IOT – BASED DECISION SUPPORT SYSTEM FOR NUTRIENT FILM TECHNIQUE HYDROPONICS CULTURE MONITORED THROUGH ION-SELECTIVE ELECTRODES

An Undergraduate Capstone Project

Presented to the Faculty of the IT & Physics Department

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In Partial Fulfillment of the Requirements for the Degree

Bachelor of Science in Information Technology

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RECOMMENDATION FOR ORAL DEFENSE

In partial fulfillment of the requirement for the degree of **BACHELOR OF SCIENCE IN INFORMATION TECHNOLOGY,** *this UNDERGRADUATE Capstone Project entitled:*

IOT – BASED DECISION SUPPORT SYSTEM FOR NUTRIENT FILM TECHNIQUE HYDROPONICS CULTURE MONITORED THROUGH ION-SELECTIVE ELECTRODES

has been prepared and submitted by, **SOFIA B. MACALUDOS, JESSIE CONN RALPH M. SAM, ZAKI C. SARMIENTO, AND NIÑA ROSE SEBIAL** *and is recommended for* **ORAL DEFENSE.**

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This is to certify that the undergraduate capstone project entitled "**IOT – BASED DECISION SUPPORT SYSTEM FOR NUTRIENT FILM HYDROPONICS CULTURE MONITORED THROUGH ION-SELECTIVE ELECTRODES**" prepared and submitted by **SOFIA B. MACALUDOS, JESSIE CONN RALPH M. SAM, ZAKI C. SARMIENTO, AND NIÑA ROSE SEBIAL** in partial fulfillment of the requirements for the degree **BACHELOR OF SCIENCE IN INFORMATION TECHNOLOGY** is hereby recommended for approval.

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Our acknowledgements will not be complete without expressing our deep appreciation to God, whose divine guidance and blessings have always been constant in our capstone project. God’s providence and wisdom have been our source of strength and inspiration in this journey, and His overwhelming grace has consoled us through tough times and uncertainties, always assuring us of success and achievement.

ABSTRACT

This study developed an IoT-based system for comprehensive, automated monitoring of essential water quality parameters in Nutrient Film Technique (NFT) hydroponic systems. The system enabled real-time monitoring and management of acidity, temperature, electrical conductivity, water flow, and container water level, with push notifications alerting farmers to critical issues like clogging or pump failure. Automation features included controlling water acidity and electrical conductivity through automated liquid dispensing and temperature regulation by adjusting water flow. Key milestones included establishing a sensor data database, creating a dashboard for vital metrics, implementing parameter control automation, and generating activity reports. Using the Post – Study System Usability Questionnaire tool for evaluation, the system showed a high satisfaction result with an overall score of 1.37, and strong reliability with α at 95% confidence. This IoT system empowers hydroponic farmers with advanced monitoring, enabling timely interventions and informed decision-making for optimized crop cultivation.

Keywords: Nutrient Film Technique (NFT), Hydroponic Systems, Internet of Things (IoT), Automated Monitoring, Post – Study System Usability Questionnaire

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CHAPTER I

1.0 Introduction

The increasing global population and the need to produce more food to meet their caloric needs is putting a strain on traditional agriculture. With statistics predicting that the population will reach 9.8 billion people by 2050, it is estimated that 593 million hectares of land will need to be converted into agricultural land to meet these needs. This puts a significant strain on ecosystems and could lead to their extinction (Ranganathan, 2018).

In order to address this problem, farmers have turned to alternative methods of agriculture, such as hydroponics. Hydroponics is a method of growing plants without the use of soil, instead using a nutrient-rich water solution to reduce water consumption and the space required for farming (Katsiroubas, 2021). It is an agricultural technique that allows plants to be cultivated in nutrient-rich water rather than soil. (Lagomarsino, 2019). In the 20th century, Dr. William F. Gericke of the University of California was the first person to mention hydroponics. He pioneered the use of hydroponics for large-scale commercial farming in the 1920s and 1930s. His work laid the foundation for all types of hydroponic cultivation. (The History of Hydroponics · the Natural Farmer, n.d.).

There are 6 main types of hydroponic systems to consider: wicking, deep water culture, ebb and flow, aeroponics, drip systems, and nutrient film technique. (Collaborator, 2019). According to Trees.com, of all these types, NFT (Nutrient Film Technique) systems are better for hydroponics because they provide a consistent and steady flow of nutrient solution to the roots of plants. Also compared to other systems, the water quality of NFT is easily monitored. Since NFT systems typically use only one water container, which circulates nutrient-rich water through the channels where the plants' roots are growing. In contrast, other hydroponic systems, such as drip or ebb-and-flow systems, may require multiple containers or substrates to support the plants' growth.

Despite the numerous benefits that this system offers, it is important to note that it also has its limitations. This system requires careful monitoring and maintenance to ensure optimal plant growth and avoid potential problems such as clogging or nutrient imbalances. In an interview during our data gathering, interviewee stated that one of the main challenges of using hydroponics is the need for frequent monitoring of numerous factors, such acidity, temperature, and total dissolved solids in the water to maintain optimal growing conditions for plants. Manual monitoring can be a labor intensive and time-consuming task, especially for larger operations.

To mitigate this challenge, the research team proposes the development of an Internet of Things (IoT)-based decision support system for Nutrient Film Technique (NFT) hydroponic culture, which will leverage ion-selective electrodes for remote monitoring and automation. This system will incorporate technology to perform automation and remote monitoring to take the place of manual monitoring in the NFT hydroponics system. With the modified Waterfall methodology, the project is divided into distinct phases, each with its own goals and deliverables. The Waterfall methodology is used as it allows for a clear and predictable project timeline, making it easy to plan and manage the project and ensuring that it is completed on schedule and within budget. Modifying the Waterfall method is necessary due to its inflexibility in projects with rapidly changing or undefined requirements.

1.1 Statement of the Problem

NFT Cultured Hydroponics has become a popular alternative method of agriculture because of the huge task of agricultural systems to stimulate food production. However, like any alternative, this system also presents significant challenges. This system is present in some local and national areas, but most of the work is still done by hand. A shortage of rapid overview platforms for farmers of their hydroponics setup could lead to negligent management and eventually losses. Monitoring is a vital factor of this system. Monitoring is significant as it allows growers to ensure optimal growing conditions for the plants, which in turn leads to better yields and healthier plants. According to a study by the National Center for Biotechnology Information (NCBI), "the success of this method (hydroponics) depends on the proper management of the nutrient solution, including pH, temperature, and water electric conductivity.” This means that by regularly monitoring and adjusting the water pH levels, temperature conductivity (total dissolved solids), hydroponic growers can ensure that the plants are receiving the appropriate levels of nutrition. Which is crucial for their growth and development.

The researchers have recognized the challenges and difficulties faced by farmers in manually monitoring their hydroponics systems, leading to potential negligent management and losses. To address these issues, the proposed solution is the development of an IoT-based decision support system. This system aims to ensure efficient, accurate, and real-time monitoring of hydroponic farms.

1.1.1 General Objectives of the Study

The researchers aim to develop an Internet of Things (IoT) based system that enables comprehensive monitoring of the crucial factors affecting water quality in NFT hydroponics, including acidity, temperature, electric conductivity, water flow, and container water level. This system will incorporate push notifications for farmers when human intervention is necessary, such as in cases of clogging, pump failure and low water level in container, and will also feature automation capabilities to control water acidity, and electric conductivity via automated dispensing of liquid solution in the water container and temperature via increasing the water flow of the system.

1.1.2 Specific Objectives of the Study

1. Provide a database that stores data from sensors.

2. Provide a dashboard of water acidity, temperature, electrical conductivity (total dissolved solids), water flow and water level.

3. Provide automation for controlling water acidity, electric conductivity, and temperature in the NFT system by automating the dispensing of liquid solution into the water container and adjusting water flow.

4. Generate a printable report detailing system activity and sensor data.

5. Provide system push notifications for abnormal water quality and problems that need human intervention such as clogging, pump failure and sudden low of container water level.

1.2 Scope and Limitation

The study aims to develop an IoT-based decision support system for NFT hydroponics farms that will be tested in General Santos City will enable comprehensive monitoring of the crucial factors affecting water quality, including acidity, temperature, electric conductivity, water flow, and container water level. The system will have a database that stores data from sensors, a dashboard that displays the sensor data, automation capabilities to control water acidity, electric conductivity, and temperature via automated dispensing of liquid solution in the water container and increasing water flow. The system will also generate printable reports of system activity and sensor data and provide systems push notifications for abnormal water quality and problems that require human intervention, such as clogging, pump failure, and sudden low of container water level. However, there are some limitations to the study. Firstly, the testing scope of the study will be limited to NFT hydroponics farms in General Santos City and will not be tested in other areas. Secondly, the system will only monitor and control the crucial factors affecting water quality and no other factors that may affect plant growth and development. Thirdly, the system's automation capabilities will be limited to controlling water acidity, electric conductivity, and temperature via automated dispensing of liquid solution in the water container and increasing water flow. Fourthly, the system's notifications will only be sent via systems push notifications and will not include other forms of communication. Lastly, it should be noted that the IoT device will not function properly in case of a power interruption, such as a brownout.

1.3 Significance of the Study

The development of an IoT-based decision support system for NFT hydroponics farms that will be tested in General Santos City is significant **for the hydroponics farmers**. Firstly, the system can help farmers optimize the growing conditions of their hydroponic crops, which can lead to better yields and healthier plants. By providing comprehensive monitoring of the crucial factors affecting water quality in NFT hydroponics, including acidity, temperature, electric conductivity, water flow, and container water level, the system can help farmers ensure that their plants are receiving the appropriate levels of nutrition. Secondly, the system's automation capabilities can reduce the need for manual labor, which can help farmers save time and resources. The automation of water acidity, electric conductivity, and temperature via automated dispensing of liquid solution in the water container and increasing water flow can provide farmers with more time to focus on other aspects of their hydroponics farms, such as crop selection, planting, and harvesting. Thirdly, the system's notifications can alert farmers to abnormal water quality and problems that require human intervention, such as clogging, pump failure, and sudden low of container water level. By providing timely notifications, farmers can take immediate action to resolve the issues and prevent further damage or losses. Lastly, the study's findings can help farmers in General Santos City and beyond understand the benefits of using IoT-based decision support systems in agriculture. The study can serve as a reference for farmers who may be interested in adopting similar systems for their own hydroponic farms, which can lead to increased productivity, profitability, and sustainability.

1.4 Definition of Terms

Database - a structured collection of organized data, usually kept electronically in a computer system.

Propagators – The one that makes sure that the environment is humid and warm enough for the plant to thrive in so that it can become resilient enough to survive anything.

IoT - refers to both the overall network of connected devices as well as the technology that enables communication between connected devices as well as between them and the cloud.

Decision Support System - A decision support system (DSS) is a computer-based system that is designed to assist users in making decisions. DSSs are typically interactive systems that allow users to input data and then use that data to generate recommendations or solutions to a problem.

pH level - A measure of how acidic/basic water is. Microcontroller – A compressed microcomputer manufactured to control the functions of embedded systems in office machines, robots, home appliances, motor vehicles, and several other gadgets.

Nutrient Film Technique (NFT) - a hydroponic system where a shallow stream of nutrient-rich water is continuously circulated over the plant roots. The plant roots are suspended in a sloping, narrow trough, or channel, with a thin film of nutrient solution flowing over the roots. The nutrient solution is typically re-circulated through the system and can be adjusted to meet the plant's specific needs. NFT is a popular hydroponic system because it uses less water and nutrients than traditional soil-based farming, is suitable for a wide range of plants, and can be used in a variety of settings, including urban environments and areas with limited access to water.

Summary of Readings - displays all the data collected from all sensors included in a system or device. This consolidated view provides users with a comprehensive overview of the sensor readings, allowing them to quickly assess the current status or performance of the system. By presenting data from multiple sensors in a single interface, the summary feature enhances user convenience, facilitates monitoring and analysis, and supports informed decision-making.

Liquid Solutions

- **pH-Up Solution** - expertly crafted solution to counteract low pH levels in hydroponic setups. Formulated with precision using potassium hydroxide and potassium carbonate. Recommended initial dosing is one milliliter per gallon, followed by a 15 to 30 minute wait before retesting pH levels. Typically, a dosage of 1 to 2 milliliters per gallon maintains optimal pH levels, fostering robust plant growth.
- **pH-Down Solution** - a solution that features food-grade phosphoric acid in its formulation, known for its consistent and reliable pH-lowering capabilities. Ideal for hydroponic systems, it helps maintain an optimal environment for crops. Just like its counterpart, the pH-Up solution, it's recommended to start with an initial dosing of one milliliter per gallon, with a 15 to 30 minute wait before retesting pH levels. Typically, a dosage of 1 to 2 milliliters per gallon ensures a balanced pH for robust plant growth.

- **FloraGro Solution** - is a leading nutrient solution in hydroponic cultivation, crucial for managing total dissolved solids (TDS) and promoting thriving plant growth. When TDS levels drop below this range, supplementing with FloraGro® is essential. Adding 1 to 2 teaspoons per gallon of water helps bolster TDS levels effectively.

CHAPTER II

Review of Related Literature and Technologies

In this chapter, the researchers have summarized the literature and technologies they have discovered. The following sections will provide background information that will aid in achieving the final objective of the system. The analysis of current technologies and their features will then be used to highlight the differences between them, and the system being suggested.

2.1 Review of Related Literature

Agriculture's fastest-growing industry, hydroponics, may eventually control how food is produced. People will use cutting-edge technology like hydroponics and aeroponics to establish extra channels of crop production when the population rises and arable land shrinks as a result of poor land management. Some countries in Asia and Africa have seen success with hydroponics. It's possible that hydroponics will be used in space as well. (Dholwani et al., 2018)

Unlike growing in soil, where there are so many different influences (pH, light, air temperature, microorganisms, tilth, and so on), hydroponic growing can be almost completely controlled. This is because it effectively removes the plant from a natural environment and instead creates what is, at least in theory, an optimized 'ecosystem' designed to grow in the absence of soil. The plants are fed a nutrient solution that can come in many forms, but usually, it's water with a mix of fertilizers and minerals or trace elements that plants require for food. (Gericke, 2012).

There are many plants you can grow hydroponically. While almost anything can be grown using hydroponics, some plants thrive in these conditions much more than others (Jamie, 2022). From vegetables, fruits, and herbs you can all grow them hydroponically some may be simpler than others while some can be more complicated. Some plants that can be grown hydroponically are Palay/Paddy/Rice, Corn, Coconut, Sugarcane, Banana, Pineapple, Coffee, Mango, Tobacco, Abaca, Peanut, Mungbean, Cassava, Sweet Potato, Tomato, Garlic, Onion bulb, cabbage, eggplant, calamansi, and rubber.

2.1.1 Hydroponics and Its Types

There are 6 major types of hydroponics: Wicking system, Deep-water culture (DWC), Nutrient Film Technique (NFT), Ebb and Flow System, Aeroponics system, and Drip systems. According to the Collaborators of HydroPros (2019), there are several variables to consider when choosing a hydroponic system. From price to plants to waste, it's important to research the perfect hydroponics system for a garden. It means choosing the right system is critical to hydroponic gardening success. If people want something low-cost and relatively low maintenance, especially for new growers, they should consider a wicking system, DWC, or NFT. If people are a more advanced grower looking for greater yield with stronger monitoring processes, they should consider ebb and flow or aeroponics.

2.1.1.1 Wick System/Wicking System

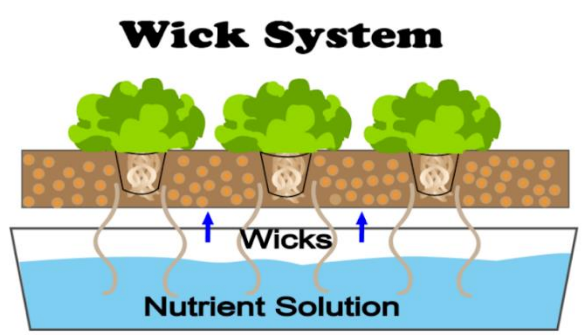


Figure 2.1. 1 Wick System

According to NoSoilSolutions (2022), The wick system is the most simplistic type of hydroponic system requiring no electricity, pumps, or aerators. Among the different types of hydroponic systems, it's the only one that can be a completely passive system (no electricity needed).

HRG Distribution (n.d.) stated that this is an ideal setup for newer hydroponic growers, or for those who want a low-maintenance hydroponic cultivation system. This is because it is a hands-off system, one of the most basic types of hydroponics system, and ideal for smaller plants.

According to Trees (2022), the wick system operates by drawing up nutrient solutions from the reservoir to the plants through the capillary movement like a wick into the growing medium. With this system, plants are placed in a net pot and are held by a floating platform above a container of nutrients and water. Plant roots are suspended and stretched into the nutrient-rich oxygenated solution.

2.1.1.2 Deep Water Culture (DWC)

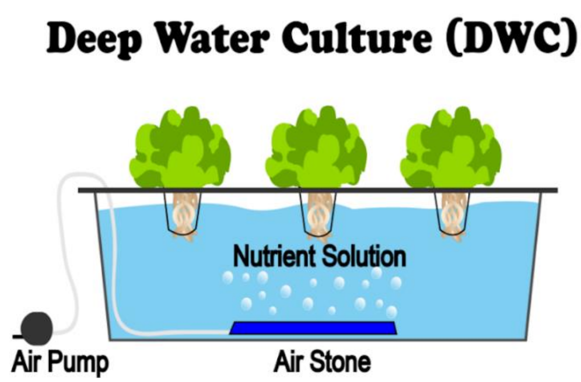


Figure 2.1. 2 Deep Water Culture

According to Trees (2022), DWC is the simplest and easiest to maintain. However, compared to the Wick system, it is an active recovery system, so there are moving parts. Trees also stated that of all active systems of hydroponic growing, this is the simplest.

NoSoilSolutions (2022) stated that DWC works great for almost all plants but works especially well for large plants with big root systems or ones that grow an abundance of fruit. This is because the roots will become huge and will be less prone to root diseases. The plant's roots are suspended in the nutrient solution and the air is provided directly to the roots with an air stone or diffuser. This system functions by submerging plant roots directly in the highly oxygenated nutrient solution of the reservoir.

2.1.1.3 Nutrient Film Technique

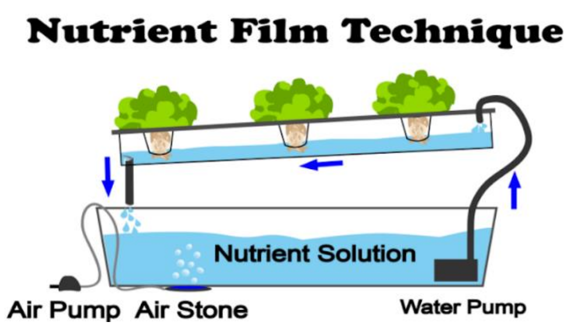


Figure 2.1. 3 Nutrient Film Technique

NoSoilSolutions(2022) stated that one of the go-to techniques for commercial growers is the simple concept, which makes it simple to set up a system to grow a lot of plants. Of all the different kinds of hydroponics systems, NFT hydroponics systems are the most scalable. According to HRG Distribution(n.d.), NFT system is one of the most straightforward types of hydroponics. It entails a very thin stream of water that is fully nutrient dissolved for hydroponic plant growth.

According to Trees (2022), It works by continuously flowing the solutions, so there is no need for a timer. The nutrient is pumped into the growing tray (or a tube) and delivered to the plant roots; once the flow reaches the channel's end, it drains back to the reservoir through the slightly downward tube. The roots suspended above the water level are constantly moist; they also receive plenty of oxygen from the air around them. Since no growing medium is used, plants are typically held in a grow-basket or a supporting collar. Because there is no growing medium to hold moisture, an extended period of interruption of the nutrient solution can cause the roots to dry, and plants' death. To provide oxygen in the water, and the grow tube, air stones or capillary matting must be placed in the reservoir. This also helps keep the system running for long without manually and frequently checking.

According to HRG Distribution NFT has its pros and cons. The Nutrient Film Technique (NFT) system has advantages like less reliance on growing medium, water conservation through recirculation, and improved oxygenation for root health, but it is susceptible to pump failures and power outages, unsuitable for large plants, needs regular monitoring to ensure proper delivery, and may experience problems with root blockage. Understanding these benefits and drawbacks enables researchers and growers to choose hydroponic techniques for specific crop needs. NFT systems excel in cultivating leafy green plants with short growth periods, making them a preferred choice for crops like lettuce and herbs. More will be discussed in the next section.

2.1.1.4 Ebb and Flow System

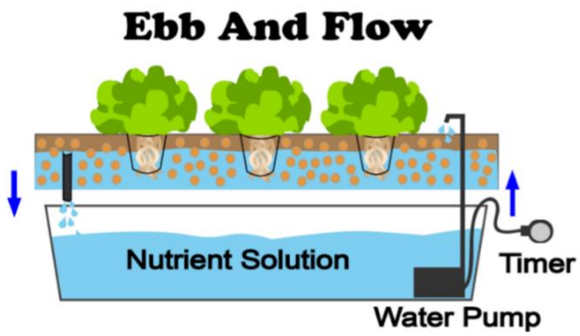


Figure 2.1. 4 Ebb and Flow

According to HRG Distribution (n.d.), The ebb and flow system, also known as the flood and drain method, is simple to set up and can be easily automated. Plants are grown in a grow tray or container with a nutrient-rich growing medium, and the hydroponic system works by flooding the roots with nutrient-rich water and then draining it back into the reservoir.

Ebb and Flow encourages efficient nutrient, water, and energy use, it ensures sufficient oxygenation of the roots, it promotes healthy root development, and it is good for water-craving plants like lettuces and spinach. However, it uses a lot of growing media which requires expertise with the system and roots of the plants can quickly dry out and die if the pumps stop. (HRG Distribution, n.d.)

2.1.1.5 Aeroponics

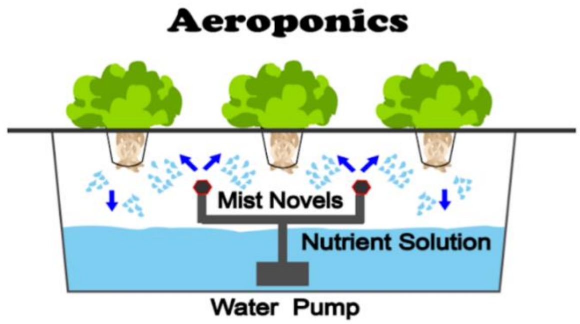


Figure 2.1. 5 Aeroponics

Trees (2022) stated that the Aeroponics system is the most advanced and expensive but also the most successful. It is probably the most high-tech type of the six listed. In Aeroponics, the nutrient solution is continuously pumped and sprayed onto the root systems rather than flowing through a thin film of nutrients as in the NFT system, where the plant roots hang freely in the air without the use of a growing medium. Since the roots are exposed to the air, the roots will be dried out quickly in case of a misting cycle interruption and this system is not as cheap, and easy to set up as other types. However, the cycle is much shorter compared to other hydroponic types, typically being a few minutes between each misting interval.

According to HRG Distribution(n.d.), Aeroponics offers several advantages. The roots in aeroponic systems receive superior oxygenation compared to those submerged in water, leading to potential increases in yields and growth rates. Additionally, aeroponics requires minimal or no growing medium, reducing costs and simplifying the system setup. However, there are certain drawbacks to consider. Aeroponic setups can be expensive, requiring careful investment. Regular observation of the nutrient solution nozzles is necessary to prevent failure and root drying. Due to its complexity, aeroponics is generally not recommended for beginners. Moreover, aeroponic systems are more susceptible to drying out during power outages, necessitating contingency plans to mitigate this risk.

2.1.1.6 Drip System

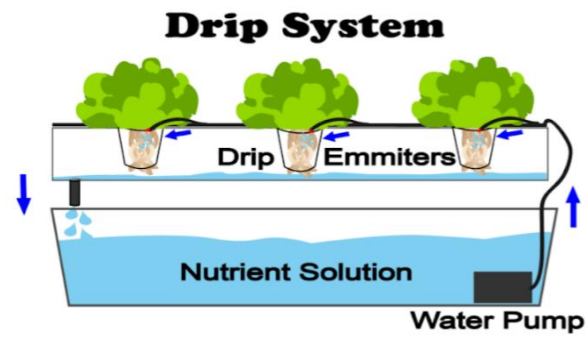


Figure 2.1. 6 Drip System

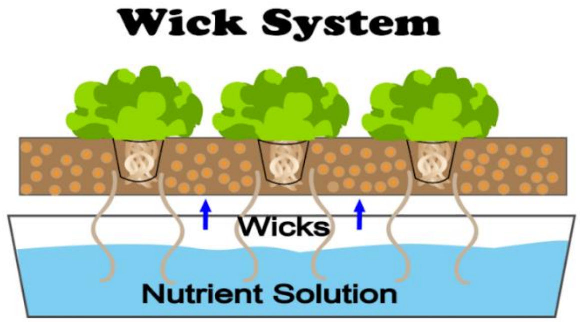
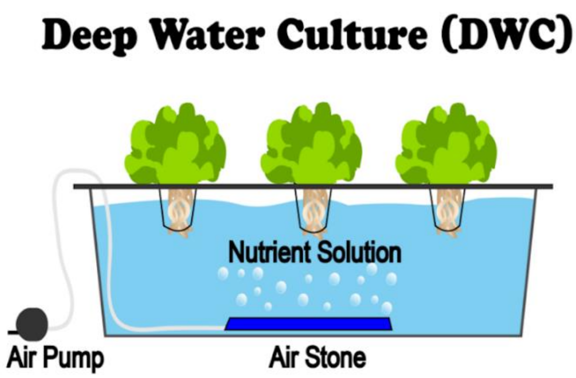
Drip systems are more commonly used in commercial settings, similar to NFT but with a continuously circulating pump for increased oxygenation and nutrient uptake. (6 Types of Hydroponic Systems & Choosing The Right One | HydroPros.Com — HP, 2019)

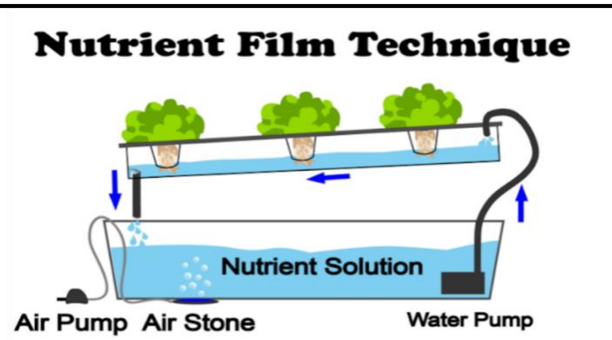
According to Trees (2022), Drip systems can be an active recovery or non-recovery type system. In a recovery drip system, the nutrient solution is returned to the reservoir through the drip tray, allowing for efficient use of the solution. On the other hand, the non-recovery system does not collect the leachate, which is considered less efficient and is typically utilized in the early stages of hydroponics. However, the recovery system proves to be more efficient and cost-effective as it allows for the reuse of excess solutions. In contrast, the non-recovery system requires less maintenance since the solution is not recycled, resulting in minimal impact on the pH levels of the reservoir.

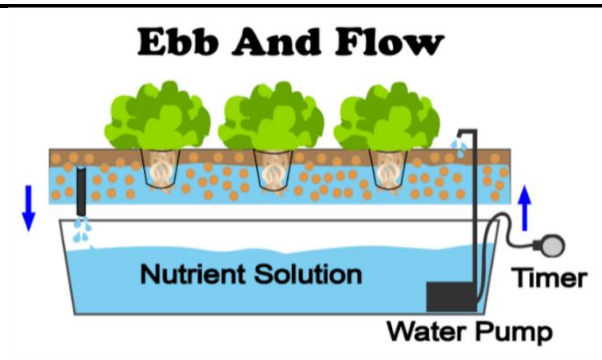
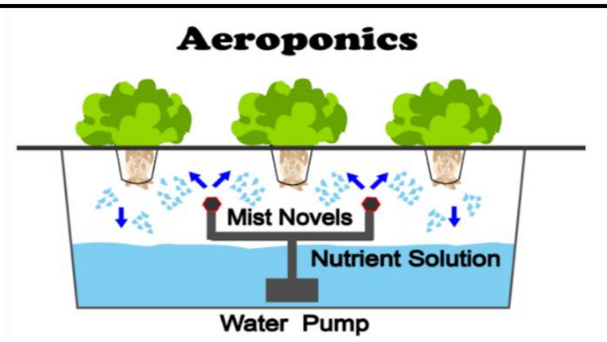
Trees (2022) also stated that the main principles behind the system are quite simple yet effective. This system is easier to control the nutrients and water delivery, the setup and maintenance of the system is relatively cheap, and it's easier to build and use. However, pH and nutrient fluctuations may rise and the system is more suited to larger gardens.

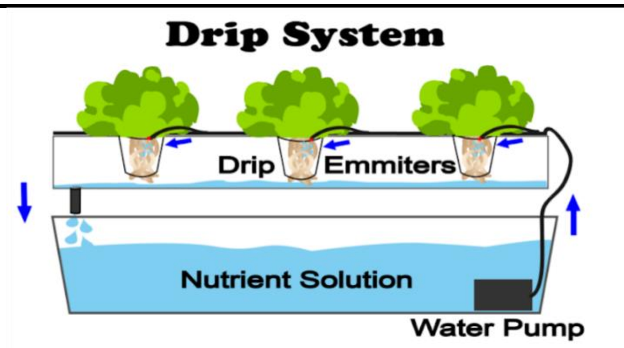
The table below (table 2.1) provides an overview of various hydroponic systems setups and characteristics. The Wick System is highlighted as beginner-friendly, utilizing capillary action for nutrient delivery without the need for electricity or pumps. Deep Water Culture (DWC) involves suspending roots in a nutrient solution, particularly beneficial for larger plants requiring optimal oxygen levels. Nutrient Film Technique (NFT) systems feature continuous nutrient flow for suspended roots, favored by commercial growers but demanding careful maintenance. Ebb and Flow Systems, also known as Flood and Drain, automate nutrient delivery through flooding and draining cycles, promoting healthy root growth but risking desiccation if pumps fail. Aeroponics suspends roots in air for superior oxygenation and yield potential but is complex and costly, not recommended for beginners. Drip Systems, using continuous pumps for enhanced oxygenation and nutrient absorption, are highlighted, with active types being more efficient but requiring more maintenance, suitable for larger gardens but susceptible to pH and nutrient fluctuations.

Table 2. 1 Summary of Each Type of Hydroponics System

Hydroponic Type	Setup	Summary
Wick System/Wicking System		The Wick system is a beginner-friendly hydroponic method that uses capillary action to deliver nutrients and water to plant roots without the need for electricity or pumps. It is low-maintenance and suitable for growing smaller plants.
Deep Water Culture (DWC)		DWC is a simple hydroponic system that involves suspending plant roots in a nutrient solution. It provides optimal oxygen

		levels to the roots, making it ideal for larger plants. Unlike the passive wick system, DWC requires an air pump to ensure continuous oxygenation of the nutrient solution.
Nutrient Film Technique		NFT hydroponics, popular among commercial growers, features a continuous flow of nutrients to nourish suspended plant roots. Despite the benefits of saving water, these systems require careful maintenance and

		can be susceptible to pump failure.
Ebb and Flow System		Also known as Flood and Drain, the Ebb and Flow system is easily automated, flooding plants with nutrient-rich water prior to re-entry to promote healthy yet reliable root growth high growth rates, risking root desiccation if the pumps fail.
Aeroponics		Aeroponics provides nutrients mixed with roots suspended in the air, providing better oxygenation and yield. However, in

		addition to the risk of root canal use and system failure, the complexity and cost make it unsuitable for beginners.
Drip System		Drip systems use a continuous pump to improve oxygen and nutrient absorption, while active varieties are more efficient but require more maintenance and are more cost-effective and manageable and are better suited for larger gardens and can experience pH and nutrient fluctuations.

2.1.2 Hydroponics and Its Solution

In hydroponics, plant nutrients are categorized into macronutrients and micronutrients. (D' Anna, 2022) Macronutrients, needed in larger quantities, include carbon, phosphorous, hydrogen, nitrogen, oxygen, sulfur, potassium, magnesium, and calcium. The primary macronutrients for hydroponic systems, known as NPK, are nitrogen, phosphorus, and potassium. (Pomelo, 2023) primary macronutrients are crucial for leaf growth, root development, and overall plant health. Secondary macronutrients like calcium, magnesium, and sulfur are also essential in contributing in cell structure, chlorophyll production, and protein synthesis.

Micronutrients, required in smaller amounts, include zinc, nickel, boron, copper, iron, manganese, molybdenum, and chlorine. Each plays a vital role in plant metabolic processes. (Pomelo, 2023) A balanced mix of macronutrients is crucial for optimal plant growth, and achievable through commercial blends or customized solutions. They are essential for chlorophyll production, enzyme activation, growth hormone synthesis, root development, cell wall strength, cell division, carbohydrate metabolism, nitrogen fixation, and photosynthesis.

According to Pomelo (2023), Inadequate or excessive levels of these elements can lead to nutrient deficiencies or toxicity, impacting plant health and productivity in hydroponic systems. The amount of nutrients required in a hydroponic system is influenced by several factors, including the type of plant being grown, the system's size, and the stage of growth. Each plant has specific nutrient needs, and understanding these requirements is crucial to providing the appropriate amount of nutrients. Larger systems with a greater number of plants demand a higher nutrient volume than smaller setups.

According to General Hydroponics (n.d.), water quality significantly influences the outcome of your readings. When in doubt, it's prudent to apply a conservative amount of nutrients rather than risking over-application. Maintaining the nutrient solution within the range of 800 to 1500 ppm is recommended unless specific information about the plant's ppm tolerance level is available. This approach ensures a cautious and balanced nutrient application in hydroponic systems.

General Hydroponics offers two essential solutions for maintaining optimal pH levels and one essential solution for managing total dissolved solids in hydroponic systems. They are as follows:

2.1.2.1 General Hydroponics pH-Up Solution:

General Hydroponics offers a pH-Up Solution designed to address low pH levels in hydroponic systems. The base solution is carefully formulated using potassium hydroxide and potassium carbonate. This product is versatile and suitable for various high-value crops, including hemp, vegetables, herbs, fruits, flowers, and more. For initial dosing, it's recommended to start with one milliliter per gallon, followed by a waiting period of 15 to 30 minutes before retesting the pH. The normal dosage typically falls between 1 to 2 milliliters per gallon of the pH-Up solution, ensuring optimal pH levels for healthy plant growth.

2.1.2.2 General Hydroponics pH-Down Solution:

General Hydroponics also provides a pH-Down Solution, using food-grade phosphoric acid in its formulation. This product is recognized for its consistency and reliability in lowering pH levels, maintaining an optimal environment for hydroponically grown crops. For initial dosing, such as with the pH-Up solution, it's recommended to start with one milliliter per gallon, followed by a waiting period of 15 to 30 minutes before retesting the pH. The normal dosage typically falls between 1 and 2 milliliters per gallon of the pH-Up solution, ensuring optimal pH levels for healthy plant growth.

Table 2.2 provides an overview comparison of two hydroponic solutions that are essential for maintaining the pH level in a hydroponic system: pH-Up Solution and pH-Down Solution. The pH-Up Solution is formulated with potassium hydroxide and potassium carbonate to increase pH levels in nutrient solutions when they are too low. Conversely, the pH-Down Solution, containing food-grade phosphoric acid, decreases pH levels when they are too high. Both solutions not only serve their primary purposes but also contribute to pH stability, crucial for ensuring optimal plant growth and health in hydroponic systems.

Table 2. 2 Comparison of the Key Features of the Two Essential Hydroponic Solutions for Maintaining the pH Level in Hydroponic Systems

Hydroponic Solution	**Formulation**	**Purpose**	**pH Stability**
pH-Up Solution	The base solution, containing potassium hydroxide and potassium carbonate,	Used when the nutrient pH is too low, the pH-Up Solution brings it to the proper	In addition to its main purpose, the product is recognized for its ability to enhance pH

	serves as an efficient method for increasing the pH levels in nutrient solutions.	level, ensuring an optimal environment for plant growth.	stability, a vital factor for ensuring the overall health and growth of plants.
pH-Down Solution	Comprised of food-grade phosphoric acid, the pH-Down Solution provides a dependable method for decreasing the pH of nutrient solutions.	Used when the nutrient pH is too high, the pH-Down Solution brings it to the proper level, ensuring an ideal growth environment.	Similar to the pH-Up Solution, this product promotes pH stability.

2.1.2.3 General Hydroponics FloraGo Solution:

In the realm of hydroponic cultivation, the effective management of total dissolved solids (TDS) is fundamental to nurturing thriving plants. Among the array of nutrient solutions available, FloraGro® stands out as a premier brand renowned for its efficacy. Maintaining ppm levels within the prescribed range ensures optimal growth outcomes, with FloraGro® serving as a reliable solution. When TDS readings dip below the recommended 800 to 1500 ppm range, supplementing with FloraGro® becomes imperative. By adding 1 to 2 teaspoons of FloraGro® per gallon of water—where each teaspoon equates to approximately 14.79 milliliters—growers can bolster TDS levels effectively. Yet, it's vital to acknowledge the significance of water quality in influencing ppm accuracy. Hence, a cautious approach, favoring conservative nutrient supplementation, is advocated to mitigate the risk of over-fertilization. This aligns with FloraGro®'s commitment to providing balanced nutrition tailored to plant needs, thereby fostering robust growth and yielding optimal hydroponic results.

2.1.3 Hydroponics and the Use of Nutrient Film Technique (NFT)

Hydroponic systems employ various methods to deliver nutrient water to plants, either actively or passively. Active systems, such as the Nutrient Film Technique (NFT), utilize pumps to circulate water, whereas passive systems maintain plants floating above the water without mechanical assistance (Soto, 2020). The Nutrient Film Technique (NFT) stands out for its versatility and efficiency, particularly favored by growers for its simple design.

Commonly utilized for cultivating smaller, quick-growing plants like lettuce, herbs, baby greens, and strawberries (Trees.com Staff, 2022), the NFT system involves delivering nutrient water to plants via channels or trays, where pumps recycle unused water back into the reservoir.

This system's water-saving advantage is notable, as it consumes minimal water due to its continuous flow design (Soto, 2020). In NFT systems, plants sit in small openings atop enclosed channels, allowing gravity to draw nutrient water down the channel and through a drain, back into the reservoir for reuse. Shorter trays are preferred to ensure even nutrient distribution and prevent issues like root rot or uneven nutrient uptake. Additionally, NFT systems minimize the need for excessive growing media and mitigate salt build-up concerns.

Effective water management is crucial in hydroponic cultivation, with recommended practices including regular water changes every two to three weeks for average-sized systems and maintaining clean water tanks to prevent nutrient accumulation, bacterial growth, and fungal proliferation. Furthermore, ensuring a consistent nutrient solution flow through NFT systems, with rotation every four hours, promotes optimal nutrient uptake and oxygenation for sustained plant health and productivity (Admin, 2021).

2.1.4 Internet of Things (IoT)

Over the past few years, IoT has become one of the most important technologies of the 21st century. Now that we can connect everyday objects—kitchen appliances, cars, thermostats, baby monitors—to the internet via embedded devices, seamless communication is possible between people, processes, and things. (Oracle, n.d) By means of low-cost computing, the cloud, big data, analytics, and mobile technologies, physical things can share and collect data with minimal human intervention. In this hyperconnected world, digital systems can record, monitor, and adjust each interaction between connected things. The physical world meets the digital world—and they cooperate.

According to Gillis (2022), the Internet of Things, or IoT, is a system of interrelated computing devices, mechanical and digital machines, objects, animals or people that are provided with unique identifiers (UIDs) and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction. This definition is widely accepted in the field of computer science and engineering, IoT is a rapidly growing field with a wide range of applications in various industries such as healthcare, transportation, manufacturing, and more.

An IoT ecosystem consists of web-enabled smart devices that use embedded systems, such as processors, sensors and communication hardware, to collect, send and act on data they acquire from their environments. (Gillis,2022). IoT devices share the sensor data they collect by connecting to an IoT gateway or other edge device where data is either sent to the cloud to be analyzed or analyzed locally. Sometimes, these devices communicate with other related devices and act on the information they get from one another. The devices do most of the work without human intervention, although people can interact with the devices -- for instance, to set them up, give them instructions or access the data.

2.1.5 Hydroponics IoT Monitoring System

O'Donnell (2022) claims that hydroponics is a very helpful approach for growing, but it is very reliant on keeping an eye on the pH and EC of the nutrient solution being utilized. Growers may optimize their hydroponic systems and produce big, healthy plants by measuring and controlling pH and EC properly. O'Donnell emphasizes that hydroponics is a helpful approach for growing but it is very reliant on keeping an eye on pH and EC of the nutrient solution. The pH of the solution should be kept in the range that is suitable for the plants being grown, usually between 5.5 and 6.5 for most plants. EC measures the concentration of dissolved minerals in the solution and should be kept within the optimal range for the plants being grown. By measuring and controlling pH and EC properly, growers can optimize their hydroponic systems and produce big, healthy plants.

It's crucial to keep an eye on the PPM/EC/TDS levels in a hydroponic garden because healthy plant growth and development require a particular ratio between all of these values. (Hale, 2022) If they are too low, there won't be enough nutrient ions in the water, and if they are too high, plants won't be able to absorb them and toxicity issues may result. Hale, on the other hand, claims that maintaining a particular ratio between PPM, EC, and TDS is crucial for healthy plant growth and development. These values are used to indicate the strength of the nutrient solution and are interrelated. Maintaining the correct ratio between these values ensures that the plants have access to the right balance of nutrients for optimal growth. If the levels are too high or too low, it can lead to nutrient deficiencies or toxic levels of nutrients, which can inhibit plant growth or even kill the plants.

According to research by Spandana et al. (2020), the control process in hydroponics continues to be carried out in a traditional manner or with the use of human labor. Farmers or owners of hydroponic farming systems occasionally spend a lot of time controlling the density level of the nutrient solution, for instance, which is done at least once a day. If the density of nutrients is too high or too low, then add water or nutrients. Due to the fact that it is ineffective and inefficient, this develops into a pretty significant issue.

According to Autogrow (n.d.), Hydroponic grow systems are a sustainable method of growing with water with savings between 70% and 90% depending on the type of plant and your grow set-up. This is because the water is recycled and re-used in a closed-loop system, rather than being lost to evaporation or runoff. Additionally, hydroponic systems can be designed to use less water overall, as they allow for precise control over the amount of water and nutrients that the plants receive. The water savings achieved through hydroponic growing can be quite substantial. Depending on the type of plant and the specific grow set-up, water savings can range between 70% and 90%. Crops grown in hydroponic environments include microgreens, leafy greens and medicinal cannabis. Rockwool is one of the most common substrate options on the market but others include perlite, vermiculite, coir, coco, clay pellets or even peat moss, sawdust, sand and gravel.

Manual Hydroponics can give inconsistency as it is somehow hard to keep track of everything without assurance aside from the test kits bought online or in store. (Autogrow, n.d.) With hydroponics any interruption in watering or feeding can ruin the plants fast. Where the root zone is exposed (NFT) plants can dry out quickly, leading to crop wastage. An automated hydroponic monitoring system ensures things run accurately. The size and scope of a hydroponic operation may require different solutions. Keeping track of everything in a manual hydroponic system can be challenging as it requires the grower to manually measure and adjust the pH and PPM/EC/TDS levels of the nutrient solution, as well as monitor the temperature and humidity. This can be time-consuming and labor-intensive, and it can be difficult to maintain consistent conditions throughout the entire growing process. Manual hydroponics can be less accurate as it relies on the grower's own measurements and judgment. This can lead to variations in the nutrient solution, pH and temperature, which can affect the growth and development of the plants.

2.1.6 Philippines and Hydroponics

The Philippines, characterized by its tropical climate with an average temperature of 27°C, provides a conducive environment for the cultivation of hydroponic crops. Notably, tomatoes, cucumbers, green beans, lettuce, peppers, and strawberries have emerged as the predominant hydroponic crops in the country (Jagdish, 2022). The Philippine Hydroponics Development Corporation (PHDC) reports the presence of approximately 120 operational hydroponic farms in the Philippines, contributing to an annual production capacity of 800 metric tons. Hydroponic produce, known for its lower input costs, is deemed to be more economically profitable compared to traditional agriculture (Brosas, 2023).

Hydroponics farming, in conjunction with its associated agribusiness ventures, has attracted attention from agricultural experts as a potential solution to address prevalent agricultural challenges in the Philippines. Over time, long-term initiatives have been implemented to enhance the accessibility of hydroponics among the Filipino population, thereby promoting its integration into the agricultural sector (YCP Solidiance, 2022).

Despite rice being the primary crop cultivated in the Philippines, with significant emphasis noted in the Major Crops Statistics of the Philippines, it is technically viable to grow rice in a hydroponics system. Nevertheless, rice cultivation in hydroponics necessitates additional effort and considerations compared to shallow-rooted vegetables such as mustard greens or lettuce (Simons, 2022).

2.1.7 South Cotabato and Hydroponics

According to MindaNews (2021), the provincial government of South Cotabato is pushing for the expansion of hydroponics farming in the critical Lake Sebu to help improve the quality of its waters and overall condition. They interviewed Siegfred Flaviano, head of the Provincial Environment Management Office (PEMO), who shared that they are currently working with the local government of Lake Sebu and other stakeholders for the establishment of more hydroponic gardens within the 354-hectare lake. Flaviano also mentioned that studies showed hydroponics could be a “natural remedy” to the declining condition of the lake’s waters. They believed that with the help of hydroponics they could enhance the dissolved oxygen in the lake’s water and address its waste problem as Flaviano cited the deterioration of the lake’s dissolved oxygen level these past years.

The provincial government, through PEMO, launched the hydroponics program in 2016 as part of the Lake Sebu Rehabilitation, Conservation and Development Program (MindaNews, 2020). They trained at least 25 households in the area regarding the innovative system and helped establish vegetable gardens along the lake. The program has so far thrived, with the household-beneficiaries now selling their “organic and chemical-free” vegetables such as lettuce to the area’s hotels and resorts. Flaviano said, by expanding the program, we will not only help save the lake but provide alternative livelihood to residents as well. He also mentioned that the program will complement the continuing regular clean-up activities at the lake conducted by PEMO and the municipal government as well as the rehabilitation of its watershed areas.

In General Santos City, a few hydroponics setups are already used as part of some businesses. Wilz Hydroponics Garden and Ferax Farm Produce are some of the businesses that use hydroponics to produce their products to the market. They are new businesses who tried to use hydroponics as they researched some alternative ways in producing crops and it did not fail them.

2.1.8 Post-Study System Usability Questionnaire (PSSUQ)

In the field of educational technology and interactive software, assessing usability is crucial for ensuring effectiveness and user satisfaction. The Post-Study System Usability Questionnaire (PSSUQ) has emerged as a prominent tool for this purpose. Vlachogianni and Τσέλιος (2023) conducted a systematic review exploring usability perceptions of educational technologies, using the PSSUQ among other measures. Their analysis of 42 papers revealed an average PSSUQ score of 72.75, offering valuable insights into usability across various educational technologies.

The findings from the systematic review suggest that the PSSUQ and the Computer System Usability Questionnaire (CSUQ) are effective tools for evaluating the perceived usability of educational technologies. The average usability score derived from these questionnaires was found to be satisfactory, indicating that users generally perceive these technologies as usable.

Hodrien (2021) addressed the challenge of navigating evaluation methods for interactive software, emphasizing the lack of consensus on usability models. They provided guidance on post-study and post-task measures, aiding researchers and practitioners in selecting appropriate methods. Understanding the psychometric properties of evaluation instruments like the PSSUQ is essential. AMCIS (2005) conducted a comparative analysis, highlighting its adaptability and validity across diverse contexts.

Although Lewis (1992) obtained satisfactory psychometric testing results, reports on the length of the PSSUQ emerged, raising generalizability issues. Nevertheless, a recent study identified similar PSSUQ-reported results based on a large sample size of 250 people, providing a different perspective on factor analysis and item clustering. This study proposed a better criteria fit model with three factors, affirming the PSSUQ's robustness in measuring user satisfaction across different domains.

Despite initial concerns, recent validation efforts underscore the PSSUQ's resilience in measuring user satisfaction. This review aims to synthesize insights from these studies, emphasizing the PSSUQ's significance in evaluating educational technologies and interactive software. By examining its usage in different contexts and exploring its psychometric properties, we aim to offer a comprehensive understanding of its role in advancing usability assessment practices.

2.2 Review of Related Technologies

Table 2.3 provides a comparison of various hydroponics-related applications and their features. The "Hydroponic Scale" app focuses on maintaining a database of sensor data but lacks a user-friendly dashboard, automation options, printable reports, and notifications. The "Hydroponics Calendar" app offers a dashboard with information on water acidity, temperature, and electrical conductivity (specifically pH, EC, and temperature), but it doesn't provide automation features, comprehensive sensor data coverage, printable reports, or notifications. The "BudLab - Hydroponics Grow App" includes a sensor data database and a dashboard that specifically tracks water acidity (pH). While it lacks automation, it does offer printable reports and push notifications for updates and news. The "Hydroponics Nutricalc" app, unfortunately, doesn't provide a sensor data database, dashboard, automation, printable reports, or notifications. However, the "IoT-Based Monitoring System by MSU - GSC" stands out with its comprehensive features. It allows users to track sensor data, monitor water acidity, temperature, electrical conductivity (total dissolved solids), water flow, and water level through an easy-to-use dashboard. It also offers automation capabilities to control water acidity, electrical conductivity, and temperature. Additionally, it provides printable reports and sends push notifications for abnormal water quality or issues requiring human intervention.

In research from J. (2019), the best hydroponic controller systems have features that allow for flexibility for specific plant needs. Based on table 2.3t, only the proposed system has this feature where users can see data from the hydroponic system through a dashboard. The researchers added this feature as they believed that each plant (e.g. Paddy, Corn, Lettuce, Basil, etc.) has different needs in any variables for growing like pH, EC, water level, and water flow. Also, J. (2019) claims that growers need a hydroponic controller system to provide constant monitoring of the variables needed in a hydroponics garden without the need for manual testing. This is why automation, and systems push notifications are some of the features of the proposed system for growers to know the changes in the hydroponics system in real-time and can provide automated control for the water acidity, electric conductivity, and temperature.

In this proposal, the researchers aimed to provide an efficient hydroponics monitoring system which in comparison to the other already existing hydroponics applications has a lot of features that can help the farmers address the challenges they face in monitoring and maintaining the optimal growing conditions for their plants. This will also provide a more efficient and accurate way of monitoring and maintaining the hydroponics system which will lead to better yields, healthier plants, and more successful hydroponics operations.

Table 2. 3 Overall Comparison of the Features of the Selected Related Applications and the Proposed System

Application Name	**Database for sensor data**	**Dashboard (water acidity, temperature, electrical conductivity (total dissolved solids), water flow, water level)**	**Automation for controlling water acidity, electric conductivity, and temperature in the NFT system by automating the dispensing of liquid solution into the water container and adjusting water flow.**	**Printable reports of system activity and sensor data**	**System push notifications for abnormal water quality and problems that need human intervention (e.g. clogging, pump failure, sudden low of container water level)**

Hydroponic Scale	x	✓	x	x	x
Hydroponics Calendar	x	✓ (only covers pH, EC, and temperature)	x	x	x
BudLab - Hydroponics Grow App	x	✓ (only covers pH)	x	✓	✓ (only for updates and news)
Hydroponics Nutricalc	x	x	x	x	x
IoT – Based Monitoring System by MSU - GSC	✓	✓	✓	✓	✓

2.2.1 Hydroponic Scale

Figure 2.2. 1 Logo of Hydroponic Scale

For hydroponic growers, the Hydroponic Scale application is a useful resource that aids in determining the specific nutrient requirements of various plant types by taking into account variables like pH, electrical conductivity (EC), conductivity factor (CF), and parts per million (PPM) of nutrients. The app offers plant varieties divided into flowers, fruits, roots, and vegetables, and provides tailored recommendations.With the help of this application, growers can perfect the pH, EC, and nutrient levels for their hydroponic plants to grow in the best possible conditions.

Table 2. 4 Hydroponic Scale Features

Application Name	Feature/s
Hydroponic Scale	• Plant (Vegetable, Leaf, Flower) Requirements

2.2.2 Hydroponics Calendar

Figure 2.2. 2 Logo of Hydroponics Calendar

Regardless of the specific system used, hydroponic agriculture requires meticulous preparation, which is a critical component. The Hydroponics Calendar app offers invaluable assistance throughout the entire growth process, guiding growers from the initial stages to the final harvest, whether it involves a modest one-bottle window herb garden, a balcony pot setup, or a more extensive commercial hydroponics system. The app's capacity to ease the maintenance of a thorough log allows growers to painstakingly record crucial information and insights, which is a key feature.

Growers can avoid missing important details while switching to upcoming crop cycles by meticulously documenting methods and modifications. As one becomes more accustomed to the cultivation process, some elements that may now appear obvious could be easily overlooked in subsequent endeavors. Gardeners can use the app as a dependable tool to record their learnings and uphold uniformity and effectiveness in their hydroponic activities. The app also encourages growers to keep a careful eye on the development of their plants, taking pictures to document growth and sharing successes with friends and other hydroponics enthusiasts.

The application in question has garnered significant popularity within the hydroponics community, establishing itself as a favored choice. However, amidst the positive reception from users, certain criticisms have surfaced regarding the user interface (UI) of the system.

Table 2. 5 Hydroponics Calendar Features

Application Name	Feature/s
Hydroponics Calendar	• Calendar/Scheduling/Tracker • Temperature of Setup

2.2.3 BudLab – Hydroponics Grow App

Figure 2.2. 3 Logo of BudLab - Hydroponics Grow App

BudLabs is a mobile hydroponics grow guide developed by Advanced Nutrients, designed to assist both beginner and experienced growers. It provides organization and guidance throughout the entire growing process, including a feeding schedule with specific proportions of Advanced Nutrients products for each week.

Key features of BudLabs include a nutrient calculator that tailors a feeding schedule based on the growth phase, nutrient base, grow experience, and reservoir size. The Labs feature allows users to manage multiple virtual crops simultaneously, visualize growth phases, set start dates, and manage daily tasks. The app also provides information on Advanced Nutrients products, their purposes, and effects on plants.

BudLabs offers news and promotions from Advanced Nutrients, allows users to locate nearby retailers, and provides contact information for customer support. With its comprehensive features, BudLabs aims to help growers achieve reliable and consistent results while facilitating efficient management of their grow rooms.

Users think it is a fancy mobile version of the online nutrient calculator that is useful as it can print out the schedule. It is one of the top-rated hydroponics related applications in Google Play. However, it would be better if they improve the system more as they can't customize or delete unnecessary items from the nutrients or data needed. The system also needed logging in and out of the application that sends loops of sending confirmation over and over. Another concern is that it is not easy for new users to change units of the measurements needed.

Table 2. 6 BudLab - Hydroponics Grow App Features

Application Name	Feature/s
BudLab – Hydroponics Grow App	• Nutrient Calculator • Labs

	• Products • News • Market Place • Grower Support

2.2.4 Hydroponics NutriCalc

Figure 2.2. 4 Logo of Hydroponics NutriCalc

The "Easy-to-Use Calculator" is a handy tool that takes inspiration from the calculation method developed by "MHPGARDENER" for MasterBlend's 4-18-38 and ZENNOR Blend fertilizers. This calculator is designed with simplicity in mind, making it accessible even for those new to hydroponics. It provides a convenient way to determine the ideal nutrient ratios for growing vegetables using popular hydroponic methods like the "Kratky Method" or systems such as Dutch Buckets. By inputting specific details about your hydroponic setup, the calculator takes the guesswork out of nutrient calculations and provides you with accurate measurements and ratios of the fertilizers required. It's a valuable tool that helps streamline the process, ensuring your plants receive the precise nutrients they need to thrive in your hydroponic garden.

Despite being a highly regarded application, there is a lack of publicly available user reviews for this particular system, limiting the comprehensive understanding of user experiences and feedback.

Table 2. 7 Hydroponics NutriCalc Features

Application Name	Feature/s
Hydroponics NutriCalc	• Nutrient Calculator

Table 2.8 provides a summary of different hydroponics-related applications, outlining their focus, strengths, and weaknesses. The "Hydroponic Scale" application concentrates on defining the required pH, EC, CF, and PPM nutrients for plants, offering an easily understandable table to organize the data. However, a limitation is the incomplete storage of data, as it lacks temperature, water level, and water flow information. The "Hydroponics Calendar" app emphasizes careful planning for hydroponic systems and excels in maintaining detailed logs for effective system management. Nonetheless, it requires manual data insertion, which can be time-consuming. The "BudLab - Hydroponics Grow App" aims to track plants' nutrient intake and offers a wide range of features, including a nutrient calculator, labs, product information, shop locations, news, and grower support, catering to the needs of new hydroponic farmers. However, it lacks direct integration with the hydroponics system, relying on manual data entry. The "Hydroponics Nutricalc" application calculates nutrient requirements based on the "MHPGARDENER" method, providing guidance for normalizing water solutions. Nonetheless, it is limited to calculations based on this specific method and cannot accommodate custom solutions. Finally, the "IoT-Based Monitoring System by MSU - GSC" offers an easier monitoring system for farmers, storing and

displaying comprehensive data for informed decision-making. However, its limitation lies in only displaying data from a single hydroponics system, limiting its applicability for monitoring multiple systems simultaneously.

Table 2. 8 Comparison of the Focus, Strengths, and Weaknesses of the Selected Related Applications and the Proposed System

Application Name	Focus	Strength	Weakness
Hydroponic Scale	Defining Required pH, EC, CF, and PPM nutrients of plants.	Keeps data required for each plant on a table that can be easily understood.	Incomplete data (they don't have the temperature, water level, and water flow data) is stored.
Hydroponics Calendar	Careful planning for the hydroponic system.	Keeps detailed logs about your system.	Manual insertion of data is needed.
BudLab - Hydroponics Grow App	Keep track of plants' nutrient intake.	It has a lot of features (nutrient calculator, labs, products they sell, location of shops near the farmer, news, and grower	It is not connected to the hydroponics system. Manual insertion of data is needed.

		support) that can easily help farmers who are new to hydroponics.	
Hydroponics Nutricalc	Calculating based on the calculation of "MHPGARDENER."	Calculates needed nutrients for a solution to normalize the water.	It only calculates based on the MHPGARDENER calculation and can't calculate based on one's solution.
IoT – Based Monitoring System by MSU - GSC	Easier monitoring system for farmers to use.	Stores and displays all the data needed by the farmer for decision-making.	It only shows data from one hydroponics system.

Chapter III
METHODOLOGY

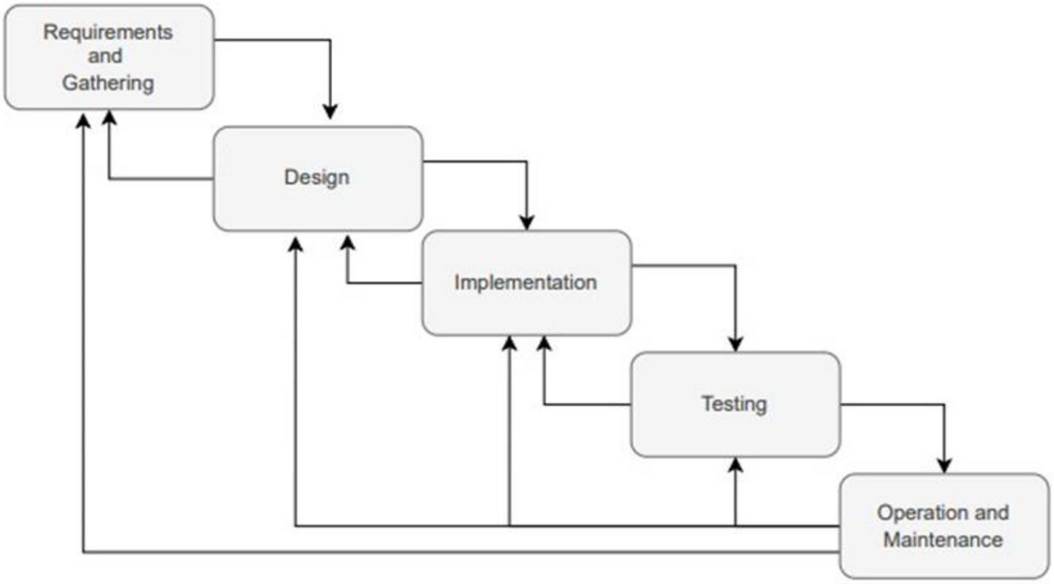


Figure 3. 1 Modified Waterfall Methodology

3.1 Modified Waterfall Methodology

The developers utilized Steve McConnell's Modified Waterfall methodology, which addresses some drawbacks of the original model by allowing for phase overlap and enabling verification and validation of earlier work. This method comprises five stages: requirement collection, design, implementation, testing, and maintenance.

The linear sequential approach of the Waterfall methodology is well-suited for software development projects like this one, offering a clear and structured process. Each stage builds upon the previous one, ensuring a comprehensive development process tailored to the project's needs.

The Waterfall methodology is an ideal choice for developing the IoT-based decision support system for hydroponics culture. It provides clarity and structure, ensuring the final product meets requirements, is functional, reliable, user-friendly, and well-maintained.

The design stage focuses on creating a detailed plan for the system, covering hardware, software, and user interface, to ensure functionality, reliability, and user-friendliness. Implementation follows, involving the actual construction of the system, including software development and hardware assembly. Finally, testing and maintenance ensure the system works as intended, with bugs identified and resolved, and ongoing upkeep to keep it up-to-date and functioning smoothly.

3.2 System Objectives, Activities, and Result

Table 3.2. 1 System Objectives, Activities, and Results

Objectives	Activities	Results
1. Provide a database that stores data from sensors. **2.** Provide a dashboard of water acidity, temperature, electrical conductivity (total dissolved solids), water flow and water level. **3.** Provide automation for controlling water acidity, electric	1. Requirements Gathering 2. Design 3. Implementation 4. Testing 5. Operation and Maintenance	IoT – based decision support system for nutrient film technique hydroponics culture monitored through ion-selective electrodes.

conductivity, and temperature in the NFT system by automating the dispensing of liquid solution into the water container and adjusting water flow. **4.** Generate a printable report detailing system activity and sensor data. **5.** Provide systems push notifications for abnormal water quality and problems that need human intervention such as clogging, pump failure and sudden low of container water level.		

Table 3.2.1 summarizes the objectives, activities, and results of a project related to hydroponics. The objectives section lists the goals of the project which include providing a database for storing sensor data, a dashboard for monitoring various parameters such as temperature and acidity, and automated control for certain aspects of the hydroponics system. The activities section outlines the steps that will be taken to achieve these objectives, including requirements gathering, design, implementation, testing, and

operation and maintenance. Finally, the results section states that the project will result in an IoT – based decision support system for nutrient film hydroponics culture monitored through ion-selective electrodes.

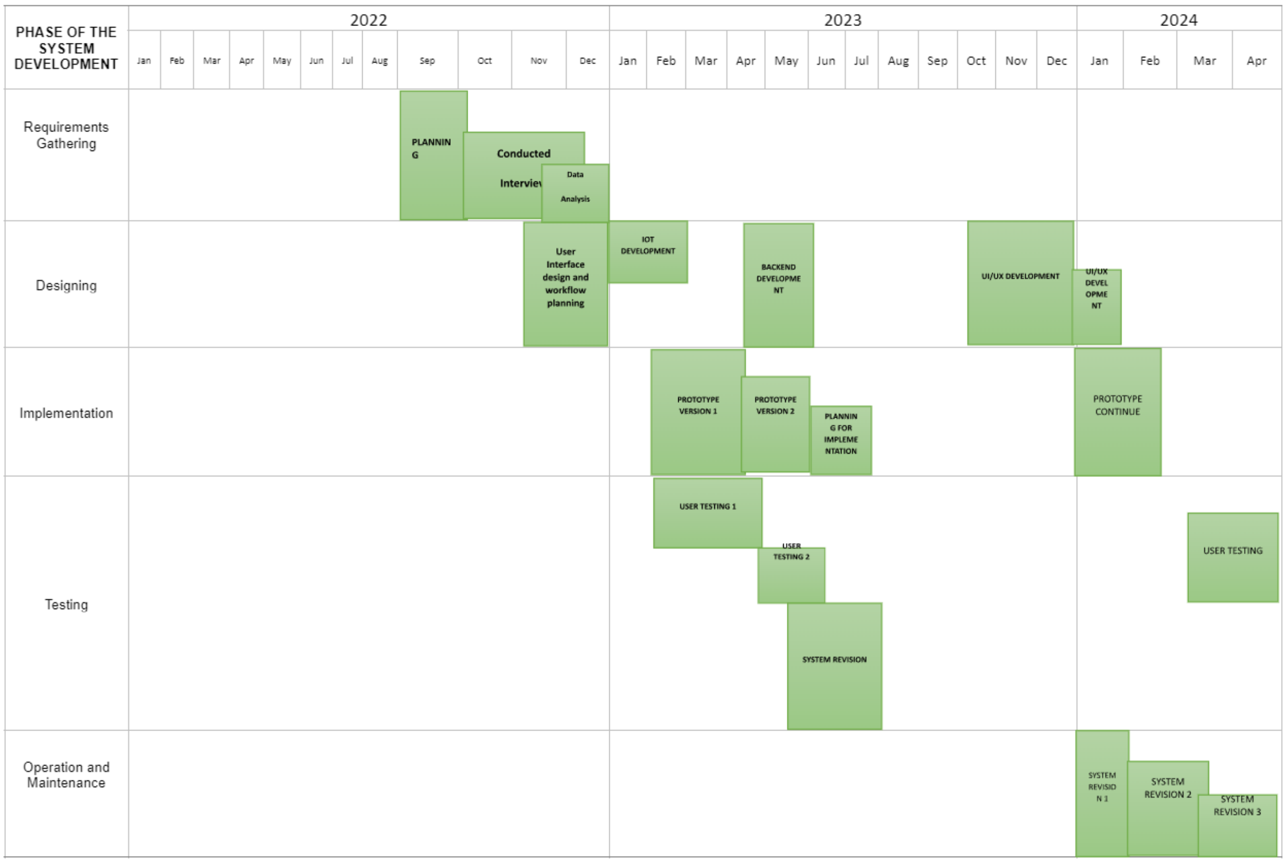


Figure 3. 2 Phases of the System's Development Gantt Chart

3.3 Phases of the System’s Development Gantt Chart

The system's developers got started on the project by gathering the data they would need to make it work. Interviewing farmers who are currently employing NFT techniques in hydroponics to learn how they process and produce products from this alternative kind of farming was one of the tasks the developers undertook during the requirements gathering phase. Following the collection of the required data, the data is next analyzed by the developers before moving on to the design step.

The system model and the IoT workflow were planned first by the developers during the design phase. Use case diagrams were first created by the developers as a way to organize the system's user interface. However, this approach was later changed to context level data flow diagrams to facilitate better analysis of complex systems. The framework that the developers came up with based on the data they analyzed from the farmer's experiences was the foundation for the construction of IoT and database systems. The system's prototype version one was put into use by the developers. Prototype version one of the systems received system adjustments based on recommendations that needed to be incorporated to the design and features of the system following system testing. In order to move forward with system prototype version two, the developer went back to the design phase for data validation and verification. Based on the feedback that was taken into account while developing the system, the developers were able to accomplish the goal of the proposed system by moving on to prototype version two. The system underwent its last testing to see whether it had accomplished its goal of serving the demands of the user. To assess the finished system, the creators ran training and tests. Individuals familiar with hydroponics served as respondents in the testing. Minor system changes were taken into consideration during the system's final testing phase. The developers were able to go on to the last phase, which is the operation and maintenance phase, after implementing the adjustments in the user testing phase.

3.4 Modified Waterfall Methodology Model

The development phase of the suggested system is built on the modified waterfall model. By using this approach, the classic waterfall model's phases are validated and verified in between. The model is a sequence of phases that enables the system's developers to return to an earlier phase in the event that any deviations in the development process need to be corrected. The modified waterfall approach model was chosen by the creators of the proposed system because it enables early design modifications. The design of the system was initially based on the farmer's experiences and difficulties using the NFT technique in hydroponics. The construction of the farmers' present system offered the researchers an idea that the system would go through a number of design and functionality upgrades. The project's design and functionality are based on ideas that have been added to (or withdrawn from) the system during development, therefore the developers must return to the initial phase of system requirements. The system's development will proceed through a number of stages until the intended result is attained.

3.5 Requirements Gathering

A crucial step in creating the project's system was the developers' requirement collection. The initial step was to acquire crucial data that aided developers in the system development so that the researchers could establish project objectives and requirements. The researchers conducted an interview with the farmer who owned an NFT hydroponic system in San Jose General Santos City throughout the requirements gathering process. The interview covered the process of growing crops, the system's capacity, and the difficulties the existing system faced. The project's goals and the system structure required for the IoT monitoring system's development stage were determined by the researchers through analysis of the data collected. Based on the objectives, the researchers developed an IoT-based decision support system for nutrient film hydroponics, with features that included a sensor data database, a dashboard displaying temperature, acidity, water flow, electrical conductivity, and printable reports on water conditions, and systems push notifications for problems that required human intervention, and the ability to control water acidity without human intervention.

3.6 Design

The NFT hydroponics system's operation and difficulties were examined by the developers during the system's design phase. The developers were able to acquire vital data during the requirements phase, which is crucial for creating the IoT system. The information that was examined will serve as the foundation for the workflow and system model visualization. The developers were able to define the layout of the system using context level data flow diagrams to depict the required features of the proposed system after examining the current NFT hydroponics system utilized by the farmers.

The researchers initially examined the information provided by the farmers regarding their ability to monitor the system's water quality to determine the system's workflow. This data will serve as the foundation for creating the framework for notifications for human intervention, automation of the solution, and water quality monitoring. The developers can recognize the design for systems dashboard from the information about how they are unable to visualize some data readings through manual monitoring.

The frequency with which they manually check the water quality each day, and the connections between the variables (such as pH level, temperature, etc.) that affect changes. The developers used this information to determine the system architecture for the farmer's user account. Farmers themselves will handle the registration procedure for user accounts, which will aid developers in creating system features based on the input, process, outputs, and sequence of events of the system.

The information regarding the suggestions made by farmers for the chart and diagrams was used by the system's developers when choosing the charts. Entity relationship diagrams of the system show how the database has evolved. The system's data flow is decided by this process. This would provide the developer with a clearer understanding of how to organize the system's functionality in order to accomplish the system's development goals.

3.7 Implementation

3.7.1 Writing the code

In this phase, the system design and functionality that had been formulated in the previous phase were developed and implemented. The project's functionality and design changed over time, and recommendations were added to (or removed from) the project. As a result, this stage was continuously revisited by the researcher. The developers wrote the scripts to implement the changes that the researchers discovered for the system's improvement after the researchers raised the changes or needed to add to the system's functionality during this phase. These adjustments were based on advice and comments from farmers who used NFT hydroponics systems.

3.7.2 IoT Device Prototype

The developers started by creating a prototype for the IoT device after defining the design specifications required for the IoT side. The design built to meet the needs of the system design is this prototype. The sensors sent signals to the device, allowing it to track information regarding the condition of the water. The system's software, written in C, instructed the microcontroller to read the signal and transfer it to the database using the GSM module. Processing, a considerably basic hardware programming language that was like the C language, was used for the automation side of the device. It was programmed to open the relay, which starts the motor, anytime the device detected an anomaly in the measurements.

3.7.3 Web Prototype Version 1

With the system's design criteria established, the creators moved on to create prototype version 1. The first prototype design that the developers were able to execute, and which satisfied the fundamental functional requirements of the system design, is known as prototype version 1. The first prototype's fundamental functionality allowed farmers to create accounts using already-registered accounts on the login page. The system's administrator, a farmer, could manage accounts, including changing passwords and usernames. The prototype's development framework was created utilizing a variety of web development scripts, including HTML script. Cascading style sheets (CSS) were utilized by the web page designers to style the HTML structure. The web-based application was created using the PHP programming language for the prototype's backend. During this stage, the prototype design was tested and evaluated to consider the relevant requirements. Revisions to the code script, which served as the developers' first prototype, would also be considered during the system's testing and assessment phases of development.

3.7.4 Web Prototype Version 2

Building upon the design assessed in Version 1, Version 2 reflects enhancements to usability and aesthetics. Notably, Version 2 features more visible buttons and improved navigation, contributing to a simpler theme overall.

3.8 Testing

The development process of the system will end when the testing and implementation phase is completed, following successful testing. Our initial plan for testing involved engaging farmers in San Jose, General Santos City, for Alpha and Beta testing of the NFT hydroponics decision support system. However, due to farmer inactivity, we've adjusted our approach.

The revised plan involves selecting 25 individuals with knowledge or familiarity with NFT hydroponics and an interest in providing feedback. The prototype of the decision support system will be installed at Mindanao State University. Participants will undergo comprehensive training on using the system and its features. They will gain hands-on experience operating the system and adjusting water qualities to simulate real-world conditions. Afterward, participants will complete a questionnaire, offering detailed feedback on the system's performance and suggesting potential improvements.

The Post-Study System Usability Questionnaire (PSSUQ) was chosen by the researchers as their testing framework for the testing phase (See Appendix C). This choice was taken in light of a number of considerations that made PSSUQ the ideal choice for assessing the NFT hydroponics decision support system's usability and user satisfaction. First of all, PSSUQ provides an organized and regulated method for evaluating user perceptions, which is in line with the requirement for a systematic assessment procedure. Second, as the questionnaire is so extensive, the researchers may collect input on a wide range of usability factors, such as interface design, information quality, and system usefulness—all of which are significant facets of the decision support system that they are examining.

Additionally, the PSSUQ's ability to provide an overall satisfaction score and detailed insight into specific areas of strength and weakness provides a rich understanding of program performance. The researchers considered the PSSUQ to be the ideal testing framework due to its robustness, comprehensiveness, and appropriateness for assessing the usefulness of the NFT hydroponics decision support system.

A panel of experts will conduct the final evaluation to assess the system's readiness for deployment.

This adjusted testing plan ensures that we gather valuable insights from knowledgeable individuals, enhancing the system's effectiveness in NFT hydroponics environments. It welcomes all types of individuals, whether seasoned NFT hydroponics practitioners or those aspiring to start their own NFT hydroponics setups, fostering a diverse and inclusive testing environment.

3.8.1 User Profile

Table 3.8.1.1 shows the breakdown of respondents by user group and gender for the evaluation of the NFT hydroponics decision support system. Among students with the knowledge of hydroponics, there were 12 male and 10 female participants, for a total of 22 students of users, resulting in 3 farmers contributed to the research design This distribution provides valuable insights into the gender distribution within each user group.

Table 3.8.1. 1 User Profile

User Groups	Male	Female	Total Number of Respondents
Students with knowledge of Hydroponics	12	10	22 Students
Farmers	1	2	3 Farmers

3.9 Operation and Maintenance

The Modified Waterfall Methodology's last step, Operation and Maintenance, sees the end users of the built system use it in its actual setting. To ensure that newly introduced systems will function as intended, maintenance is frequently required.

3.10 Deployment Plan

The system will be implemented for simulation purposes at the MSU campus in General Santos City, with the panelists simulating the setup instead of utilizing an existing NFT hydroponics farm. The simulation will involve replicating the water and nutrient conditions of an NFT hydroponics system. Developers will concentrate on monitoring the simulated NFT hydroponics setups with input from the panelists. The IoT device will be deployed to monitor the simulated hydroponic system, while panelists access the system to provide setup information and feedback.

3.11 Tools and Technology

Software development involves the use of numerous tools and technologies. This program runs on the web. The technology and tools the researchers utilized to create this software are described here along with their rationale.

Table 3.11. 1 Tools and Technology

Title	Tools and Technology	Description
Programming Languages		
	Hypertext Markup Language (HTML) 5.0 or higher	This programming language is used to enhance the website with paragraphs, headings, graphics, and links.
	Cascading Style Sheets (CSS)	Cascading Style Sheets is a styling language that works with HTML to describe how items are presented visually in an HTML document.
	PHP (Hypertext Preprocessor)	A server-side scripting language and interpreter for HTML. The proposed system is created using PHP, a general-purpose programming language, which connects to the database and executes the essential system functions.

	JavaScript	It is utilized in the creation of the proposed website for the purpose of client-side validation, AJAX Queries and design implementation rules. Additionally, it supports external libraries and the loading of PDF files. Without ever reloading the page, it may load content into a document anytime the user requests it. In the proposed system, this software is typically utilized to create functional, dynamic, and interactive web pages.
	C++	This language is used to program the microcontroller to perform tasks like automating whenever a sensor detects odd readings, transmitting data from the device to a database using a GSM module, etc.

Code Editor		
	VSCode	Is a source-code editor made by Microsoft for Windows, Linux and macOS. Features include support for debugging, syntax 35 highlighting, intelligent code completion, snippets, code refactoring, and embedded Git. In this study, this is used as the main source code editor in designing and developing the alumni information system.
	Arduino IDE	A toolbar with buttons for typical functions, a text editor for writing code, a message area, a text console, and a number of menus. In order to upload programs and communicate with them, it connects to the Arduino hardware.
Server and Database tools		
	PhpMyAdmin	Software that is used to manage MySQL from a web browser. Using a web browser, it is used to

		carry out SQL queries and other database operations.
	MySQL	A Relational Database Management System (RDBMS) that is open source and enables the storing and handling of data by software programs.
	APACHE	A web server that handles HTTP requests and delivers web resources and information. Apache and PHP coexist.
Microcontroller		
	Arduino	An open hardware development board that makers, amateurs, and tinkerers can use to create things that can interact with the physical environment.
Sensors		
	pH level	Designed to determine the acidity or alkalinity of a substance by determining the pH value of a solution.

	Electric Conductivity	Determines a liquid's electrical conductivity, including saltwater, brine, and others.
	Water Level	Used to determine how much stuff can flow.
	Water flow	A piece of electronics that gauges or controls the flow of gases and liquids through tubes and pipelines
	Temperature	A temperature sensor is a device that measures temperature and converts the temperature measurement into an electrical signal that can be read by a control system or data acquisition system.
Modules		
	GSM	Utilizing the GSM library, an Arduino board is able to make voice calls, send and receive SMS, and connect to the internet. The shield is already compatible with the Arduino Uno. With a slight adjustment, the shield will

		function with the Mega, Mega ADK, Yun, and Leonardo boards. It is used to send data to the database. The GSM module, when connected to an Arduino board, enables internet connectivity by establishing a connection to mobile data networks through a SIM card. Integrated with the Arduino via serial communication, the module is initialized to configure settings and connect to the network. With this setup, the Arduino can send and receive data packets over the internet, utilizing protocols like HTTP or HTTPS to communicate with remote servers. In this project, data collected by the Arduino will be transmitted to a database by making HTTP requests to a server. It's essential

		to ensure security measures, such as using HTTPS and implementing authentication, to safeguard sensitive information during data transmission. The GSM module provides a versatile solution for enabling internet connectivity in Arduino-based projects, facilitating communication and data exchange with remote services over mobile networks.

3.12 Materials and Costing

This section presents a comprehensive overview of the materials used and the costing considerations integrated into the development of the device. Recognizing the pivotal role played by materials selection and costing in the realization of technological innovations, the researchers provide an in-depth account of the materials utilized and the associated cost structure. Through transparent disclosure of the materials procurement process and costing methodology, this section aims to afford readers a clear understanding of the foundational aspects that underlie the development of the device.

Table 3.12.1 offers a comprehensive breakdown of the materials utilized and their associated costs in the development of the device. Each component is meticulously detailed, including specifications, quantities, and individual costs. Notable items such as power supplies, sensors, modules, connectors, and accessories are outlined with their respective model numbers and technical specifications, showcasing the diverse range of components incorporated into the device.

The table documents the technical specifications of critical components such as the DC 6-12v food-grade diaphragm pump, Waterproof Ultrasonic Module, and the SIM900A Mini Wireless Data Transmission Module, providing insights into their operational parameters and compatibility with the device. Additionally, costs are meticulously recorded for each component, offering transparency into the financial investment required for the project.

The total cost of materials used for the device is summarized at the end of the table, providing a clear snapshot of the overall budgetary considerations for the development endeavor.

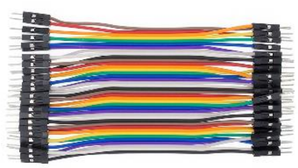
Table 3.12. 1 Materials Utilized for the Prototype Device and Its Cost

Name	**Specifications**	**Sample Image**	**Cost (₱)**	**Quantity**	**Total Cost (₱)**
5V4A DC CCTV LED Centralized Power Supply Adapter	Model: S20-5 S504 Output voltage: DC 5V 4A Input voltage: AC110/220V ± 15% Grid frequency: 50/60HZ		180	1	180

Relay Module 6 Channel 5v With Optocoupler Projects Arduino Compatible	Control Voltage: 5V DC Max Control Capacity:10A@250 VAC or 10A@30VDC		155	1	155

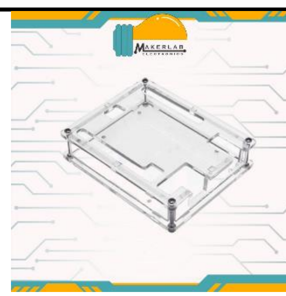
DC 6-12v food grade 385 diaphragm pump self-priming micro pump DC computer circulating water	Pump size:1.6*3.5*1.4inch (40mm*90mm*35 mm) Working voltage: DC12V Working current: 0.5-0.7 A (power must be more than 6W) Flow: 1.5-2 L/Min (or so) The largest suction:78.7inch(2m) Pump Head: vertical maximum 118inch(3m) Life: 2500 h(maximum) Water temperature: up to 80 ℃		159	3	477

High Quality Passive Buzzer Module for Arduino DIY Kit	1 passive internal without shock source, so if use dc signal can't make it.Must use 2 k ~ 5 k square wave to drive it For more than 2 sound frequency control, can make "m hair sola west" effect. 3 in some particular case, can reuse and LED a control		43	1	43
Waterproof Ultrasonic Module JSN-SR04T / AJ-SR04M Water Proof Integrated Distance Measuring	Electrical parameters: JSN-SR04T Operating voltage: DC 5V Quiescent current: 5mA Total current work: 30mA Acoustic emission frequency: 40khz Farthest distance: 4.5m Blind: 25cm Wiring: + 5V (positive power supply) Trig (control side) RX Echo (the receiver) TX GND (negative) Module size: 41mm * 28.5mm Resolution: about 0.5cm Angle: less than 50 degrees Working		230	1	230

	temperature: -10 ~ 70 ° Storage temperature: -20 ~ 80				
Sim900a Sim900 Mini V4.0 Wireless Data Transmission Module GSM GPRS Board Kit w/Antenna for arduino	Size: 49mm*47mmNet Weight: 28g Weight: 38g		687	1	687
Dupont Line	10 cm Male to Male		48	1	48
Dupont Line	20cm Female to Female		55	1	55
Dupont Line	20cm Female to Male		58	1	58

12V Water Flow Sensor DC 5-18V Flowmeter Hall Flow Sensor Water Control Liquid Flow Sensor Switch 1-30L/min 2.0MPa YF-S201	External threads: 1/2" Temperature: -25~+80 Allowing Pressure: pressure 1.75Mpa Operating Humidity range: 35%~90%RH (no frost) Use Temperature: 80 Load Capacity: 10 mA (DC 5V) Working Voltage Range: DC 5~18 v Maximum Operating Current: 15 mA (DC 5V) Lowest Rated Working Voltage: DC 4.5 5V-24V Size : 6x4cm Color : Black		127	1	127
DS18B20 Temperature Sensor Module Kit Waterproof 100CM Digital Sensor Cable Stainless Steel Probe Terminal Adapter For Arduino (1 SET)	Temperature sensor supply voltage: 3.0V ~ 5.5V Temperature sensor resolution: 9 to 12 adjustable resolution Temperature range: -55 ~ +125 ° (lead can only withstand the highest temperature of 85 degrees) Temperature Sensor Output Lead: Yellow (DATA) Red (VCC) and Black (GND)		99	1	99

	Adapter Cables: DATA, VCC, BLK, Suitable platform: for Arduino and Raspberry Pi				
TDS Sensor Water Conductivity Sensor for Arduino Liquid Detection Water Quality Monitoring Module DIY TDS Online Monitor	Input Voltage: DC 5V Output Voltage: DC 1.0V-24.0V Output Power: 3W(Max) Conversion efficiency: 94% Working current: 30mA Working Temperature range: -20℃~85℃ Working Humidity range: 0%-95%RH Size: 70*26*22mm		359	1	359
DFRobot Gravity: Analog pH Sensor/ Meter Kit For Arduino	Module Power : 5.00V Module Size : 43 x 32mm(1.69×1.26″) Measuring Range :0 – 14PH Measuring Temperature: 0 – 60 ℃ Accuracy : ± 0.1pH (25 ℃) Response Time : ≤ 1min pH Sensor with BNC Connector pH2.0 Interface (3 foot patch) Gain Adjustment Potentiometer Power Indicator LED		1,763	1	1,763

20x4 LCD Display I2C White on Blue	20*4 lcd display with I2C adapter board		273	1	273
MB102 Breadboard 830 points for electronics or Arduino prototyping	compatible with breadboard power supply Arduino compatible standard pitch 2.54mm 830 points with slots for connection with other breadboards sticker base		89	1	89
12V Oil Pump Electric Water Pump Fuel Dispenser	Power: 12V		825	1	825
Arduino UNO R3 Acrylic Case	3mm acrylic Light and easy to transport good heat dispersion Dimensions: 80mm x 65mm		43	1	43
PH-4502C Liquid PH Sensor with E201-BNC probe (Kit)	V+: 5V DC input G: Ground pin Po: pH analog output Do: 3.3V DC output To: Temperature output		999	1	999

Diode 1N4007	1N4007/1N4001 Characteristics: Maximum Recurrent Peak Reverse Voltage 1000V/50V. Maximum RMS Voltage 700V/35V. Maximum DC Blocking Voltage 1000V/50V. Average Forward Current: 1.0A. Peak Forward Surge Current: 30A Maximum Instantaneous Forward Voltage: 1.0V Maximum DC Reverse Current At Rated DC Blocking Voltage: 5.0µA @ 25°C Typical Junction Capacitance: 15pF Typical Reverse Recovery Time: 2.0us Mounting Type: Through Hole Operating Temperature: -55°C ~ 150°C		15	3	45
pH Buffer Solutions (Set)	pH 4.01, pH 6.86, and pH 9.18		30	1	30

SIM Card	TNT		50	1	50
SIM Card Load	TNT		100	1	100
Garden Hose	½"		30	2	60
Base Box Electric Control Box Indoor Distribution Box Powerful Control Box	25*30*14cm		670	1	670
Base Box Electric Control Box Indoor Distribution Box Powerful Control Box (Electronic Protection)	(Electronic Protection)		41	1	41

Altering of Base Box	Altered to put the LCD Display on the front of the base box		300	1	300
TOTAL COST OF MATERIALS USED FOR THE DEVICE (IN PHILIPPINE PESO (₱))					**7806**

CHAPTER IV
RESULTS AND DISCUSSION

In this chapter the researchers presented the result and discussions of developing an IoT-based decision support system for hydroponics culture using nutrient film technique monitored through ion-selective electrodes. The development and implementation of project objectives were shown in this chapter using figures and screenshots.

4.1 Log In page

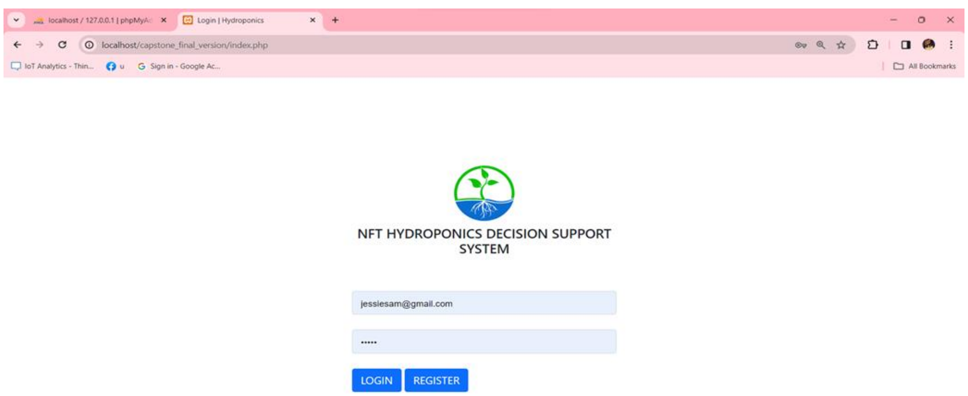


Figure 4. 1 Log In Page

The IoT-based decision support system for hydroponics culture using nutrient film technique monitored through ion-selective electrodes can only be accessed by the farmer user account registered in the system. Users have to register and log in to the

system to access its features and functionalities.

4.2 Registration Form

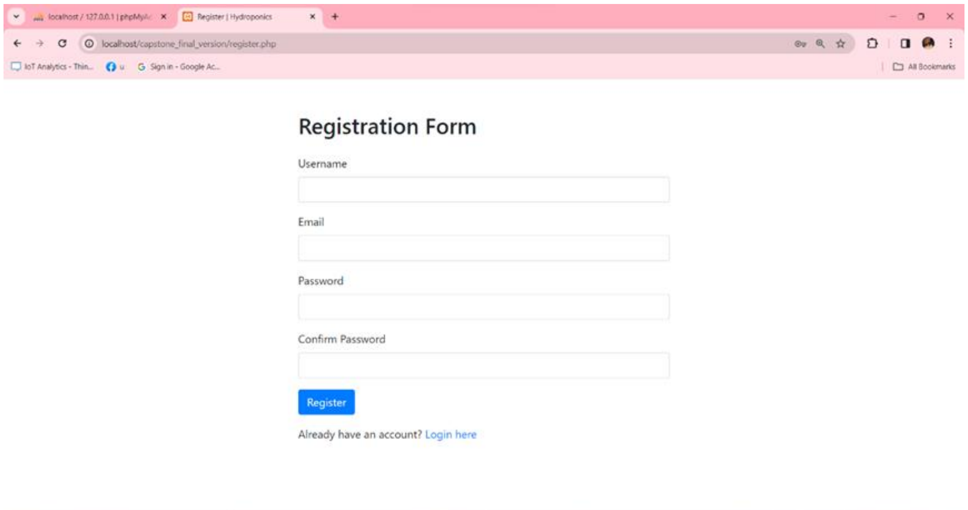


Figure 4. 2 Registration Page

To initiate registration for the IoT-based decision support system in hydroponics culture, complete the registration form by providing requisite details including chosen username, email, and password. Consent to the terms, proceed with form submission, and, if mandated, execute email verification to obtain access to the system.

4.3 Main Dashboard

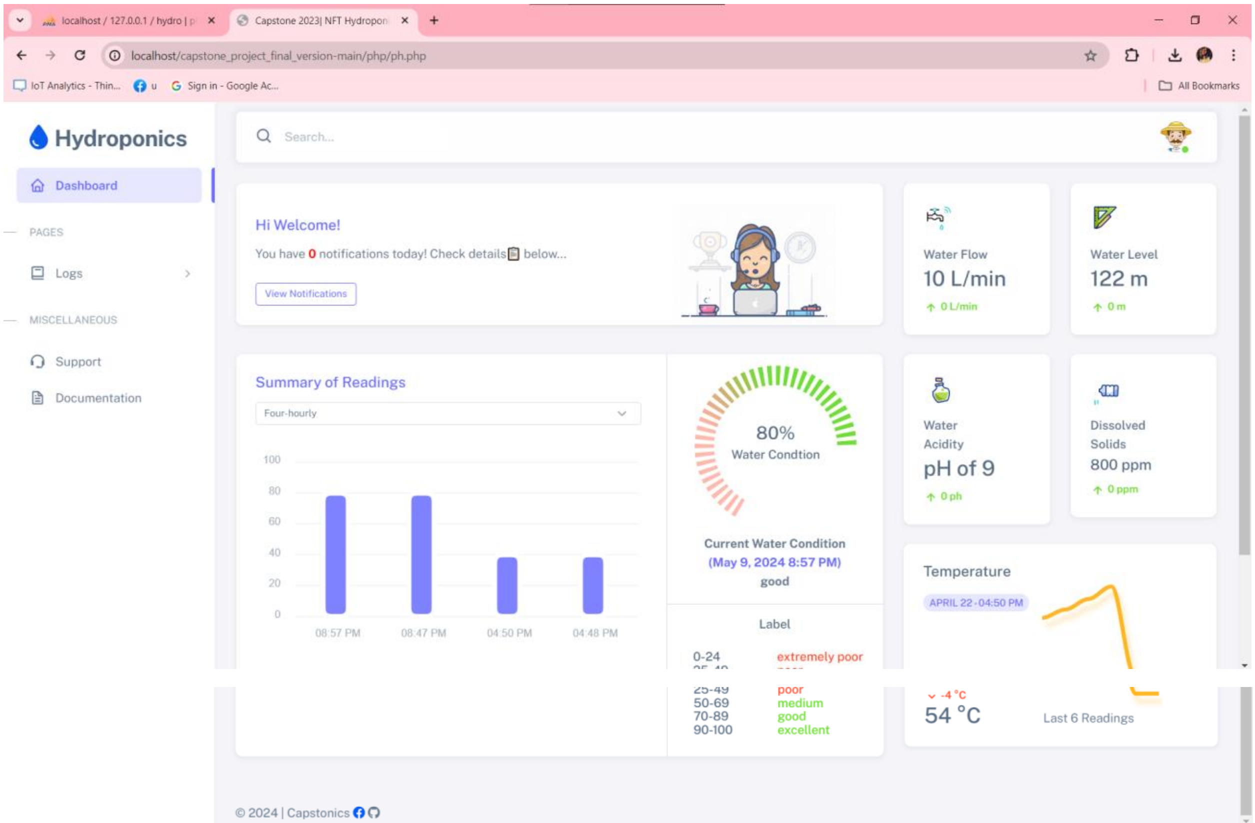


Figure 4. 3 Main Dashboard

The user account creation process unveils a comprehensive interface featuring sections like Water Flow, Water Level, Logs, Notifications, Support, Overall Water Conditions, and Documentation. The interface provides detailed metrics, including water flow rate, water level, and overall water condition.

4.4 Menu Bar

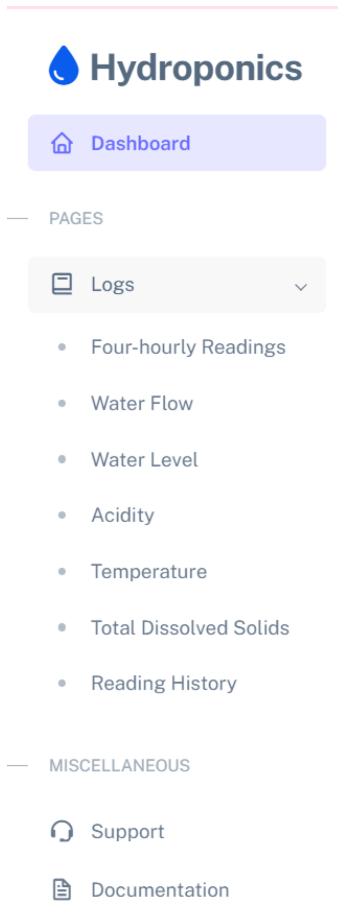


Figure 4. 4 Menu Bar

The menu bar is the nucleus of effortless navigation, housing a quartet of icons designed to streamline your journey. With just a tap, the Dashboard beckons, offering a panoramic vista of insights and real-time updates. Dive deeper into activity records with the Logs icon, your gateway to a comprehensive repository of events and transactions. Need guidance? The Documentation icon stands ready, providing access to a wealth of resources and tutorials. And should questions arise, the Support icon serves as your direct line to expert assistance, ensuring smooth sailing through any challenge. Together, these icons form the backbone of efficiency and empowerment, guiding users seamlessly from exploration to resolution.

4.5 Logs

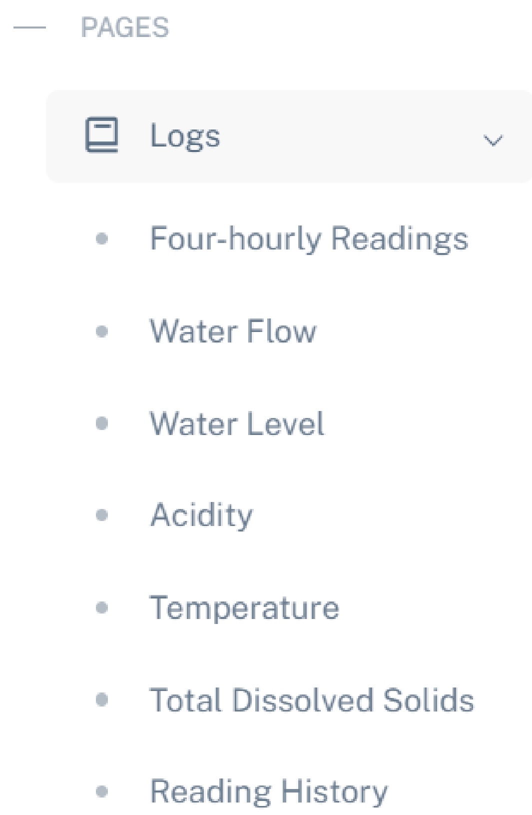


Figure 4. 5 Logs

The displayed screenshot showcases a comprehensive dashboard with dedicated pages for logs and various readings, covering essential parameters like water flow, water level, acidity, temperature, and total dissolved solids. Notably, the interface seamlessly integrates a specialized section for miscellaneous elements, including support and documentation.

One noteworthy feature is the automatic updating of readings every four hours, with the latest data prominently displayed on the logs page. This ensures that users have real-time access to the most recent measurements and enables effective monitoring of the system's performance and environmental conditions.

4.5.1 Four hourly Readings

Figure 4.5. 1 Four Hourly Readings

The showcased screenshot demonstrates a tabulated data representation featuring an array of metrics and statuses intricately linked to water conditions, encompassing parameters such as acidity, total dissolved solids, water flow, water level and temperature. Moreover, the table integrates interactive functionalities for executing specific actions alongside dedicated provisions for miscellaneous support services.

The displayed table features data encompassing readings and statuses, organized into columns for date & time, readings, average, status, and actions pertaining to acidity and Total DissolvedSolids (TDS). Notably, navigation controls at the bottom facilitate seamless pagination, allowing easy access and navigation through the dataset.

4.5.2 Water flow

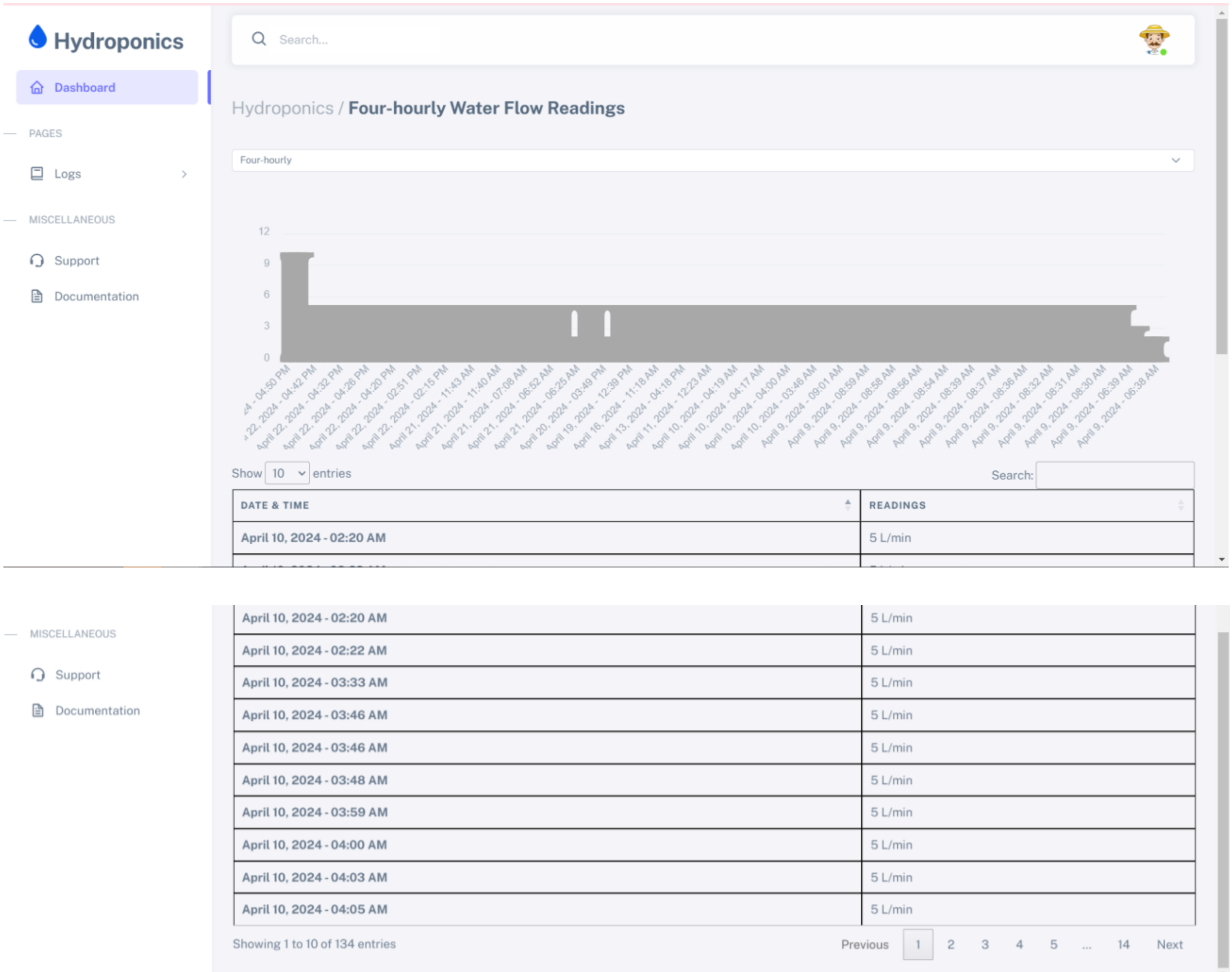


Figure 4.5. 2 Water Flow

The presented table illustrates chronological date and time readings, coupled with water flow values quantified in liters per minute. Streamlined navigation elements and supplementary miscellaneous information collectively enhance the comprehensiveness of the user experience.

4.5.3 Water level

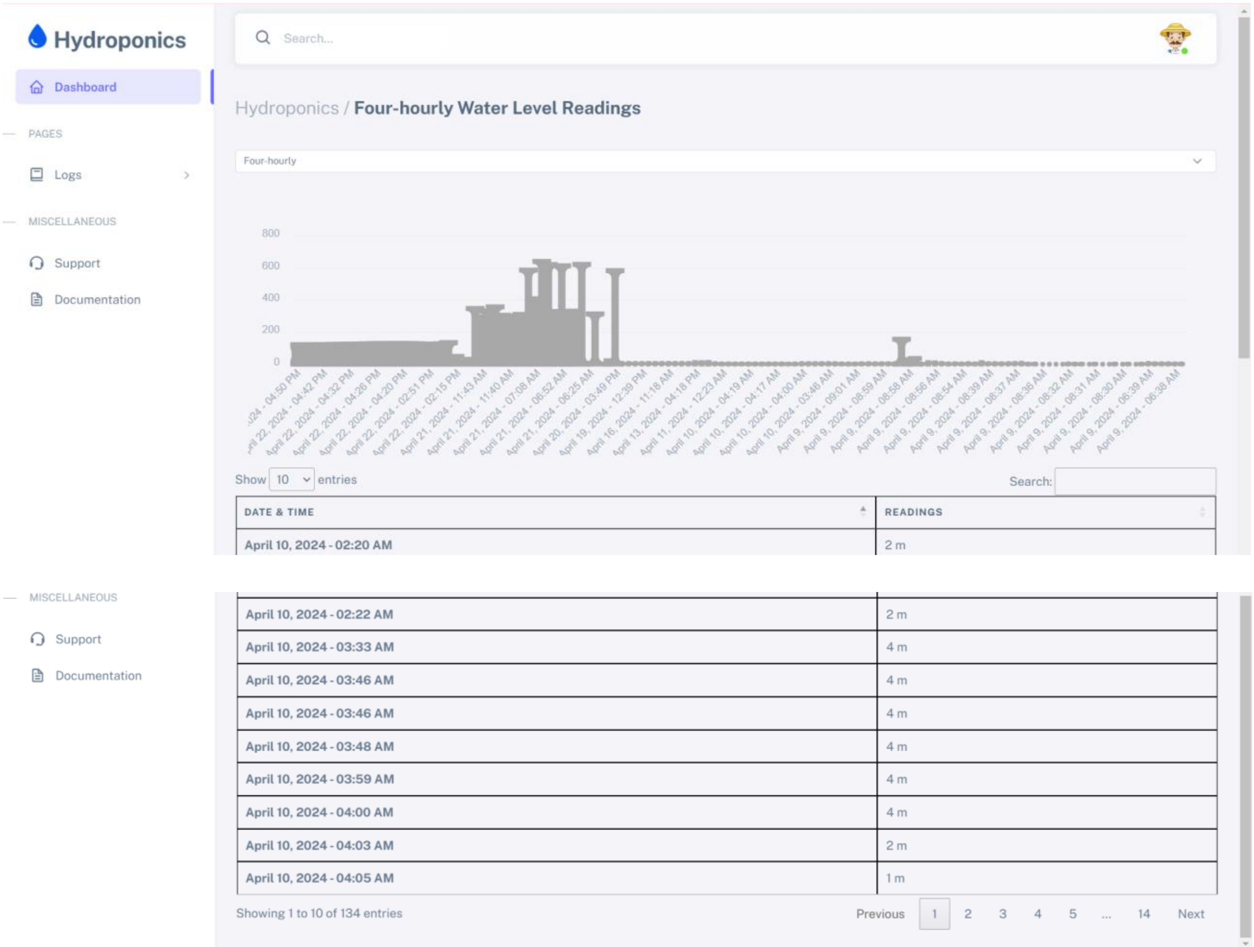


Figure 4.5. 3 Water Level

The presented table encapsulates varied data entries related to water level readings. Its meticulously structured layout integrates columns for date & time, readings, and miscellaneous information, ensuring a well-organized representation.

4.5.4 Acidity

Figure 4.5. 4 Acidity

The displayed table is specifically designed to showcase acidity readings, with a meticulous arrangement of columns for date & time, readings, and actions. The focus lies on presenting pH readings recorded at various time intervals, providing a comprehensive overview of the acidity data.

4.5.5 Temperature

Figure 4.5. 5 Temperature

The presented screenshot showcases a tabulated dataset encompassing recorded temperature readings, accompanied by precise temporal information in the form of dates and timestamps. This arrangement facilitates a detailed and comprehensive overview of the temperature dataset.

4.5.6 Total Dissolve Solids

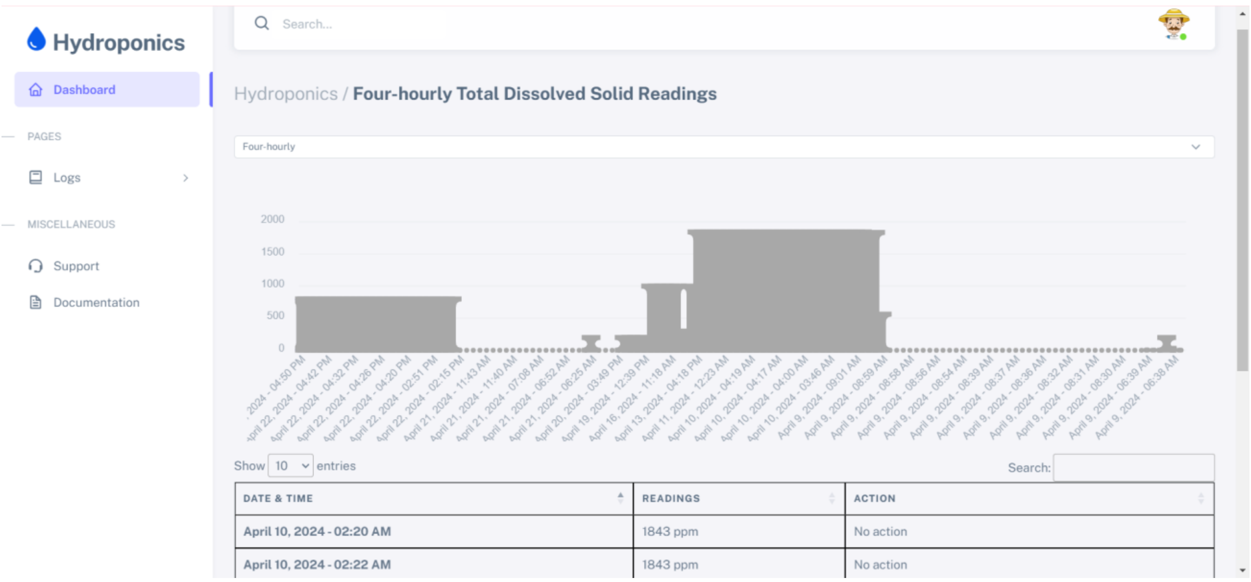


Figure 4.5. 6 Total Dissolved Solids

The displayed screenshot showcases a tabulated dataset containing detailed information on Total Dissolved Solids (TDS), incorporating precise date-time stamps, recorded actions, and miscellaneous details. This presentation provides a thorough and nuanced overview of the dataset.

4.5.7 Reading History

Figure 4.5. 7 Reading History

The reading history page offers a concise record of notifications, ensuring clear visibility into past interactions and updates.

4.6 Notification

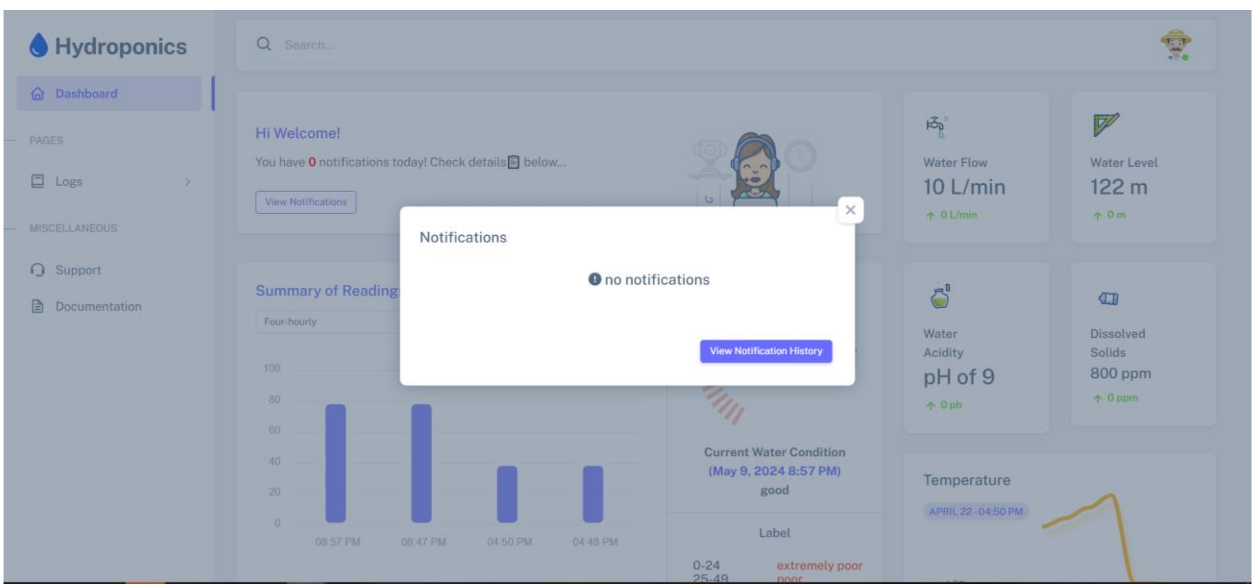


Figure 4.6. 1 Notifications

The push notification for notifying farmers if there's abnormalities or an immediate need for their intervention.

4.6.1 Notification History

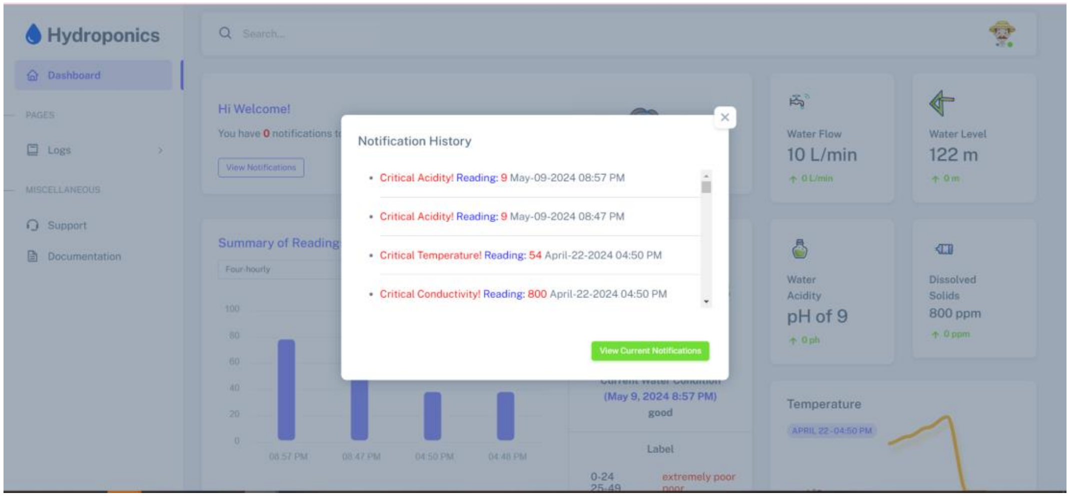


Figure 4.6. 2 Notification History

The Notification History page provides a concise archive of past notifications, offering users easy access to review and track previous alerts and updates.

4.7 Print

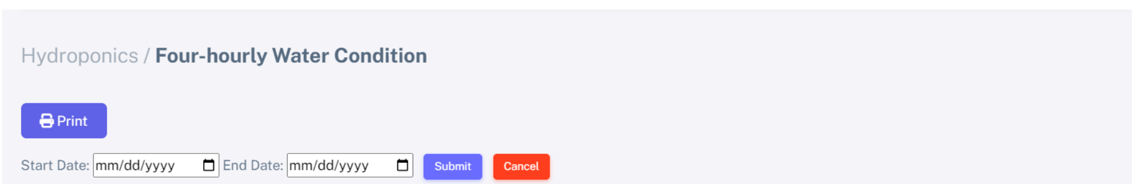


Figure 4.7 1 Print

The print function where the farmer can filter the date needed.

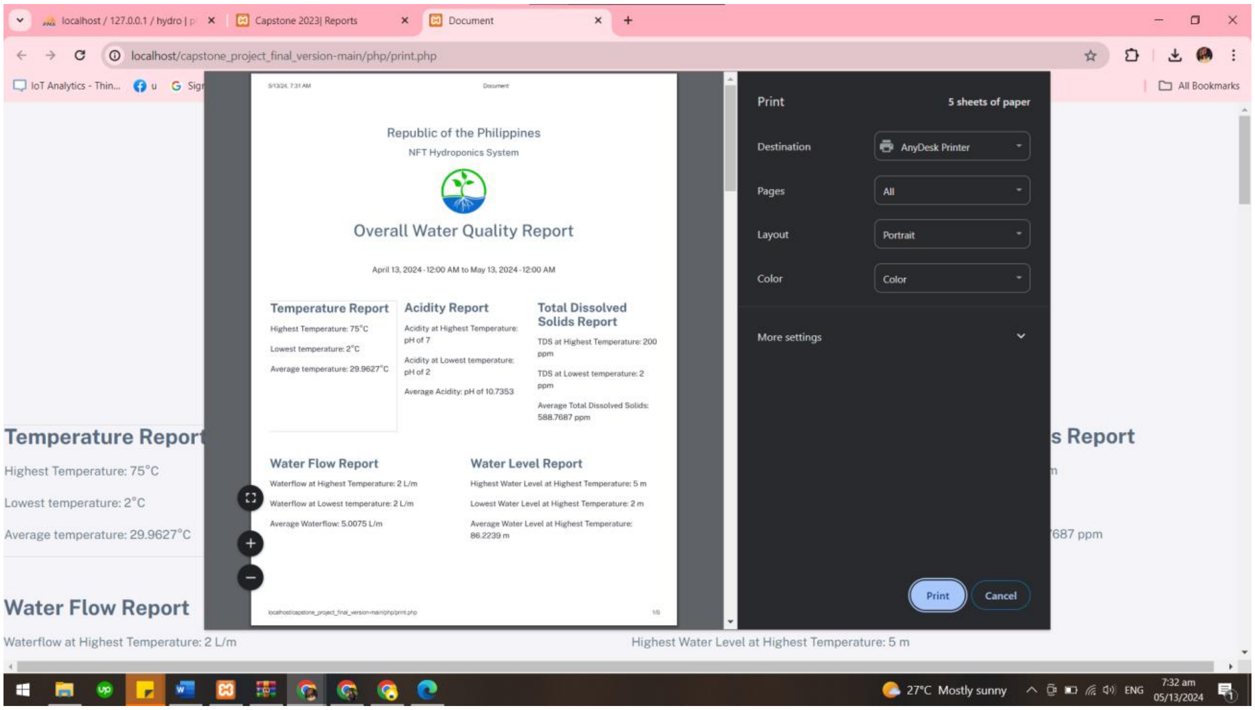


Figure 4.7 2 Print Preview

4.8. Report Preview

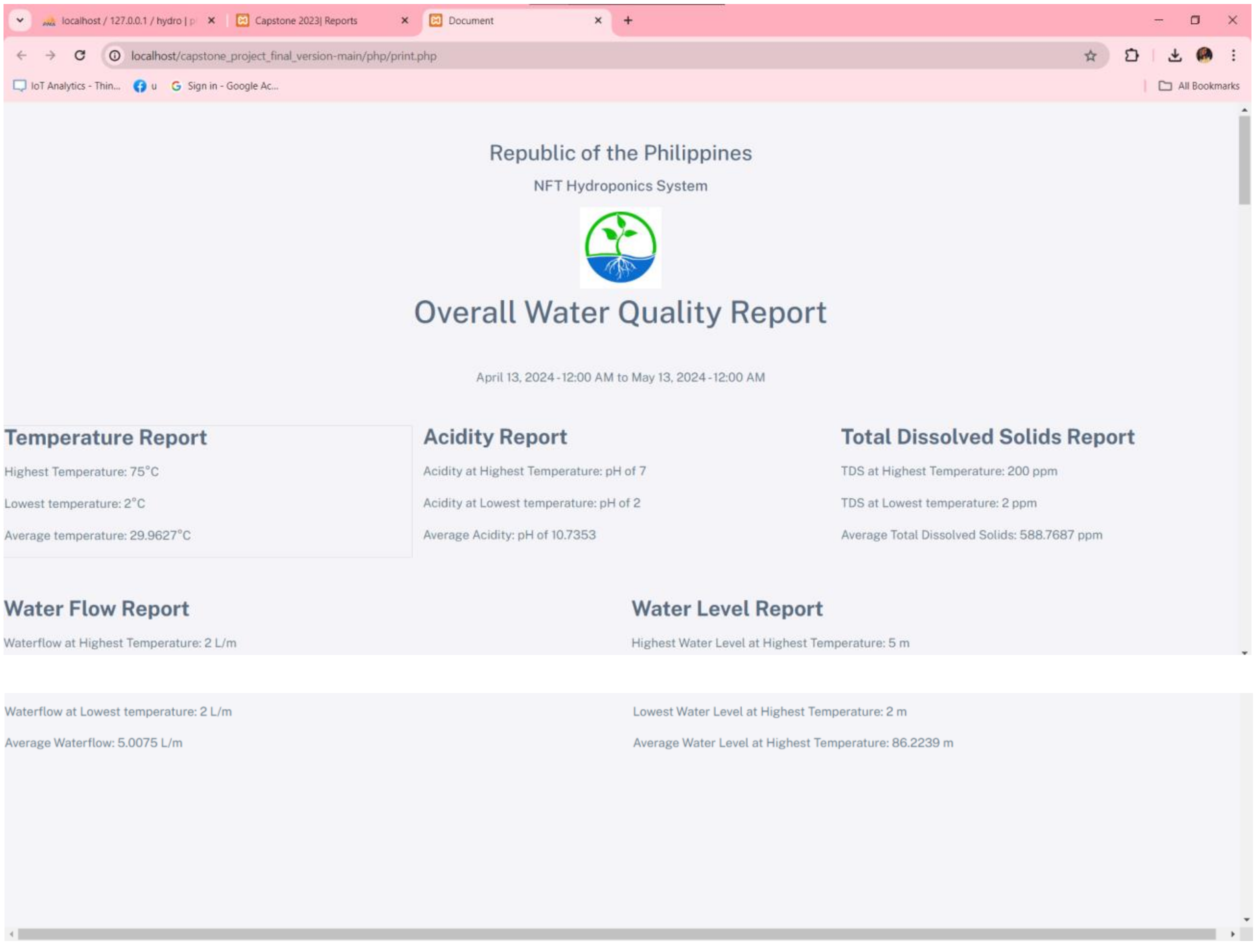


Figure 4.8. 1 Report Preview

Farmers will have the option to print the report or not, but either way, they will be presented with a comprehensive report to aid in their decision-making process regarding NFT hydroponics.

4.9 Network Implementation Plan

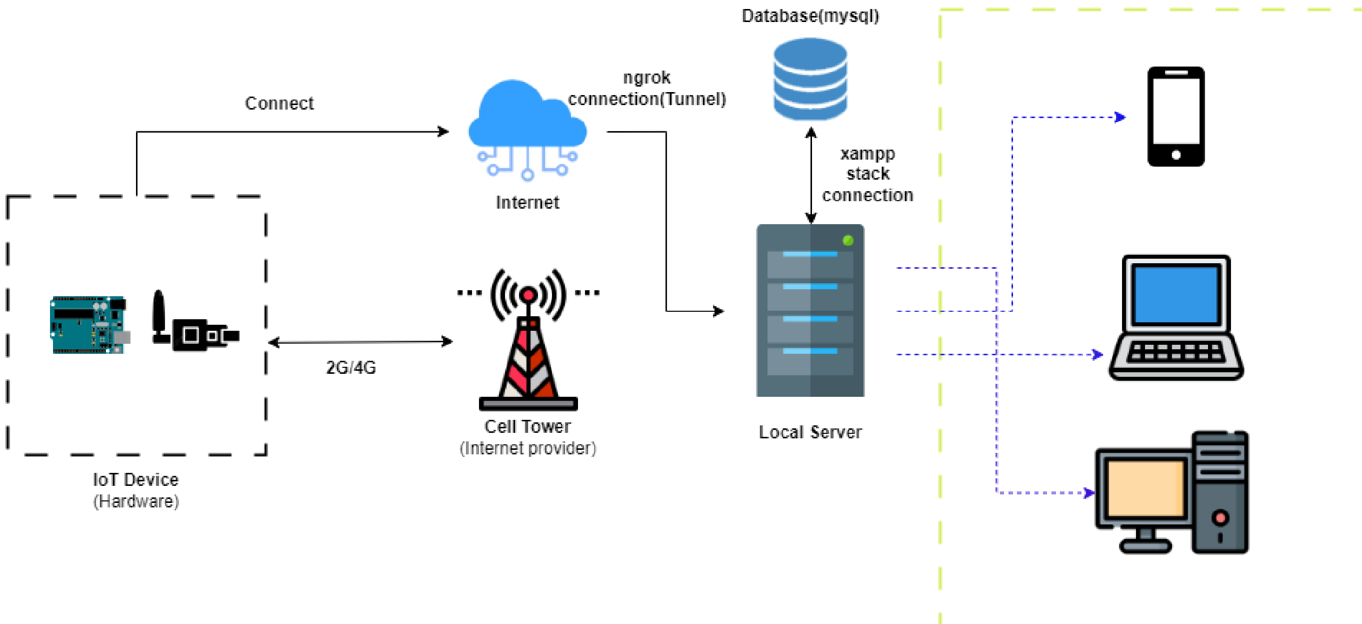


Figure 4.9. 1 Network Implementation Plan

Network implementation plan integrates IoT devices equipped with GSM modules supporting 2G/4G connections, utilizing Ngok tunneling for secure internet connectivity. Through Ngok, these devices establish tunnel to our local server, enabling real-time data transmission and remote management. The server, accessible publicly, acts as the hub for receiving and processing data, ensuring flexibility and accessibility for users. With security measures in place, including authentication, our network architecture guarantees the integrity and confidentiality of transmitted data. Designed for scalability and flexibility, this architecture lays the foundation for seamless expansion and adaptation to future needs, empowering organizations to harness the full potential of IoT technology.

4.10 Device

Figure 10. 1 Device Case

A case designed to protect and house advanced hydroponics monitoring sensors for various environmental applications.

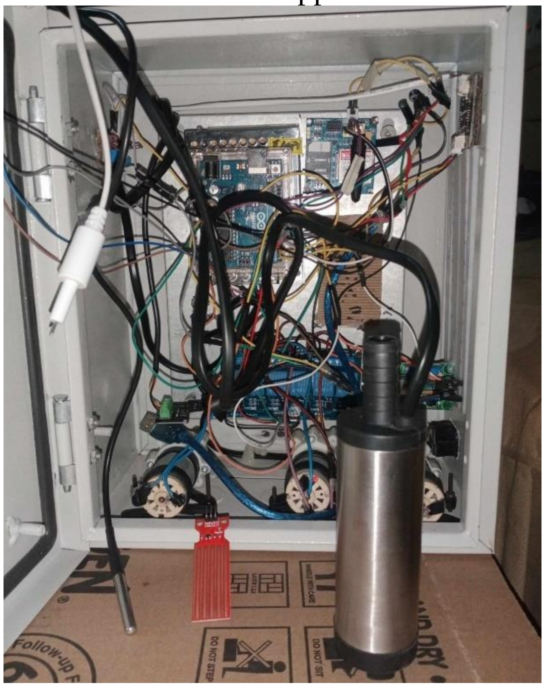


Figure 10. 2 Inside of the Device

A compact array of high-tech sensors meticulously arranged to monitor water quality for hydroponics, featuring indicators for acidity, temperature, dissolved solids, flow rate, and water level.

4.11 Post – Study System Usability Questionnaire Results

The survey results provide valuable insights into users' experiences and perceptions of a hydroponics cultivation system. Using the Post – Study System Usability Questionnaire, participants shared their feedback on various aspects of the system's performance, usability, reliability, and integration.

Overall Score (OVERALL):

$$OVERALL = \frac{\sum_{i=1}^{n} \text{Item Score}_i}{n}$$

SYSUSE Score:

$$SYSUSE = \frac{\sum_{i=1}^{n} \text{Item Score}_i}{n}$$

INFOQUAL Score:

$$INFOQUAL = \frac{\sum_{i=1}^{n} \text{Item Score}_i}{n}$$

INTERQUAL Score:

$$INTERQUAL = \frac{\sum_{i=1}^{n} \text{Item Score}_i}{n}$$

Figure 4.11. 1 Formulae Used

4.11.1 Ordinal Scale

Table 4.11.1. 1 Ordinal Scale

Likert- Scale Description	Likert Scale
Strongly Agree	1
Agree	2
Somewhat Agree	3

Neither Agree nor Disagree	4
Somewhat Disagree	5
Disagree	6
Strongly Disagree	7

4.11.2 Results

Upon analyzing survey responses from 25 users, it's clear that the hydroponic system's success hinges on user satisfaction with its functionality, ease of use, and information quality. The overall satisfaction levels, moderately positive across all categories, lay a foundation for success. Users' perception of the system's usefulness (SYSUSE) and the quality of information it provides (INFOQUAL) are crucial factors influencing their satisfaction and ultimately the system's success. However, variability in ratings regarding interface quality (INTERQUAL) suggests areas for improvement. Addressing these issues could further enhance user satisfaction and contribute to the system's effectiveness in supporting hydroponic operations.

The usability evaluation using SYSUSE, INFOQUAL, and INTERQUAL scales provided insights into the system's favorable attributes, with high internal consistency and significant differences among user groups detected. These findings underscore the importance of system usability in achieving success, emphasizing the need to prioritize user-centric design and functionality.

Statistically, the overall satisfaction scores ranged from 1.32 to 1.68, SYSUSE scores ranged from 1.36 to 1.68, INFOQUAL scores ranged from 1.28 to 1.60, and INTERQUAL scores ranged from 1.28 to 1.56. Using the Post-Study System Usability Questionnaire tool for evaluation, the system showed a high satisfaction result with an overall score of 1.37, SYSUSE of

1.46, INFOQUAL of 1.45, and INTERQUAL of 1.44, where one or closest to 1 indicates strong agreement and high acceptance.

The factor analysis revealed that the three factors collectively accounted for 87% of the total variance, with coefficient alpha values ranging from .91 to .96 across the subscales. Significant differences among user groups were detected for overall satisfaction ($F(2,29)=4.35$, $p=0.02$), SYSUSE ($F(2,36)=6.9$, $p=0.003$), INFOQUAL ($F(2,33)=3.68$, $p=0.04$), and INTERQUAL ($F(2,35)=3.74$, $p=0.03$). INFOQUAL exhibited a significant system effect ($F(2,33)=3.18$, $p=0.05$). Correlation analyses showed a strong correlation between the overall scale and user ratings from scenario-based assessments ($r(20)=0.80$, $p=0.0001$). The overall scale also correlated moderately with the percentage of successful scenario completion ($r(29)=-0.40$, $p=0.026$), while SYSUSE and INTERQUAL correlated moderately with the percentage of successful scenario completion (SYSUSE: $r(36)=-0.40$, $p=0.006$; INTERQUAL: $r(35)=-0.29$, $p=0.08$).

Table 4.11.2. 1 Results

Item	**Scale**	**Factor 1**	**Factor 2**	**Factor 3**
1	1.68	1.36	1.48	1.28
2	1.40	1.40	1.28	1.44
3	1.56	1.68	1.56	1.44
4	1.32	1.36	1.36	1.32
5	1.44	1.52	1.60	1.44
6	1.32	1.36	1.32	1.36

7	1.44	1.40	1.40	1.36
8	1.48	1.52	1.48	1.44
9	1.52	1.60	1.52	1.56
10	1.48	1.56	1.48	1.52
11	1.44	1.36	1.40	1.44
12	1.48	1.40	1.48	1.40
13	1.48	1.44	1.48	1.48
14	1.48	1.48	1.48	1.52
15	1.44	1.36	1.40	1.44
16	1.48	1.56	1.48	1.56

CHAPTER V
CONCLUSION AND RECOMMENDATION

5.1 Conclusion

This aims to address the absence of comprehensive automated monitoring for crucial factors affecting water quality in NFT hydroponics, encompassing acidity, temperature, electrical conductivity, water flow, and container water level. The developed system aims to assist farmers by integrating notifications, alerting them when human intervention becomes necessary.

In addition, the developers have specified objectives regarding the matter, which

they followed and achieved:

1. An IoT-based system with a database that stores data from sensors.

2. An IoT-based system with a dashboard of water acidity, temperature, electrical conductivity (total dissolved solids), water flow and water level.

3. An IoT-based system with an automation to control the water acidity, electric conductivity via automated dispensing of liquid solution in the water container and temperature via increasing the water flow of the NFT system.

4. An IoT-based system with a printable report of system activity and sensor data.

5. An IoT-based system with systems push notifications for abnormal water quality and problems that need human intervention such as clogging, pump failure and sudden low of container water level.

5.2 Recommendations

The developed IoT-based decision support system for hydroponics culture, with its array of functionalities, successfully caters to the farmer's requirements for effective cultivation management. However, in exploring avenues for future enhancements and considering the evolving landscape of hydroponic systems, several potential functionalities for system improvement and expanded utility come to light:

- Develop a Mobile Application: Creating a mobile application dedicated to the IoT-based hydroponics system would offer the farmer greater accessibility and on-the-go management capabilities.

- Integrate a Messaging Module: Incorporating a messaging module within the system would facilitate communication among users, enabling farmers to share insights, discuss best practices, and seek advice directly through the platform.

- Guest Access for Profile Viewing: Allowing unregistered guests or visitors to view the system's sensor data or hydroponics parameters could foster transparency and offer insights into the cultivation process.

- Job Listings and Announcements: Implementing a feature to share job listings or important announcements directly with registered farmers via email could enrich the system's utility, offering relevant opportunities or updates within the hydroponics domain.

- Enable Addition of Multiple Parameters: Enhancing the system to accommodate the addition of multiple parameters or functionalities, akin to double majors/courses in an educational context, would broaden its scope and adaptability to varied hydroponics setups or additional sensor inputs.

● SMS Notification for Farmers: Integrate SMS notifications for farmers so that they receive important updates and alerts even when they are outside their homes, ensuring timely responses to critical events or changes in the hydroponic system.

● Implement Security Measures: Incorporating robust security features into the IoT-based decision support system is imperative to safeguard sensitive data and ensure the integrity of the hydroponics setup. Measures such as encryption protocols, user authentication mechanisms, and regular security audits can mitigate risks associated with unauthorized access or tampering, enhancing overall system reliability and trustworthiness.

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Appendices

Appendix A: Interview Questionnaire

- Why did you choose hydroponics as a method for farming?
- How many years have you been practicing hydroponics?
- What were the problems you encountered while planting with the use of hydroponics?
- How did you solve the problems you faced using the hydroponic system?
- How do you monitor your water in your hydroponic system?
- How often do you monitor your hydroponics system?
- If ever given a chance to enhance this type of method in farming, what do you want to suggest to enhance?

Appendix B: Diagrams

Context Level Diagram

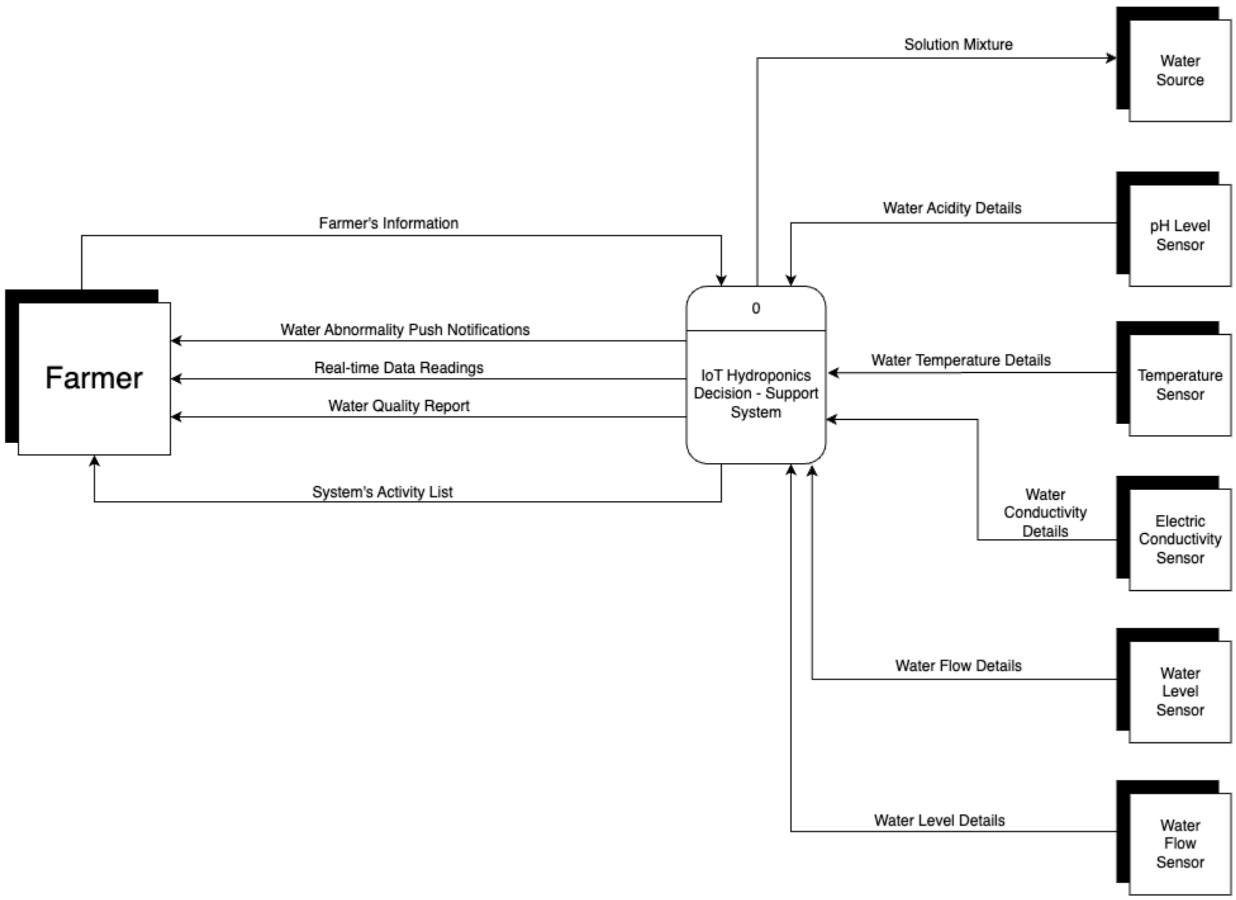


Figure B. 1 Context Level Diagram

Diagram 0

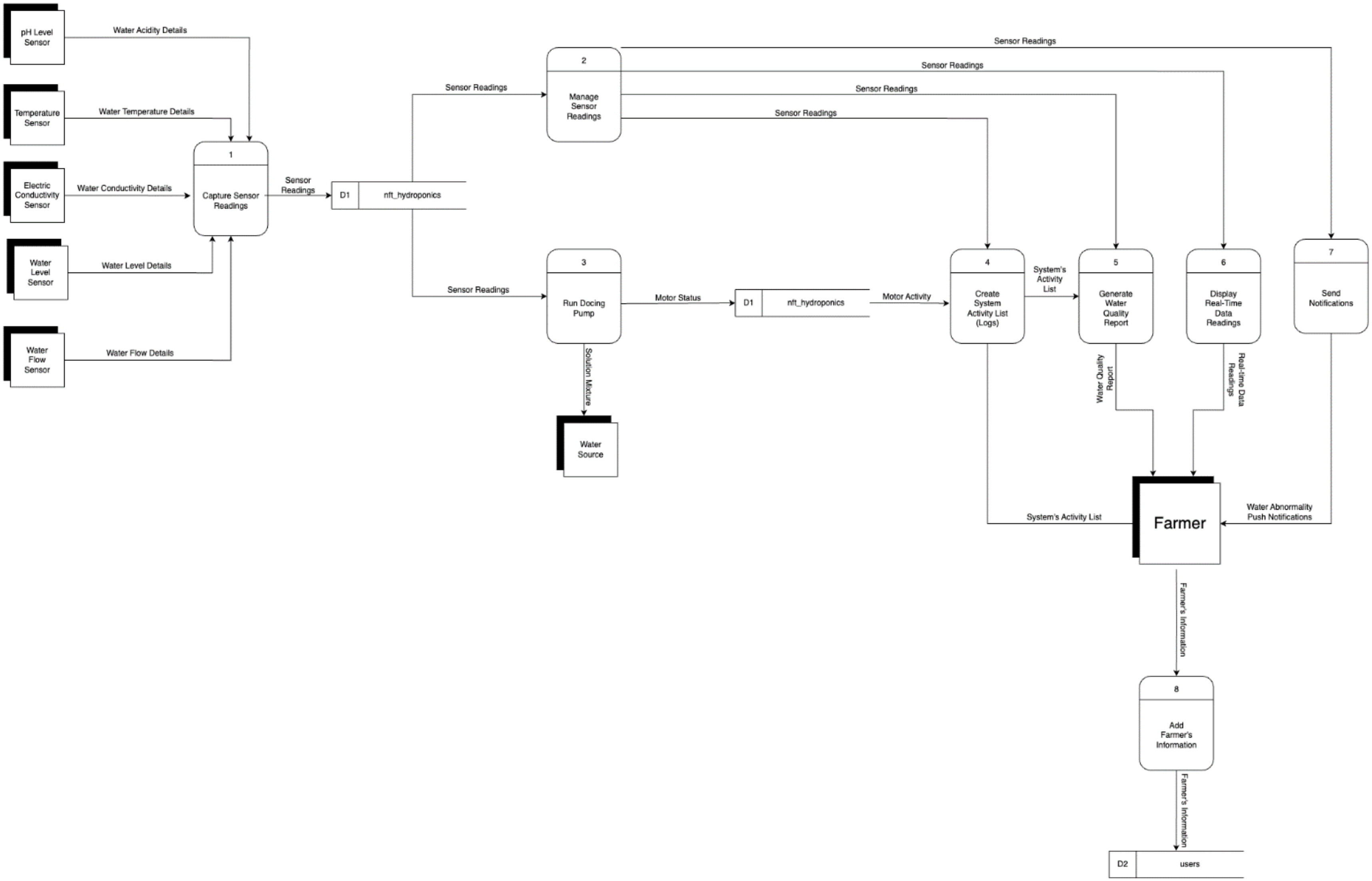


Figure B. 2 Diagram 0

Child Diagram/s

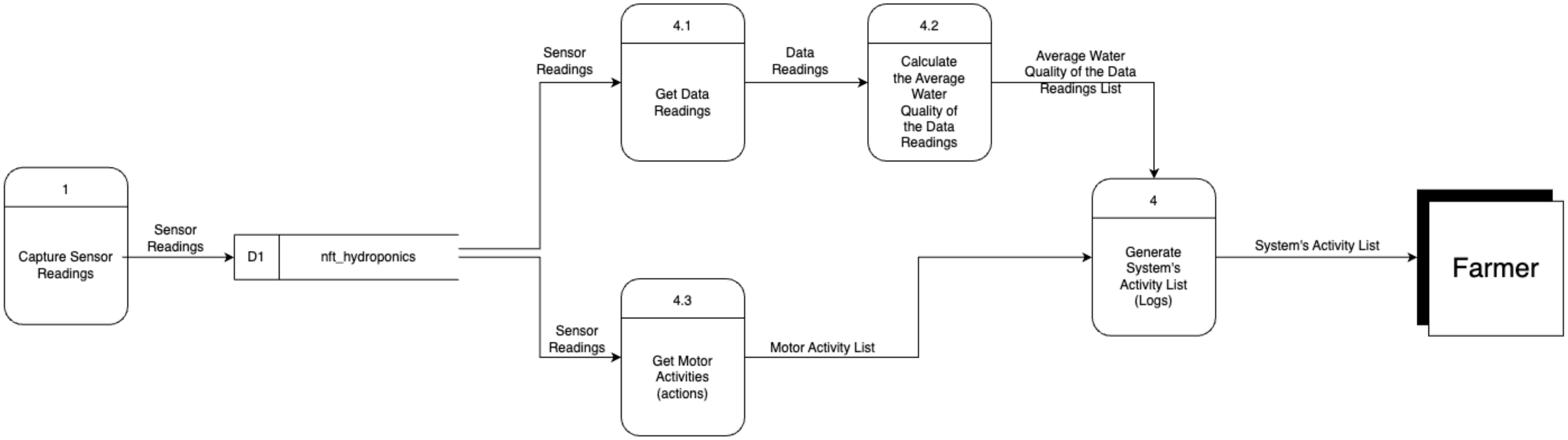


Figure B. 3 Child Diagram - Generate System Activiy List (Logs)

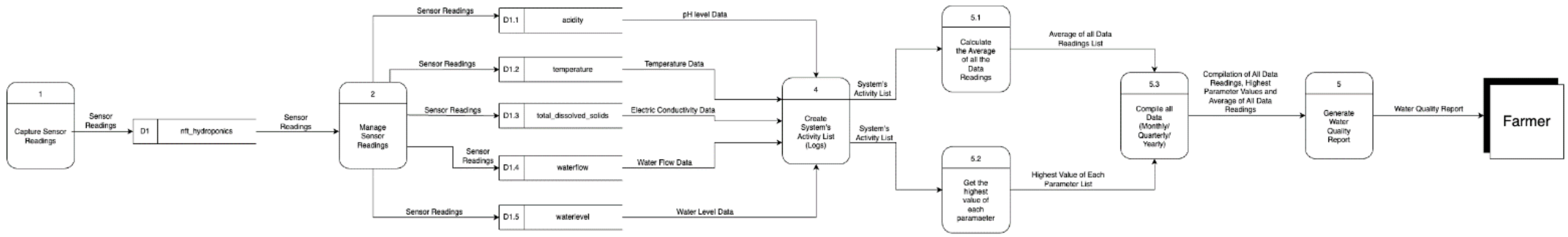


Figure B. 4 Child Diagram - Generate Water Quality Report

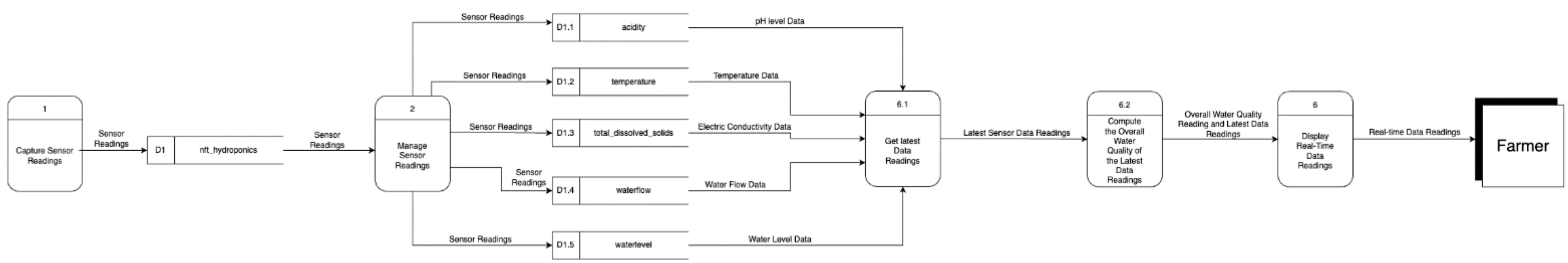


Figure B. 5 Child Diagram - Display Real-Time Data Readings

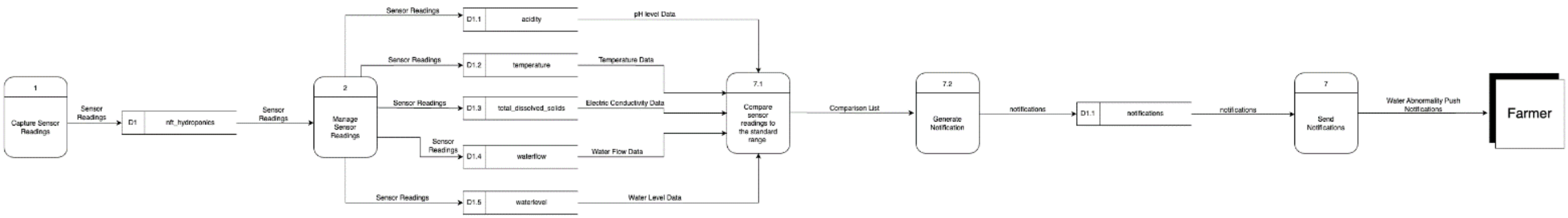


Figure B. 6 Child Diagram - Send Notifications

Entity Relationship Diagram (ERD)

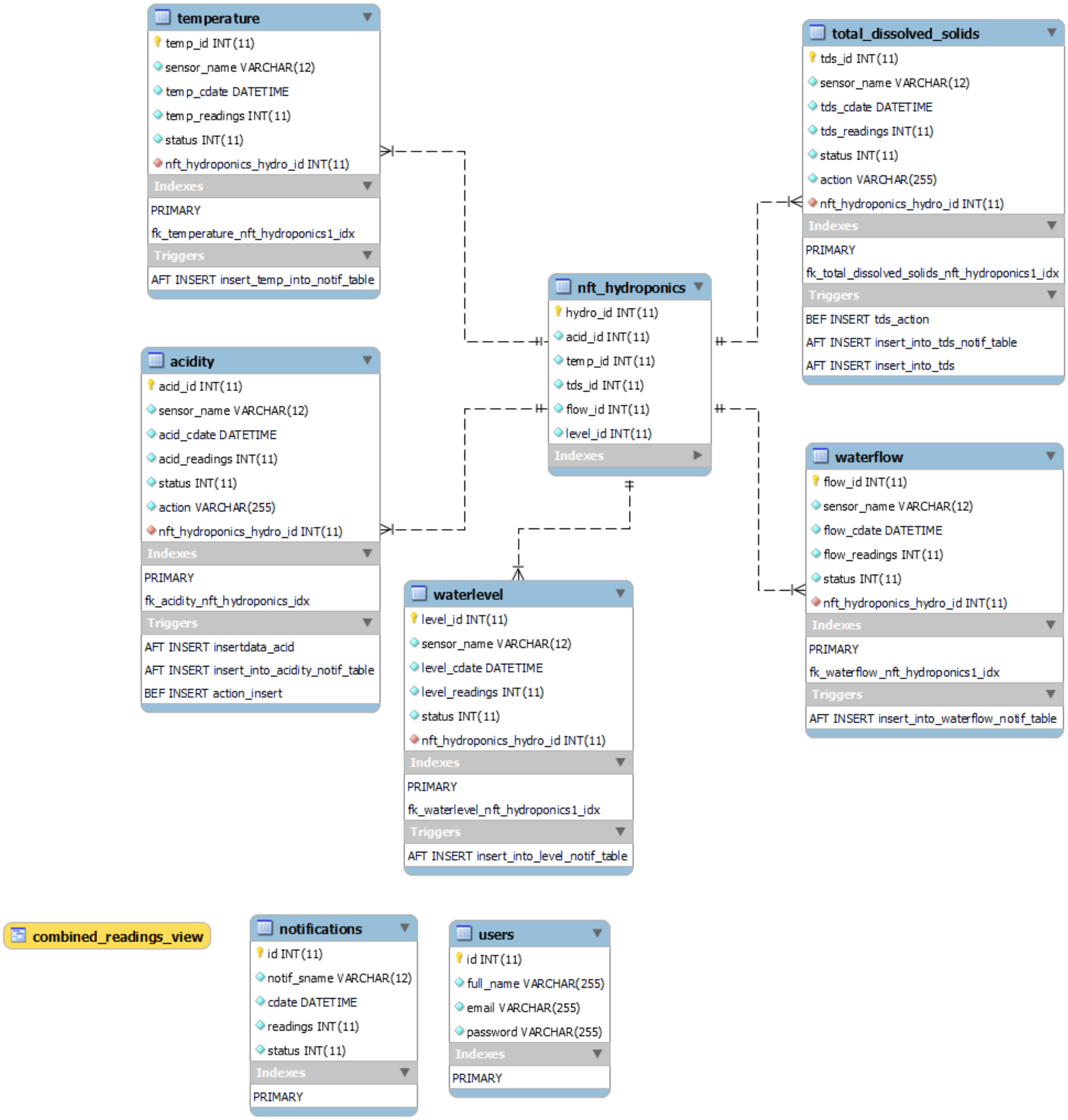
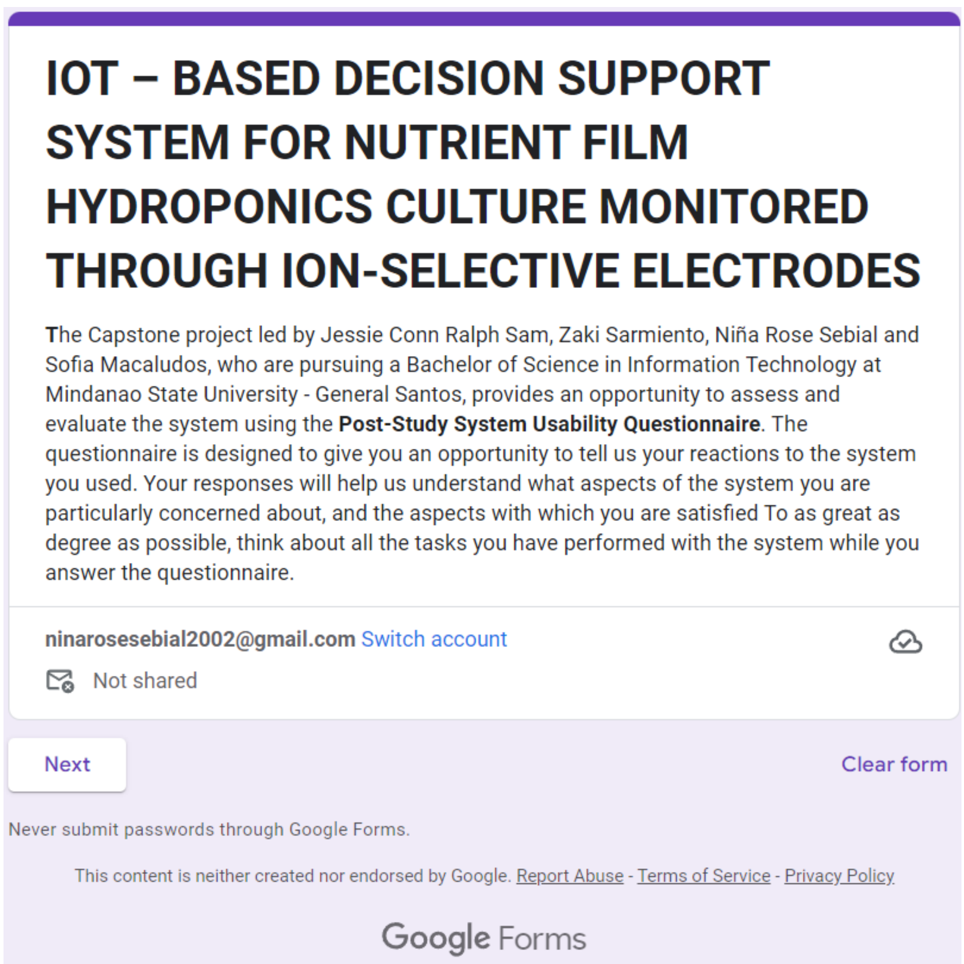


Figure B. 7 Entity Relationship Diagram

Appendix C: Test Questionnaire

Questionnaire

The Capstone project led by Jessie Conn Ralph Sam, Zaki Sarmiento, Niña Rose Sebial and Sofia Macaludos, who are pursuing a Bachelor of Science in Information Technology at Mindanao State University - General Santos, provides an opportunity to assess and evaluate the system using the Post – Study System Usability Questionnaire. A Post – Study System Usability Questionnaire is a tool to gather feedback from users about their experiences and satisfaction levels with a product or service.



IOT – BASED DECISION SUPPORT SYSTEM FOR NUTRIENT FILM HYDROPONICS CULTURE MONITORED THROUGH ION-SELECTIVE ELECTRODES

The Capstone project led by Jessie Conn Ralph Sam, Zaki Sarmiento, Niña Rose Sebial and Sofia Macaludos, who are pursuing a Bachelor of Science in Information Technology at Mindanao State University - General Santos, provides an opportunity to assess and evaluate the system using the **Post-Study System Usability Questionnaire**. The questionnaire is designed to give you an opportunity to tell us your reactions to the system you used. Your responses will help us understand what aspects of the system you are particularly concerned about, and the aspects with which you are satisfied To as great as degree as possible, think about all the tasks you have performed with the system while you answer the questionnaire.

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Figure C. 1 Questionnaire

Instructions

Read each statement and indicate HOW STRONGLY YOU AGREE OR DISAGREE WITH THE STATEMENT by circling a number on the scale. If a statement does not apply to you, disregard it to indicate N/A. We encourage you to write comments to elaborate on your answers. After you complete this questionnaire, we'll go over your responses with you to make sure we understand all of your responses. Thank you!

Name: *

Your answer

Year & Course/Professions: *

Your answer

Are you familiar with hydroponics? *

- Yes
- No

Figure C. 2 Questionnaire

1. The system has all the functions and capabilities I expect to have.

	1	2	3	4	5	6	7	
Strongly Agree	○	○	○	○	○	○	○	Strongly Disagree

2. Overall, I am satisfied with the system.

	1	2	3	4	5	6	7	
Strongly Agree	○	○	○	○	○	○	○	Strongly Disagree

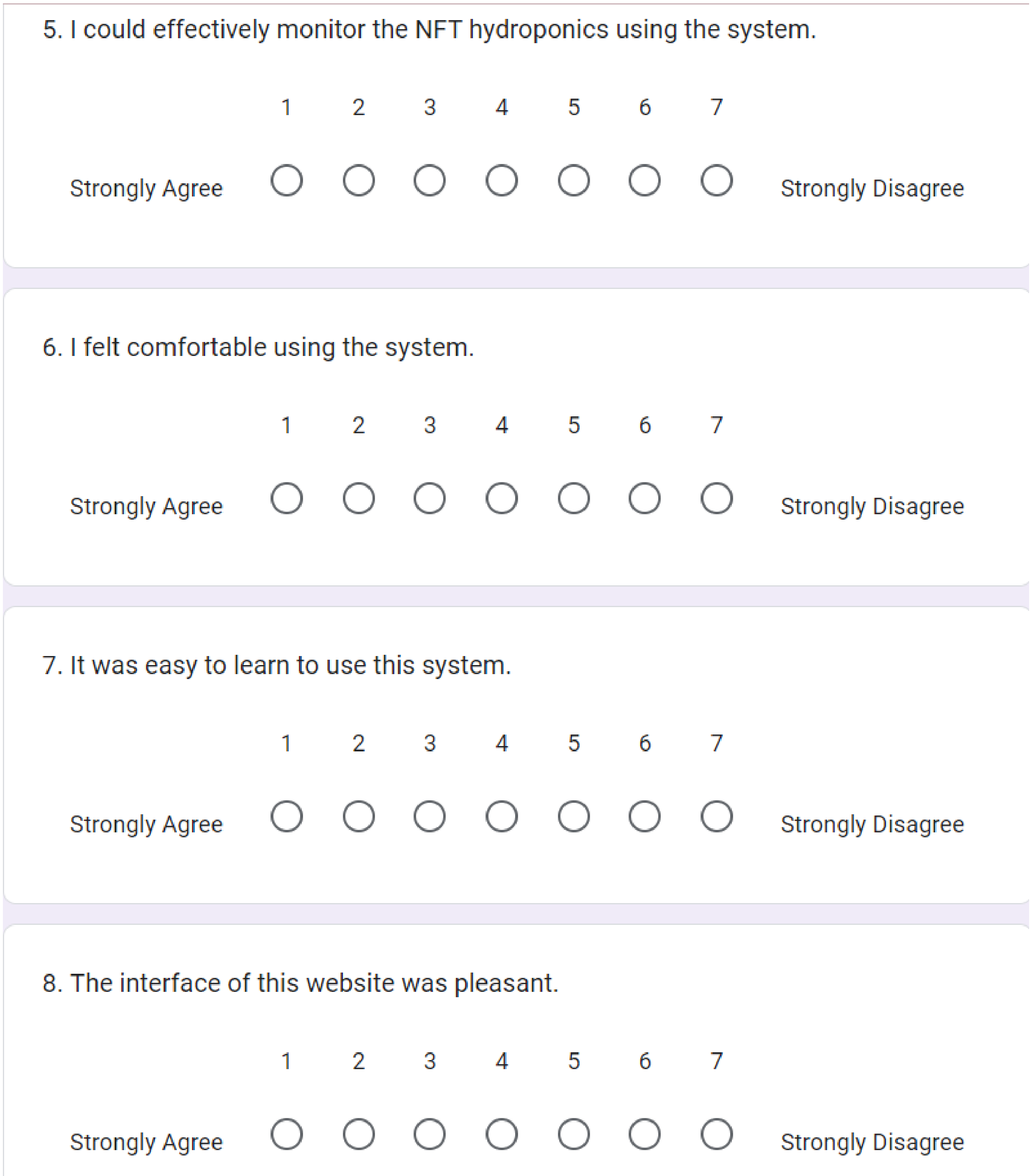
3. Overall, I am satisfied with how easy it is to use this system.

	1	2	3	4	5	6	7	
Strongly Agree	○	○	○	○	○	○	○	Strongly Disagree

4. It was simple to use this system.

	1	2	3	4	5	6	7	
Strongly Agree	○	○	○	○	○	○	○	Strongly Disagree

Figure C. 3 Questionnaire



5. I could effectively monitor the NFT hydroponics using the system.

	1	2	3	4	5	6	7	
Strongly Agree	○	○	○	○	○	○	○	Strongly Disagree

6. I felt comfortable using the system.

	1	2	3	4	5	6	7	
Strongly Agree	○	○	○	○	○	○	○	Strongly Disagree

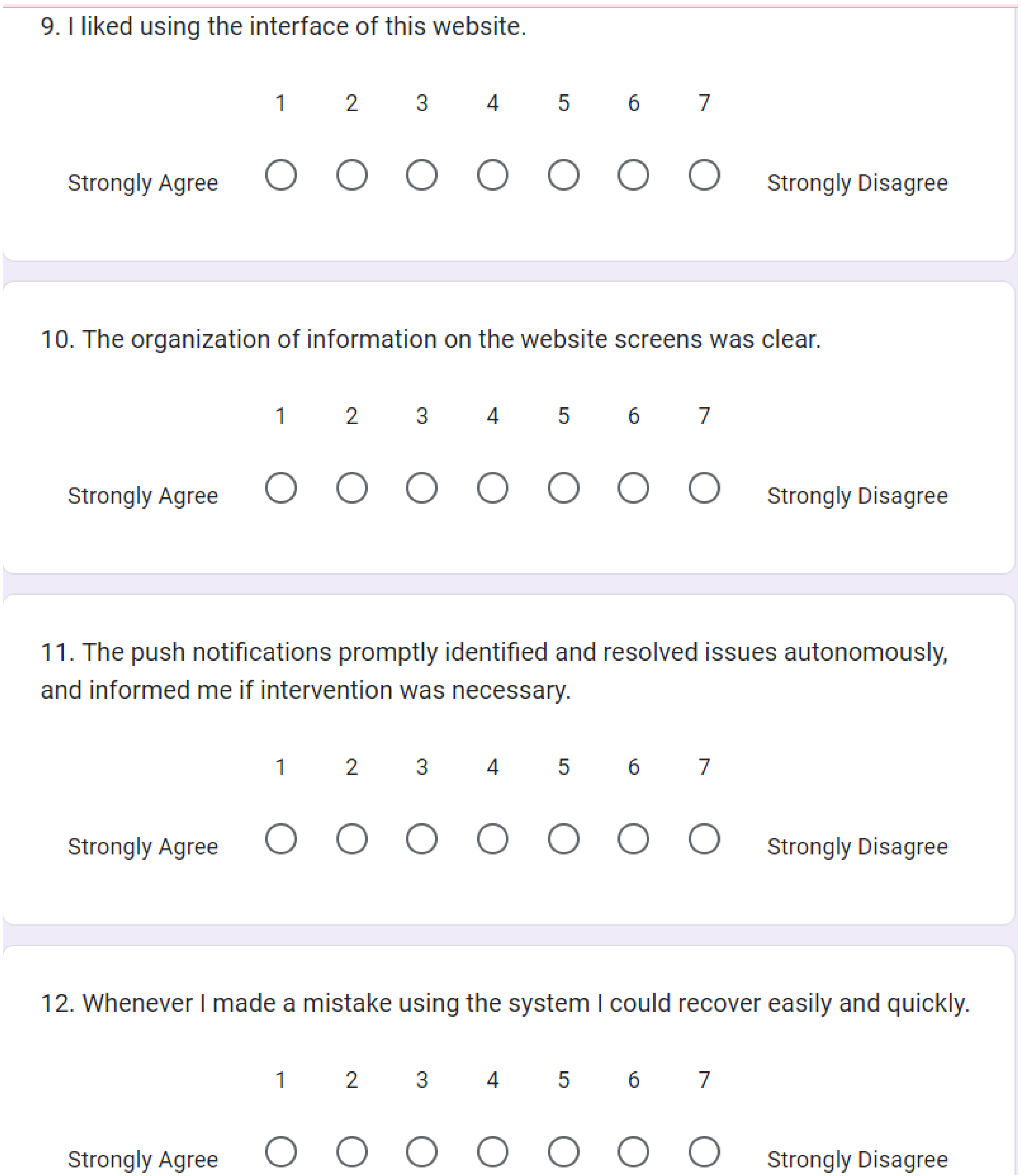
7. It was easy to learn to use this system.

	1	2	3	4	5	6	7	
Strongly Agree	○	○	○	○	○	○	○	Strongly Disagree

8. The interface of this website was pleasant.

	1	2	3	4	5	6	7	
Strongly Agree	○	○	○	○	○	○	○	Strongly Disagree

Figure C. 4 Questionnaire



9. I liked using the interface of this website.

	1	2	3	4	5	6	7	
Strongly Agree	○	○	○	○	○	○	○	Strongly Disagree

10. The organization of information on the website screens was clear.

	1	2	3	4	5	6	7	
Strongly Agree	○	○	○	○	○	○	○	Strongly Disagree

11. The push notifications promptly identified and resolved issues autonomously, and informed me if intervention was necessary.

	1	2	3	4	5	6	7	
Strongly Agree	○	○	○	○	○	○	○	Strongly Disagree

12. Whenever I made a mistake using the system I could recover easily and quickly.

	1	2	3	4	5	6	7	
Strongly Agree	○	○	○	○	○	○	○	Strongly Disagree

Figure C. 5 Questionnaire

13. The Information provided with this system (on-line help, documentation) was clear.

	1	2	3	4	5	6	7	
Strongly Agree	○	○	○	○	○	○	○	Strongly Disagree

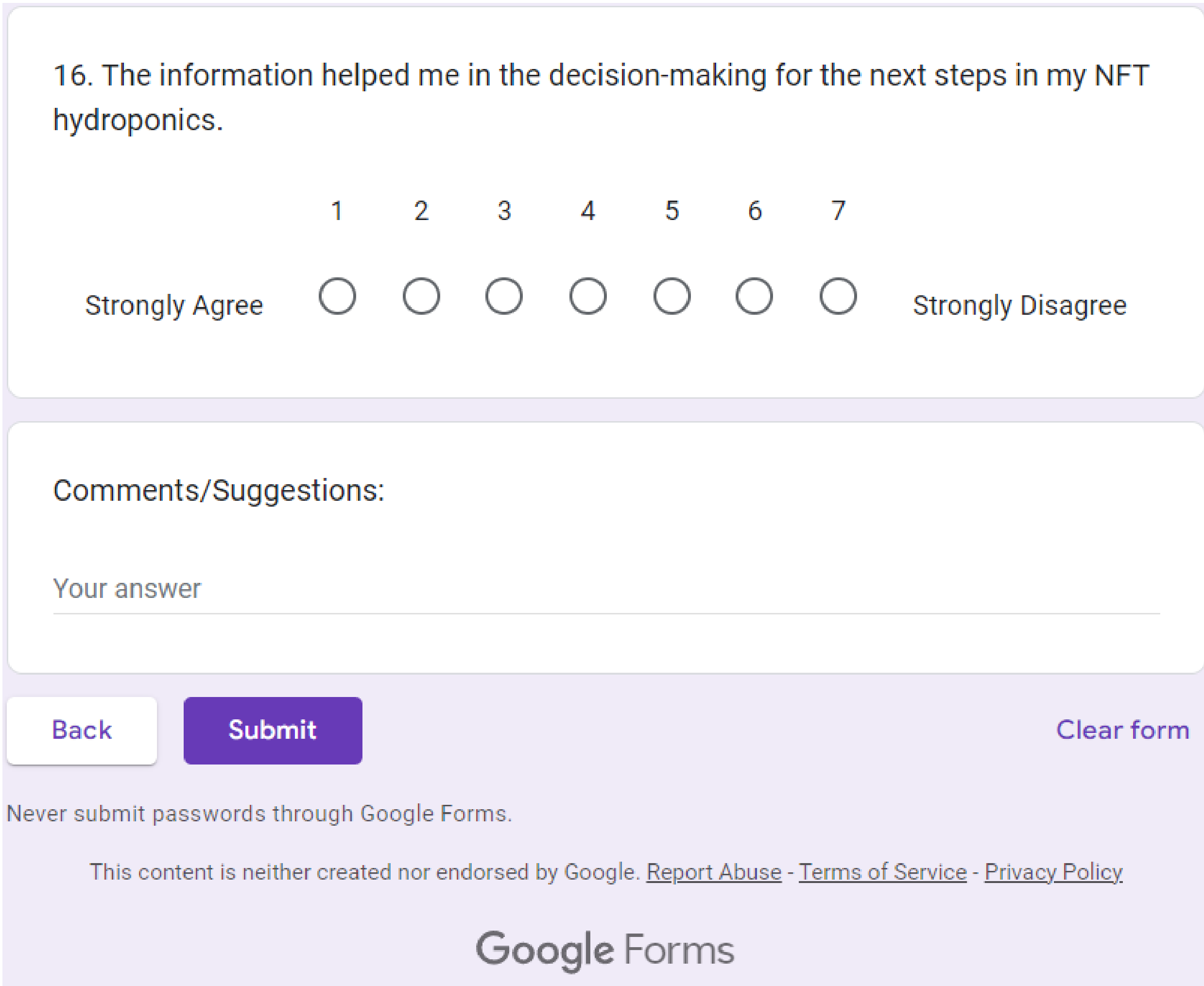
14. It was easy to find the information I needed.

	1	2	3	4	5	6	7	
Strongly Agree	○	○	○	○	○	○	○	Strongly Disagree

15. The information provided for the system was very easy to understand.

	1	2	3	4	5	6	7	
Strongly Agree	○	○	○	○	○	○	○	Strongly Disagree

Figure C. 6 Questionnaire


16. The information helped me in the decision-making for the next steps in my NFT hydroponics.

	1	2	3	4	5	6	7	
Strongly Agree	○	○	○	○	○	○	○	Strongly Disagree

Comments/Suggestions:

Your answer

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Figure C. 7 Questionnaire

Appendix D: IoT Data Workflow

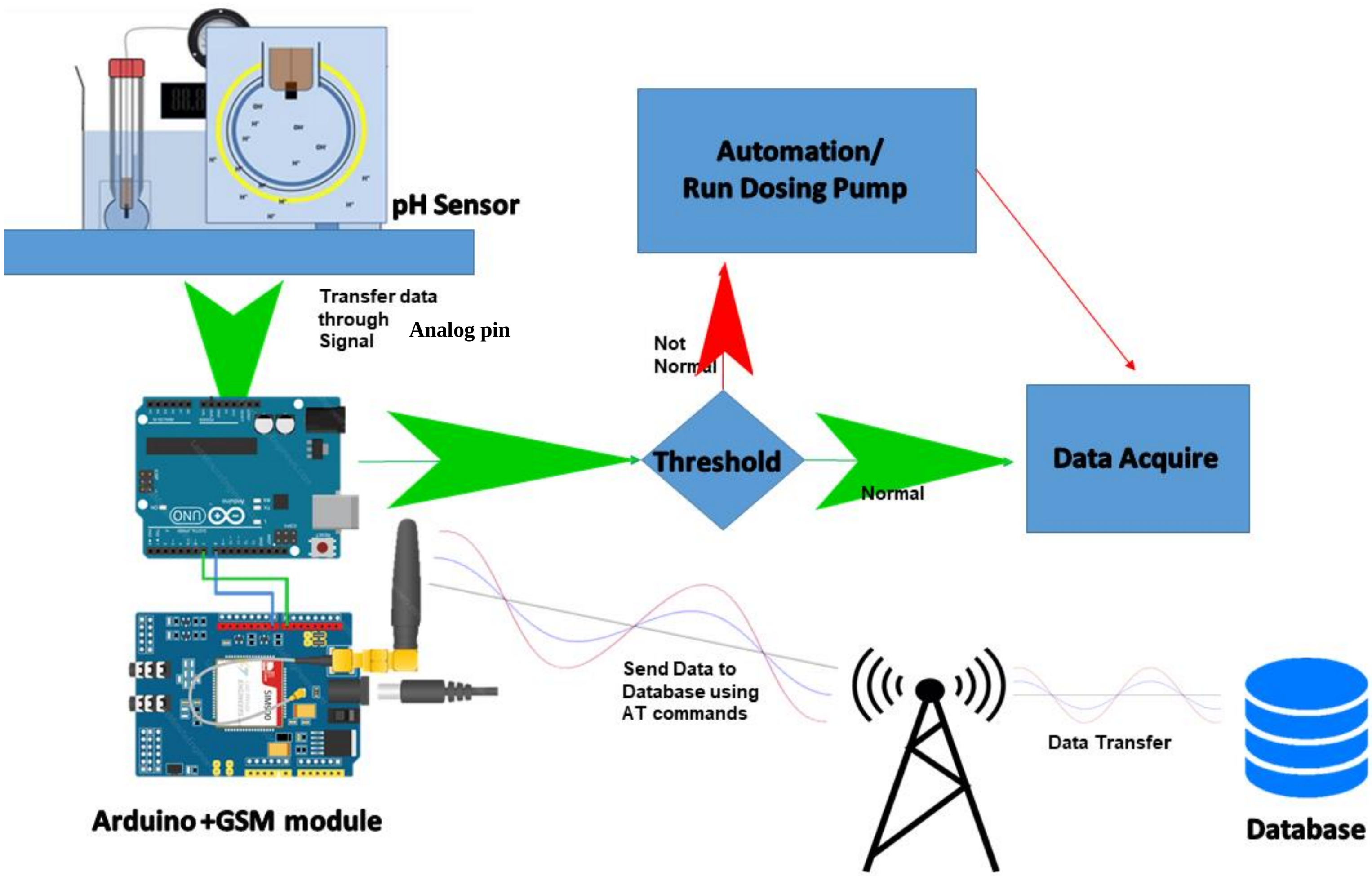


Figure D. 1 Water Acidity Data Workflow

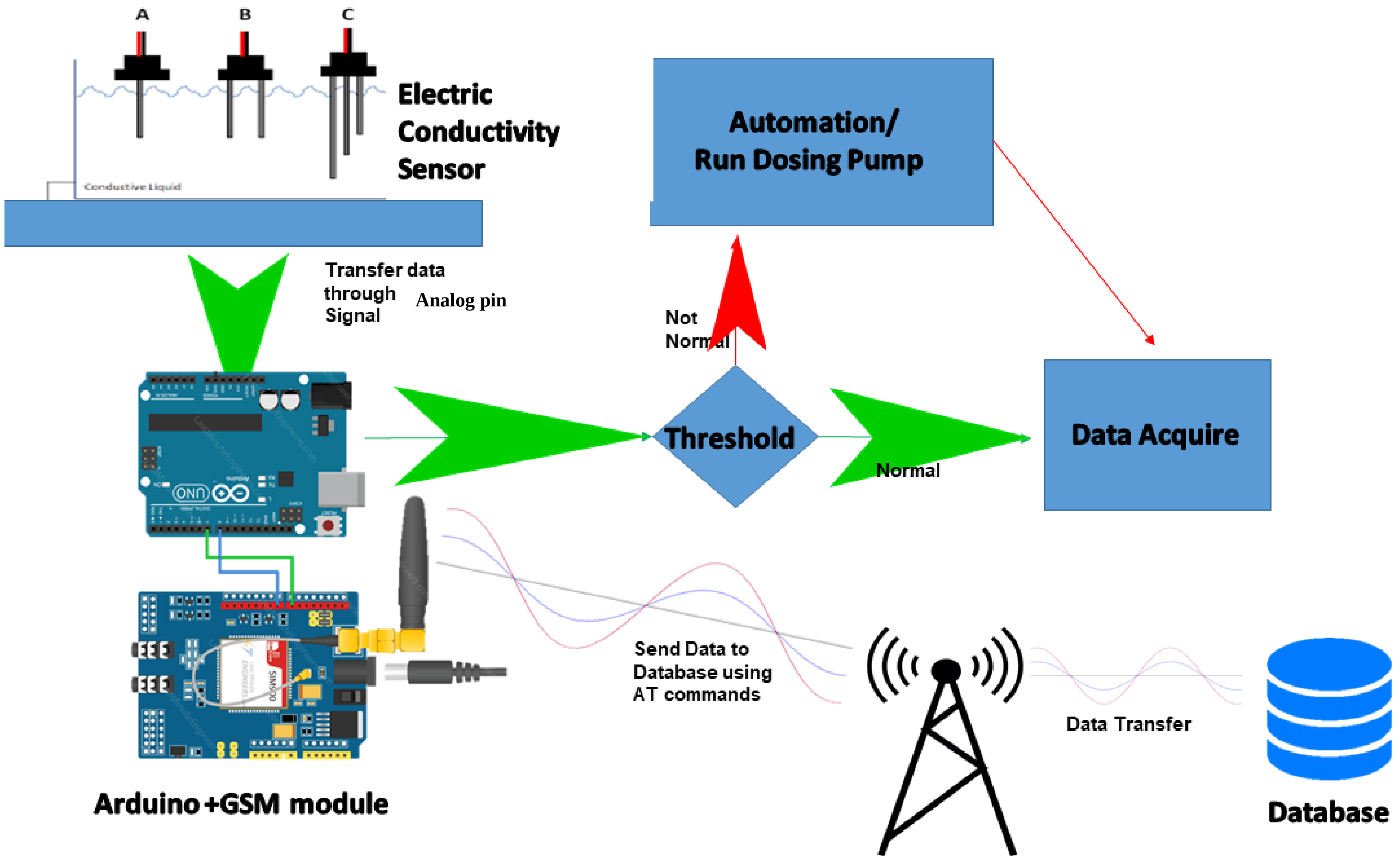


Figure D. 2 Total Dissolved Solids Data Workflow

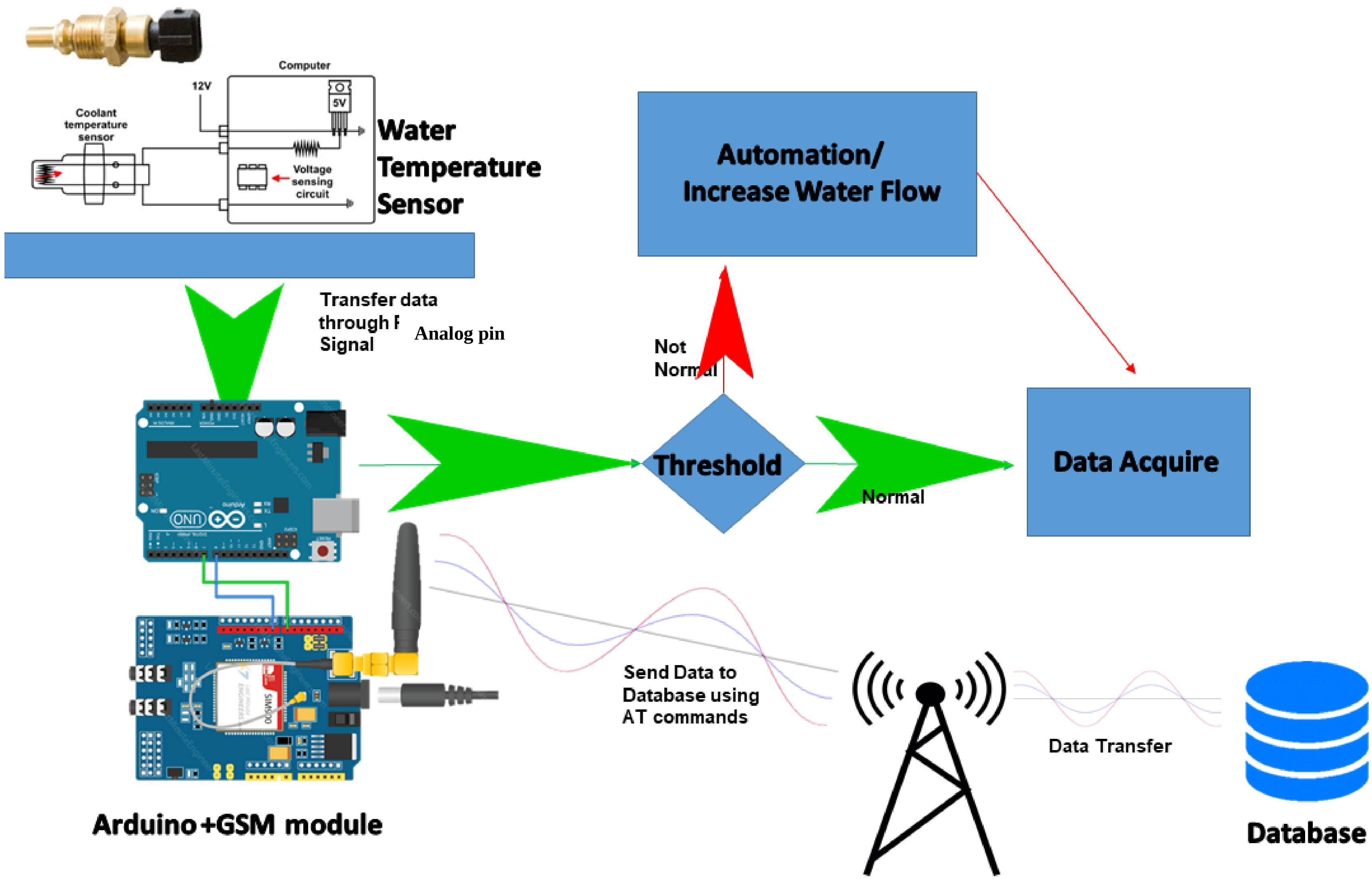


Figure D. 3 Water Temperature Data Workflow

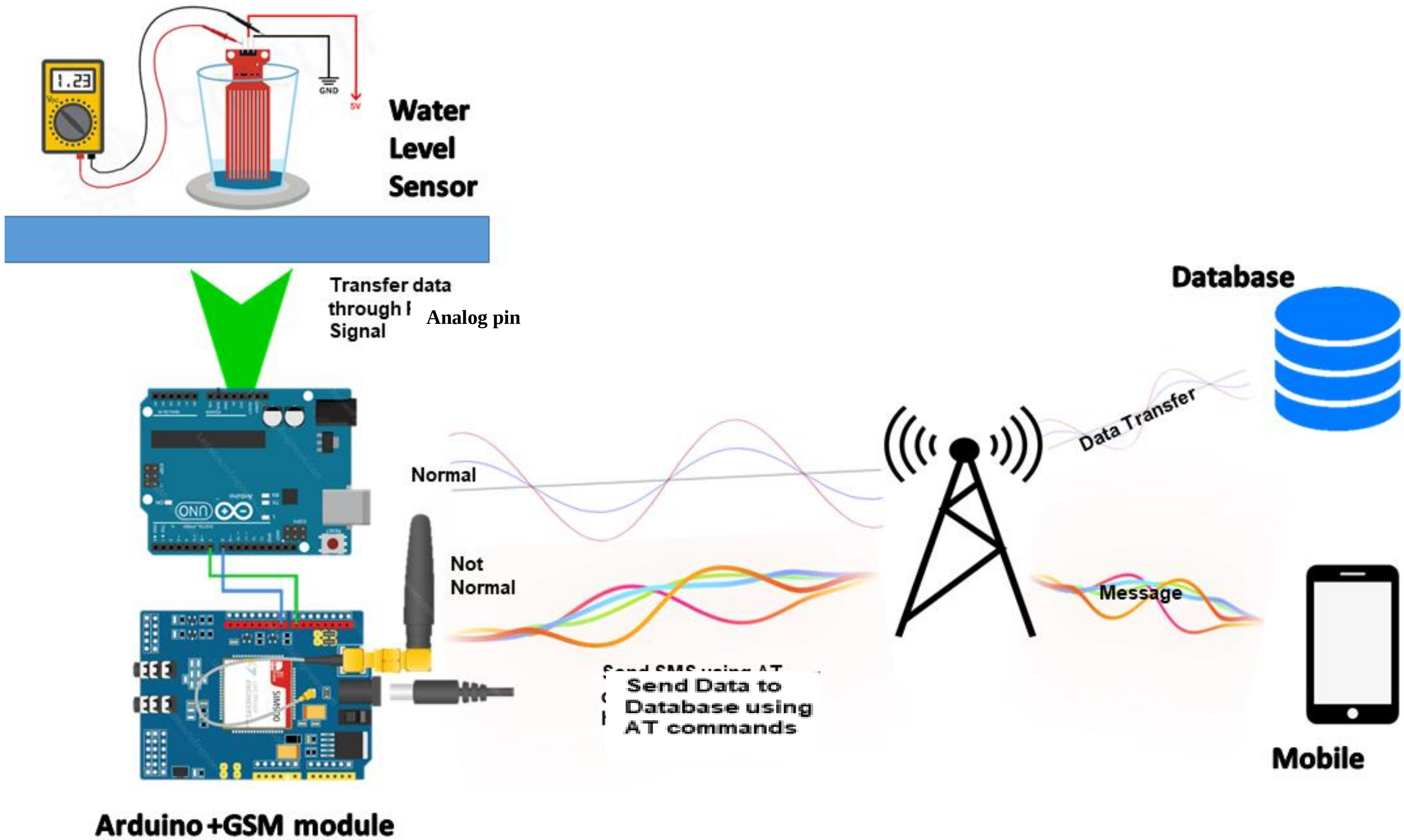


Figure D. 4 Water Level Data Workflow

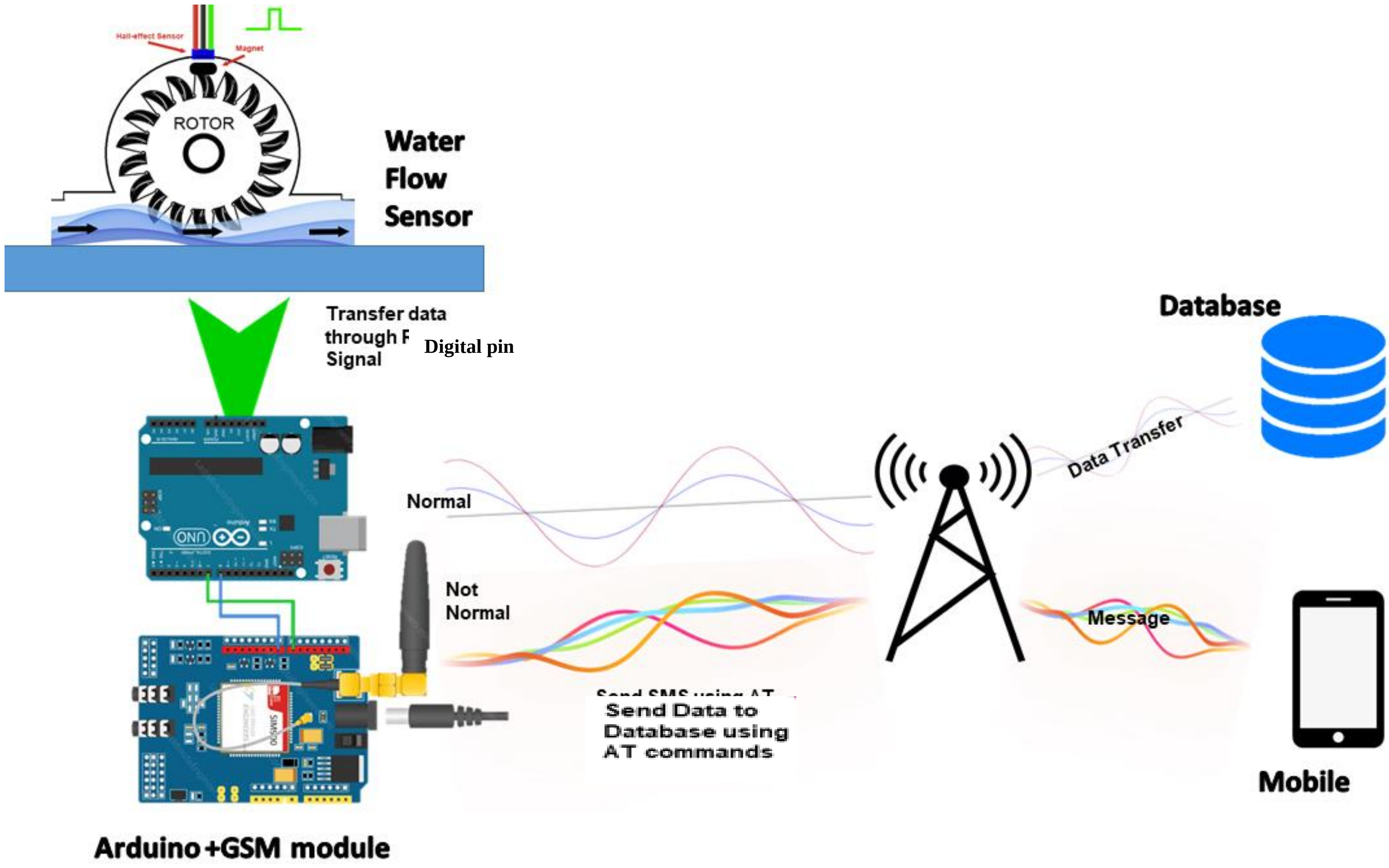


Figure D. 5 Water Flow Data Workflow

Appendix E: Water Condition Average Data Samples

1	Date, Average, Label
2	09/04/2024 9:01,66.33333333,medium
3	09/04/2024 9:01,66.33333333,medium
4	09/04/2024 9:00,66.33333333,medium
5	09/04/2024 9:00,66.33333333,medium
6	09/04/2024 8:59,91.66666667,excellent
7	09/04/2024 8:59,65.66666667,medium
8	09/04/2024 8:58,65.66666667,medium
9	09/04/2024 8:58,55.66666667,medium
10	09/04/2024 8:58,49,poor
11	09/04/2024 8:57,42.33333333,poor
12	09/04/2024 8:57,68,medium
13	09/04/2024 8:56,35.66666667,poor
14	09/04/2024 8:56,62.33333333,medium
15	09/04/2024 8:55,68,medium
16	09/04/2024 8:55,39,poor
17	09/04/2024 8:54,65.66666667,medium
18	09/04/2024 8:54,45.66666667,poor
19	09/04/2024 8:53,42.33333333,poor
20	09/04/2024 8:53,65.66666667,medium
21	09/04/2024 8:52,55.66666667,medium
22	09/04/2024 8:39,41.66666667,poor
23	09/04/2024 8:38,65,medium
24	09/04/2024 8:38,55,medium
25	09/04/2024 8:37,55,medium
26	09/04/2024 8:37,38.33333333,poor
27	09/04/2024 8:37,38.33333333,poor
28	09/04/2024 8:36,61.66666667,medium
29	09/04/2024 8:36,61.66666667,medium

Figure E. 1 Data Sample

30	09/04/2024 8:36,65,medium
31	09/04/2024 8:35,55,medium
32	09/04/2024 8:35,67.33333333,medium
33	09/04/2024 8:35,67.33333333,medium
34	09/04/2024 8:32,67.33333333,medium
35	09/04/2024 8:32,55,medium
36	09/04/2024 8:32,67.33333333,medium
37	09/04/2024 8:31,67.33333333,medium
38	09/04/2024 8:31,55,medium
39	09/04/2024 8:31,61.66666667,medium
40	09/04/2024 8:30,55,medium
41	09/04/2024 8:30,61.66666667,medium
42	09/04/2024 8:30,61.66666667,medium
43	09/04/2024 8:29,67.33333333,medium
44	09/04/2024 8:29,65,medium
45	09/04/2024 8:28,61.66666667,medium
46	09/04/2024 6:39,36.66666667,poor
47	09/04/2024 6:38,20,critical
48	09/04/2024 6:38,20,critical
49	09/04/2024 6:38,77.66666667,good
50	09/04/2024 6:38,40,poor
51	09/04/2024 6:38,16.66666667,critical

Figure E. 2 Data Sample 2

Appendix F: Water-Quality-Monitoring-Device

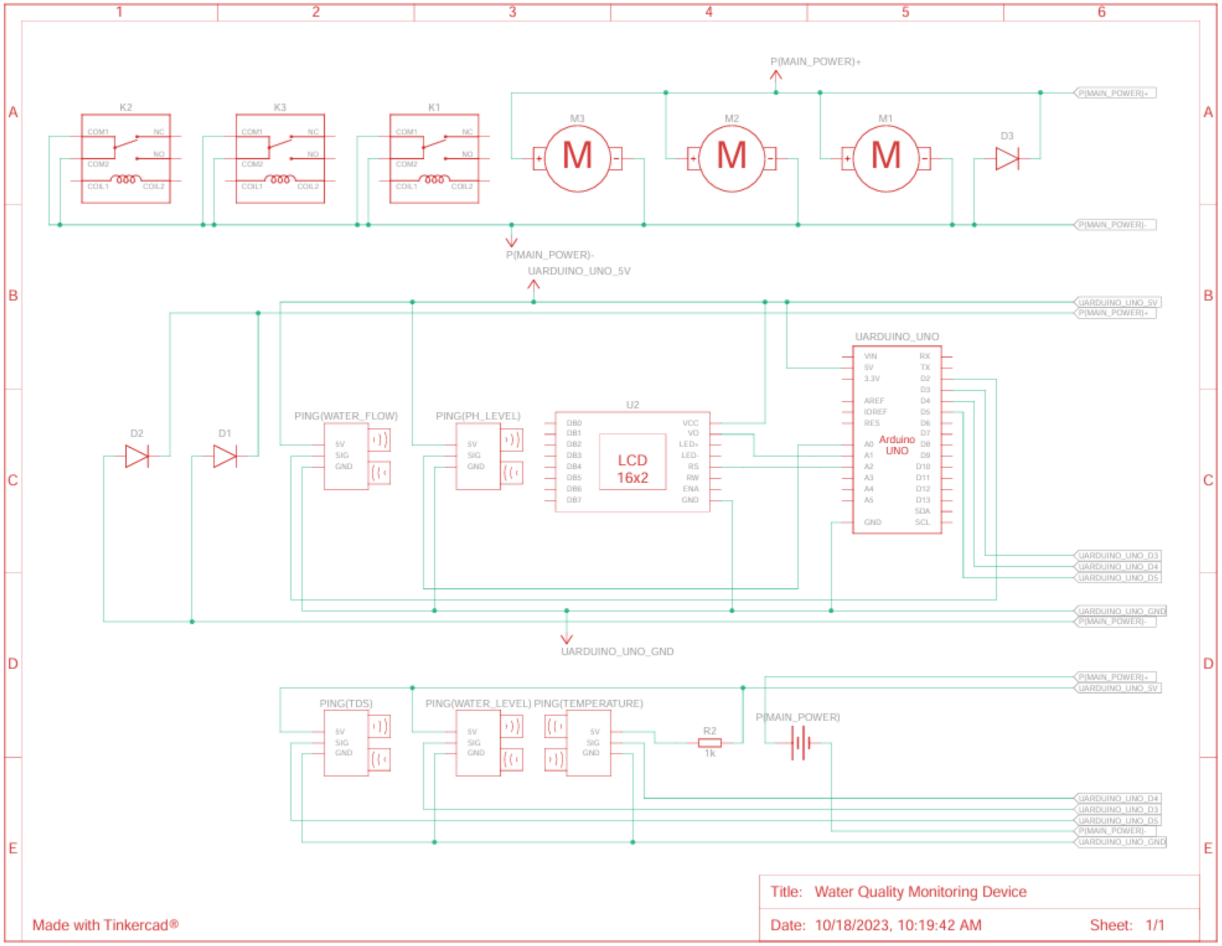


Figure F. 1 Schematic Diagram of the Device

Appendix G: System and Device User Manual

User Manual: IoT – Based Decision Support System for Nutrient Film Hydroponics Culture Monitored Through Ion-selective Electrodes

Congratulations on acquiring the IoT – Based Decision Support System for Nutrient Film Hydroponics Culture Monitored Through Ion-selective Electrodes! This user manual will guide you through the setup process and provide detailed instructions on how to utilize the system effectively.

Table of Contents:

a. Introduction:

The IoT – Based Decision Support System for Nutrient Film Hydroponics Culture Monitored Through Ion-selective Electrodes is a state-of-the-art solution designed to simplify the monitoring and management of hydroponic setups. This system utilizes IoT technology and advanced sensors to provide real-time data on crucial parameters such as water flow, water level, acidity, temperature, and total dissolved solids (TDS).

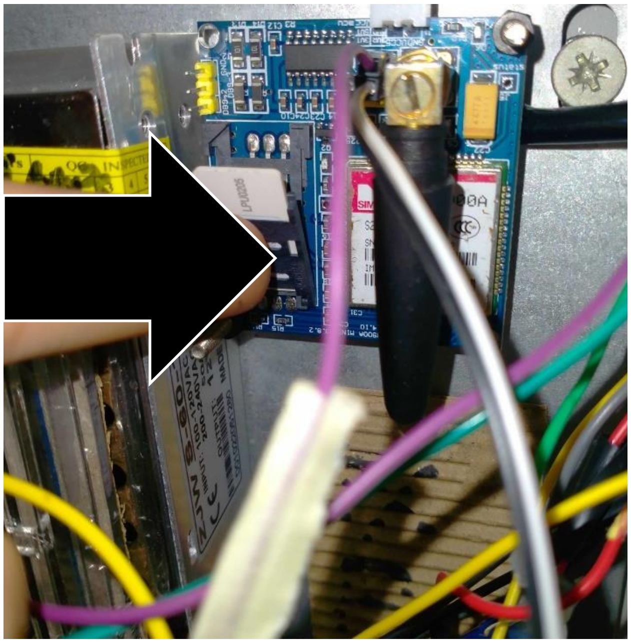
b. Getting Started:

To begin using the Automated Hydroponic Monitoring System, follow these steps:

- Insert the SIM card of your choice into the SIM holder located in the GSM module. Only use a 2G/4G SIM card.
- Plug in the device to a power source.

- Ensure that the SIM card inserted is topped up. If it's not, please recharge it.

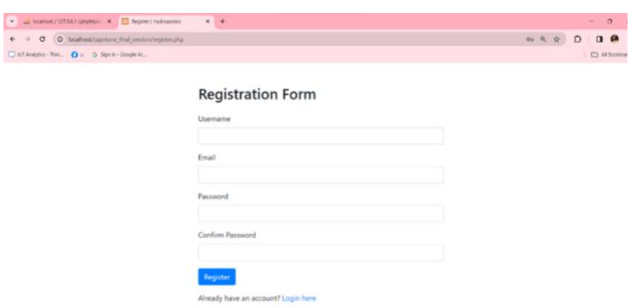
We suggest using a promotional plan with unlimited data for optimal usage.



- Access the system through the website link provided.

c. Registration Process:

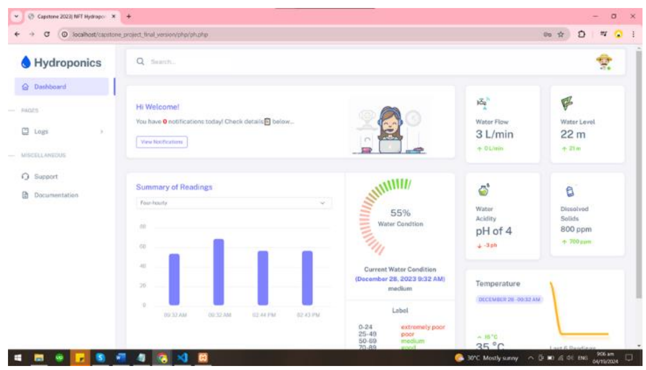
After accessing the link, you will be directed to this form:



To access the features and functionalities of the system, users must register and log in. Follow these steps to complete the registration process:

- Navigate to the registration page on the system's website.
- Complete the registration form by providing your chosen username, email, and password.
- Submit the registration form.
- If required, verify your email to gain access to the system.

d. Main Dashboard Overview:



Upon successful registration and login, you will be directed to the main dashboard. The dashboard provides a comprehensive interface with the following sections:

Overall Water Conditions

Logs

Four Hourly Readings

Water Flow

Water Level

Acidity

Temperature

Total Dissolve Solids

Support

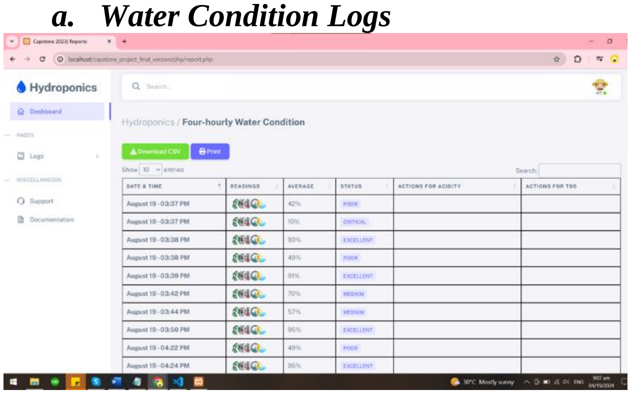
Documentation

Each section offers detailed metrics and information related to your hydroponic setup.

e. Logs:

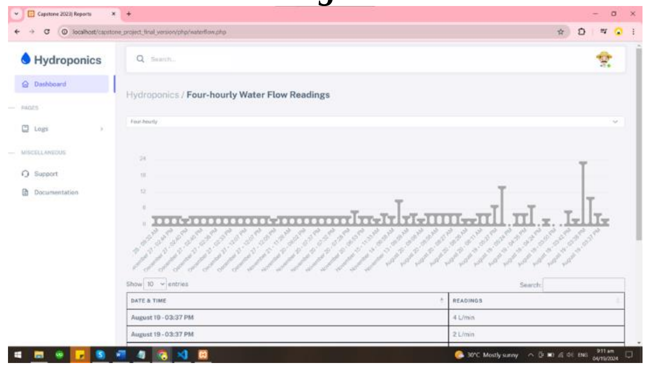
The Logs section of the dashboard provides detailed insights into various parameters monitored by the system. The following logs are available:

a. Water Condition Logs



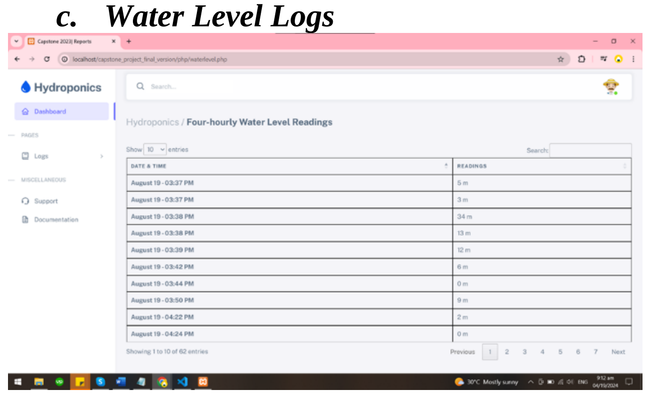
A data table presenting water condition metrics like acidity, total dissolved solids, water flow, water level, and temperature and total dissolved solids (TDS), with interactive features for actions and navigation controls for easy browsing.

b. Water Flow Logs



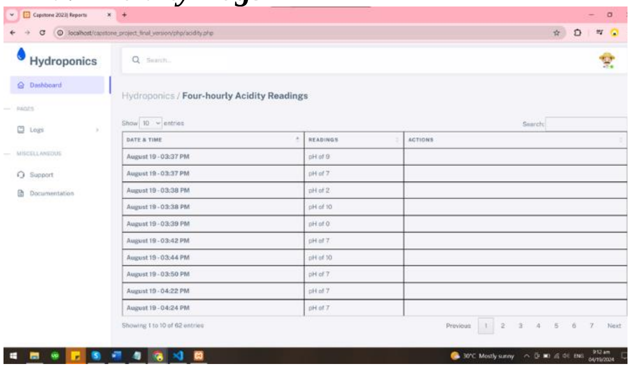
Illustrates chronological date and time readings, coupled with water flow values quantified in liters per minute. Streamlined navigation elements and supplementary miscellaneous information collectively enhance the comprehensiveness of the user experience.

c. Water Level Logs



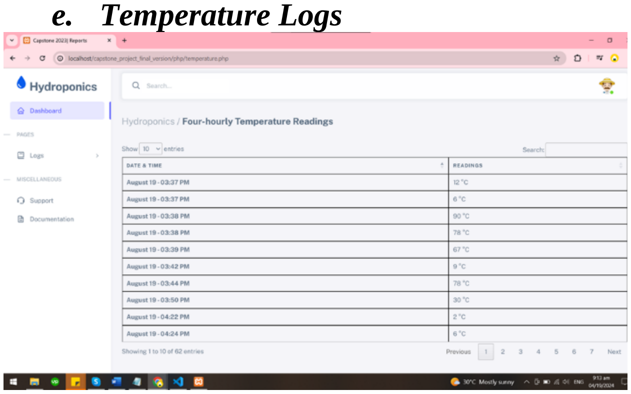
Encapsulates varied data entries related to water level readings. Its meticulously structured layout integrates columns for date & time, readings, and miscellaneous information, ensuring a well-organized representation.

d. Acidity Logs



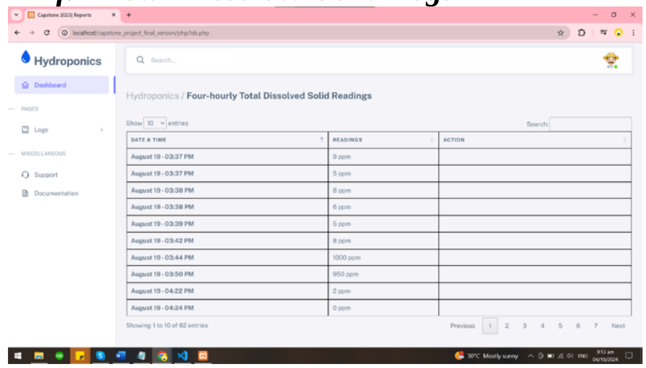
Showcases acidity readings, with a meticulous arrangement of columns for date & time, readings, and actions. The focus lies on presenting pH readings recorded at various time intervals, providing a comprehensive overview of the acidity data.

e. Temperature Logs



Showcases a tabulated dataset encompassing recorded temperature readings, accompanied by precise temporal information in the form of dates and timestamps. This arrangement facilitates a detailed and comprehensive overview of the temperature dataset.

f. Total Dissolved Solid Logs



Contains detailed information on Total Dissolved Solids (TDS), incorporating precise date-time stamps, recorded actions, and miscellaneous details. This presentation provides a thorough and nuanced overview of the dataset.

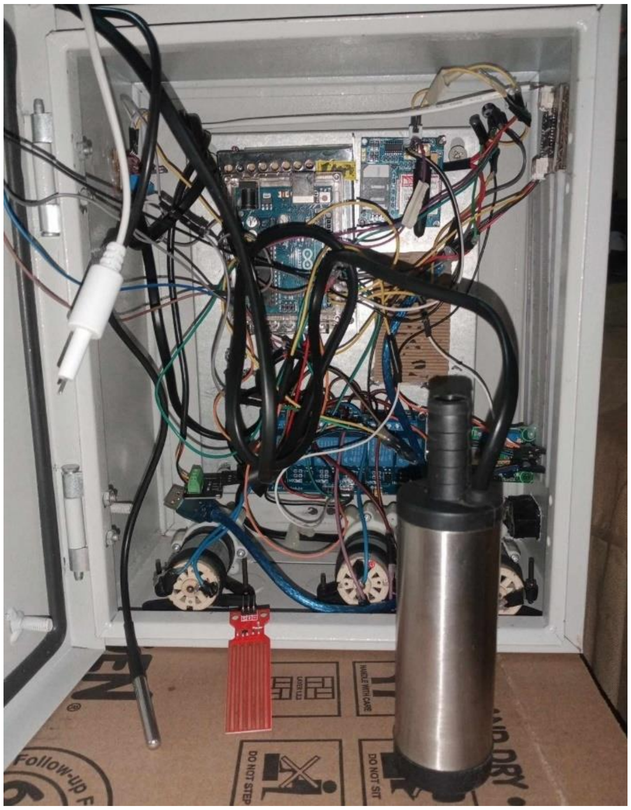
These logs display chronological data readings and provide interactive functionalities for further analysis.

f. Device Overview:

The Automated Hydroponic Monitoring System consists of a compact device housing advanced sensor.

The device includes:

Device Case: Designed to protect and house monitoring sensors for various environmental applications.



Inside of the Device: A compact array of high-tech sensors arranged to monitor water quality, including indicators for acidity, temperature, dissolved solids, flow rate, and water level.

With the Automated Hydroponic Monitoring System, managing your hydroponic setup has never been easier. Utilize the real-time data and comprehensive features provided by the system to optimize your crop production and ensure optimal growing conditions. If you encounter any issues or have any questions, refer to the support section of the dashboard or consult the documentation. Happy farming!

Appendix H: Sample of Printed Report

Printed Report Format

5/13/24, 10:26 AM Document

Republic of the Philippines

NFT Hydroponics System

Overall Water Quality Report

April 13, 2024 - 12:00 AM to May 13, 2024 - 12:00 AM

Temperature Report

Highest Temperature: 75°C

Lowest temperature: 2°C

Average temperature: 29.9627°C

Acidity Report

Acidity at Highest Temperature: pH of 7

Acidity at Lowest temperature: pH of 2

Average Acidity: pH of 10.7353

Total Dissolved Solids Report

TDS at Highest Temperature: 200 ppm

TDS at Lowest temperature: 2 ppm

Average Total Dissolved Solids: 588.7687 ppm

Water Flow Report

Waterflow at Highest Temperature: 2 L/m

Waterflow at Lowest temperature: 2 L/m

Average Waterflow: 5.0075 L/m

Water Level Report

Highest Water Level at Highest Temperature: 5 m

Lowest Water Level at Highest Temperature: 2 m

Average Water Level at Highest Temperature: 86.2239 m

localhost/capstone_project_final_version-main/php/print.php 1/5

Figure H. 1 Sample Report

5/13/24, 10:26 AM Document

Table of Readings

(April 13, 2024 - 12:00 AM to May 13, 2024 - 12:00 AM)

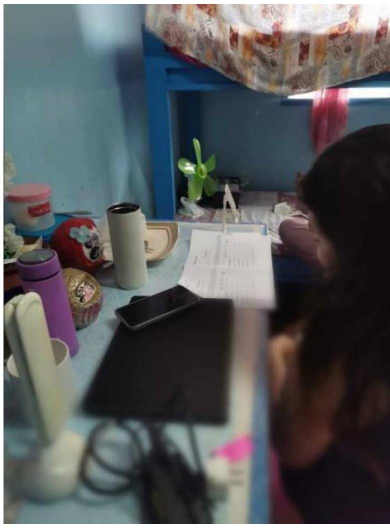
DATE & TIME	ACIDITY	TEMPERATURE	TDS	FLOW	LEVEL
April 13, 2024-3:58 PM	pH of 7	30 °C	1843 ppm	5 L/m	4 m
April 13, 2024-4:14 PM	pH of 8	32 °C	1843 ppm	5 L/m	11 m
April 13, 2024-4:15 PM	pH of 4	32 °C	1843 ppm	5 L/m	10 m
April 13, 2024-4:18 PM	pH of 4	32 °C	1843 ppm	5 L/m	10 m
April 13, 2024-5:57 PM	pH of 8	34 °C	1000 ppm	5 L/m	5 m
April 13, 2024-6:03 PM	pH of 7	25 °C	300 ppm	5 L/m	5 m
April 16, 2024-11:02 AM	pH of 8	25 °C	1000 ppm	5 L/m	5 m
April 16, 2024-11:18 AM	pH of 8	25 °C	1000 ppm	5 L/m	5 m
April 16, 2024-11:28 AM	pH of 7	34 °C	1000 ppm	5 L/m	5 m
April 16, 2024-11:31 AM	pH of 9	54 °C	1000 ppm	5 L/m	5 m
April 16, 2024-11:31 AM	pH of 8	54 °C	1000 ppm	5 L/m	5 m
April 19, 2024-12:39 PM	pH of 7	38 °C	200 ppm	5 L/m	5 m
April 19, 2024-12:41 PM	pH of 7	38 °C	200 ppm	5 L/m	5 m
April 19, 2024-12:41 PM	pH of 7	38 °C	200 ppm	5 L/m	5 m
April 19, 2024-3:23 PM	pH of 7	75 °C	200 ppm	2 L/m	5 m
April 20, 2024-3:49 PM	pH of 21	36 °C	0 ppm	5 L/m	584 m
April 20, 2024-3:50 PM	pH of 21	36 °C	0 ppm	5 L/m	22 m

localhost/capstone_project_final_version-main/php/print.php 2/5

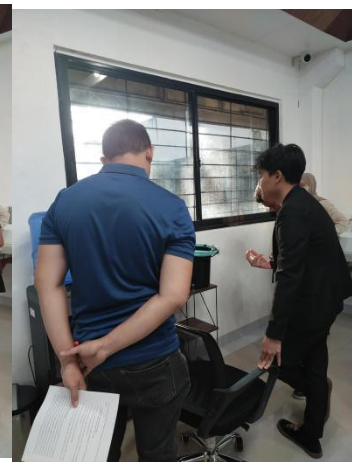
Figure H. 2 Sample Report

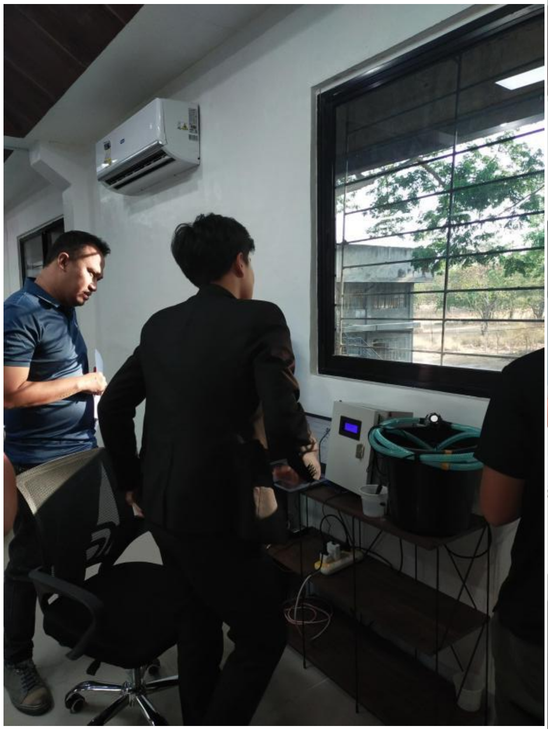
Appendix I: Documentation

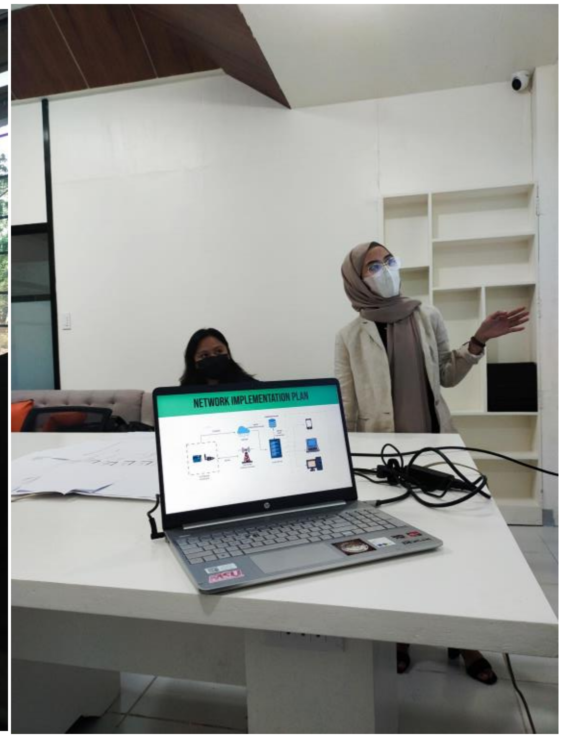
Photo Documentation






NETWORK IMPLEMENTATION PLAN