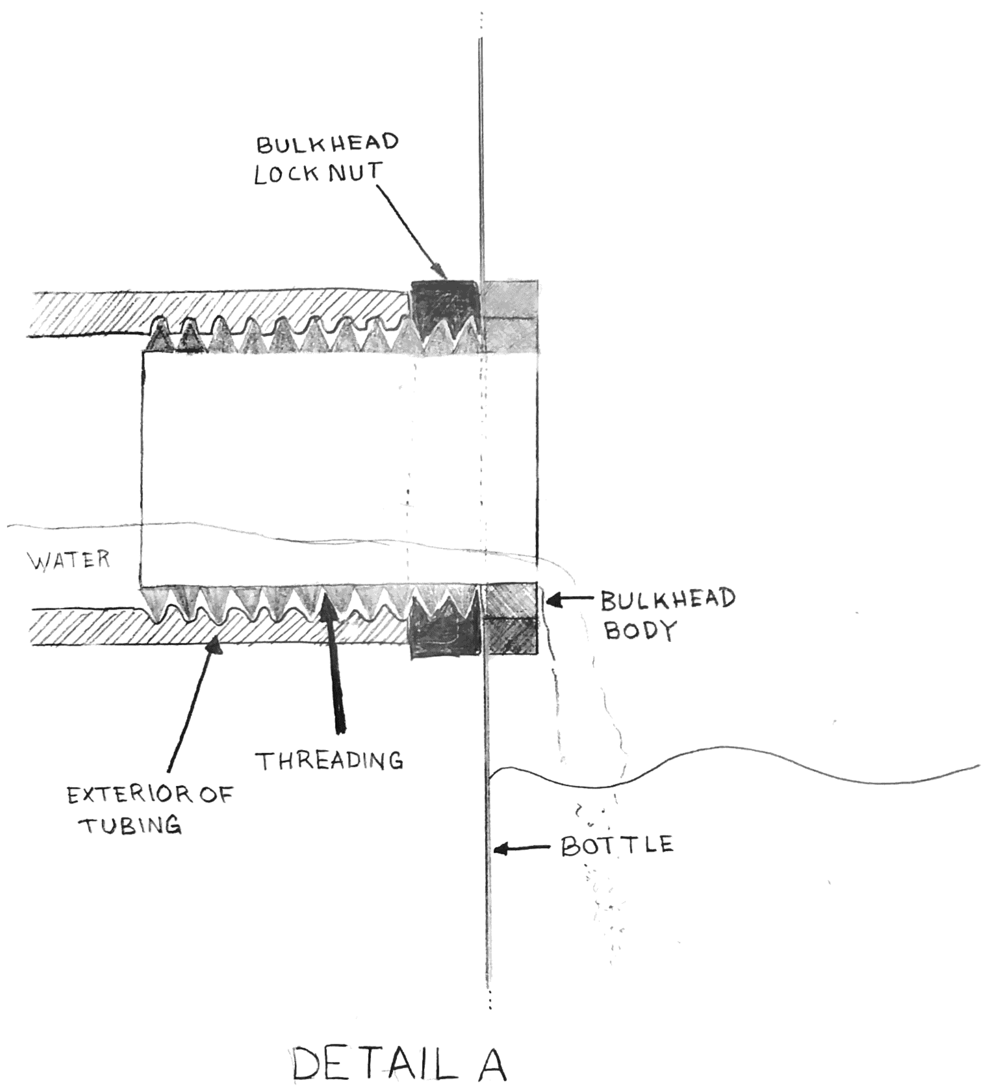

Figure 4: Bulkhead Fitting Connected to Bottle and Tubing

5 Subsystem Analysis

The water delivery subsystem is critical to the overall success of the team's system. Because of this, extensive testing is required to ensure that the subsystem works. The following is a list of the tests for the water delivery subsystem that have been identified by the team:

1. **Test Pump Head:** The pump must have enough head to raise the water from the reservoir to the level of the topmost bottle. The team has tested the head of two pumps, the *Pondmaster 35 GPH Magnetic Drive Utility Pump* and the *EcoPlus®* *Eco 66 Bottom Draw 75 GPH*. Unfortunately, both pumps had insufficient head. The *Pondmaster* brand pump was only able to raise the water about 1′ 6″. The team then tested the The *EcoPlus®* brand pump which performed better and was still only able to raise water about 2′ 6″.
2. **Test Bottle Connections:** The tubing must fit properly onto the bulkhead fitting and the bulkhead fitting must seal the hole in the bottle.
3. **Test Amount of Pump Time Required to Maintain Sufficient Level of Water:** It is important that the wicking material (designed in the Hydroponic Bottle Subsystem) never becomes dry. This would occur if it ran out of water, thus the water in the hydroponic soda bottles needs to be replenished periodically.

6 Summary

After testing the *Pondmaster* brand pump the team assumed that doubling the GPH would double the head. This assumption was disproved after testing the *EcoPlus®* which had over twice the GPH of the *Pondmaster* pump. The team then considered other ways to increase the head of the pumps that they already had. One idea was to decrease the diameter of the tubing, increasing pressure in the tube and hopefully pushing the water higher. The team has not started testing this idea.

If decreasing the tube diameter does not increase the head, the team will find a different pump with more head. Although finding such a pump is critical to the final design, other testing can occur before a pump is found.

The connection from the tubing to the bottles is critical to the overall success of the solution and thus is the most critical test for the water delivery subsystem. Because of this, these connections will be tested by November 10, 2016. In the case that the bulkhead fittings do not seal the holes in the bottle well enough, other options such as trying to utilize the built-in threads on the soda bottle may be considered.

In the final product, all of the fittings will, in addition to being watertight, need to be easily to install so that the stakeholder can create the bottle with limited technical knowledge. Because of this, the team will test for leakage by performing a stress test. This stress test involves turning the pump on for 12 hours and measuring any leakage through the bulkhead fittings.

In summary, the water delivery subsystem is essential to the functionality of the overall system and requires extensive testing to ensure that it works properly and interfaces correctly with the other subsystems.

References

[1] Centers for Disease Control and Prevention (2012). *A Look Inside Food Deserts* [Online]. Available: http://www.cdc.gov/features/FoodDeserts/index.html. [Accessed Sept. 11, 2016].

[2] United States Department of Agriculture Economic Research Service (19 Oct. 2016). *Food Access Research Atlas* [Online]. Available: http://www.ers.usda.gov/data-products/food-access-research-atlas/go-to-the-atlas.aspx. [Accessed: Oct. 28, 2016].

[3] J. Camas (04 Sept. 2014). *Home Hydroponics* [Online]. Available: http://www.epicurious.com/archive/blogs/editor/2014/09/home-hydroponics-easy-tips-for-growing-fresh-produce-all-year.html. [Accessed: Nov. 2, 2016].

[4] Washington State Department of Ecology. *Algae Information* [Online]. Available: http://www.ecy.wa.gov/programs/wq/plants/algae/lakes/AlgaeInformation.html. [Accessed: Oct. 19, 2016].

[5] United States Plastic Corp (2008). *How does a bulkhead fitting work?* [Online]. Available: http://www.usplastic.com/knowledgebase/article.aspx?contentkey=437 [Accessed: Nov. 3, 2016].