Chapter 1
THE PROBLEM AND ITS SETTING

Introduction

The Philippines is evaluated as one of the calamity prone countries worldwide due to its location lying alongside the West Pacific Ocean (WPO). Heavy rainfall especially during rainy season can lead to unanticipated floods, flash floods and landslides. It shows that death and damage of property can cause trauma to the affected people and it seems difficult to overcome calamities (Acosta, Eugenio, Macandog, Lin, Cura, & Primavera, 2016).

A set of color-coded advisories was released by the Philippine Atmospheric, Geophysical, and Astronomical Services Administration (PAGASA) to indicate the amount of rain identified in a given area. The colors are Yellow, Orange and Red. The "YELLOW" signal is the most basic level. It means a heavy rain with 7.5mm to 15mm of rain has been identified for the past hour and expected to be at this level in the next two hours. Flooding is possible and the residents must monitor climate conditions and stay tuned to weather updates. The "ORANGE" signal is the next level of warning. It means intense rain around 15mm to 30mm of rain has been identified in the past hour and expected to be at this level in next two hours. Thus, an ORANGE warning is an indication with intense rains, flooding is threatening, and the residents are alert for possible evacuation. The "RED" signals an emergency. Serious flooding is expected particularly in low lying areas because the quantity of rain has attained critical level with more than 30mm in the past hour. Hence, residents must evacuate immediately (www.pagasa.dost.gov.ph/).

The Pampanga River basin is ranked fourth on the biggest river basins in the Philippines and second in Luzon after the Cagayan River. The position of the river is shown in (Navarrete, Tee, Unson, & Hallare, 2018). The parts of the river are surrounded by the provinces namely: Aurora, Bataan, Bulacan, Nueva Ecija, Nueva Vizcaya, Pampanga, Pangasinan, Rizal and some parts of National Capital Region (NCR). Farmers in the said provinces used water in Pampanga River as supply for the irrigation of the rice fields (Disaster Risk and Exposure Assessment for Mitigation Program, 2015).

The frequency of typhoons in Pampanga River is five in every three years. One of the major sources of water in Pampanga River is Pantabangan Dam located in Pantabangan, Nueva Ecija. It is estimated around 9,000 people are affected in Region III when typhoon, heavy rainfall and over flowing of the dam connected to the river cause unanticipated floods and flash floods (Okazumi, Miyamoto, Shrestha & Sawano, 2014).

There are a number of different dams and their watersheds located in Central Luzon that provide irrigation and additional electricity to nearby areas. Pantabangan dam irrigates 102,000 hectares of farm lands in Central Luzon with 107 meters height, 1,615 meters long and spilling level of 221 meters, which could provoke the National Irrigation Administration (NIA) to discharge water to low-lying regions (Official Website of National Irrigation Administration, 2018).

San Simon is located at the southeast part of Pampanga, a municipality in the fourth district of the province with a land area of 5,736 hectares and approximately 54,000 populations as of 2015 census. It consists of fourteen barangays namely: San Juan, San Jose, San Pedro, San Miguel, Sta. Cruz, San Nicolas, Concepcion, Sto. Niño, Sta. Monica, San Agustin, San Isidro, Dela Paz, San Pablo Propio, and San Pablo Libutad (Official Website of Municipality of San Simon).

According to Mr. Benjamin P. Santos (2019), an officer of Municipal Disaster Risk Reduction Management Council (MDRRMC) in the Municipality of San Simon regarding the calamities that resulted to massive floods in the municipality, he stated that the elevation of Pampanga River thirteen meters above the sea level contributes to the occurrence of flood. It is considered as a catchment basin for the provinces of Tarlac, Aurora, and Nueva Ecija. Six barangays are affected when the river overflows (San Juan, San Jose, San Miguel, Sta. Cruz, San Nicolas and San Pedro) which are near the river. Although San Simon has seven barangays that were labeled high flood risk area, only barangay Dela Paz is not affected by the overflowing of the river. During the typhoon Lando in 2015, San Simon experienced massive flooding because of the heavy rainfall and overflowing of Pantabangan Dam and the massive amount of water from Aurora and Nueva Ecija.

With these given information, the researcher came up with a monitoring system specifically on the rain and river water level that will help the residents of the affected areas in the Municipality of San Simon, in the Province of Pampanga.

Theoretical Framework

Rainfall Measurement. Daily rainfall is commonly measured each day every 9 o'clock in the morning at local time. However, there are some weather stations which report 48 or 72-hour totals during weekends or when the observer is not able to be present. These measurements are commonly known as accumulated observations.

Rainfall is commonly measured to the nearest 0.2mm (1 point, or 1/100th of an inch prior to 1970). In the recent years, some observations are being reported to 0.1mm. Any moisture less than this is recorded as a trace.

In modern automatic weather stations, a device called Tipping Bucket Rain Gauge (TBRG) is employed, which has an aperture of 203mm. There are two advantages of this type of rain gauge. First, it never needs to be emptied, and secondly the amount of rainfall can be read automatically including the rate at which the rain is falling. An electronic pulse is generated each time the volume of water collected in one of the small brass buckets causes the bucket to tip. This is equivalent to 0.2mm of precipitation.

Water Depth Sensing. Water depth sensing utilizes sensors in measuring the level of water. Using ultrasonic sensors, water depth calculation is made by determining the distance between the sensor and the surface of the water. In this case, the ultrasonic sensor serves as the transceiver as it transmits a short ultrasonic pulse to the water surface and receives it back. The travel time of the pulse as it travelled from the sensor and back is measured to determine the distance between the sensor and the water surface.

This method of measurement using ultrasonic sensors is also described as water level measurement. This is made by subtracting the distance of the sensor to the base or bed of the water, from the measured distance from the sensor the water surface.

Short Message Service. Short message service (SMS) is defined as the most basic communications technology for mobile data transfer. It is also characterized by the exchange of alphanumeric text messages between digital line and mobile devices. It holds up to 140 bytes of data, allowing 160 characters in an alphanumeric message in the default 7-bit alphabet.

SMS is supported by Global System for Mobile Communications (GSM) technology. The message is sent from a SMS-generating capable device to a Short Message Service Center (SMSC). It then communicates with mobile networks to determine the location of the subscriber. The message is forwarded to the destination device as small data packets.

Conceptual Framework

The researcher applied the research paradigm presented in Figure 1 for the development of rainfall and river water level monitoring system as basis for disaster preparedness. In conceptualizing the whole process of this research, the researcher adopted the Input-Process-Output (IPO) template.

The important data which served as requirements for the development of the study were stated in the input block and were categorized as follows: (1) Knowledge Requirements which are the theories and ideas that served as pre-requisites for the further development of the study; (2) Software Requirements which are the computer programs or applications that would be used in the development of the system; and (3) Hardware Requirements which include the list of necessary components and modules that would be integrated for the whole function of the system to be developed.

The steps to be followed in developing the study are presented in the process block of the research paradigm. These steps would lead to the title of this research which is "Development of Rainfall and River Water Level Monitoring System: Basis for Disaster Preparedness" as stated in the output block of the research paradigm. Also, a feedback block was included in the research paradigm which is interpreted as a closed system for the research paradigm of the study.

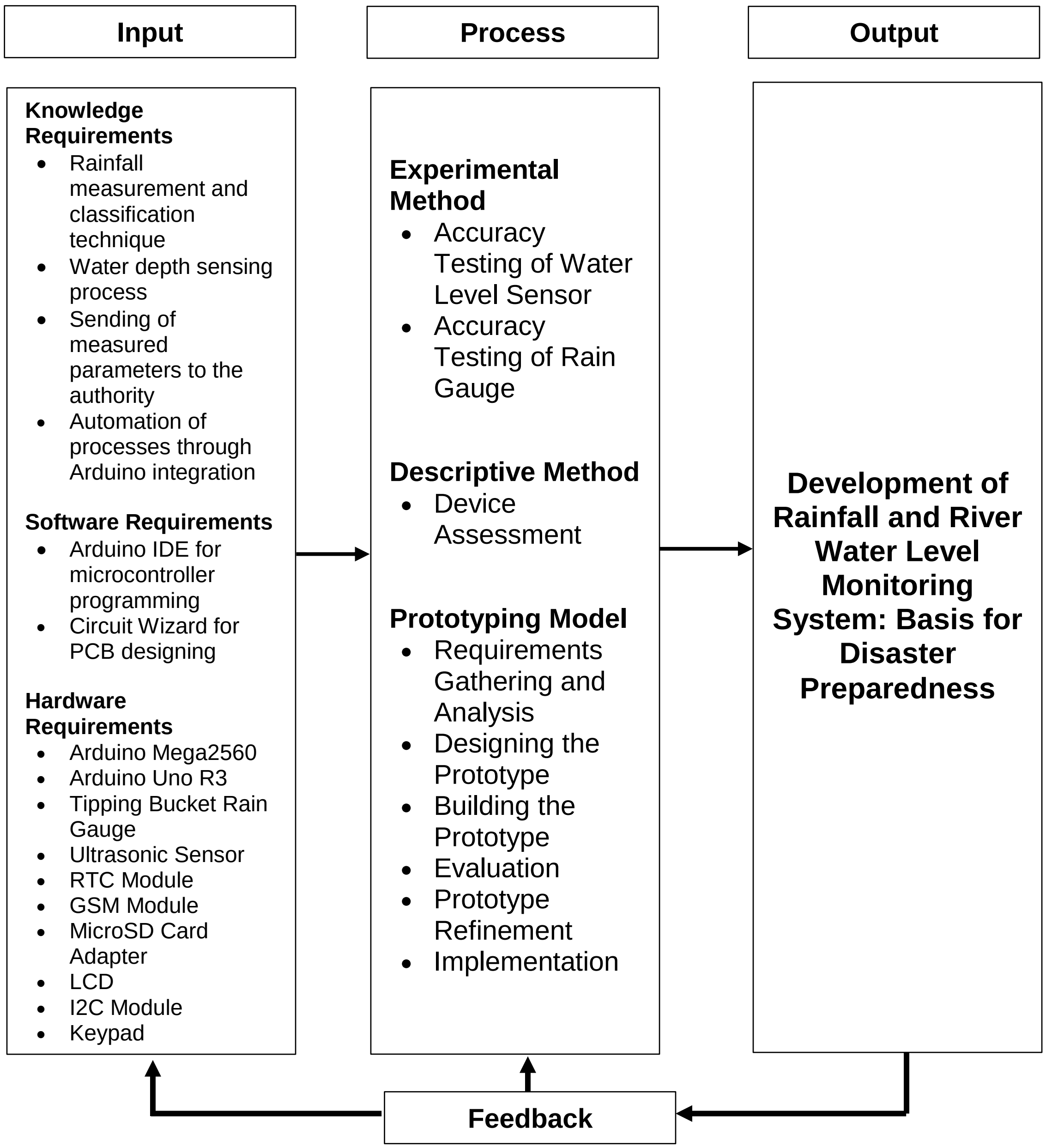


Figure 1. Research Paradigm of the Study

Several topics became prerequisites for the development of the system. These are the techniques in measuring the rainfall and its classifications based on the rules and guidelines of PAGASA, the processes involved in measuring water level specially in the river, the techniques of sending notifications to the authority for awareness of the rainfall and water level conditions, and the knowledge in the integration of different modules used in an Arduino microcontroller.

The computer applications used in the development of the system are the Arduino IDE and Circuit Wizard. It is important to have a deeper understanding in these software applications to have their efficient use in the design of the printed circuit boards and the development of the source codes. The system also requires different hardware components and modules to perform their functions for the system. These are the Arduino Mega2560 and the Arduino Uno R3 as the microcontroller units, the Tipping Bucket Rain Gauge in measuring the rainfall, Ultrasonic Sensor for water depth sensing, RTC Module for time monitoring and application, GSM Module for SMS sending, MicroSD Card Adapter and MicroSD Card for storage of data, LCD for display, I2C Module to incorporate modules requiring I2C connections, and Keypad as an input device.

The processes involved in the research were the different methods and models used in achieving the objectives of this study. An Experimental Method was used for achieving the answers in measuring the accuracy level of the sensors in performing their functions in the system which are the TBRG and ultrasonic sensor. The research also utilize the Descriptive Method to measure the assessment level of the users in the device in terms of different criteria. For the whole process of constructing the system, the prototyping model was incorporated. This model consists of different steps which are Requirements Gathering and Analysis, Designing the Prototype, Building the Prototype, Evaluation, Prototype Refinement and Implementation.

These inputs, processes, and the feedback produce the outcome of this study.

Statement of the Problem

Pretermission to prepare the residents of San Simon, Pampanga from flooding due to rainfall and water level rise has been a problem in the municipality.

General: This study aims to develop a rainfall and river water level monitoring system as basis for disaster preparedness. Specifically, it aims to answer the following:

1. What are the stages in the Development of Rainfall and River Water Level Monitoring System: Basis for Disaster Preparedness using prototyping method?
2. What is the accuracy level of the sensor used in measuring the water level in the Pampanga River in comparison to the manual measurement presently used in San Simon, Pampanga when tested in real-time basis?
3. What is the accuracy level of the rain gauge used in measuring the rainfall in San Simon, Pampanga in comparison to the device used by PAGASA when classified to the following color coding advisory:

   3.1 Red;

   3.2 Orange; and

   3.3 Yellow?
4. What is the level of acceptability in the respondents' assessment on the developed Rainfall and River Water Level Monitoring System in terms of the following characteristics:

   4.1 Functionality;

4.2 Reliability; and

4.3 Usability?

Scope and Limitations

The system is capable of calculating the total rainfall measured in millimeter using a tipping bucket rain gauge and classify them according to color-coded rainfall advisory system of PAGASA. The tipping-bucket used sends a pulse to the microcontroller every tip which represents 0.2794 mm of rain. The total number of tips in an hour is calculated to determine its classification. The tipping-bucket is tested for accuracy through comparative measurements in the office of the DOST-PAGASA located at Diosdado Macapagal Government Center in Barangay Maimpis, City of San Fernando, Pampanga.

The system also measures and monitor the water level in the Pampanga River using an ultrasonic sensor. The ultrasonic sensor used is waterproof, and it can sense the water level within 2cm to 400cm range from the sensor. The distance from the riverbed to where the sensor will be installed was measured using sounding weight. The distance is 8.45m. The accuracy testing was done on March 6-8, 2020. During accuracy testing, the sensor is installed in San Miguel Bridge and is calibrated to measure its distance from the water surface of the Pampanga River. The actual water level is obtained by subtracting the distance of the riverbed from the sensor to the distance of the ultrasonic sensor to the water surface.

A Global System for Mobile communication (GSM) module is used for transmitting the data stored by tipping bucket rain gauge, and ultrasonic sensor to the registered mobile number. The mobile number can be registered using a keypad.

Two microcontrollers are used in the system. The first one is an Arduino Mega 2560 with 54 digital input/output pins of which 14 can be used as pulse wave modulation (PWM) outputs, 16 analog inputs, four hardware serial ports, a 16 MHz crystal oscillator, a universal serial bus (USB) connection, a power jack, an in circuit serial programming (ICSP) header, and a reset button. The modules connected to the Arduino Mega 2560 connected are the tipping-bucket, ultrasonic sensor, real-time clock, keypad, microSD card and LCD. The other microcontroller is an Arduino Uno R3 with 20 digital input/output pins of which 6 can be used as PWM outputs and 6 can be used as analog input. The module connected to the Arduino Uno R3 is the GSM module.

This conduct of this research started on December 2020 where necessary initial information were collected and would be used in March, 2020 at its locale. The device would be installed in Barangay San Miguel in the Municipality of San Simon, Pampanga where the San Miguel Bridge is located.

Significance of the Study

Engr. Patrick Parungao (2019), head of MDRRMC in the Municipality of San Simon discussed their methods of monitoring the river. When the water level of the river is increasing rapidly, the first barangay affected is Sta. Cruz, then some parts of San Juan and San Pedro followed by San Nicolas, San Miguel and San Jose respectively. The MDRRMC in San Simon does not have water level monitoring station; rather, they rely on stations located in Candaba and Arayat to monitor the water level of the river. The completion of this research will benefit the following:

Barangay and the Vulnerable Population. The affected barangay in flooding, specially its residents, will be the first ones who will benefit in this study. They can be easily updated regarding the weather situation in their area and the Pampanga River whenever its water level is increasing. They will be able to prepare before an evacuation or any necessary actions happen.

Concerned Departments. The concerned departments in the local government units such as in the barangays and the municipality will be aware on the weather and water level situations in their areas of responsibility. This will help them to prepare themselves for the necessary actions they may take in times of disasters.

MDRRMC. The developed Rainfall and River Water Level Monitoring System will enable the Municipality of San Simon, Pampanga to have its own monitoring system rather than relying on stations located in the Municipalities of Candaba and Arayat. This will help its authority monitor the current situation in the area in terms of the rainfall and the water level in the Pampanga River. This is projected to serve as a basis for disaster preparedness, as it will help lessen the pretermission of the residents to prepare for incoming flash floods in the area. This system can also be adopted by other cities or municipalities near river basins who also experiences flooding in their areas.

Future Researchers. This research is open for any other future researches that will enhance or widen the coverage of the study. Future researchers will have initial data as stated in this study which they can use for the further development of their study which can focus on water level monitoring, rainfall measurement or disaster preparedness.

Definition of Terms

Accuracy is the degree to which the result of a calculation, measurement, or specification conforms to the correct value or a standard.

Catchment Basin is a location in low-lying areas in which water from higher areas collected to single point.

Disaster Preparedness is the measure on how prepared a certain body or organization in an upcoming disaster which will help them reduce its effect and mitigate its impact on vulnerable populations.

Functionality is the quality of being suited to serve a purpose well.

Global System for Mobile Communication is a digital cellular phone technology used in transmission and reception of mobile phone calls and short messages.

Prototyping refers to the activity or stages of making an initial or basic model or design of a system for a specific purpose.

Rain Gauge is a device for collecting and measuring the amount of rain which falls.

Rainfall is the amount of precipitation or the quantity of rain measured in a given area within a given time.

Rainfall Classifications refer to the standards released by DOST-PAGASA in classifying the amount of rainfall based on its ranges of intensity.

Real-time Clock is a computer clock used in keeping track of the current time.

Reliability is the degree to which the result of a calculation, measurement, or specification can be depended on to be accurate

Riverbed is the bottom of the river.

River Water Level is the depth of the water measured from the riverbed up to the surface of the water.

Sensor is a device used to detect events or changes in its environment and send the information to another electronic device.

Tipping Bucket is a type of rain gauge that sends a pulse when it tips.

Ultrasonic are sound waves having very high frequency that humans cannot hear.

Ultrasonic Sensor is a type of sensor that measures distances based on transmitting and receiving ultrasonic signals.

Usability is the degree to which something is able or fit to be used. It is also defined as the ease of use and learnability of a human-made object such as a tool or device.

Water Level Monitoring System is a closed system which measures the water depth in real-time and automatically submit these measurement to the users and/or authorities.

Chapter 2

REVIEW OF LITERATURE AND STUDIES

The researcher gathered several related literature and studies from articles in journals and websites that are used in the development of this study. Some of these focus on the disaster, and some are weather-related studies that were based in the Philippines and in the Province of Pampanga. Studies related about the methods used in the answering the stated problems were also gathered. There are also studies regarding the variables tested such as rainfall, water level monitoring, and the different components used in the system developed in the study.

Disaster Preparedness

This study focuses on the development of a rainfall and river water level monitoring system as a basis for disaster preparedness. Disaster preparedness is an important part of a body to lessen the possible damages brought by disasters.

Disasters are events that produce stress for individuals who suffer from personal loss and for the whole community affected (Khankeh, Khorasani-Zavareh, & Johanson, 2011). During the past two decades, 3 million families around the world had been affected by natural calamities (Roudini, Khankeh, & Witruk, 2017). The lack of preparation for these disasters lead to the severe effects to the vulnerable population.

According to Grant (2018), disaster preparedness refers to the measures taken in preparing for and reducing the effects of disasters. Disaster preparedness activities with risk reduction measures can prevent disaster situations and can also result in saving maximum lives and livelihoods during any disaster situation.

Due to the geographical location of the Philippines, the impact of typhoons increases its vulnerabilities to flooding. It experiences high temperatures and large amounts of rain throughout each year, as it is classified as a moist tropical climatic region. Tropical cyclones occur often from July to November every year, peaking at around the month of August. Due to the increasing weather variability, the Philippines now also experiences storms as early as the month of May. As a result, some parts of the Philippines, most particularly the part of Luzon, experience more tropical cyclones than other areas (Rivera & Navarra, 2015).

The Philippines is a hotbed of disasters as it is a locus of tropical cyclones, tsunamis, earthquakes, and volcanic eruptions. These natural calamities inflict deaths and damage to properties. The country is situated in a region where the climate and geophysical tempest is common. Because of this, it is expected to suffer inevitably from calamities similar to those experienced in the past years. It is also expected that damage to infrastructure and losses of human lives would persist or even rise unless appropriate measures are implemented by the government immediately as the development continues and the population grows in hazard prone areas. In 2012, the Philippines launched a responsive program called the Nationwide Operational Assessment of Hazards (Project NOAH) for disaster prevention and mitigation. This is intended specifically for government warning agencies to be able to provide a six-hour lead-time warning to vulnerable communities against impending floods and to use advanced technology to enhance current geo-hazard vulnerability maps (Lagmay, Racoma, Aracan, Alconis-Ayco, & Saddi, 2017).

In a study conducted by Acosta et al. (2016), loss and damage from floods and landslides are escalating in the Philippines. This is due to the increasing frequency and intensity of typhoons. Based on their study, people preferences were assessed on adaptation measures and perceptions on human-nature links on occurrence of disasters. Human loss and property damage were also revealed to cause psychological distress to affected people, undermining capacity to adapt to the next disasters.

The national government of the Philippines has a council called the National Disaster Risk Reduction and Management Council (NDRRMC). This is responsible for monitoring situations for possible disasters, and developing concrete plans that will be able to lessen the possible effects of these disasters. For the local government units like provinces, cities and municipalities, a counterpart of this national council also exists. For municipalities, mostly are called Municipal Disaster Risk Reduction and Management Council. They do monitoring and planning for disasters in their areas of responsibilities. Unlike the NDRRMC, most of them lack necessary equipment in their locales and rely on the data released by the national council and/or the nearby units.

The most disastrous problem in low-lying areas is severe flooding caused by sudden rise of water in river basins. During rainy days, possible flash floods are being monitored in these areas. The inadequacy of necessary equipment causes pretermission for the people to prepare for necessary evacuation.

The Pampanga River Basin as shown in Figure 2, with a total area of 9,759 square kilometers, is considered the fourth largest basin in the Philippines. The river basin encompasses parts of Aurora, Bataan, Bulacan, Nueva Ecija, Pampanga, Pangasinan, Rizal, Valenzuela, Caloocan, and Quezon City (University of the Philippines & Department of Science and Technology, 2015). A lot of people are affected in Region III due to typhoons, heavy rainfalls and overflowing of the Pantabangan Dam located in Nueva Ecija.

In the Pampanga River, the frequency of typhoons that directly affects the river is five in every three years (Okazumi et. al, 2014).

Figure 2. Pampanga River Basin

Navarette et. al (2018) mentioned that Pampanga River Basin ranks second in Luzon. Okazumi, Miyamoto, Shrestha and Gusyev (2014) also conducted a case study in the Pampanga River Basin. They highlighted the uncertainty estimation during the process of flood risk assessment in developing countries like the Philippines. They stated that flood risk assessment should be one of the basic methods for disaster damage mitigation. This is to identify and estimate potential damage even before disasters happen. Also, this is necessary to provide appropriate information for countermeasures. The development of flood monitoring should be significant as the risk assessment takes place.

Figure 3 shows the dams in Region III and their watersheds that contributes to the rise of the water level in the Pampanga River Basin. During strong rainy days, dams tend to release water when they are in the highest alert level. This water released flows into the Pampanga River that can cause flooding in highly affected areas.

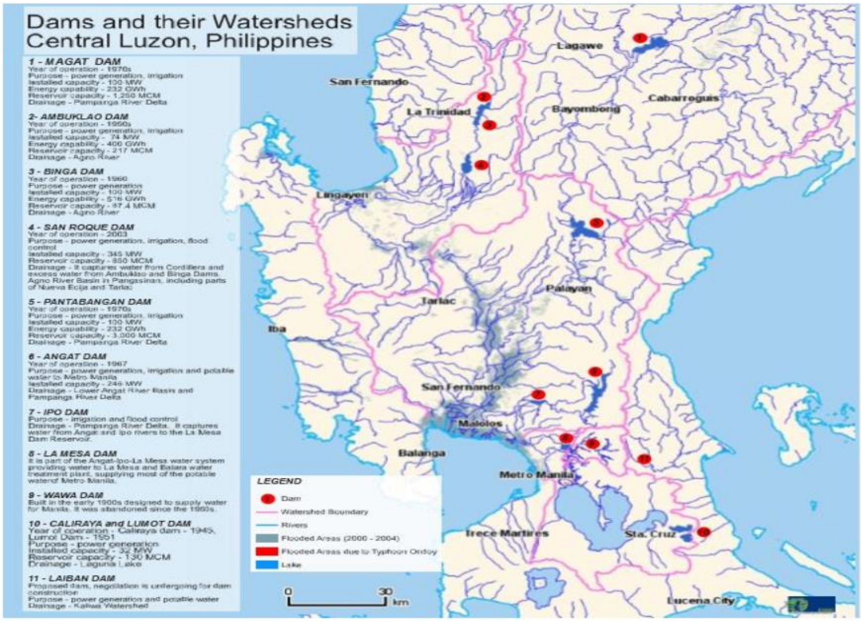


Figure 3. Dams and Their Watersheds in Central Luzon

Four out of seven provinces found in the Pampanga River Basin are listed in the top ten highly susceptible provinces to flooding in the country. These are the provinces of Pampanga, Nueva Ecija, Tarlac, and Bulacan, all of which have major tributaries connected from the deforested Sierra Madre Mountains. Pampanga is the most-flood prone with 79.54% of its land susceptible to flooding (Locsin, 2014). East of the Pampanga river shows high susceptibility to flooding particularly. Eight towns are highly susceptible to flooding from the Pampanga, including the Municipality of San Simon (Rivera & Navarra, 2015).

Figure 4 represents the hazard map in the Municipality of San Simon, Pampanga showing the highly-susceptible areas when it comes to flooding. It can be seen that areas near the river are most likely to suffer severe flooding. This is due to the rise in the water level of the river.

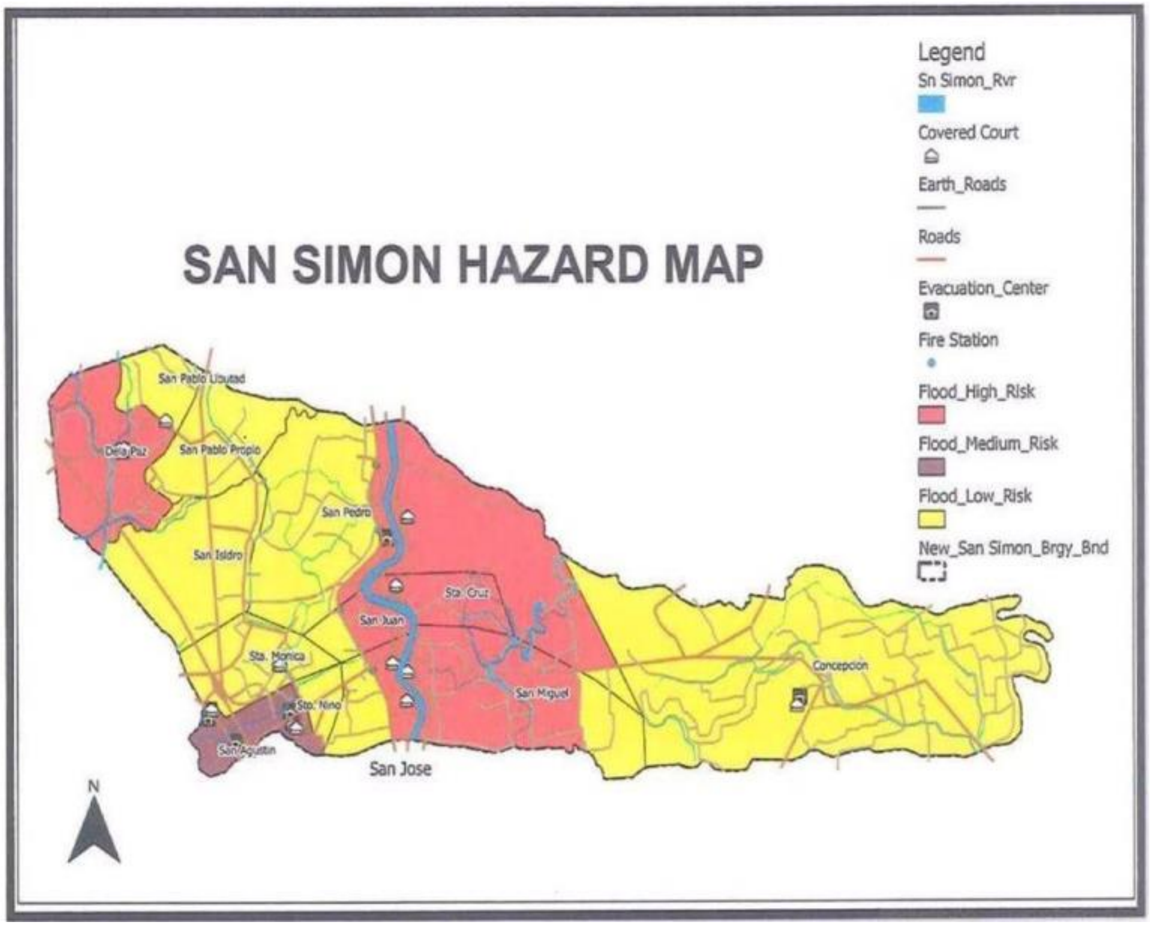


Figure 4. San Simon, Pampanga Hazard Map

In an article written by Arcellaz in 2018, the continuous and uninterrupted rains due to the southwest monsoon and other weather disturbances triggered flooding in several barangays in the Municipality of San Simon, especially those situated along the riverside. She also stated that according to Councilor Archiebald Basilio, thirteen of the fourteen barangays got affected of flood when waters from higher places start to go down to the low-lying areas.

Prototyping

Prototyping method was used in the design and development of the device for this study. As stated in the first specific problem, the stages in the development of the device are required using the prototyping model.

According to Kim (2019), prototype is defined as the start of the design, the basis and the standard. It leads the researcher to his/her assuming-solving process in the duration of the design processes. Also, one advantage of prototyping is for its economic benefits. The prototyping method is an answer to the rapid changes in the contemporary requirements.

Prototyping model is best used and applicable in a system wherein the requirements are unstable and quickly changing. Instead of delaying the requirement gatherings before starting to design and program, a quick design of the prototype can be built to understand the requirements. Some of the model's advantages includes the product being built in the preliminary stages which can receive early feedbacks, also, new requirements can be added and tested resulting into a clearer and accurate product (Bautista, Tamayo, & Yalung, 2019).

The importance of the prototyping model involves product development and innovation. It is a representation of a design idea consisting of iterations of trial and error in developing a product. Prototyping was also found as a means of increasing creativity, innovation and synthesis skills in product innovation engineering programs. (Berglund & Edin Grimheden 2011).

Many forms of research designs includes the design and development of prototypes in some roles. In comparison to the approaches of research in other fields, prototyping is likely to connect to the role and focuses on the things designed as components of the research process. Prototype and prototyping has very important roles in research development. These are as an experimental component, means of inquiry, research archetype, and vehicle of inquiry (Matthews & Wensveen, 2015).

Prototyping has several stages which are requirements gathering and analysis, designing the prototype, building the prototype, evaluation, refining the prototype, and implementation. These stages are necessary to complete the engineering device for actual implementation.

Accuracy

Accuracy is an important topic to be included in this chapter, as it is involved in the second and third specific problems. According to Menditto, Patriarca, and Magnusson (2007), accuracy is a characteristics of qualitative performance. It expresses the level of closeness of agreement between the actual and expected values. A quantitative approximation of the accuracy of measurements is important to define the degree of confidence which can be placed in it and the reliability of decisions based on the acquired results. Accuracy can be classified according to the following: 0.95 to 1.00 as high, 0.85 to 0.95 as moderate, 0.65 to 0.85 as low, and 0 to 0.65 as very low. These levels of accuracy will also determine on how likely measurements to change or vary from the expected or true values.

Accuracy has been also defined by standards. ISO 5725-1 states that accuracy is the closeness of agreement between a test result and the accepted reference value. Accuracy can be expressed as a tolerance limit, a percentage of nominal capacity, a percentage of measurement reading, a percentage of operating range, or any combination of these. The accuracy of a measuring instrument is an indication of quality of the ability of the instrument to indicate close responses of the parameters to be measured (Velayudhan, 2012). Accuracy is sometimes referred to as precision, though the two are different. Precision is a measure of consistency of successive measurements.

Accuracy can be computed by subtracting one from the calculated error using the formula on error. The percent accuracy can be calculated by multiplying the calculated accuracy to one hundred percent.

Accuracy testing may also be done using trial and error by determining the number of passed trials as used by Bautista, et. al (2019). This can also be used with “passed or failed” testing of devices for several trials.

Water Level Monitoring and Ultrasonic Sensor

The researcher also gathered research studies about water level monitoring. Some studies on ultrasonic sensor and its application to water level monitoring were also included to determine its utilization in the study. These would also be used for the second specific problem which is about the comparison between the monitoring of the river water level using the ultrasonic sensor and the manual measurement.

Many water related disasters occur frequently around the world (Iwami, Hasegawa, Miyamoto, Kudo, Yamazaki, Ushiyama, & Koike, 2017). Recently, the impact of floods has become greater due to their increasing frequency and scale, the number of population and economic activities around river basins, and the economic interdependency due to globalization. Flood disasters cause serious damage, including loss of lives, property and livelihoods. Agriculture and households are the major exposures in flood-prone areas (Shrestha, Okazumi, Miyamoto, & Sawano, 2015).

In a study made by Cabad, Canonoy, Terez, and Relacion (2014), a system that monitors the water level on the flood prone rivers in Davao City was developed. This was lessen the worries of the residents about the immediate flooding in their areas. A real-time monitoring system of the water level sends the data to the authorities through an SMS via a GSM cellular network. The system was targeted to be implemented as a flood warning tool to respective local authorities such as in the barangays and in the city.

Cordova, Galvez, Garcia, Prades, and Sioson (2015) conducted a study and developed a device that monitors the water level in the river. This system consists of probe sensor to measure the water level in Guagua, Pampanga. The probe sensor has low accuracy because it cannot show the exact measurement of the water level. For every 15 minutes the system will send a notification via SMS about the water level to the trusted officials of the Municipality of Guagua, Pampanga.

The introduction of new sensors that can simultaneously observe floods in urban areas based on the composition of remote temperature sensing and ultrasonic range finder was observed. There are three main non-contact sensing technologies namely ultrasonic rangefinders, Ultra-Wide Band (UWB) and Light Detection and Ranging (LIDAR). Among those non-contact sensors, ultrasonic rangefinders are low-cost and more precise than the other two sensors (Mousa, Zhang & Claudel, 2016).

A study explained the ultrasonic sensor functions and specifications. It has a supply voltage of 5 volts direct current, supply current of 30 milliAmperes and with a sensing range of 2 to 3 meters. It can produce high frequency sound waves and analyze the water level of a specific reservoir through the echo which is transmitted and received by the sensor (Mamun, Ahmed, Ahamed, Rahman, Ahmad & Sundaraj, 2014).

In an article, JSN-SR04T sensor module was introduced for obstacle detection. It is identical to HR-SR04 which is the commonly used ultrasonic sensor. The transmitter terminal releases 40 kHz ultrasonic sound wave with respect to time and the sound waves continuously travel until it detects an obstacle. Echo is the reflected sound wave caused by the detection of obstacle. The receiver detects the echo and stops the timer. The sound waves has a velocity of 340 m/s. In calculating the distance from the object, the formula is expressed by: D = (Velocity x Time)/2. Where D is the distance, V is the speed of the sound wave and T is the time. It is divided by 2 due to the waves reflected. JSN-SR40T can accurately sense an obstacle within a range of 2cm to 400 cm (Parkar, Paradkar, Parmar, Panchal, & Shah, 2018).

A monitoring system for automatic measurement of liquid levels was developed and evaluated, and demonstrated by monitoring water levels in evaporation pans used in evaporation studies and irrigation scheduling. It is composed of an ultrasonic sensor that measures the distance from the sensor to the liquid surface (Fisher & Sui, 2013).

In 2014, Mohamed and Wei developed a real-time wireless flood monitoring system using ultrasonic waves. According to them, the monitoring of the water level in a river or in a reservoir is important in several applications. The chosen method in measuring the water level in a river is through the use of ultrasonic waves. An ultrasonic sensing system requires no contact with the target object making it compatible in measuring the water level.

A wireless liquid monitoring system using ultrasonic sensors was developed. An ultrasonic sensor was used to sense the amount of liquid inside the tank. This sensor sends out high frequency waves which are reflected back after striking the liquid surface. The time span between the transmitting and reflecting waves is measured by the microcontroller. This time of flight is used to determine the distance travelled by the waves, and extrapolate the depth of the liquid in the tank from the point where sensor is placed. The microcontroller sends a pulse through the software code, to the ultrasonic sensors which in turn transmits a wave form. Simultaneously, a timer in the software code is activated and runs until the waveform is received back. Once the waveform is received, the sensor sends a signal to the microcontroller and the timer value is counted and the distance is determined. The depth of the liquid is calculated accordingly and stored in the flash memory available for transmission to the server via the GSM Module (Viswanath, Belcastro, Barton, O'Flynn, Holmes, & Dixon, 2015).

The advantages of ultrasonic sensing was its superb capability and reliability of sensing all media specifically solids, liquids and gases. It functions perfectly as stated in the description provided and tested successfully based upon separate conditions (Natividad & Mendez, 2017).

Rainfall Measurement and Tipping-Bucket Rain Gauge

Articles and studies about rainfall measurements and the use of tipping bucket rain-gauge were also gathered in determining the process of rainfall measurement and the utilization of tipping bucket in measuring the amount of rainfall. This is also required for determining the process of answering the third specific problem which is about the accuracy of the TBRG in measuring rainfall as compared to the instrument used by PAGASA.

In Figure 5, the rainfall color coding advisory released by PAGASA is displayed. This includes three warning levels: Yellow Warning for Heavy Rains, Orange Warning for Intense Rains, and Red Warning for Torrential Rains. Each level includes and range of rainfall measurement. Each also has a necessary action to be conducted which are “monitoring the weather condition” for Yellow, “alert for possible evacuation” for Orange, and “forced evacuation” for Red.

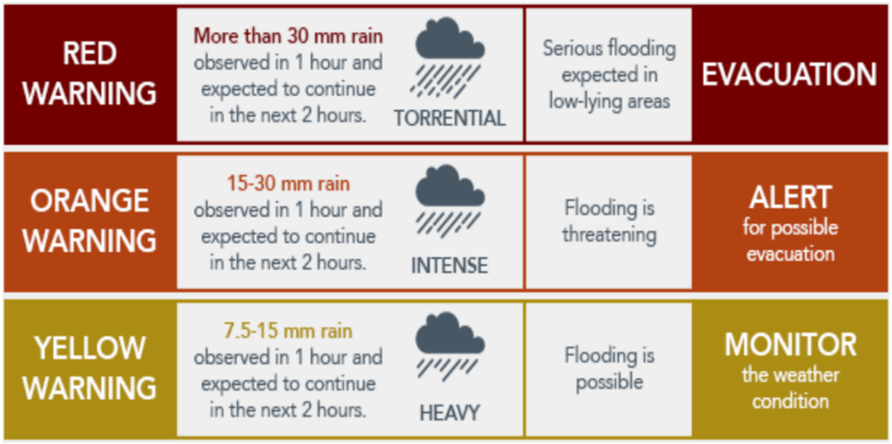


Figure 5. PAGASA Rainfall Color Coding Advisory

Figure 6 shows the average monthly rainfall in Pampanga from 1998 to 2017. This is based from the results of the research conducted by Lacap and Magat (2019). It can be seen that the months of July and August has the highest rainfall amount. During these months, the significant monitoring in the water level is needed for proper and advanced planning for possible actions.

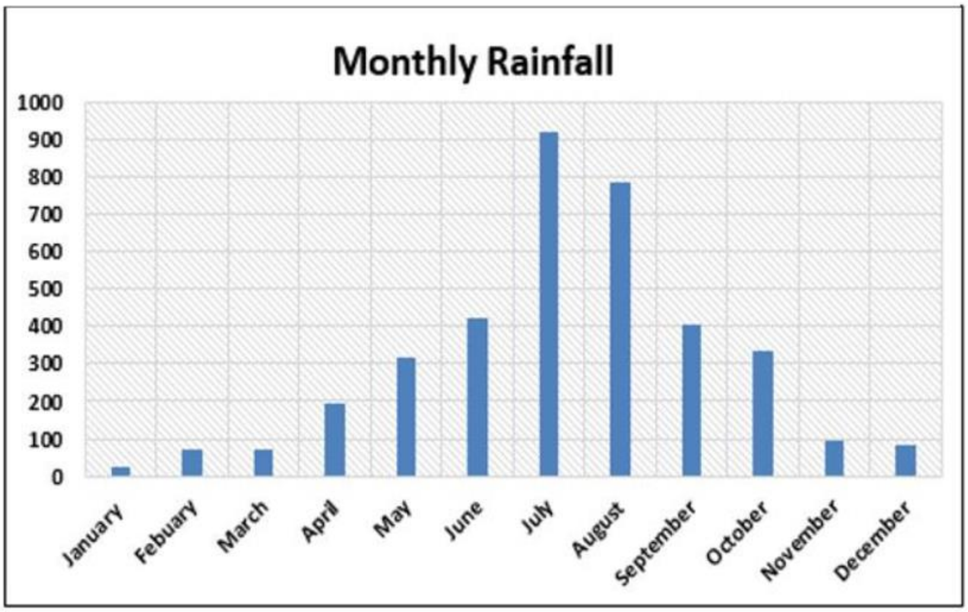


Figure 6. Average Annual Rainfall of Pampanga (1998-2017)

According to Liguori, Rico-Ramirez, Schellart, and Saul (2017), the rainfall information at temporal and spatial resolutions of a typical area of 1 km by 1 km, and 5 min generated by most operational weather radars is considered valuable for hydrological analysis and forecasting. However, Peleg, Ben-Asher, and Morin (2013) mentioned that using radar in rainfall measurement has significant limitations. Rainfall is measured indirectly, on an atmospheric volume with a size depending on the distance from the radar station. This may not be representative for rainfall at ground level. It is evident that an increase of the number of measurements would result to a higher accuracy of rainfall measurement. It would also improve hydrological applications (de Vos, Leijnse, Overeem, & Uijlenhoet, 2017).

In flood detection, the data from the rain intensity is significant for the hydrologist and/or geologist to estimate rainfall and amount of water flowing into the affected area. The tipping bucket rain gauge is commonly used in rainfall estimation especially in the ground-based rainfall measurement (Lewlomphaisari & Saengsatcha, 2012).

Tipping-bucket (TBR) is a rain gauge designed and implemented by the application of tipping-bucket method designed and tested with positive outcome. It measures the quantity of rainfall by using millimeter per time and determines the measurement when the bucket is tipped. Arduino can be used as tipping-bucket microcontroller (Ghozali, 2017). The accuracy of the TBR measurement was based on the data-logger and calibrated altogether or separately (Santana, Guimarãez & Lanza, 2017).

Tipping-bucket rain gauge is an automatic device that determines rainwater with a scale of certain millimeter on one tip. It is a small seesaw-like vessel that collects water in the bucket that tips uniformly when the desired weight was reached and releases with gravitational force (Omoruyi, Chinonso, Adewale, John, Robert & Okokpujie, 2017) The occurrence of this tip is recorded. The precipitation volumes and rates are transmitted as the number of tips and the rate at which they occurred. Compared to weighing gauges which is another type of rain gauge, tipping bucket gauges are less expensive, and they demand significantly less maintenance (Sunjray Infosystems, 2016).

Prakosa, Wijonarko, and Rustandi (2018) conducted a research that tested the measurement performance especially the measurement repeatability of tipping bucket rain gauge when the water intensities were varied. Water intensities were obtained by converting the volume of the water flow rates that enter to the section or mouth area of the rain gauge. They used an experimental method in conducting the study. The result of the study showed that by changing the water flow rate between 24-100 ml/min three times, the water volume in the tipping bucket were (18.93±0.60), (17.89±0.92) and (17.80±0.60) ml/tip respectively. A high level of accuracy had been determined even when the water intensities were varied.

Functionality, Reliability and Usability Assessment

The fourth specific problem is about the agreement level of the respondents based on their assessment on the device on it functionality, reliability and usability.

Functionality, reliability and usability are defined in ISO/IEC 9126. They are part of the representation of the quality level of a software. As the developed device has a software in the presence of the program in the microcontroller, the framework of the device quality can be assessed or evaluated.

Jung and Hong (2012) evaluated the quality control of a software based on functionality, reliability and usability. They were able to perform the evaluation as quantity. An evaluation instrument can be developed following the subtopics for each criteria to gather quantitative results.

Based from the study of McNamara and Kirakowski (2006), functionality and usability are needed to be considered in designing the evaluation a technological product. Functionality is a technical issue which refers only to the product itself. It should be evaluated on what does the product do. Usability, on the other hand, is based on the product-user interaction.

Functionality, reliability and usability were also the three components of ISO/IEC 9216 used as criteria by Mata-Domingo (2018) in the evaluation on the effectiveness and usability of the developed collaborative interaction management system. Each of these characteristics is defined by some indicators constructed in research instrument to obtain the responses of the participants.

Arduino, GSM and RTC

Studies focusing on the different components used in the development of the device were also included. These are about Arduino microcontroller, Global System for Mobile Communication, and real-time clock.

Arduino is an open-source platform which is used for constructing and in programming of electronics devices and projects. It can be easily utilized in sending and receiving data from other hardware components. People find it easier to use due to its simplified version of C++ programming (Badamasi, 2014).

Nowadays, Arduino is being used to develop interactive objects, taking inputs from a variety of switches or sensors, and controlling a variety of lights, motors, and other physical outputs. Arduino projects can be stand-alone, or they can communicate with software running on the computer. The boards can be assembled by hand or purchased pre-assembled. The part of the Arduino microcontroller responsible for controlling modules is equipped regularly on the board called ATMEGA. This chip can be programmed using Arduino IDE programming language. The open-source IDE can be downloaded for free. Arduino program is written by interfacing the board with computer in order to create programming user interface area to startup controlling tasks properly (Mahmood & Hasan, 2017). Because of its flexibility, it is also used in today's weather monitoring system by collecting the parameters in the surroundings, and sending them over to another device or network (Krishnamurthi, Thapa, Kothari, & Prakash, 2015).

The study of Bhavsar, Patil, Salunkhe and Dusane (2015) used GSM Module in examining a specific monitoring system. In the field of agriculture, different sensors were used to observe the specifications and to send an SMS or short message service to the user about the condition of the said parameters.

This proposed system observed the specific qualities of water in a real time basis through a GSM Module and sent an information with the use of short message service (SMS) in the monitoring station. It is not practical to take water sample to the laboratory after every hour for measuring so they proposed automation to meet the demand of water quality today. The GSM module made it possible to monitor the quality of the water without human intervention (Jadhay & Pingle, 2016).

The idea of the system of Singh, Singhal, Jain, Gupta and Vijayyargiya (2017) was about a wireless digital electronic board that uses GSM technology in sending messages or information from an authorized person to the users by relying the message in the electronic notice board. The message was sent to different mobile users whose numbers were saved in the memory of microcontroller. This helped in rapid spreading of messages. It was implemented on remote areas that were lacking in technology. This system helped the locals to be notified through the use of electronic notice board. This shows the importance of GSM technology in the field of communications.

In 2015, Pagatpat, Arellano and Gerasta, proposed a real-time monitoring and warning system in case of flood in Mandalug River in the Philippines. The project used water level sensor to monitor the increasing level of water. They used GSM module to inform the local officials and local subscribers about the potential occurrence of flood.

An article describes a program which tallies the occupancy of the visitor in a company in a real-time basis for adjusting the demand-controlled ventilation (DCV). It provides information regarding the movement of each person from different parts of the building. Aduino was used in programming the counting system with a pulse for the visitor sensor from a pedestrian lane. To save the present time from Real Time Clock (RTC), the main program of the system checks the flag and adds a text using UNIX epoch format and stored via CSV file on the memory card (Kuutti, Saarikko, & Sepponen, 2014).

Ferdaus and Mohammed presented and implemented an energy saver hybrid dual axis solar tracking device in 2014. The system was divided into two parts: mechanical and electrical system design. Linear actuator, carrier panel, and panel carrier rotator were the main components of mechanical system while electrical system was divided into three units: sensor, control, and movement unit. Sensor unit consists of three sensors: light sensor to measure the intensity of light, position sensor to detect the annual motion of the sun, and a real-time clock.

Two Arduino microcontrollers were used for the study. These are the Arduino Mega 2560 and Arduino Uno R3. Based on the study of De Asis (2019), the connection of the GSM Module should be separated from other devices in an Arduino microcontroller to avoid the delays in sending and receiving SMS data.

Synthesis of the Reviewed Literature and Studies

The cited related literatures and studies were used as foundations in the development of this study. These also served as basis on formulating the steps in answering the specific problems stated in Chapter 1. A review in the history of the Philippines and the province of Pampanga in terms of the calamities, especially in flooding is essential in elaborating the need of the Municipality of San Simon in providing data about the rainfall and the water level in the Pampanga River. The developed device is intended to serve as a basis for disaster preparedness, so studies about disaster preparedness were also gathered and reviewed. It is important to determine the concept and steps on determining the accuracy of a measurement.

Literature about these were reviewed for the purpose of developing the steps in determining the accuracy of the sensors used for the system. Some studies about the use of tipping-bucket and ultrasonic sensor in rainfall and water level measurements were also included in this chapter as echoes of how these components were used in the previous studies, and how can they be utilized in the purpose of the study. About the assessment of the quality of the device and software, studies based on the ISO/IEC 9126 were collected to support the claims on process of the evaluation of the device based on its functionality, reliability and usability. Other components such as the Arduino microcontroller, GSM and RTC were also included in the list of related literatures as references on how they will be integrated in the system.

Chapter 3

METHODOLOGY

This chapter explains the different research methods used in gathering and analyzing the data, and the processes involved in development of the device and answering the research problems.

Methods of Research

The proposed project is used to notify the authorities in San Simon, Pampanga and to monitor rainfall intensity, and the water level in the Pampanga River that affect the residents near river and the residents located at the catch basin areas of the municipality of San Simon. The prototyping method was be used for specific problem number 1. An experimental method was used to support the data that lead to the development of the designed prototype. This method will answer the specific problems number 2 and 3.

A descriptive method was also used in achieving the answer to the specific problem number 4 wherein the users of the developed prototype will assess the device in different criteria as indicated in the Statement of the Problem.

Research Locale

The locale of the study is the Municipality of San Simon in the Province of Pampanga. According to the official website of the municipality, San Simon is located at the southeast part of Pampanga, a municipality in the fourth district of the province with a land area of 5,736 hectares and approximately 54,000 populations as of 2015 census. It consists of fourteen barangays namely: San Juan, San Jose, San Pedro, San Miguel, Sta. Cruz, San

Nicolas, Concepcion, Sto. Niño, Sta. Monica, San Agustin, San Isidro, Dela Paz, San Pablo Propio, and San Pablo Libutad. The satellite map of San Simon is shown in Figure 7.

Figure 7. Screenshot of San Simon, Pampanga from Google Maps

The site location where the device would be installed is at the San Miguel Bridge located in the Barangay of San Simon, Pampanga with the coordinates 14°59'41"N 120°46'50"E. It connects the barangays of San Miguel and San Juan which are separated by the Pampanga River. A photograph of the bridge is shown in Figure 8.

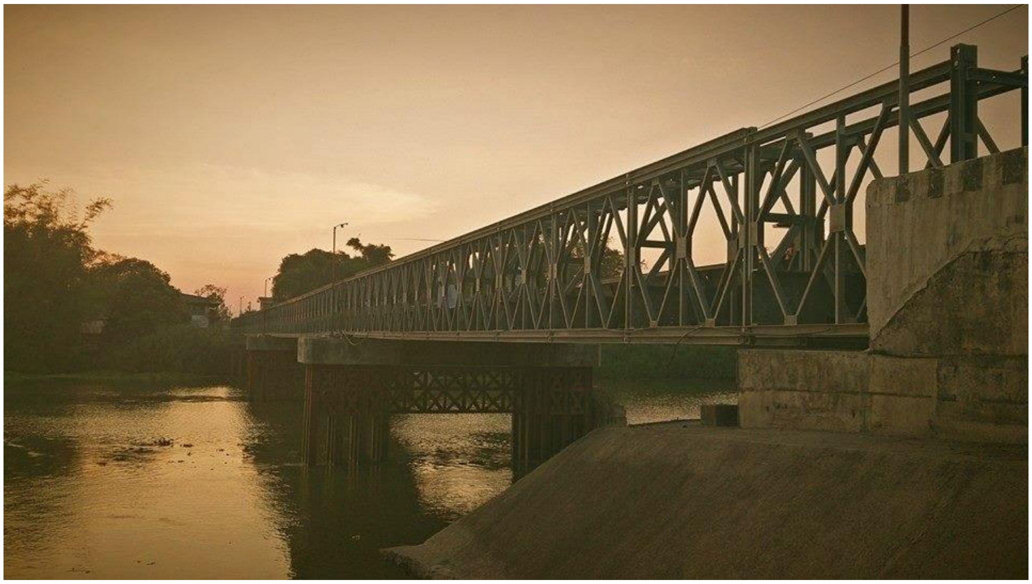


Figure 8. A photograph of San Miguel Bridge by *Anak ning Siuálâ ning Ginu*

Description of Research Instrument Used

The researcher developed a research instrument that will be used for the evaluation of the prototype and to answer the fourth specific problem. There are three criteria indicated in the evaluation tool. These are functionality, reliability and usability. These criteria were based from ISO/IEC 9126. Functionality is defined as a set of attributes or functions and their specified properties. The functions are those that satisfy the needs stated or implied. Therefore, these should focus on the expected functions to be performed by the system such as measurement of rainfall and river water level, and the sending of notifications to the authorities.

Reliability focuses on the capability of the device or software to maintain its level of performance under stated conditions and period of time. This would imply that reliability focuses on the accuracy of the data measured and sent. Usability is can be measured on how the user would interact with the device regarding its functions.

Also, the concerns of the MDRRMC based from an interview with Engr. Parungao were also considered in the development of these criteria based on the requirements they need as a system to be basis for disaster preparedness. These include the measurement of rainfall and water level and notification to the authorities so that they will be able to inform the people to the earliest time possible to avoid pretermission to prepare.

Each criteria has five items and the respondents will answer the instrument based on how they agree for each item.

Material Requirements

Several materials are needed for the development of the system. A control system is required to efficiently control the function and performance of different sensors and modules. The ultrasonic sensor and TBRG are needed to detect the required parameters namely rainfall and river water level. A microcontroller unit (MCU) is used for monitoring and storing of data of the water level and rainfall measurements in a real-time basis using RTC module. The MCU also transmits the data to the GSM module to be sent to the authorities. The rest of the components are defined and discussed on how they function on the system.

Data Gathering Procedure

The researcher used the system in gathering data to solve the specific problems stated in Chapter 1.

The first specific problem is about the stages in the development of the system. These were stated in steps from the gathering of requirements up to the implementation.

In the second specific problem, the researcher installed the system on the San Miguel Bridge with the help of the barangay officials responsible for monitoring the water level of the river. Their manual method of water level measurement is through a sounding weight. A load is suspended to a string and is dropped under the bridge. When the load is felt to be at the riverbed, it is pulled again. A measuring tape is used to measure the length of the water mark on the string. This is compared with the measurement of the system with the following experimental procedure.

The researcher will determine five samples of water level measurement each day with an interval of two hours for three days. The manual method and the developed system will be used at the same time in gathering the samples.

The third specific problem requires the accuracy of the tipping-bucket used in the system to be tested. The researcher brought the system in the office of the DOST-PAGASA in San Fernando, Pampanga. The system and the instrument used by PAGASA were tested using comparative measurements with fifteen test points as samples.

The fourth specific problem aims to determine the assessment level of the users to the system. An instrument was provided to thirty individuals who will evaluate the prototype. These consist of officials from the Municipal Disaster Risk Reduction and Management Office and the different barangays in the municipality. The results are interpreted using appropriate statistical tools.

Statistical Treatment of Data

The first two specific problems requires the computation of accuracy level. In solving for the accuracy, the following formula is used:

$$Accuracy = 1 - \frac{|Accepted\ Value - Measured\ Value|}{Accepted\ Value}$$

The accepted value is the value determined using the methods and devices currently used in measuring the river water level and the rainfall, while the measured value is the value determined using the developed system. The accuracy level then is determined using the verbal interpretations stated in Table 1. The mean of the accuracy will also be computed and interpreted.

Table 1

Accuracy Level Verbal Interpretation

Accuracy Range	Verbal Interpretation	Meaning
Greater than 0.95	High Accuracy	Not likely to change much
0.85 to 0.95	Moderate Accuracy	Small change possible
0.65 to 0.85	Low Accuracy	Some change likely
Less than 0.65	Very Low Accuracy	Possibility of change with more data

In determining the assessment level of the users, an instrument was given to them with each item to be rated based on the Likert scale in Table 2.

Table 2

Likert Scale for Device Assessment

Rating	Scale	Verbal Interpretation
4	3.51 – 4.00	Highly Acceptable
3	2.51 – 3.50	Acceptable
2	1.51 – 2.50	Unacceptable
1	1.00 – 1.50	Highly Unacceptable

The weighted mean of the ratings of the assessors was determined for each item using the formula:

$$\frac{\sum_{i=1}^{n} x_i w_i}{x_i}$$

where x_i is the frequency for each rating, w_i is the weight or value of each rating, and n is the number of rating/scale which is four in the scale used. The weighted mean for each item will then be interpreted using the Likert scale in Table 2.

Chapter 4

RESULTS AND DISCUSSION

This chapter includes the presentation, analysis and interpretation of the data gathered. The sequence is based on the specific research problems as stated in Chapter 1. Necessary figures and tables are included to present the topics discussions in detail and answer the problems stated.

1. Stages in the Development of Rainfall and River Water Level Monitoring System: Basis for Disaster Preparedness Using Prototyping Method

Prototyping Model is widely used as a system development model. The process starts by gathering all the requirements including articles and journals to strengthen the feasibility of the study. Designing the prototype was the next stage in prototyping model. A quick design of the prototype was created leading to the next stage which is building the prototype. The documents used in building the initial prototype that supports the desired functions were gathered. Once there were problems or malfunctions, the prototype is refined further to eliminate them. The process continues before the user approves the prototype and can be finally used by the community.

Figure 9 shows the stages in the development of the system using prototyping method.

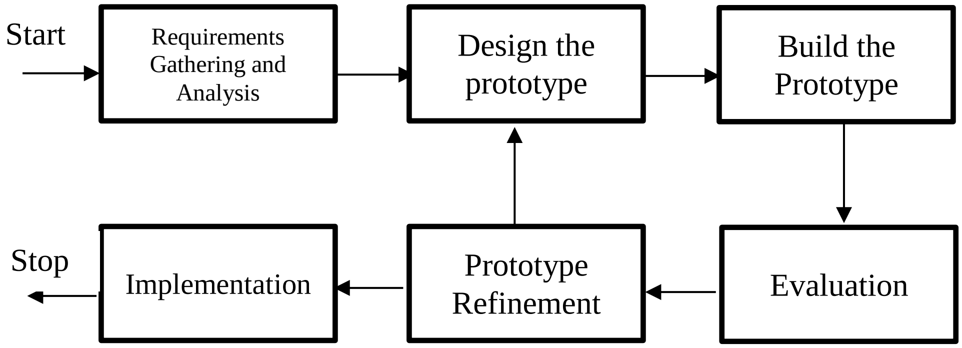


Figure 9. Stages in the Development of the System Using Prototyping Method

Requirements Gathering and Analysis. Prototyping method starts with gathering and analyzing the components needed. The data were gathered and studied from articles and interview. The plans, ideas for the product and components to be used are evaluated in terms of their specifications, costs, functionalities, and availability.

Design the Prototype. The initial design will be introduced before the actual construction of the project. The design of the integration of the water level sensor and tipping-bucket will be constructed, finalized and decided on the appropriate and effective materials to be used. This included the construction of a sample simulation and testing for the input sensor. The materials to be used for the sensors and components were selected with the help of their specification sheets and advice from experts.

Monitoring of the rainfall and the water level in the river is needed by the residents of the affected areas in the Municipality of San Simon, Pampanga to be able to assess the situation in real time and do necessary preparations whenever flooding is approaching. This can be done by using proper sensors to detect and measure the rainfall and water level in real time.

The MDRRMC serves as the authorities that will be able to receive the notifications from the system. They will then disseminate the information in whatever medium possible.

The sensors utilized in the system are the tipping-bucket and the ultrasonic sensor. The tipping-bucket will be used in measuring the amount of rainfall in the affected area. The ultrasonic sensor will be used in measuring the water level in the river near the affected area. The sensors send the data to the Arduino Mega 2560 microcontroller to process. A real-time clock (RTC) module will also be utilized to determine the time of the measurements and to set up the time to when to send the data to the authorities. A keypad is also integrated with the system used as an input device for the mobile number to which the data will be sent. An LCD will also be attached to the system for the monitoring of the current situation of rainfall and water level. The data sent to the authorities is also saved in a microSD memory card for future uses.

The Arduino Mega 2560 microcontroller is connected to the Arduino Uno R3 microcontroller using their serial ports. A GSM module is connected to the Arduino Uno R3 and will be used for notification purposes. It will send the data from the microcontroller through SMS to the authorities.

Build the Prototype. Modification of the gathered data from the design phase will be used to construct and develop the actual prototype. Different parameters will be tested to prove the efficiency and feasibility of the system.

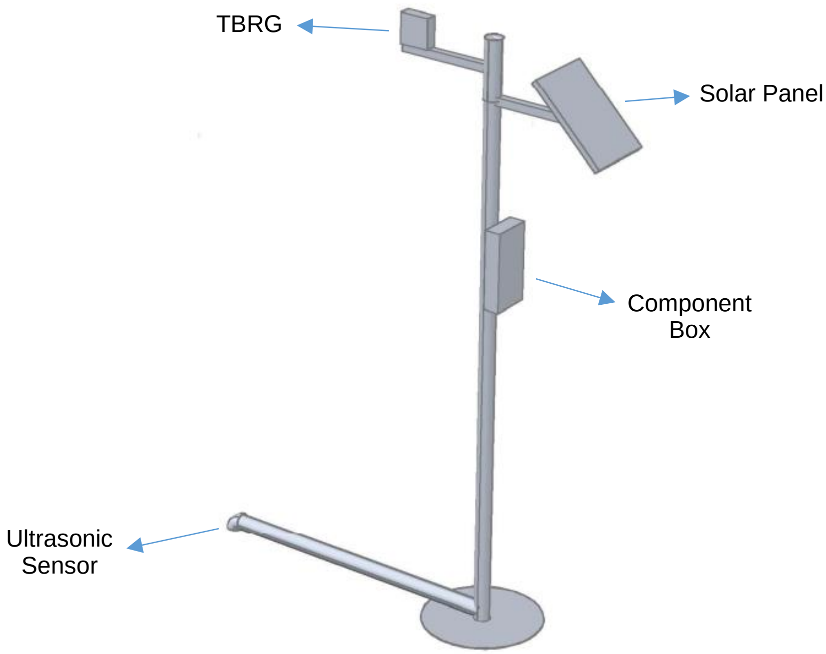


Figure 10. AutoCAD Sketch of System Physical Components

Figure 10 shows the AutoCAD sketch of the positioning of the components of the Rainfall and River Water Level Monitoring System. From the figure, he TBRG and solar panel are placed at the top of the pole. This will help the TBRG to collect rainfall and the solar panel to collect sunlight without physical interventions. The component box, where the microcontrollers, display and circuit boards are located, was placed ate the middle part where it can be easily reached and viewed. The ultrasonic sensor is placed at the bottom, running from the base of the pole to the edge of the bridge. This is to sense the surface of the water without other obstructions.

Evaluation. After building of the prototype, the device will be evaluated. Functionality of the device is the key factor that needs to be demonstrated so that the evaluators can carefully examine the prototype. The evaluators will assess the product for further enhancement.

Prototype Refinement. After the prototype presentation, all remarks and recommendations of the evaluators were recorded. Based on the recommendations of the evaluators, changes in the system and features were added. In the previous phase, applying the changes in the schematic of the prototype and updating the added features in the monitoring system were implemented.

Implementation. This is the last phase of the prototype model. In this phase, the product was evaluated and had satisfied the need of the municipality. This is the working device and was already implemented but the maintenance and progress of the device is monitored to prevent failures.

As stated in the research locale, the system device would be installed in San Miguel Bridge. The placement of the device is illustrated in Figure 11 and Figure 12. It is placed on the support on the roadside of the bridge to avoid obstructions and interventions.

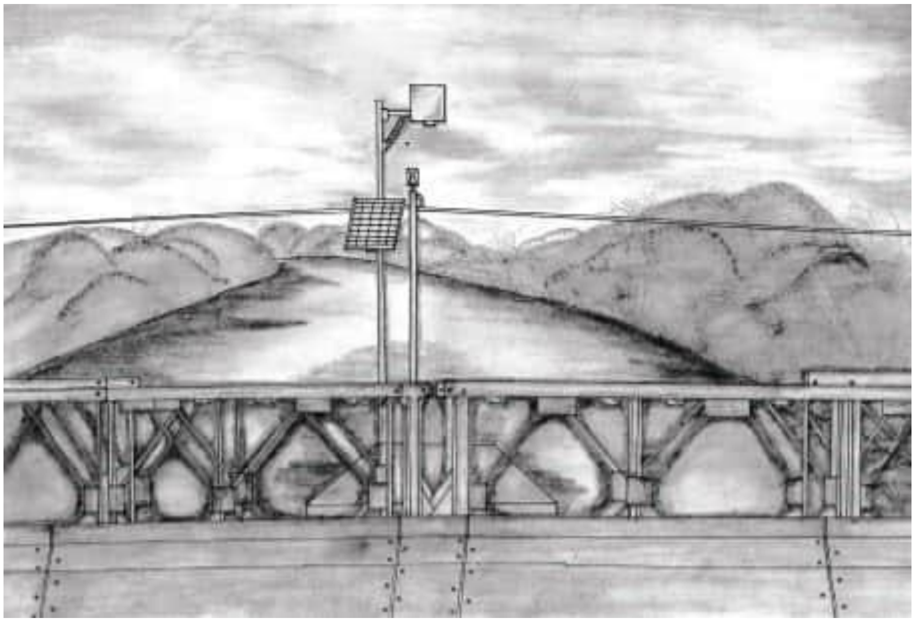


Figure 11. Sketch of the System Device as Installed in San Miguel Bridge

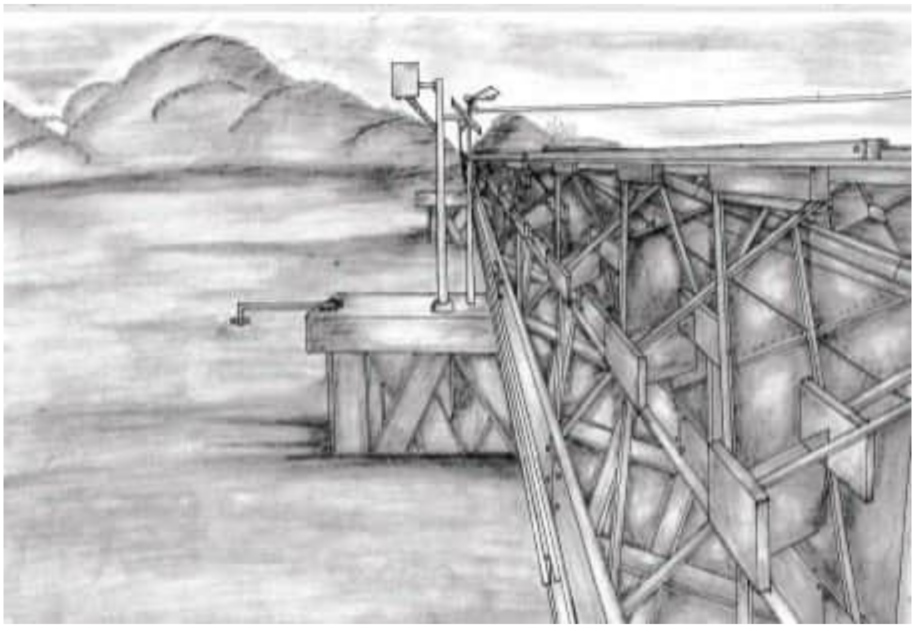


Figure 12. Sketch of the System Device as Installed in San Miguel Bridge

(Other Perspective)

2. Accuracy level of the sensor used in measuring the water level in the Pampanga River in comparison to the manual measurement presently used in San Simon, Pampanga when tested in real-time basis

Table 3

Sensor Accuracy in Pampanga River Water Level Measurement

Day	Time	Manual Measurement (m)	Sensor Measurement (m)	Accuracy	Verbal Interpretation
1	8:00am	2.15	2.07	0.9628	High Accuracy
	10:00am	2.35	2.40	0.9787	High Accuracy
	12:00pm	2.60	2.43	0.9346	Moderate Accuracy
	2:00pm	2.75	2.59	0.9418	Moderate Accuracy
	4:00pm	2.80	2.82	0.9929	High Accuracy
2	9:00am	2.20	2.10	0.9545	High Accuracy
	11:00am	2.25	2.18	0.9689	High Accuracy
	1:00pm	2.30	2.17	0.9435	Moderate Accuracy
	3:00pm	2.60	2.42	0.9308	Moderate Accuracy
	5:00pm	2.85	2.48	0.8702	Moderate Accuracy
3	10:00am	2.35	2.18	0.9277	Moderate Accuracy
	12:00pm	2.40	2.53	0.9458	Moderate Accuracy
	2:00pm	2.40	2.36	0.9833	High Accuracy
	4:00pm	2.60	2.46	0.9462	Moderate Accuracy
	6:00pm	2.75	2.80	0.9818	High Accuracy
			Mean	**0.9509**	**High Accuracy**

Table 3 shows the accuracy of the sensor used in measuring the water level in the Pampanga River. Fifteen samples were collected from the manual measurement and the sensor measurement each made at the same time. The values were processed using the accuracy formula stated in Chapter 3. The accuracy results were verbally interpreted using the word interpretations in Table 1.

One the first day, at 8:00am, the measured water level through manual measurement was 2.15m while the sensor measured a 2.07m water level. This gives a "High Accuracy" rating of 0.9628. At the 10:00am measurements, the manual measurement was 2.35m while the sensor measurement was 2.40m. This is equivalent to an accuracy of 0.9787 which was interpreted as "High Accuracy". At 12:00pm, the manual measurement and the sensor measurement were 2.60m and 2.43m respectively. This would have an accuracy of 0.9346 which is considered to be "Moderate Accuracy." At 2:00pm, the manual measurement of the river water level was 2.75m and the sensor measurement was 2.59m. The determined accuracy was a "Moderate Accuracy" of 0.9418. The manual and sensor measurements at 4:00pm were 2.80m and 2.82m respectively. This gives a "High Accuracy" of 0.9929.

On the second day of accuracy testing, five samples were also gathered with a two-hour interval within each sample. At 9:00am, the river water level measurements were 2.20m and 2.10m for the manual and the sensor respectively. This indicates an accuracy of 0.9545 which could be interpreted as "High Accuracy." The manual measurement was 2.25m while the sensor measurement was 2.18m at 11:00am. This also indicates a "High Accuracy" of 0.9689. At 1:00pm, the manually measured river water level was 2.30m while the sensor measurement was 2.17m. The accuracy from these measurements was 0.9435 which belongs to the "Moderate Accuracy" range. At 3:00pm also on the second day, the river water level was measured as 2.60m and 2.42m by the manual method and the sensor respectively. This is equivalent to a “Moderate Accuracy” of 0.9308. The manual and sensor measurements at 5:00pm were 2.85m and 2.48m respectively. This also indicates a “Moderate Accuracy” level.

Same method was applied on the third day. At 10:00am, the river water level was measured as 2.35m and 2.18m by the manual method and the sensor respectively. The sensor measurement had “Moderate Accuracy” of 0.9277 with respect to the manual method. At 12:00pm, the manual and the sensor measurement were 2.40m and 2.53m respectively. This gives an accuracy of 0.9458 for the sensor which belongs to the “Moderate Accuracy” range. The measurements at 2:00pm were 2.40m and 2.36m by the manual method and the sensor respectively. This gives a “High Accuracy” of 0.9833. At 4:00pm, the manual measurement was 2.60m while the sensor measurement was 2.46m. This is equivalent to the sensor accuracy of 0.9462 which belongs to the “Moderate Accuracy” range. At 6:00pm, the manual and the sensor measurements were 2.75m and 2.80m respectively. This gives a “High Accuracy” of 0.9818.

Out of the fifteen samples, seven got an accuracy level of greater than 0.95 which is verbally interpreted as “High Accuracy”. Eight got an accuracy level of between 0.85 and 0.95 which is equivalent to “Moderate Accuracy” interpretation. The mean of the computed accuracy levels was determined to be 0.9509 which can be interpreted as “High Accuracy”. These mean that majority of the measurements made by the sensor when compared to the accepted values using manual measurements are highly accurate.

Based from the studies stated in Chapter 2, the ultrasonic sensor has been used for distance measurement because of its high accuracy. This satisfies the measurements conducted as it was used in sensing the water depth. It is also highly accurate for river water level measurement. The accuracy results interpretation were also based on the studies in Chapter 2. Since the accuracy of the device is high, this means that its measurements are not likely to change much.

3. **The accuracy level of the rain gauge used in measuring the rainfall in San Simon, Pampanga in comparison to the device used by PAGASA when classified to the color coding advisory**

3.1. Red Warning

Table 4

Rain Gauge Accuracy in Rainfall Measurement when Classified as Red Warning

Test Point	PAGASA Measurement (mm)	Sensor Measurement (mm)	Accuracy	Verbal Interpretation
1	35	31.57	0.9020	Moderate Accuracy
2	40	35.76	0.8940	Moderate Accuracy
3	45	39.12	0.8693	Moderate Accuracy
4	50	42.47	0.8494	Low Accuracy
5	55	46.66	0.8483	Low Accuracy
		Mean	**0.8726**	**Moderate Accuracy**

In Table 4, the accuracy of the tipping bucket used in measuring the rainfall when classified as “Red Warning” is displayed. Five test points were chosen within the range of the “Red Warning”.

The first test point was 35mm. The sensor measurement for this test point was 31.57mm which gives an accuracy of 0.9020. This accuracy belongs to the “Moderate Accuracy” range. For the second test point of 40mm, the sensor measured 35.76mm of rainfall. This gives the tipping-bucket an accuracy of 0.8940 which is considered as a “Moderate Accuracy” level. For the third test point which was 45mm, the sensor had a measurement of 39.12mm. This accuracy can be interpreted as “Moderate Accuracy.” The fourth test point was 50mm. The TBRG measured 42.47mm giving an accuracy of 0.8494 which is a “Low Accuracy” level. For the fifth test point of 55mm, the measurement of the sensor was 46.66mm with an accuracy of 0.8483. This is also considered as a “Low Accuracy” level.

Three of the five test points got a “Moderate Accuracy” level while two had a “Low Accuracy” level. The mean of the accuracy is computed and had a value of 0.8726. This is verbally interpreted as “Moderate Accuracy” level. This means that the accuracy level of the TBRG used was moderately-accurate as compared by the readings of the standard device used by PAGASA.

The computation of these accuracy values were also based on the studies found in Chapter 2. The true values were the test points or the measurements of PAGASA. The measured values were the values measured by the TBRG. It also satisfies an study about the TBRG when used in rainfall measurements which stated that the accuracy of the TBRG decreases as the actual amount of rainfall increases.

3.2. Orange Warning

Table 5

Rain Gauge Accuracy in Rainfall Measurement when Classified as Orange Warning

Test Point	PAGASA Measurement (mm)	Sensor Measurement (mm)	Accuracy	Verbal Interpretation
1	15	14.53	0.9687	High Accuracy
2	19	18.16	0.9558	High Accuracy
3	23	21.79	0.9473	Moderate Accuracy
4	27	25.15	0.9315	Moderate Accuracy
5	30	27.66	0.9220	Moderate Accuracy
		Mean	**0.9451**	**Moderate Accuracy**

Table 5 shows the accuracy level of the rain gauge used in measuring rainfall as compared to PAGASA measurement when classified as “Orange Warning”. Five test points were also used in determining the accuracy of the rain gauge in measuring rainfall within the range of the “Orange Warning” classification.

For the first test point which was 15mm, the TBRG measured a rainfall of 14.53mm. This gives an accuracy of 0.9687 which belongs to the “High Accuracy” range. The second test point was 19mm. For this test point, the sensor had a measurement of 18.16mm resulting to an accuracy of 0.9558 that could be considered as a “High Accuracy”. For the third test point of 23mm, the sensor measured an amount of 21.79mm rainfall. This resulted to a “Moderate Accuracy” of 0.9473. For the fourth test point which was 27mm, the sensor gave an accuracy of 0.9315 or a “Moderate Accuracy” for its reading of 25.15mm rainfall. For the last test point for this category which was 30mm, the TBRG reading was 27.66

which was equivalent to an accuracy of 0.9220. This was interpreted as a “Moderate Accuracy” level.

As seen from the table, three out of the five test points got an accuracy between 0.85 and 0.95 which is interpreted to have a “Moderate Accuracy” level. The remaining two of the samples got an accuracy greater than 0.95 or a “High Accuracy” level. The mean of the accuracy levels is 0.9451 which also belong to the “Moderate Accuracy” range. Like the “Red Warning” classification, the TBRG used in the system is also moderately accurate as compared to the standard device readings in PAGASA. It can also be seen that the “Orange Warning” has higher accuracy than the “Red Warning”.

These readings also followed and satisfied the studies stated in 3.1 on this chapter for the determination of accuracy and the accuracy of the TBRG.

3.3. Yellow Warning

Table 6

Rain Gauge Accuracy in Rainfall Measurement when Classified as Yellow Warning

Test Point	PAGASA Measurement (mm)	Sensor Measurement (mm)	Accuracy	Verbal Interpretation
1	7.5	7.26	0.9680	High Accuracy
2	9	8.66	0.9622	High Accuracy
3	10.5	10.34	0.9847	High Accuracy
4	13	12.57	0.9669	High Accuracy
5	14.5	13.97	0.9634	High Accuracy
		Mean	**0.9690**	**High Accuracy**

Table 6 shows the accuracy of the rain gauge used when classified as “Yellow Warning.” Same with the other two color coding classifications, five test points were also used in determining the accuracy of the sensor in measuring rainfall within the range of the “Yellow Warning” category.

For the first test point of 7.5mm, the TBRG measured a rainfall amount of 7.26mm. The resulting accuracy was 0.9680 which belongs to the “High Accuracy” range. For the second test point which was 9mm, the TBRG produced an accuracy of 0.9622 for its reading of 8.66mm. This could be interpreted as a “High Accuracy” level. For the third test point of 10.5mm, the sensor measured an amount of 10.34mm rainfall. This resulted to an accuracy of 0.9847 that could be also classified as “High Accuracy.” The fourth test point was at 13mm rainfall. The sensor reading for this test point was 12.57mm and the calculated accuracy was 0.9669. This also belongs to the “High Accuracy” range. The last test point was 14.5mm. The measured rainfall amount by the sensor for this test point was 13.97mm with an accuracy of 0.9634. This was also a “High Accuracy” level.

All of the sample test points for the rain gauge accuracy testing in rainfall measurement when classified as “Yellow Warning” had an accuracy of greater than 0.95 which belongs to the “High Accuracy” range. The mean was 0.9690 which is also interpreted as “High Accuracy” level. This is higher than the accuracy of the “Red” and “Orange” classifications.

Since the values within the “Yellow Warning” category are smaller amounts of rainfall, the TBRG produced “High Accuracy” results. This was true as what stated by a study in Chapter 2 that TBRG are highly accurate when reading smaller amounts of rainfall than heavy rainfall amounts.

4. The level of acceptability in the respondents' assessment on the developed Rainfall and River Water Level Monitoring System in terms of the characteristics

4.1. Functionality

Table 7

Level of Acceptability in the Respondents' Assessment on the Developed Rainfall and River Water Level Monitoring Systems in Terms of Functionality

Functionality	Weighted Mean	Verbal Interpretation
1. The system can measure the river water level.	3.57	Highly Acceptable
2. The system can measure red rainfall level.	3.50	Acceptable
3. The system can measure orange rainfall level.	3.57	Highly Acceptable
4. The system can measure yellow rainfall level.	3.57	Highly Acceptable
5. The system can send an SMS notification to the registered mobile number.	3.47	Acceptable
Overall Weighted Mean	**3.54**	**Highly Acceptable**

Table 7 displays the level of acceptability in the respondents' assessment for the system in terms of functionality. The weighted mean of the responses of the respondents for each item was calculated and were verbally interpreted based from the interpretations listed in Table 2.

For the first item stating, "The system can measure the river water level," the weighted mean of the ratings from the respondents was 3.57. This belongs to the scale with a verbal interpretation of "Highly Acceptable." The second item which states, "The system can measure red rainfall level," garnered a weighted mean of 3.50 which was interpreted as "Acceptable." The third item states, "The system can measure orange rainfall level." The rating on this item got a weighted mean of 3.57 or a "Highly Acceptable" rating. For the fourth item stating, "The system can measure yellow rainfall level," the weighted mean was 3.57 belonging to the scale of "Highly Acceptable." The fifth item stating, "The system can send a SMS notification to the registered mobile number," got a weighted mean of 3.47 which has a verbal interpretation of "Acceptable."

Three out of five items have weighted means from 3.51 to 4.00. These acceptability levels were interpreted as "Highly Acceptable" based from the verbal interpretation in the Likert scale. The other two items have weighted means between from 2.51 to 3.50. These are interpreted in words as "Acceptable". Overall, the weighted mean is 3.54. This means that the respondents are strongly agree on the functionality of the system based from their assessment results.

Functionality is a criteria based from the ISO/IEC 9126 standard as stated in Chapter 2. The results on the assessment show that the functionality of the developed system is highly acceptable and passed the functionality characteristic of the system quality.

4.2. Reliability

Table 8

Level of Acceptability in the Respondents' Assessment on the Developed Rainfall and River Water Level Monitoring Systems in Terms of Reliability

Reliability	Weighted Mean	Verbal Interpretation
1. The measured river water level by the system is accurate.	3.30	Acceptable
2. The measured red rainfall level by the system is accurate.	2.93	Acceptable
3. The measured orange rainfall level by the system is accurate.	3.30	Acceptable
4. The measured yellow rainfall level by the system is accurate.	3.63	Highly Acceptable
5. The system sends the SMS notification in time.	3.47	Acceptable
Overall Weighted Mean	**3.33**	**Acceptable**

Table 8 shows the acceptability level of the respondents' assessment on the system in terms of reliability. The first item which states, "The measured river water level is accurate," had a weighted mean of 3.30 from the respondents' assessment. This could be interpreted as "Acceptable" based from the Likert scale used. The second item stating, "The measured red rainfall level by the system is accurate," got a weighted mean of 2.93. This belongs to the "Acceptable" scale. For the third item that states, "The measured orange rainfall level by the system is accurate," garnered a weighted mean of 3.30 which could also be verbally interpreted as "Acceptable." A "Highly Acceptable" interpretation was the result of the fourth item stating, "The measured yellow rainfall level by the system is accurate," with a weighted mean of 3.63. The fifth item which states, "The system sends the SMS notification in time," got a weighted mean of 3.47. This was verbally interpreted as "Acceptable."

One item got a weighted mean within the range of 3.51 to 4.00 which can be interpreted verbally as "Highly Acceptable." The remaining four items had weighted means within the range 2.51 to 3.50. These are interpreted as "Acceptable" based from the Likert scale verbal interpretations. The overall weighted mean was 3.33. This can be interpreted that the respondents based from their assessment in the system accepts that the system is reliable.

Reliability was also a criteria based from ISO/IEC 9126 as stated in Chapter 2. Seeing the results of the respondents' assessment, the overall rating for the reliability of the system was "Acceptable." This means that the system passed the reliability characteristic of the quality model.

4.3. Usability

Table 9

Level of Acceptability in the Respondents' Assessment on the Developed Rainfall and River Water Level Monitoring Systems in Terms of Usability

Usability	Weighted Mean	Verbal Interpretation
1. The system is fit to be used for river water level monitoring.	3.53	Highly Acceptable
2. The system is fit to be used for rainfall monitoring.	3.53	Highly Acceptable
3. The system is fit to be used as basis for disaster preparedness.	3.57	Highly Acceptable
4. The system if fit to be used in San Simon, Pampanga.	3.63	Highly Acceptable
5. The system is easy to operate.	3.33	Acceptable
Overall Weighted Mean	**3.52**	**Highly Acceptable**

The level of agreement in the respondents' assessment on the developed system in terms of its usability is seen from Table 9. Both the first and second items stating, "The system is fit to be used for river water level monitoring," and "The system is fit to be used for rainfall monitoring" got a weighted mean of 3.53. These are verbally interpreted as "Highly Acceptable." The third item which states, "The system is fit to be used as a basis for disaster preparedness," had a weighted mean of 3.57 based from the responses in the assessment. This belongs to the "Highly Acceptable" scale. The fourth item which states, "The system is fit to be used in San Simon, Pampanga," got a weighted mean of 3.63 which also belongs to the "Highly Acceptable" scale. Lastly, the item stating, "The system is easy to operate," had a weighted mean of 3.33. This was interpreted as "Acceptable."

Four items had weighted means above 3.50. Based from the verbal interpretation of the Likert scale, the acceptability level on these items can be interpreted in words as “Highly Acceptable”. The remaining item had a weighted mean of 3.33. This means that the respondents “accepts” that the system is easy to operate. Overall, the weighted mean is 3.52 for the usability of the system. The respondents’ found that the system is “Highly Acceptable” to be used for its purpose.

Same with functionality and reliability, usability was also based from the ISO/IEC 9126 as stated in studies in Chapter 2. Based from the results, the system passed usability characteristics in the quality model.

Chapter 5

SUMMARY OF FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS

This chapter presents the summary of the findings made using the methodologies used, the conclusions made from these findings, and the recommendations on how to improve this study in terms of data gathering, processing and system designing. These improvements were part of the observations during the conduct of this study.

Summary of Findings

1. The prototyping method was used in the Development of Rainfall and River Water Level Monitoring System: Basis for Disaster Preparedness. The different steps in this method were employed in the study including Requirements Gathering and Analysis, Designing the Prototype, Building the Prototype, Evaluation, Prototype Refinement and Implementation.
2. The ultrasonic sensor used in measuring the water level in the Pampanga River at the San Miguel Bridge located in Barangay San Miguel, San Simon, Pampanga showed a high accuracy level based from accuracy table used. The computed accuracy of the sensor is 0.9509.
3. The accuracy level of the tipping bucket used in measuring the rainfall was also determined using comparative measurements at fifteen test points, five for each classification. The test points used were classified based from PAGASA Rainfall Advisory which are “Red”, “Orange”, and “Yellow.

   The measured accuracy level of the tipping bucket rain gauge for “Red Warning” classification when tested was 0.8726. For the “Orange Warning” classification, the accuracy level based from the tests was 0.9451. An accuracy of 0.9690 was determined for the “Yellow Warning” classification.

4. The level of acceptability of developed device was evaluated by the target users based on its functionality, reliability, and usability. An evaluation tool using a Likert scale of 1 to 4 was provided for them to assess the device based from the given items.

   The evaluators had an overall acceptability assessment of 3.54 for the functionality, 3.33 for the reliability, and 3.52 for the usability.

Conclusions

1. The prototyping method was used effectively in the Development of Rainfall and River Water Level Monitoring System: Basis for Disaster Preparedness. The stages using this method were followed and really lead to the completion of the system.
2. The ultrasonic sensor used by the developed system in measuring the water level in the Pampanga River has a high accuracy level wherein the actual and measured values are not likely to vary much. This means that the actual readings of the sensor will give highly accurate data to the authorities in the monitoring of the river.
3. The tipping bucket rain gauge used by the developed system in determining the amount of rainfall in the area has a high accuracy level for the “Yellow Warning” classification. From this, it can be concluded that the system will give rainfall amount reading with high accuracy within the range of the “Yellow Warning” classification.

   As the actual rainfall increases, the accuracy decreases slightly. The “Orange Warning” and “Red Warning” classifications has moderate accuracy in measuring the actual amount of rainfall in the area. This means that small changes within the range of these rainfall classifications are possible. Still, a moderate accuracy level will give almost accurate rainfall data.

4. The respondents found that the developed system is highly acceptable in terms of its functionality and usability. They highly accepts the system to be used and does its functions. They also found that the system is acceptable in terms of reliability. This means that the system accepted to be reliable in serving its purpose.

Recommendations

1. A rain gauge which is more accurate specially in high rainfall is recommended to be developed and integrated to the system to have higher accuracy and consistency in rainfall measurements
2. More samples and test points are recommended to be used in testing to get more valid measurements.
3. The system is suggested to be examined in actual rain and increasing water level scenarios to further test its reliability.
4. The same system is also recommended to be implemented in other bridges in the municipality to cover a larger area and get specific measurements in other locations in the municipality.

References

Acosta, L., Eugenio, E., Macandog, P.B., Lin, E., Cura, E., & Primavera, M.G. (2016). Loss and damage from typhoon-induced floods and landslides in the Philippines: community perceptions on climate impacts and adaptation options. International Journal of Global Warming, Vol. 9, No. 1.

Arcellaz, P.C. (2018, July 26). San Simon under state of calamity. Sun Star Pampanga. Retrieved February 28, 2020 from https://www.sunstar.com.ph/article/1754814.

Badamasi, Y.A. (2014). The working principle of an Arduino. IEEE International Conference on Electronics, Computer and Computation, 10.1109/ICECCO.2014.6997578.

Bautista, G., Tamayo, C., & Yalung, M. (2019). Myoelectric-sensor based prosthetic hand for the transradial amputees of Kapampangan Development Foundation, Inc. Colegio de Sebastian – Pampanga, Inc.

G. Baustista et al., Myoelectric sensor-based Prosthetic hand for the transradial amputees of Kapampangan Development Foundation, Inc.," 2019 IEEE 11th International Conference on Humanoid, Nanotechnology, Information Technology, Communication and Control, Environment, and Management (HNICEM), Laoag, Philippines, 2019, pp. 1-6, doi: 10.1109/HNICEM48295.2019.9072760.

Berglund, A., & Edin Grimheden, M. (2011). The Importance of Prototyping for Education in Product Innovation Engineering. In 3rd International Conference of Research into Desgin 11'. Retrieved from http://urn.kb.se/resolve?urn=urn:nbn:se:kth:diva-78676

Bhavsar, K., Patil, D., Salunke, K., & Dusane, S. (2015). Energy efficient wireless monitoring system using GSM module. International Journal of Engineering and Science and Computing, Vol. 7, Issue 4.

Cabad, L., Canonoy, J.D., Terez, J., and Relacion, J.P. (2014). Water level monitoring system for the flood prone rivers in Davao City. PULSAR, The Official Journal of Engineering Research, Vol. 3, No. 1.

Cordova, M.G.P., Galvez, P.C.R., Garcia, J., Prades, H., & Sioson, A. (2015). Rainfall intensity and water level monitoring with global system for mobile communication. Don Honorio Ventura Technological State University, Bacolor, Pampanga.

De Asis, R. (2019). RFID electronic door lock system. Bulacan State University Graduate School.

de Vos, L., Liejnse, H., Overeem, A., & Uijlenhoet, R. (2017). The potential of urban rainfall monitoring with crowdsourced automatic weather stations in Amsterdam. Hydrology and Earth System Sciences, 21, 765–777, 2017.

Do Young Kim (2019). A design methodology using prototyping based on the digital-physical models in the architectural. MDPI - Sustainability 2019, 11, 4416; doi:10.3390/su11164416.

Ferdaus, R.A., Mohammed, M.A., Rahman, S., Salehin S., & Mannan, M.A. (2014). Energy efficient hybrid dual axis solar tracking system. Journal of Renewable Energy, Vol. 2014 http://dx.doi.org/10.1155/2014/629717.

Fisher, D.K. & Sui, R. (2013). An inexpensive open-source ultrasonic sensing system for monitoring liquid levels. Agricultural Engineering International: The CIGR e-journal 15(4):328-334.

Ghozali, S. (2017). Design and implementation of tipping bucket rain gauge. IEEE 17509322 DOI: 10.1109/ICICOS.2017.8276361.

Grant, C. (2018). Disaster preparedness to reduce anxiety and post-disaster stress. K4D Helpdesk Report, UK Department for International Development.

Iwami, Y., Hasegawa, A., Miyamoto, M., Kudo, S., Yamazaki, Y., Ushiyama, T., & Koike, T. (2017). Comparative study on climate change impact on precipitation and floods in Asian river basins. J-STAGE Hydrological Research Letters Online ISSN : 1882-3416.

Jadhav, S. & Pingle, N. (2016). Automatic measurement and reporting system. Imperial Journal of Interdisciplinary Research (IJIR), Vol. 2, Issue 5 ISSN: 2454-1362.

Jung HJ., Hong SJ. (2012) The Quality Control of Software Reliability Based on Functionality, Reliability and Usability. In: Kim T., Lee Y., Fang W. (eds) Future Generation Information Technology. FGIT 2012. Lecture Notes in Computer Science, vol 7709. Springer, Berlin, Heidelberg

Khankeh, H.R., Khorasani-Zavareh, D., & Johanson, E. (2011). Disaster health-related challenges and requirements: a grounded theory study in Iran. Prehospital and Disaster Medicine 26(3): 151–158. [PubMed]

Krishnamurthi, K., Thapa, S., Kothari, L., & Prakash, A. (2015). Arduino based weather monitoring system. International Journal of Engineering Research and General Science Volume 3, Issue 2.

Kuutti, J., Saarikko, P., & Sepponen, R. (2014). Real time building zone occupancy detection and activity visualization a visitor counting sensor network. IEEE 14222383 DOI: 10.1109/REV.2014.6784260.

Lacap, C.A. & Magat, L. (2019). The effects of climate change on rice yield of Pampanga. 14th National Convention on Statistic (NSC).

Lagmay, A.M.F., Racoma, B.A., Aracan, K.A., Alconis-Ayco, J., & Saddi, I.L. (2017). Disseminating near-real-time hazards information and flood maps in the Philippines through Web-GIS. Journal of Environmental Sciences Volume 59, September 2017, Pages 13-23.

Lewlomphaisari, U. & Saengsatcha, P. (2012). High accuracy tipping bucket rain gauge. IEEE 2012 Proceedings of SICE Annual Conference (SICE).

Liguori, S., Rico-Ramirez, M. A., Schellart, A. N. A., & Saul, A. J. (2012). Using probabilistic radar rainfall nowcasts and NWP forecasts for flow prediction in urban catchments, Atmos. Res., 103, 80–95.

Locsin, J. (2014, June 11). Pampanga most flood-prone; Benguet most landslide-vulnerable. GMA News Online. Retrieved February 29, 2020 from http:// www.gmanetwork.com/news/story/365179/news/regions/pampangamost-flood-prone-benguet-most-landslide-vulnerable.

Mahmood, S.N. & Hasan, F.F. (2017). Design of weather monitoring system using Arduino based database implementation. Journal of Multidisciplinary Engineering Science and Technology (JMEST), ISSN: 2458-9403 Vol. 4 Issue 4.

Mamun, A., Ahmed, N., Ahamed, N.U., Rahman, S.A., Ahmad, B., & Sundaraj, K. (2014). Use of wireless sensor and microcontroller to develop water-level monitoring system. Indian Journal of Science and Technology, Vol. 7, Issue 9, 1321-1326 ISSN: 0974-5645.

Mata-Domingo, S. (2018). Evaluation on the Effectiveness and Usability of the Developed Collaborative Interaction Management System. Research in Social Sciences and Technology, 3(1), 122-133. Retrieved July 28, 2020 from https://www.learntechlib.org/p/187544/.

Matthews, Ben & Wensveen, Stephan. (2015). Prototypes and prototyping in design research. 10.4324/9781315758466-25.

McNamara, N. & Kirakowski, J. (2006). Functionality, usability, and user experience: three areas of concern. https://doi.org/10.1145/1167948.1167972.

Menditto, Antonio & Patriarca, Marina & Magnusson, Bertil. (2007). Understanding the meaning of accuracy, trueness and precision. Accreditation and Quality Assurance. 12. 45-47. 10.1007/s00769-006-0191-z.

Mohamed, A.R.A. & Wei, W.G. (2014). Real time wireless flood monitoring system using ultrasonic waves. International Journal of Science and Research (IJSR) ISSN (Online): 2319-7064.

Mousa, M., Zhang, X., & Claudel, C. (2016). Flash flood detection in urban cities using ultrasonic and infrared sensors. IEEE 16283088 DOI: 10.1109/JSEN.2016.2592359.

Natividad, J.G., Mendez, J.M. (2017). Flood monitoring and early warning system using ultrasonic sensor. IOP Conference Series: Materials Science and Engineering 10.1088/1757-899X/325/1/012020.

Navarrete, I., Tee, K.A., Unson, J.R., & Hallare, A. (2018). Organochlorine pesticide residues in surface water and groundwater along Pampanga River, Philippines. Springer International Publishing AG, part of Springer Nature.

Okazumi, T., Miyamoto, M., Shrestha, B.B., & Sawano, H. (2014). Development of flood risk assessment method for data-poor river basins: a case study in the Pampanga River Basin, Philippines. The 6th International Conference on Flood Management, Vol. 1.

Okazumi, T., Miyamoto, M., Shrestha, B.B., & Gusyev, M. (2014). Uncertainty estimation during the process of flood risk assessment in developing countries – case study in the Pampanga River Basin. Journal of Disaster Research, Online ISSN : 1883-8030.

Omoruyi, O., Chinonso, O., Adewale, A., John, S., Robert, O., & Okokpujie, K. (2017). Wireless sensor network for rainfall measurement using a tipping bucket rain gauge mechanism. IEEE 978-1-5386-2652-8/17 DOI: 10.1109/CSCI.2017.127.

Pagatpat, J.C., Arellano, A.C., & Gerasta, O.J. (2015). GSM and web-based flood and monitoring system. IOP Conference Series: Materials Science and Engineering, Vol. 79, Conference 1 DOI: 10.1088/1757-899X/79/1/012023.

Parkar, S., Paradkar, V., Parmar, A., Panchal, D., & Shah, B. (2018). Obstacle detection using ultrasonic sensor for amphibious surveillance robot. IOSR Journal of Engineering, Vol 4 ISSN: 2250-3021.

Peleg, N., Ben-Asher, M., & Morin, E. (2013). Radar subpixel-scale rainfall variability and uncertainty: lessons learned from observations of a dense rain-gauge network, Hydrol. Earth Syst. Sci., 17, 2195–2208, doi:10.5194/hess-17-2195-2013.

Prakosa, J.A., Wijonarko, S., & Rustandi, D. (2018). The performance measurement test on rain gauge of tipping bucket due to controlling of the water flow rate. IEEE Conference of Russian Young Researchers in Electrical and Electronic Engineering (EIConRus), DOI: 10.1109/EIConRus.2018.8317291.

Rivera, T., & Navarra, N. (2015). Applying the urban resilience theory to flooding on flood-prone settlements along the Pampanga River. International Journal of Built Environment and Sustainability (IJBES), 2(3)/2015, 245-251.

Roudini, J., Khankeh, H.R., & Witruk, E. (2017). Disaster mental health preparedness in the community: a systematic review study. Health psychology open, 4(1), 2055102917711307. DOI:10.1177/2055102917711307.

Santana, M.A., Guimarãez, P.L., & Lanza, L. (2017). Development of procedures for calibration of meteorological sensors. case study: calibration of a tipping-bucket rain gauge and data-logger set. Journal of Physics: Conference Series, Vol. 975, DOI: 10.1088/1742-6596/975/1/012006.

Shrestha, B.B., Okazumi, T., Miyamoto, M., & Sawano, H. (2015). Flood damage assessment in the Pampanga river basin of the Philippines. The Chartered Institution of Water and Environmental Management (CIWEM) and John Wiley & Sons Ltd.

Singh, J., Singhal, H., Jain, H., Gupta, J., & Vijayvargiya, A. (2017). Wireless electronic notice board using GSM module. Imperial Journal of Interdisciplinary Research (IJIR), Vol 3, Issue 4 ISSN: 2454-1362.

Sunjray Infosystems Pvt. Ltd. (2016). Tipping bucket rain gauge. Retrieved February 28, 2020 from http://sunjray.com/product/jdz05-1a-stainless-steel-tipping-bucket-rain-gauge.

University of the Philippines & Department of Science and Technology (2015). Region 3 Pampanga River: DREAM ground surveys report. UP Training Center for Applied Geodesy and Photogrammetry (TCAGP): Quezon City, Philippines.

Velayudhan, Arumugham. (2012). Significance of Accuracy in Measurement. 10.13140/RG.2.1.2884.7602.

Viswanath, S., Belcastro, M., Barton, J., O'Flynn, B., Holmes, N., & Dixon, P. (2015). Low-power wireless liquid monitoring system using ultrasonic sensors. International Journal on Smart Sensing and Intelligent Systems VOL. 8, NO. 1.

APPENDIX 1

DEVICE CODE

```
#include "RTClib.h"
#include <LiquidCrystal_I2C.h>
#include <NewPing.h>
#include <Wire.h>
#include <Keypad.h>
#include <SPI.h>
#include <SD.h>

#define rf 3
#define TRIGGER_PIN  11  // Arduino pin tied to trigger pin on the ultrasonic sensor.
#define ECHO_PIN     12  // Arduino pin tied to echo pin on the ultrasonic sensor.
#define MAX_DISTANCE 500 // Maximum distance we want to ping for (in centimeters). Maximum sensor distance is rated at 400-500cm.

NewPing sonar(TRIGGER_PIN, ECHO_PIN, MAX_DISTANCE); // NewPing setup of pins and maximum distance.
LiquidCrystal_I2C lcd(0x27, 20, 4);
RTC_DS1307 RTC;
const byte ROWS = 4; //four rows
const byte COLS = 4; //four columns
char keys[ROWS][COLS] = {
  {'1','2','3','A'},
  {'4','5','6','B'},
  {'7','8','9','C'},
  {'+','0','#','D'}
};
byte rowPins[ROWS] = {47, 45, 43, 41}; //connect to the row pinouts of the keypad
byte colPins[COLS] = {39, 37, 35, 33}; //connect to the column pinouts of the keypad

Keypad keypad = Keypad( makeKeymap(keys), rowPins, colPins, ROWS, COLS );

File myFile;
const int chipSelect = 53;

int hrs, mins, secs, lhrs, lmins, lsecs, hrsl;
float wl, wlm, wla;
String pb,smslog,smsrx,smstx,riverw,rainw,data,data2,dd, mm, yy, dt, a, b, c;
bool tippose = false;
float tipval = 0.2794;
float hourlyRain = 0.0,dailyRain= 0.0;
boolean A,B,C,D;
void setup () {
```

```
 Serial.begin(9600);
 RTC.begin();
//RTC.adjust(DateTime(__DATE__, __TIME__));
 Serial1.begin(9600);
 pinMode(rf, INPUT);

 lcd.init();                    //initial display
 lcd.backlight();
 lcd.setCursor(0,0);
 lcd.print("Rainfall & River");
 lcd.setCursor(0,1);
 lcd.print("Water Level");
 lcd.setCursor(0,2);
 lcd.print("Monitoring");
 lcd.setCursor(0,3);
 lcd.print("System");
 delay(2000);
 lcd.clear();
 if (!SD.begin(chipSelect)) {
   //Serial.println("initialization failed!");
   lcd.setCursor(0,0);
   lcd.print("   SD CARD Failed");
   return;
  }
 //Serial.println("initialization done.");
 lcd.setCursor(0,0);
 lcd.print("     SD CARD OK");
 delay(2000);
 lcd.setCursor(0,1);
 lcd.print("Loading Phonebook");
        delay(5000);
        myFile = SD.open("pbook.txt");
        if (myFile) {
        while (myFile.available()) {
        smstx=myFile.readString();
        lcd.setCursor(0,2);
        lcd.print("OK");
        }
        myFile.close();
        }
        Serial1.print(smstx);
        delay(2000);
        smstx="";
 lcd.clear();
 A=true;
 B=false;
 C=false;
 D=false;
```

```
}

void loop () {
 //RTC
 DateTime now = RTC.now();
 dd=now.day();
 mm=now.month();
 yy=now.year();
 hrs=now.hour();
 mins=now.minute();
 secs=now.second();
 lhrs=String(hrs).length();
 lmins=String(mins).length();
 lsecs=String(secs).length();
 P:
 char key = keypad.getKey();
  if (key){
    Serial.println(key);
    if(key=='C'){
     lcd.clear();
     A=true;
     B=false;
     C=false;
     D=false;
     pb="";
     key="";
     goto P;
     }
     if((key=='#')&&(B==true)){
          myFile = SD.open("pbook.txt", FILE_WRITE);
         if (myFile) {
         myFile.print(pb);
         myFile.close();
         }
         B=false;
         A=true;
         key="";
         lcd.clear();
         lcd.setCursor(0,0);
         lcd.print(pb);
         lcd.setCursor(0,1);
         lcd.print("Enrolled");
         delay(2000);
         lcd.clear();
         goto P;
     }
     if((key=='#')&&(D==true)){
      lcd.clear();
```

```
     SD.remove("pbook.txt");
     lcd.setCursor(0,0);
     lcd.print("PhoneBook");
     lcd.setCursor(0,1);
     lcd.print("Deleted");
     delay(2000);
     lcd.clear();
     D=false;
     A=true;
     key="";
     goto P;
    }
    if(B==true){
      pb=pb+key;
      lcd.setCursor(0,3);
      lcd.print(pb);
      key="";
      goto P;
      }
   if(key=='A'){
     A=false;
     lcd.clear();
      lcd.setCursor(0,0);
      lcd.print("Enter Mobile Number");
      lcd.setCursor(0,1);
      lcd.print("  Start with +63");
      lcd.setCursor(0,2);
      lcd.print("Press # to enroll");
      B=true;
      key="";
      goto P;
    }
    if(key=='D'){
     A=false;
     lcd.clear();
      lcd.setCursor(0,0);
      lcd.print("Press # to Delete");
      lcd.setCursor(0,1);
      lcd.print("PhoneBook");
      D=true;
      key="";
      goto P;
    }

 }


if (lhrs<2){
```

```
 a="0";
}
else {
 a="";
}
if (lmins<2){
 b="0";
}
else {
 b="";
}
if (lsecs<2){
 c="0";
}
else {
 c="";
}


if(A==true){
dt=dd+"/"+mm+"/"+yy+"  "+a+hrs+":"+b+mins+":"+c+secs;
lcd.setCursor(0,0);
lcd.print(dt);
//Water Level
unsigned int uS = sonar.ping(); // Send ping, get ping time in microseconds (uS).
wl = (uS / US_ROUNDTRIP_CM);
lcd.setCursor(0,1);
lcd.print("Water Level= ");
if (wl>0){
wlm = wl/100;
wla = 8-wlm;
lcd.setCursor(12,1);
lcd.print(wla);
lcd.print("m");
}
//Rainfall
lcd.setCursor(0,2);
lcd.print("Rainfall/Hr= ");
lcd.setCursor(12,2);
lcd.print(hourlyRain);
lcd.print("mm");
 if ((tippose==false)&&(digitalRead(rf)==HIGH)){
   tippose=true;
   hourlyRain+=tipval;// update the hourly rain
 }

 if ((tippose==true)&&(digitalRead(rf)==LOW)){
   tippose=false;
```

```
}
  if((hrs==23)&&(mins==59)&&(secs==59)){
        dailyRain=dailyRain+hourlyRain;
        data2=dd+"/"+mm+"/"+yy+" Total Rainfall="+dailyRain;
        myFile = SD.open("dailyRain.txt", FILE_WRITE);
        if (myFile) {
        myFile.println(data2);
        myFile.close();
        dailyRain=0;
        }
  }
 if (hrs!=hrsl){
        if((wla>=4.57)&&(wla<4.87)){
          riverw=" YELLOW";
        }
        if((wla>=4.87)&&(wla<5.5)){
          riverw=" ORANGE";
        }
        if(wla>=5.5){
          riverw=" RED";
        }
        if((hourlyRain>=7.5)&&(hourlyRain<15)){
          rainw=" YELLOW /";
        }
        if((hourlyRain>=15)&&(hourlyRain<=30)){
          rainw=" ORANGE / ";
        }
        if(hourlyRain>30){
          rainw=" RED / ";
        }
        data=dt+"  Rainfall/Hr  ="+hourlyRain+rainw+"  Water  Level
="+wla+"m"+riverw;
        myFile = SD.open("logs.txt", FILE_WRITE);
        if (myFile) {
        myFile.println(data);
        myFile.close();
        }
  dailyRain=dailyRain+hourlyRain;
  hourlyRain=0;
  rainw="";
  riverw="";
  hrsl=hrs;
  smstx=data+"\n"+data2;
  Serial1.print(smstx);
 }

/* while(Serial.available()>0){
  smsrx=Serial.readString();
```

```
  }
  if(smsrx=="update"){
        smstx=data+"\n"+data2;
        Serial.println(smstx);
        smsrx="";
  }*/
 }
}
```

APPENDIX 2

RESEARCH INSTRUMENT

POLYTECHNIC UNIVERSITY OF THE PHILIPPINES
GRADUATE SCHOOL
Sta. Mesa, Manila

EVALUATION FORM

Name (*Optional*): ____________________________ Date: ___________________

Designation: ________________________

The purpose of this evaluation is to determine the user assessment level of the system developed in the study entitled, "Development of Rainfall and River Water Level Monitoring System: Basis for Disaster Preparedness, in terms of its functionality, reliability and usability.

The researcher appreciates your help in evaluation the system. Please indicate your rating by answering the given items below by putting a check mark in the corresponding scale as stated.

4	**-**	**Highly Acceptable**	**2**	**-**	**Unacceptable**
3	**-**	**Acceptable**	**1**	**-**	**Highly Unacceptable**

	4	3	2	1
Functionality				
1. The system can measure the following:				
a. river water level				
b. red rainfall level				
c. orange rainfall level				
d. yellow rainfall level				
2. The system can send an SMS notification to the registered mobile number.				
Reliability				
1. The following measured parameters by the system are accurate:				
a. river water level				
b. red rainfall level				
c. orange rainfall level				
d. yellow rainfall level				
2. The system sends the SMS notification in time.				
Usability				
1. The system is fit to be used:				
a. for river water level monitoring				
b. for rainfall monitoring.				
c. as basis for disaster preparedness.				
d. in San Simon, Pampanga.				
2. The system is easy to operate.				

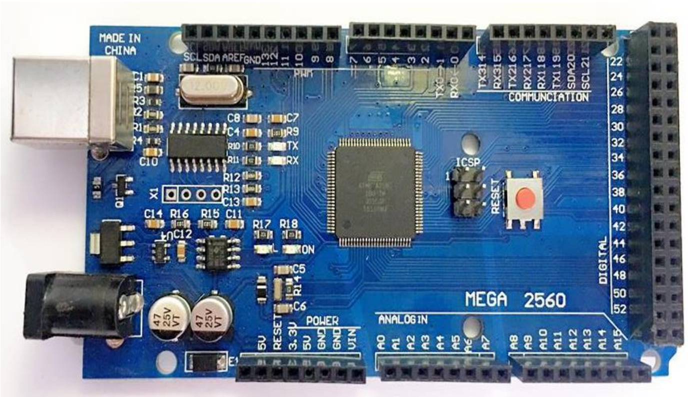
____
Signature

Thank you so much!

APPENDIX 3

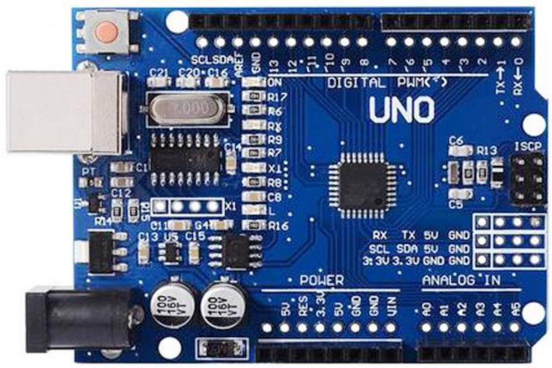
COMPONENTS USED

1. Arduino Mega 2560. Arduino Mega 2560 is a microcontroller board based on the ATmega2560. It has 54 input/output and 16 analog inputs to control the sensors and devices since it can receive input and control the output. It will be the main microcontroller of the system. It receives the data coming from the tipping bucket and the ultrasonic sensor. It controls the data displayed to the LCD, stored in the microSD card, and sent to the Arduino Uno R3 based from the time fed by the real-time clock and mobile number input by the keypad.

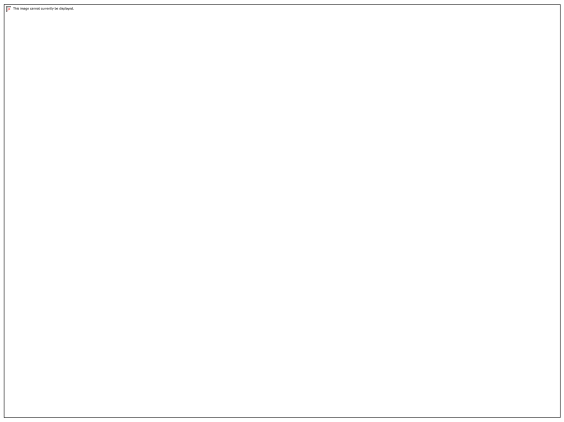


2. Arduino Uno R3. Arduino Uno R3 is an open-source microcontroller board that is based on the ATmega328P microcontroller developed by Microchip. The board has sets of digital and analog input/output pins that can be interfaced to various expansion boards and other circuits. It will serve as a supplementary microcontroller that controls the GSM module when sending SMS to the registered mobile number. This is to avoid the delay caused by the GSM module to other components

connected in the Arduino Mega 2560. It communicates to the Arduini Mega 2560 using their serial ports.



3. WH-SP-RG Tipping Bucket Rain Gauge. WH-SP-RG is a tipping bucket rain gauge model used in measuring the rainfall in an area. It transmits a pulse to the Arduino Mega 2560 microcontroller for every single tip of rain. Every tip is equivalent to 0.2794mm.



4. JSN-SR04T Ultrasonic Sensor Module. JSN-SR04T sensor module is used for water level monitoring system. It can accurately sense an obstacle within 2cm to 400cm range. If the obstacle is out of the sensor’s range, then the value is zero. It calculates

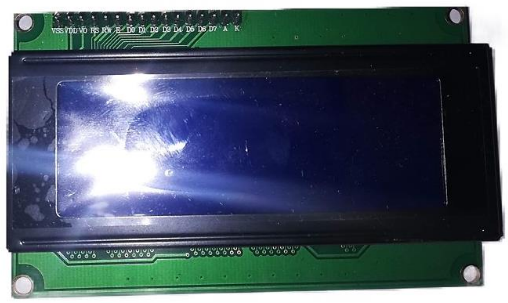
the period and strength of sound waves which are reflected back to the sensor. These calculations are made and transmitted to the Arduino Mega 2560 microcontroller.

5. DS3231 RTC Module. The application of the real-time clock (RTC) module is to monitor the actual real-time. It has a backup battery input for constant timekeeping even if the device was turned off or unexpectedly shut down. The RTC counts seconds, minutes, hours, day, date, month and year information. It can either operate in 24-hour or 12-hour format with an AM and PM indicator. This RTC module also has low power consumption and working in 3.3V operation. Its purpose is to determine every hour to when the total rainfall will be computed and to when the GSM will send an SMS notification indicating the amount of rainfall and current river water level.

6. SIM800L GSM Module. The SIM800L GSM module is a circuit used to establish communication between the system and the cellular phone of the owner. It operates on frequencies GSM580MHz, EGSM900MHz, and DSC1800MHz. In the system, the GSM module is utilized to send a notification to the registered phone number through SMS every hour to monitor the rainfall and the river water level.

7. MicroSD Card Adapter. The microSD card adapter is a microSD card reader module for reading and writing through the file system and the SPI interface driver. It is used in the system to store the data gathered by the sensors. These data are essential for future works on the rainfall and river water level situation in the locale.

8. LCD 20x4. The liquid crystal display (LCD) 20x4 is a module with a flat display panel, visual display, or video display that uses light modulating properties of liquid crystals. LCD 20x4 means that 20 characters can be displayed in each of the 4 rows with a total of 80 characters displayed at any instance of time. Its use in the system is to display the current readings of the sensors. It is also used when inputting the mobile number to where the SMS notification will be sent.



9. I2C Module. I2C Module minimizes the ports in connecting to Arduino microcontroller from the LCD. I2C is connected to LCD to reduce the number of pins connected.

10. Membrane Keypad Module 4x4. The membrane keypad module 4x4 (MKEY4X4) is a 16 key button keypad in 4x4 arrangement. It can be connected to the Arduino microcontroller with female 10cm extension flat cable. It is used in the system to encode the mobile number to which the SMS notification will be sent.

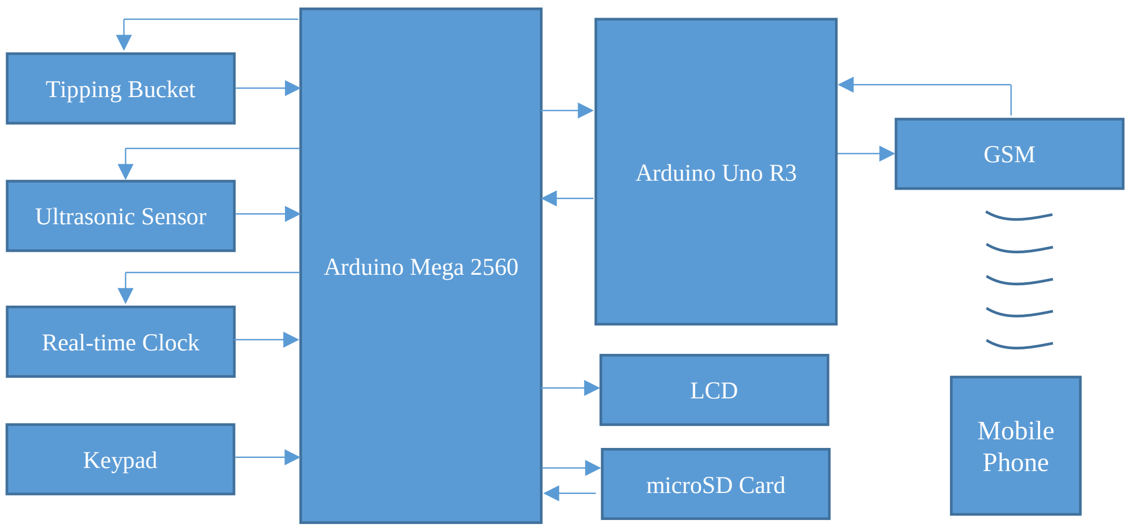
APPENDIX 4

BILL OF MATERIALS

ITEM	QUANTITY	UNIT PRICE	AMOUNT
Arduino Mega2560	1	580.75	580.75
Arduino Uno R3	1	313.75	313.75
WH-SP-RG Tipping Bucket Rain Gauge	1	882	882
JSN-SR04T Ultrasonic Sensor Module	1	276	276
DS3231 RTC Module	1	96	96
SIM800L GSM Module	1	250	250
MicroSD Card Adapter	1	379	379
LCD 20x4	1	215	215
I2C Module	1	65	65
Membrane Keypad Module 4x4	1	30	30
MicroSD Card 1GB	1	120	120
SIM Card	1	30	30
Presensitized PCB with Ferric Chloride and Developer	1	380	380
1 set of Header Pins (5pcs male and 5 pcs female)	1 set	63	63
1 set of 140pcs connecting wires	1 set	158	158
Chassis	1	3000	3000
Solar Panel (50W)	1	1500	1500
12V Battery (12Ah)	1	1040	1040
Solar Charge Controller	1	245	245
1kiloohm resistor (1/4W)	1	1	1
TOTAL			Php9624.50

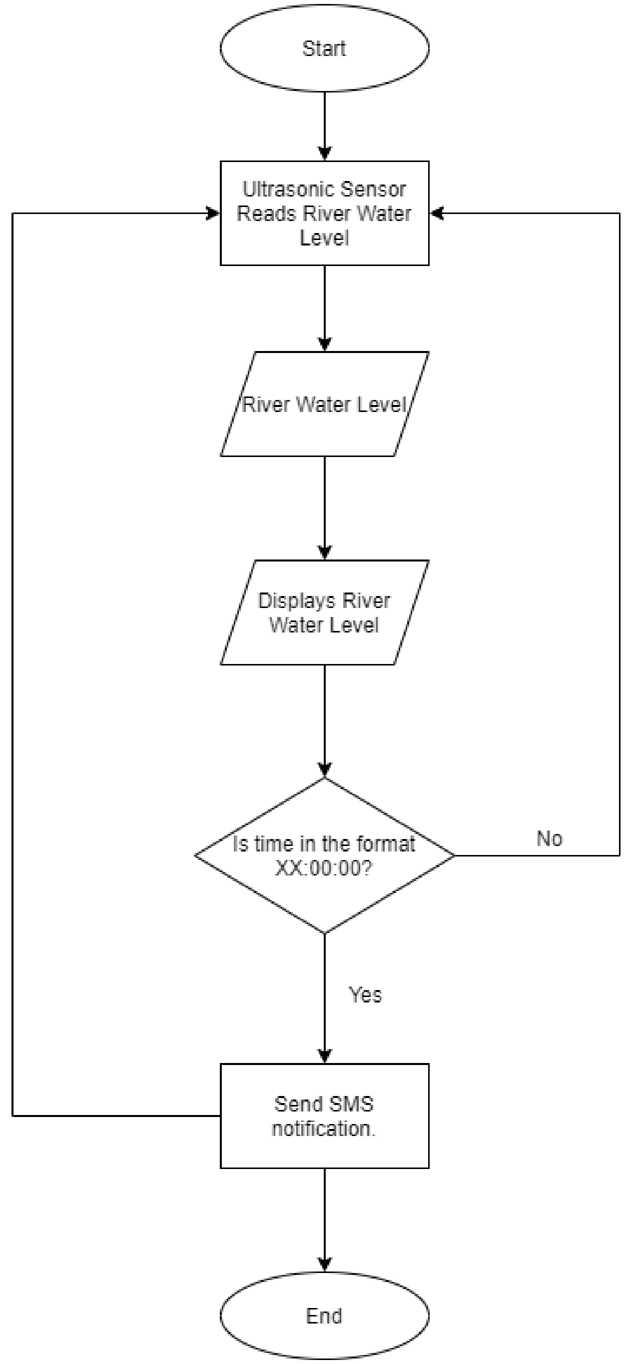
APPENDIX 5

BLOCK DIAGRAM

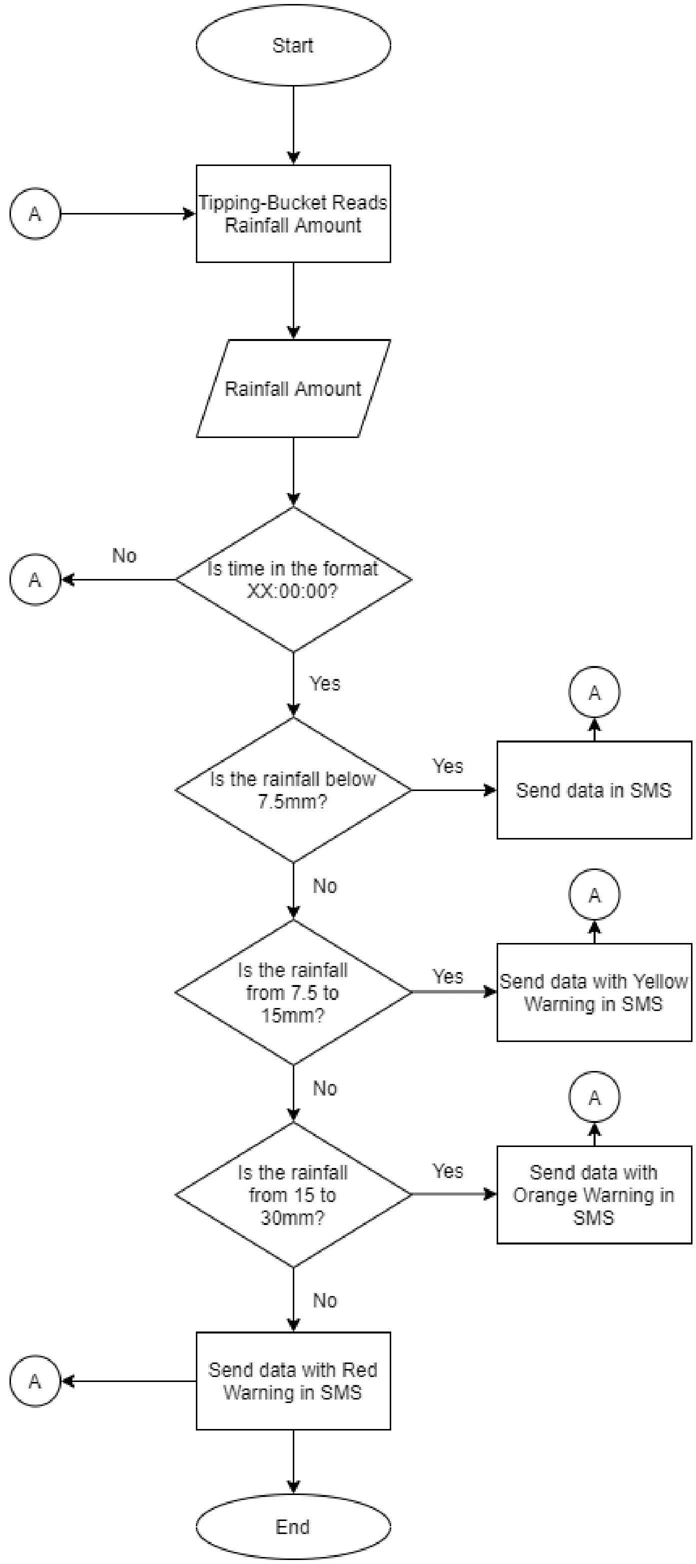


APPENDIX 6

FLOWCHARTS



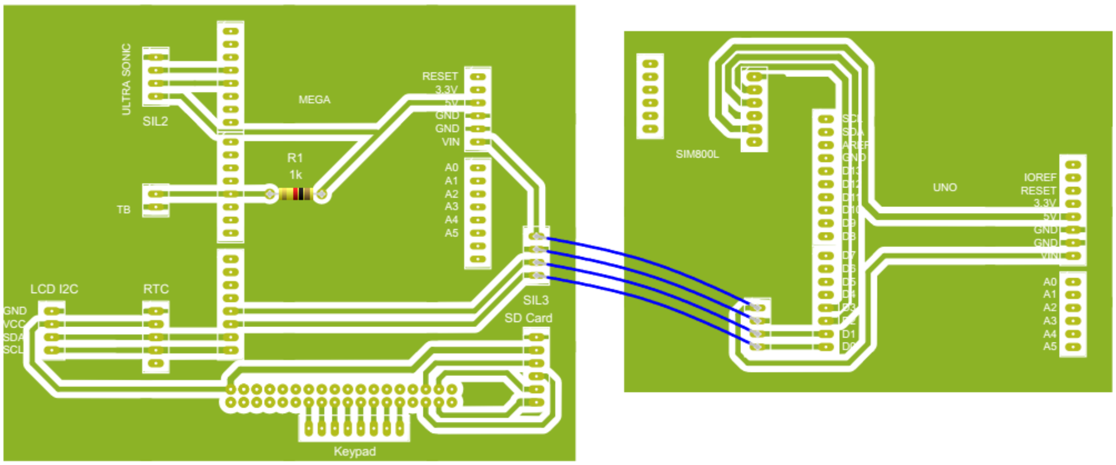
Flowchart of River Water Level Monitoring



Flowchart of Rainfall Monitoring

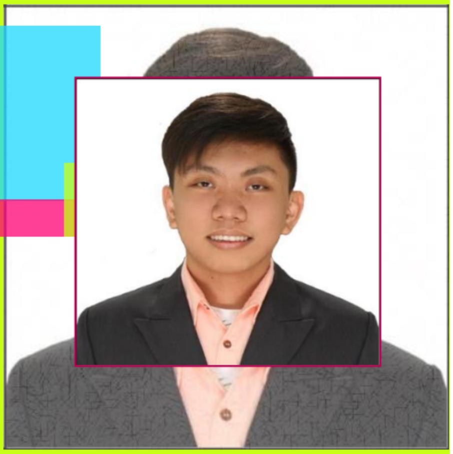
APPENDIX 7

PCB DESIGN



APPENDIX 8

RESEARCHER'S CURRICULUM VITAE



Rico Jay Sunglao Laxa

Electronics Engineer

Phone:
+63 939 877 7329

Email:
ricojaylaxaece@gmail.com

Website:
https://www.facebook.com/sirruki0laxa

Address

San Juan Nepomuceno, Betis, Guagua, Pampanga

Skills

Community-based research, Technology-aided statistical analysis

Experience

November 2016–present

Instructor
School of Engineering
Colegio de Sebastian – Pampanga, Inc.

July 2018–March 2020

Assistant Instructor
Department of Computer and Electronics Engineering
University of the Assumption, City of San Fernando, Pampanga

Education

June 2017 – present

Master of Science in Engineering with Specialization in Electronics Engineering
Polytechnic University of the Philippines – Manila

June 2011 – March 2016

Bachelor of Science in Electronics Engineering
Don Honorio Ventura Technological State University, Bacolor, Pampanga

June 2007 – March 2011

High School
Don Honorio Ventura Technological State University, Bacolor, Pampanga

Activities

Co-authored, presented, and published research entitled, "Myoelectric Sensor-based Prosthetic Hand for the Transradial Amputees of Kapampangan Development Foundation, Inc." at the 11th IEEE International Conference on Humanoid, Nanotechnology, Information Technology, Communication and Control, Environment and Management on November 2019

Delivered seminar speeches on "Industrial Revolution"

Served as undergraduate thesis panelist, adviser and statistician