FLO-G: Flood Level Identification Mapper Java Application Software Using Geographic Information System (GIS) for Guagua, Pampanga

JOSHUA IVAN D. VALENCIA[1], RHOANN V. AMIO[2], NORWIN JAY M. DELA ROSA[3], NICOLE C. GARCIA[4], ABCEDE REYN MALONZO[5], JERLINE JHIE C. TULIO[6], INLA DIANA C. SALONGA[7], JOHN VINCENT G. TONGOL[8]

[1, 2, 3, 4, 5, 6] *Student, Department of Civil Engineering, Don Honorio Ventura State University*

[7, 8] *Faculty, Department of Civil Engineering, Don Honorio Ventura State University*

Abstract*—Floods have become more frequent across the world, making them one of the most destructive events in terms of financial losses. Being able to recognize the places which are more susceptible to floods can help with flood risk reduction and management. However, flood maps are usually only accessible in the local disaster prevention division of the respective municipalities, in close cooperation with the residents, qualified experts, NGOs, and other pertinent bodies. This study developed an application that provides information about flood levels by simulating floods using open-source GIS software that can be used in Flood Risk Reduction and Management. This study helped make a flood map accessible to all the residents who live in the chosen study area by producing an application that can be downloaded to their phones to be aware of the possible flood levels and help them prepare for the coming rain. The study's findings helped the municipality of Guagua to manage the risk of flooding in the affected area mentioned in the study. People can utilize the application to locate which areas are flooded. Researchers could use the findings to identify other areas of concern and suggest appropriate solutions to help the affected areas.

***Indexed Terms*—GIS Flood Mapping, Flood Map Application, Flood Risk, Flood Map**

I. THE PROBLEM AND REVIEW OF RELATED LITERATURE AND STUDIES

1.1 Introduction

Flooding on Rivers have become more frequent worldwide, resulting in significant financial losses and making it one of the most devastating events. The increasing risks of river flooding can be caused by the increase in population, climate change impacts, and modifications to the land by people. Disasters caused a weather, climate, or water hazard happened daily on average during the previous 50 years, 115 people are killed, accumulating 202 million US dollars in damages every day. There have been five times as many catastrophes in 50 Years, primarily because of climate change, more intense weather, and better reporting. Despite the increase in catastrophes, the death toll was substantially reduced, because of timely warnings and better management of disasters. There was a total of 3 454 catastrophes in Asia, that resulted in 975, 622 fatalities, and US$ 1.2 trillion economic losses were reported from the year 1970 to 2019. Almost half (47%) of weather, climate, and disasters related to water that are reported globally, where it also accounts for a third (31%) of the associated economic losses occur in Asia, 57% of economic losses are caused by floods while storms had the largest effects on life, taking 72% of the lives lost. The most significant impact in terms of loss of life and economic damages in Asia is attributed to the top 10 natural disasters. The disaster accounts for 70% or 680,837 fatalities and 22% (US$266.62 billion) of the economic losses in the region [1]. Because of climate change, typhoons become stronger and sea surface and subsurface temperatures rises, which is made worse by global warming. Increased moisture is carried by these stronger typhoons, which might result in more precipitation, projected increases in rainfall intensity caused by climate change can also increase the frequency of flooding, and the size of floods[2].

Being able to recognize the places which are more susceptible to floods can help with flood risk reduction and management. Flood management is essential for both the best use of the land's resources and its effective management, in addition to the significant harm that floods inflict on civilization. Technically, this is impossible without accurate flood hazard and risk maps[3]. An efficient flood risk mitigation and management can be planned with a flood map. Flood mapping and prediction provide a significant role in flood hazard assessment. Through mapping and simulating current and projected flood dangers, flood type, severity, and frequency of occurrence are better understood. They are helpful for risk assessment, early warning systems in case a recurrence occurs in the future, and hydraulic design, particularly for prospective flood control and risk reduction[4]. Such flood maps can be produced using Geographic Information System (GIS) Software.

A Geographic Information System (GIS) Software is designed to store, retrieve, manage, display, and analyze all types of geographic and spatial data. Maps and other graphic displays of geographic information can be created using GIS software for study and presentation. GIS functions differently than other types of software. The distinctiveness of GIS provides capabilities in terms of maps and thorough analysis; in some instances, it was possible to provide solutions regarding economic directions. When "Where" is included as a variable in decision-making, the solutions that GIS offers come with distinct methods of doing things. Through the use of spatial information, it can encourage people to innovate in their regular activities[5]. Flood maps produced through GIS serve a significant role in flood hazard assessment and are used to disseminate information about flood risks. Soft copies and hard copies of maps are then produced to provide access to other people. Only the local disaster prevention departments of the relevant municipalities, working closely with the local population, competent professionals, NGOs, and other relevant authorities have access to flood maps. Local prevention disaster prevention departments cannot always relay information from flood maps when needed by residents other flood maps are also only accessible through a website that is accessed online. In such instances, a flood map accessed through an offline mobile application is more conducive.

Software written in Java, an object-oriented programming language, can run on various platforms. Java borrows most of its syntax from the C and C++ programming languages, and when a programmer creates a Java application, the compiled code (also known as bytecode) runs on most operating systems (OS), including Windows, Linux, Mac OS, and Android. Java applications can be accessed online and offline.

1.2 Review of Related Literature

- *Mapping using GIS*

According to new research flood risk mapping based on GIS and multi-criteria analysis is a valuable tool for estimating areas prone to flood risk, and helps water resources planners and decision makers to focus on specific areas in order to perform a further detailed assessment of flood risk (e.g., through the use of hydrological and hydraulic models). Consequently, this simplified but reliable methodology can help reduce resource requirements for fairly accurate flood risk assessment[6]. The amount of rainfall has a big impact on how a flood hazard map is generated[7]. Flood risk mapping based on GIS and multi-criteria analysis has a number of benefits, including flexibility, ease of use, and affordability, which enable it to be applied in situations where there is a lack of specific information, where obtaining large-scale flood risk maps is desired, or when policymakers need a quick flood risk assessment[8].

Flood Maps: The spatial distribution of hydrological data, such as the components of the hydrological balance, can be presented and summarized effectively using mapping (i.e. precipitation, evapotranspiration, and runoff).

Flood maps show the areas that will be covered under water during actual or possible flood occurrences. They can identify the probability of floods and their impact on structures, people, and assets. The following are the different types of flood maps.

Inundation maps: visually present the potential area that may be affected by floodwaters during floods of different intensities, or they can depict the actual extent of floodwater during real flood incidents. These maps are designed to aid communities residing in floodplains and areas prone to flood hazards in developing effective plans to prepare for such disasters.

Flood Extent or Emergency Map: is a sort of inundation map that shows the distribution or extent of water during real-time events. They help communities in floodplains better plan for emergencies and respond to them.

Flood Hazard Maps: display the findings of hydrologic and hydraulic investigations, along with locations that might flood under various conditions. Engineering maps called flood hazard maps are frequently used as regulatory maps for land use planning associated with flood mitigation.

Flood risk map: demonstrates potential negative consequences that communities may face during a flood scenario. Social, economic, environmental, and cultural issues are all part of the consequences.

Flood Awareness Maps: are communication maps that highlight the history of floods in their areas and provide a narrative together with flood risk/hazard maps. They also demonstrate the risks and possibility of future flooding.

The Qualitative Flood Risk Map: is used to categorize the flow accumulation, elevation, and rainfall intensity aspects using a natural break on the GIS platform.

The Quantitative Flood Risk (Damage) Map: concentrates on flood damage to residential buildings and assets as well as agricultural sectors for the most significant recent floods and flood events with various return periods.

The difference between Flood Hazard and Flood Risk maps is that the flood hazards map shows the potential locations for flooding. A flood risk map uses this information to identify vulnerable areas and estimate the consequences of the hazard in terms of affected populations, property damage, and/or other effects. For both surface water (pluvial) floods and undefended fluvial (riverine) flooding, maps are accessible for each return period.

Flood maps are very important in times of disaster, areas that have high exposure to flood risk can choose not to build important infrastructure, like hospitals. It helps minimize the loss and damage caused by floods, it is often used as a regulatory map for land use planning related to flood mitigation. Flood maps are only accessible in the local disaster prevention division of the respective municipalities, in close cooperation with the local residents, qualified experts, NGOs, and other pertinent bodies.

Flood Mapping in the Philippines: With the help of open data, Project NOAH aimed to give the Philippines investing in new technologies and new scientific approaches in lowering disaster risks. Instead of limiting access to public data that is essential to ensuring public safety and welfare, the model emphasizes community empowerment through open access. Hazard maps provide various levels of storm surge inundation and are classified according to advisory levels and tell you where it can be hazardous when there are typhoons. Previous low-resolution hazard maps demonstrated that every square meter of the Philippines is vulnerable to flood and rain-induced landslide threats. Hazard maps are intended to indicate the safest and most ideal sites for resettlement and the construction of evacuation routes; therefore, doing so violates their purpose of planning for communities that are resilient to disasters and the effects of climate change[9]. Nevertheless, the prediction was still able to identify storm surges will probably hit the regions. Despite the fact that the results' accuracy was dependent on the typhoon's estimated path, the forecasting procedure was nevertheless appropriate for use as a tool for early warning since it included bathymetric data, which was not that precise warning in intensity of rain fall[10].

1.3 Background of the study

The Philippines is very susceptible to flooding due to being located in the typhoon belt in the Pacific makes the Philippines prone to Tropical Cyclones. An average of 20 typhoons hit the country yearly, and the typhoons only get stronger annually. Typhoons are among the most destructive natural disasters, and they annually result in a significant number of fatalities and significant property damage. Recently, in December 2021, super typhoon Odette hit the Philippines and caused damages of 17.5 billion Pesos to houses, roads, power, and water lines in addition to 11.1 billion Pesos in losses to agricultural produce and fields[11].

The Pampanga River Basin —Fig. 1.1, the 4th largest basin in the Philippines, usually experiences extreme flooding whenever there are monsoon rainfall and typhoon, especially in the areas near its outlet point, Manila Bay. Typhoons frequently caused flooding in the Pampanga Delta, which is composed of low-lying swamps and the Pampanga River's mouth areas. It also severely damaged both public and private property in addition to the farming and fishing industries. Apalit, Arayat, Bacolor, Candaba, Floridablanca, Guagua, Lubao, Mabalacat, Macabebe, Magalang, Masantol, Mexico, Porac, San Luis, San Simon, Santa Ana, Santa Rita, Santo Tomas, and Sasmuan are the municipalities of Pampanga. Macabebe, Masantol, Guagua, and other municipalities form a part of the Delta Philippines. Flood waters from the western towns of Pampanga flow to the allied basin of the Guagua River. Every time monsoon rain or typhoon occurs Guagua is one of the municipalities that is constantly affected by flooding. Guagua is geographically flat and the worsening of climate change increases sea levels each year.

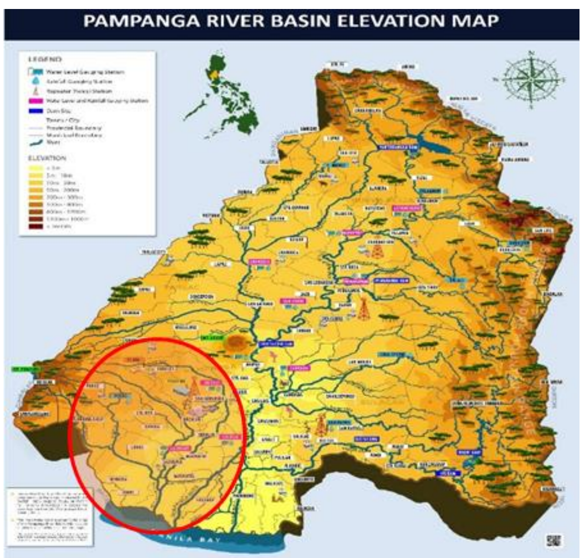

Fig. 1.1 Pampanga River Basin elevation map

Note: The encircled area shows the part of the Pampanga River basin that is close to Manila Bay

Persistent rainfall caused by the southwest monsoon in July 2021 has resulted in flooding in 96 barangays across ten local government units in Pampanga. The continuous downpour has caused significant damage to the agriculture sector in Pampanga, with the estimated cost reaching P118,280,981[12]. Every year, the town of Guagua finds itself, both literally and metaphorically, in a predicament.

Additionally, the residents of the town struggle to channel flooding into Pampanga Bay, which drains into Manila Bay, due to the two-millimeter annual rise in ocean levels caused by climate change. Guagua is also mentioned in reports of local subsidence from North Harbor in Manila to Obando, Paombong, and Hagonoy in Bulacan. Every year, subsidence measurements ranged from two to nine millimeters. Subsidence is significantly exacerbated by excessive groundwater extraction. More than ten times faster than ocean levels are rising, these towns are sinking.

Guagua is nearly flat and appropriate for all stages of development, including those in the agricultural, industrial, commercial, and other sectors.

Several streams and tributaries cross Guagua on rainy days, collecting and transferring floodwater to the Guagua river and into Manila Bay. Fine sand, silt loam, and hydrosol make up the recent alluvial origins of Guagua's soils.

Pressing more the problem of flooding in Guagua is its dense population. In the 2020 census of the Philippine Statistic Authority (PSA), Guagua, having a population of 128,893, placed third among the municipalities or cities in Pampanga that has the highest population density. This represented 5.29% of the total population of Pampanga province or 1.04% of the overall population of the Central Luzon region. Based on these figures, the population density is computed at 2,648 inhabitants per square kilometer or 6,860 inhabitants per square mile. Urban flooding is having a significant impact, particularly in terms of both direct and indirect economic losses. The population is rising at an unprecedented rate in many cities in developing nations. As a result, there are now more urban centers, industrial zones, and infrastructures in risky locations like the places inside dried-up rivers or the lands beneath rivers[13]. Thus, several barangays of Guagua, Pampanga is experiencing flooding for quite a long time. During typhoon Ulysses floods remained in the affected area for a few days to over a week. Floods at lower sections of the Pampanga River persisted for less than a week. The affected area experienced flood depths ranging from 1 meter to more than 4 meters. In the Province of Pampanga, at least 14 municipalities with 135 barangays were devastated by floods (Pampanga PDRRMC Report on Typhoon Ulysses). Flooding often happens when heavy rain falls for an extended period of time over a short period of time, or when a river or stream overflows due to an ice or debris trap. It can also happen when a levee or other water-controlling structure, like a dam, fails. While flood mitigation lessens the chance that a structure will sustain flood damage overall as well as the extent of such damage when it does. In order to provide information about the danger of flood hazard mapping will be used to identify coastal areas which are at risk of flooding.

Most flood maps used today are maps of theoretical floods rather than maps of actual floods, which are used to give communities a sense of where particularly flood-prone locations is likely to be. These are sometimes referred to as "100-year flood maps," although that term is a little deceptive because it is based on statistical probability for a given site instead of an entire region. However, residents can only access flood maps from the local disaster prevention division of the respective municipalities. Furthermore, flood maps are often color-coded and offer a snapshot of the flood risk at a specific time without explicitly displaying the water level. Hence, FLO-G is being introduced. FLO-G is a mobile application developed using GIS that envisions providing ease of access to information about possible flood levels in the municipality that can help residents to prepare in case of flooding.

1.4 Objectives of the study

General Objective: This study aims to develop an application that provides information about flood levels by simulating floods using open-source GIS software that can be used in Flood Risk Reduction and Management.

Specific Objectives: The specific objectives include:
To develop a flood map using an open-source GIS software and develop a Java-based application software that can be accessed offline through a mobile application;

To conduct a pilot testing of Flo G with selected respondents and validation survey that evaluated and assess the performance, usability, and effectiveness of the flood map application software, the evaluation will focus on the overall usefulness of the flood map application software. This assessment encompassed its aesthetics, user-friendliness, usefulness, and accessibility.

1.5 Significance of the Study

This study is conducted to benefit the following:
To the Municipal Disaster Risk Reduction and Management Office (MDRRMO), the outcome of this study will help them to formulate an efficient strategy and approach to flood hazard reduction and management in the municipality of Guagua.

To the Residents of Guagua, this study can help to increase the accessibility of flood maps to the residents of Guagua so that they can be informed about the locations of flood-prone areas in the municipality so that they can be aware of the risk.

To Future Researchers, this study will be an instrument that will guide them to discover reliable and dependable data that are really necessary and essential information for further understanding the topic. This study will help enlighten, them to be a source of information and be a useful reference that will be needed in their future studies

1.6 Scope and Limitations

The focus of the study is to increase the accessibility of flood maps by creating an application that can be easily accessed by residents. This study informed residents about the possible flood levels they can experience in each rain classification. The data gathered were collected within the vicinity of Guagua, Pampanga, and were used to form a flood map. Recent studies were used as a reference in forming an updated and accessible flood map.

The limitation of this study was the availability of the data software for making a flood map. Also, this study had a restriction on gathering some sensitivity of data; it is limited to the use of Geographic Information

Systems (GIS) as a method of producing a flood map. The output of this study depended on the gathered data whether it is primary data or secondary data. In the Java application, the selected study area was implemented the flood map. It did not cover the other problems that are not necessarily connected to flood maps such as factors that are outside the scope of this study. However, the output only reflected on a selected study area which is Guagua, Pampanga, it is not applied to other locations, but the procedure can be used as a reference. It cannot guarantee the same output if used in other areas, but the flow of the procedures can be used as a reference. Additionally, the purpose of the survey that accomplished was only for the acceptability of the study in the chosen study area. It is only limited to a certain population; it is not possible to do it to the whole population.

1.7 Conceptual Framework

The conceptual framework as presented in―Fig. 1.2 shows the general flow of the methodology of the study. The Data Collection stage includes the collection of data that served as input to the open-source GIS software to create the flood map and gathering information that was used for the Pilot Testing and Validation Survey. Using Java and JavaScript Object Notation (JSON) the created flood map was used as the basis to produce the mobile application. The Pilot testing of the application and feedback survey were conducted. The results were used to create conclusions and recommendations for the research.

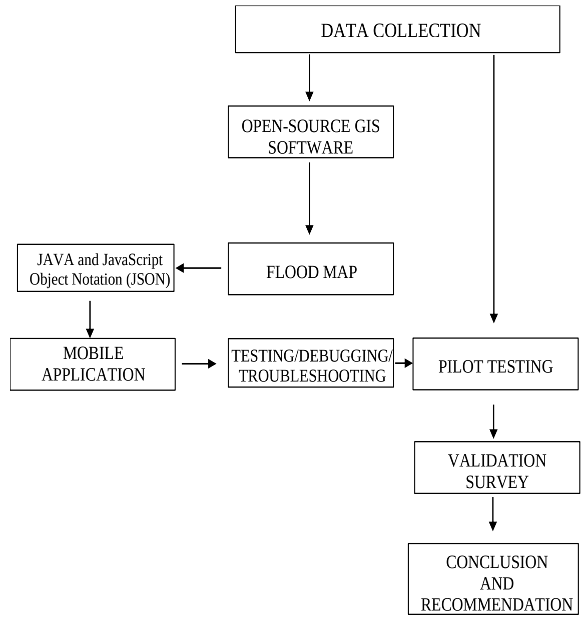

Fig. 1.2. Conceptual Framework

II. METHODOLOGY

2.1 Phase 1 – Methodological Framework

- *Research Design*

An Action Method Design was used as used as a quantitative method for this study. The results from quantitative design were prioritized and involved a variety of techniques used to investigate social phenomena methodically while employing numerical or statistical data to calculate and analyze data for all forms of measurement. It requires measurement and assumes that it is possible to measure the phenomenon being studied. It aims to analyze data for patterns and connections as well as to validate the measurements[14].

The procedure is deductive reasoning wherein it used a logical process and moves from broad concepts to specific conclusions[15]. Since the investigation was carried out unbiasedly and objectively, a quantitative design was used to acquire numerical and measurable data from different agencies and institutions.

As for the philosophical approach of this research, positivism is adopted. Quantitative methodology is a result of positivism and involves the exact, measurement-based collecting of scientific data that is then frequently statistically analyzed with the goal of generalizing the results[16].

Research Locale
This research was carried out in Guagua, Pampanga, which is where flood is common in this area. It is also where the interviews with the respondents took place.

2.2 Phase 2 – Data Collection
A letter of approval signed by the Research Adviser and Research Coordinator was presented to ask permission to conduct a study outside the university premises. Additionally, a letter was sent to the mayor's office of the Municipality of Guagua, Pampanga to request authorization to collect rainfall data and flood levels in the office of Municipal Disaster Risk Reduction and Management Office (MDRRMO). Furthermore, this study gathered secondary data based on related literature and articles from the internet and sources that are relevant to the topic.

The following procedures were used to collect data from Local Government Units (LGUs) and/or Private Companies:

1. The data such as the related academic literature was gathered to help in analyzing the Flood Risk of the Municipality of Guagua, Pampanga.
2. With the approval of the thesis adviser, a letter was written a letter to the Municipal Disaster Risk Reduction and Management Office (MDRRMO) of Guagua, Pampanga, to gather and ask about the recorded flood level in Guagua, Pampanga.
3. For the meteorological data, such as rainfall data of the subject area, a letter was sent to the Head Hydrologist of PAGASA, to gather the computed Rainfall Intensity Duration Frequency (RIDF) in Guagua, Pampanga.

Research Ethics: The letter includes the aims of the study and its intention to help the municipality. the identity and privacy of the respondents was insured and their answers to the provided data is confidential to others. The collected data was statistically treated, examined, and interpreted after collection. This study is not gender-biased and can be used by any gender.

2.3 Phase 3 – Data Analysis and Evaluation

Flood mapping using GIS
Water balance, Hyetograph, and Return Period
The ratio of the body's water intake to its water loss is known as the water balance. Additionally: the state of the body when this ratio comes close to unity. According to the law of water balance, each water system or area's inflows must match its outflows plus any changes in storage over a given period of time. A water balance equation in hydrology can be used to explain how water enters and exits a system.

The equation for a catchment's water balance is
$P = Q + AET + GW + DS$ (1)

where P stands for precipitation,

Q for runoff, AET for actual evapotranspiration,
GW for exchange with a groundwater aquifer, and
DS for change in soil storage. (All terms are stated in millimeters per year.)

A hyetograph—Fig. 2.1 shows the distribution of rainfall intensity over time graphically. It represents a graph of the time interval's average rainfall intensity. It developed from the mass curve and is typically shown as a bar graph. The entire amount of precipitation that occurred during the period is shown by the area beneath a hyetograph. It is also to know the duration and the amount of the precipitation before it turned into a runoff.

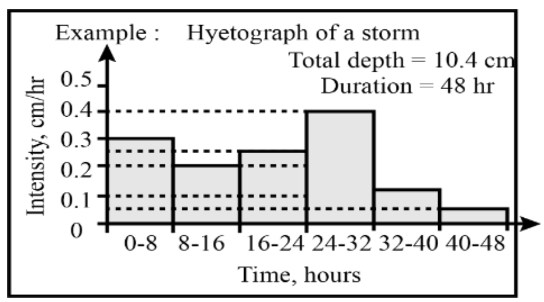

Fig. 2.1. Hyetograph

The chance that a random variable (like rainfall) will have a magnitude that is equal to or greater than a given magnitude is represented by the letter P. Return Period —Fig. 2.2 is defined as:
$T = \frac{1}{P}$ (2)
where P is the Probability of a variable surpassing its limit. P can be computed by Weibull's formula:
$P = \frac{m}{(N+1)}$ (3)
where m is the order number and N is the recorded number of years.

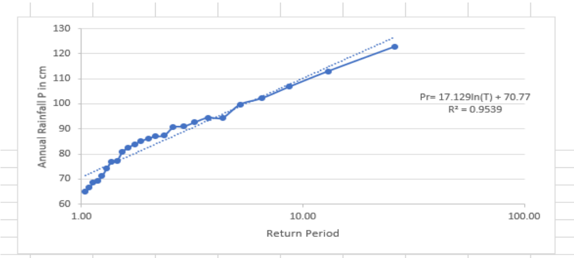

Fig. 2.2. Return Period

- *GIS Mapping*

An Open-Source Geographic Information System (GIS) software was utilized to create the desired flood map. The rainfall and historical flood level data needed was from the Municipal Disaster Risk Reduction and Management Office (MDRRMO) office. To begin mapping a map layer should be created to visualize the target area —Fig.2.3.

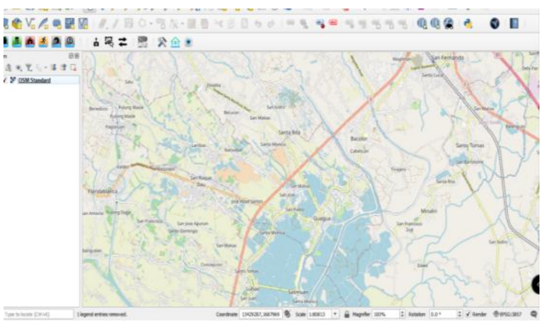

Fig.2.3. Map Layer

A shapefile layer was created to create the flood map to represent the area of interest—Fig. 2.4. After creating a representation of the area of interest a comma separated values(csv) file was created that contains the latitude, longitude and depth of the station. The csv file will be imported using add delimited text layer station layer was created to represent the location of the barangays where the flood level data was collected —Fig. 2.5.

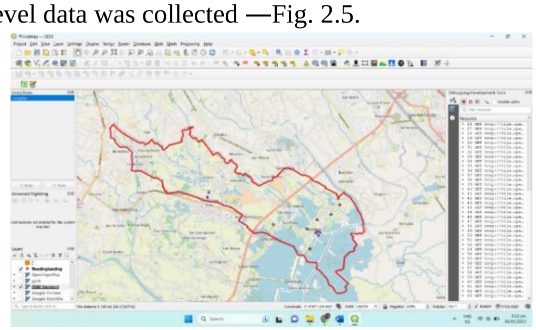

Fig.2.4. Shapefile and Stations Layer

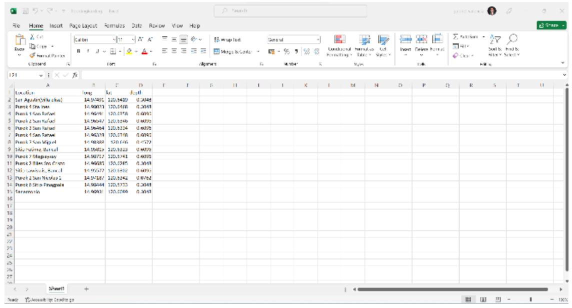

Fig.2.5. Flood Level Data with corresponding coordinates

To simulate the flood level surrounding the stations, the flood level data was interpolated using a function of the Open-Source Geographic Information System (GIS) software. Thus, producing a flood map containing the flood levels of the desired area based on the historical flood level data —Fig. 2.6.

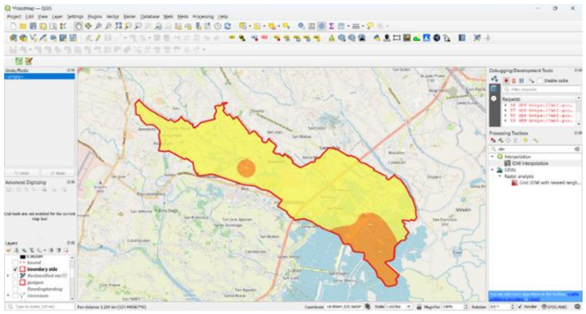

Fig.2.6. Interpolated flood level data

After the producing the flood map, boundary shapefile—Fig. 2.7 was created to indicate the boundaries of the barangay, the shapefile of rivers, streams—Fig. 2.8, wetlands fishpond and inland water were also created—Fig. 2.9. The river/streams and wetlands shapefile were produced using a plugin of the GIS software. The boundary map was produced by georeferencing the boundary map from the Comprehensive Land Use Plan (CLUP) of Guagua and manually tracing the boundaries to create the shape file

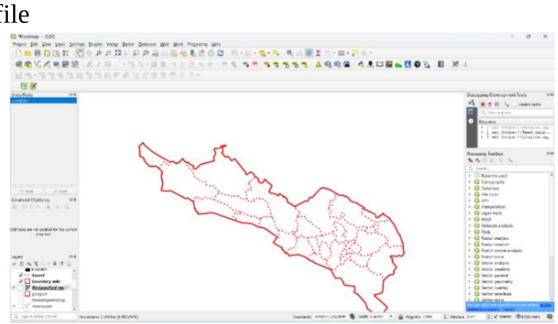

Fig. 2.7. Boundary Shapefile

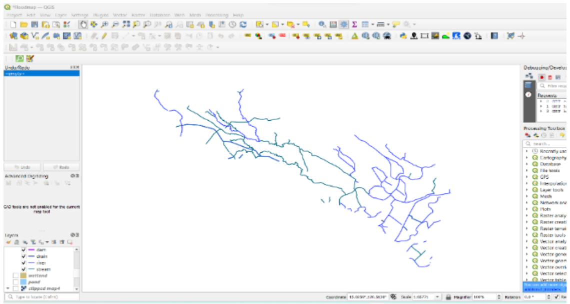

Fig. 2.8. River and Streams Shapefile

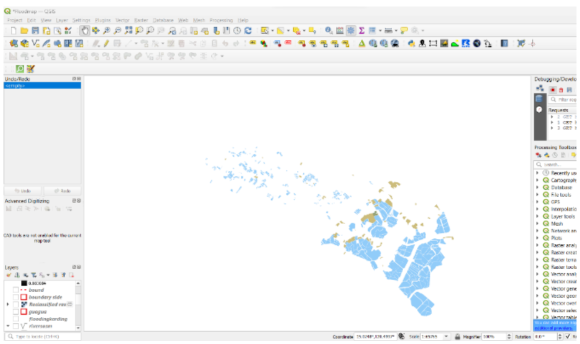

Fig. 2.9. Wetlands, Ponds and Inland Waters

- *Creating the Java Flood Map Application*

The Flo-G Mobile application was a flood-level identification mapper. The first step in creating a Flo-G mobile application was to create a pseudocode, which was a plain-language description of the steps in an algorithm or another system. Pseudocode often used the structural conventions of a normal programming language but was intended for human rather than machine reading. The second step was to flatten the design for the GUI, or graphical user interface (GUI), which was a digital interface in which a user interacted with graphical components such as icons, buttons, and menus. In a GUI, the visuals displayed in the user interface convey information relevant to the user as well as actions that they could take. The third step was the database for the data holder, which was an organized collection of structured information, or data, typically stored electronically in a computer system. After the first three steps, the next step was to download a Java IDE, which is an integrated development environment for programming in Java; many also provide functionality for other languages. IDEs typically provide a code editor, a compiler or interpreter, and a debugger that the developer accesses through a unified graphical user interface (GUI). The last step was to start creating back-end code, which comprised a site's structure, system, data, and logic.

FLO-G Pilot Testing and Feedback Survey

FLO-G Pilot Testing

The proposed study was carried out in the city of Guagua, Pampanga, showing the residents what the application provides. They tried the application and experienced the FLO-G application firsthand. The features and content of the app were discussed and were asked to accomplish the feedback survey to determine what they think about the application.

Feedback Survey

The population of this study consists of 128,893 total citizens as oof May 1, 2020. For the sample of this population, the selected participants would be the citizens of Guagua, Pampanga. In order to draw statistical conclusions about a population, a simple random sampling technique is used. According to Thomas (2022) simple random sample is a randomly selected subset of a population. Each person in the population has an exact equal probability of being selected through this sampling technique. This method is not complicated of all the probability sampling methods, since it only involves a single random selection and requires little knowledge about the number of populations. It has lower risk for research biases like sampling bias and selection bias because it uses randomization and any research performed on this sample should have high internal and external validity. The Raosoft website was used to compute the total sample of respondents that was needed. With a 95% confidence level and a 5% margin of error, a total of 384 is the minimum standard size of the survey—Fig. 2.10.

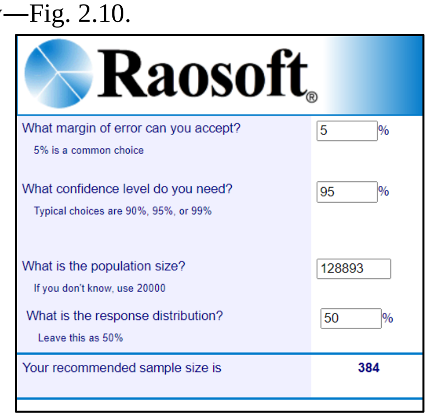

Fig. 2.10. Sample Size calculation using Raosoft website

In gathering the data needed in the study, a survey questionnaire was distributed as the principal instrument to gather the applicable data.

Based on the literature reviewed and other relevant documents available, the survey questionnaire was personally drafted and served as the main instrument for gathering the necessary data and information. A closed-type questionnaire was also used to elicit information from the respondent.

The questionnaire is made up of five parts: if it is Aesthetically Pleasing, User Friendly, Useful, Easy to Access, and whether The Application served the purpose when it comes to accessing the application. These questionnaires aim to gather recommendations about their flood hazard map.

- *Statistical Treatment of Data*

The following statistical treatment was used to aid in the analysis of data.

1. The Likert Scale was utilized to evaluate various aspects of the application, such as its aesthetic appeal, user-friendliness, usefulness, and ease of access. Additionally, it helped assess whether the application serves a specific purpose. The ratings were collected using a four-point scale and then converted into descriptive ratings based on the calculated mean.

Table I. Four-point Scale

Scale Value	*Range Interval*	*Description*
4	3.26 – 4.00	Strongly Agree
3	2.51 – 3.25	Agree
2	1.76 - 2.50	Disagree
1	1.00 – 1.75	Strongly Disagree

2. Percentage distribution and Mean were utilized to describe whether application is Aesthetically Pleasing, User Friendly, Useful, Easy to Access, and if The Application Serves a Purpose

III. RESULTS AND DISCUSSION

In this section, the study's goals are examined, and the findings are presented and analyzed accordingly.

- *Flood Map using GIS*

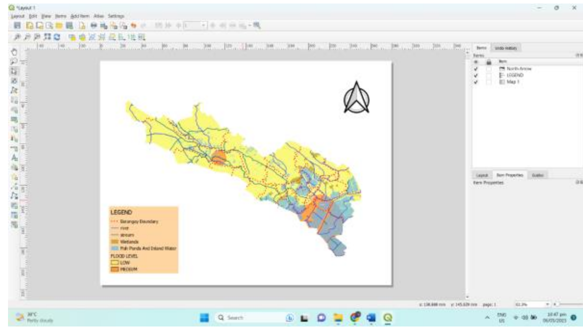

Fig.3.1. Flood Map

The produced flood map—Fig. 3.1 using QGIS has been exported as Portable Network Graphics(png) file format. The map presents the flood levels produced by interpolating flood depth from Guagua's MMRDMO Situational Report for Typhoon Karding. The map shows the level of flooding caused by low to moderate rainfall.

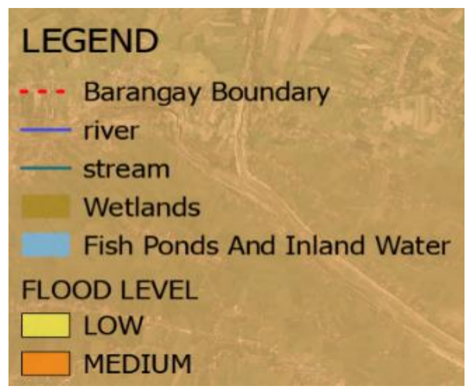

Fig. 3.2. Legend of the Map

The yellow color represents low flooding in the affected areas while the orange color represents moderate flooding in those areas. The blue lines represent rivers and streams that flows throughout the municipality. The red broken line represents the boundary of the barangays in Guagua. The light brown and light blue colors represent wetland and inland water/ponds respectively—Fig. 3.2.

- *The Java Flood Map Application*

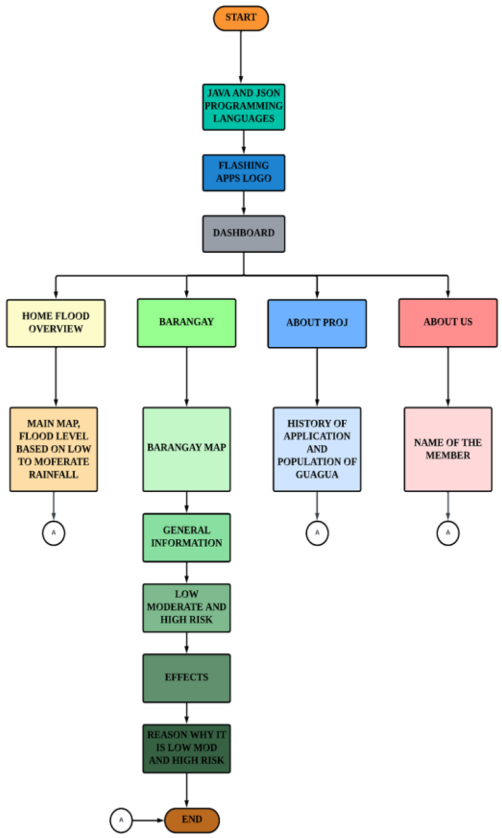

Fig. 3.3. Flow Diagram

Upon opening the app, the user will be directed to the home section which contains the map containing the overview of the possible flood levels—Fig. 3.4.

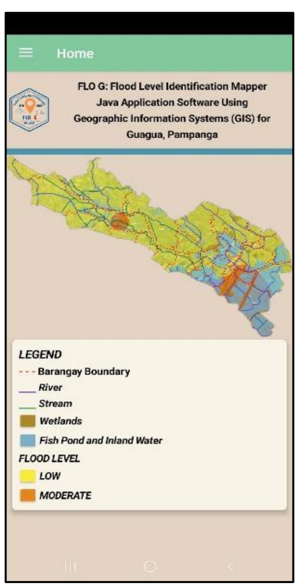

Fig. 3.4. Home

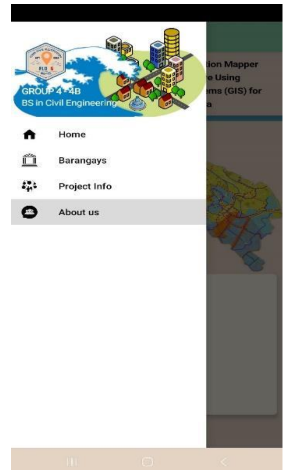

Fig. 3.5. FLO-G Dashboard

The dashboard on the left side—Fig. 3.5 contains all the different sections that the FLO-G app provide. The home button is where the main map located it contains the overview of the flood levels. The barangay section —Fig. 3.6 contains more detailed information about the flood levels and its possible effects, buttons for general information, and the low, moderate, and high risk—Fig. 3.7 can be clicked to display information about the effects, and reasons why it is low, moderate, or high risk are located.

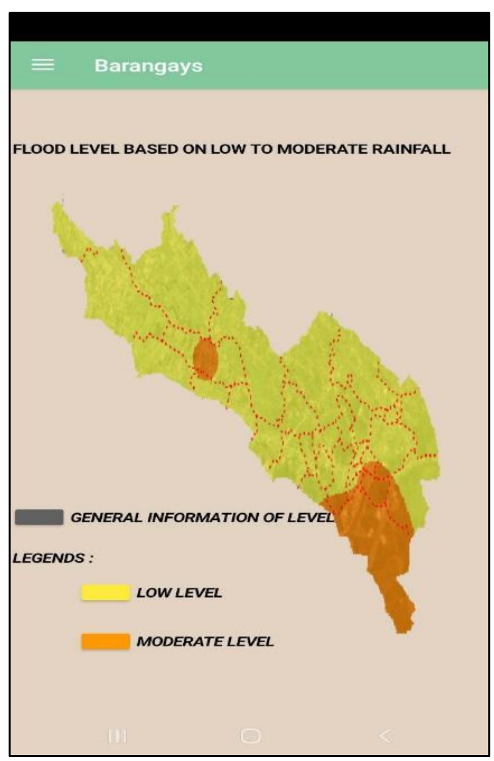

Fig. 3.6. Barangay Section

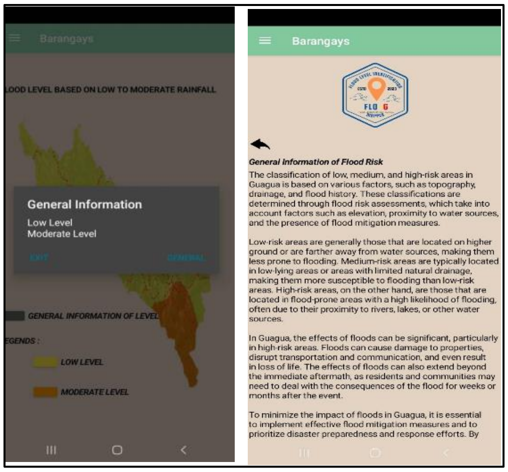

Fig. 3.7. Detailed Information

The Project info section displays the information about the project and the population of Guagua. The About Us section contains information about the researchers involved in the making of the FLO-G application—Fig. 3.8.

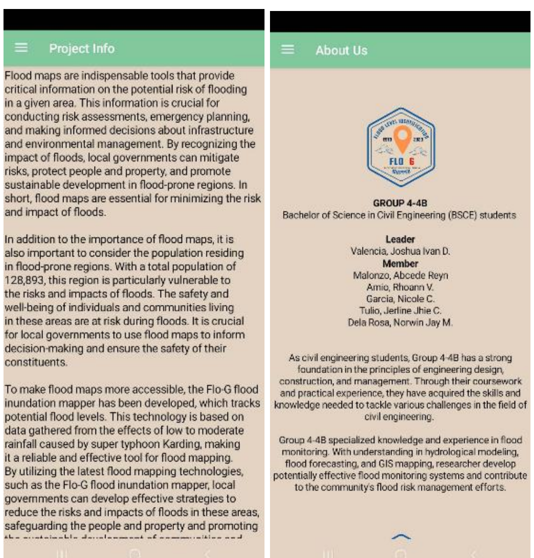

Fig. 3.8. Project info and About us section

Feedback Survey

Aesthetically Pleasing

—Table II presented the reaction of the people if the application is Aesthetically Pleasing. Item number 1 which states "The colors used in the application is visually appealing", obtained a mean of 3.09 which translates verbal description "Agree" supported by 196 out of 384 respondents with a percentage of 51.04%. Item number 2 which states "The layout of the application is easy to navigate", obtained a mean of 3.41 which translates verbal description "Strongly Agree" supported by 208 out of 384 with a percentage of 54.17%. Item number 3 which states "The icons and graphics used in the application re visually appealing", obtained a mean of 3.44 which translates verbal description "Strongly Agree" supported by197 out of 384 respondents with a percentage of 59.90%. Item number 4 which states "The application use animations or transitions in a way that enhances the user experiences", obtained a mean of 3.54 which translates verbal description "Strongly Agree" supported by 230 out of 384 respondents with a percentage of 59.90%.

Table II. Aesthetically Pleasing

Aesthetically Pleasing	Mean	Description
The colors used in the application is visually appealing	3.09	Agree
The layout of the application is easy to navigate	3.41	Strongly Agree
The icons and graphics used in the application re visually appealing	3.44	Strongly Agree
The application use animations or transitions in a way that enhances the user experiences	3.54	Strongly Agree
General Mean	3.37	Strongly Agree

- *User Friendly*

—Table III presented the reaction of the people if the application is User friendly. Item number 1 which states "The application provides clear instructions and guidance throughout the process", obtained a mean of 2.99 which translates verbal description "Agree" supported by 213 out of 384 respondents with a percentage of 55.47% of the respondents. Item number 2 which states "The application load quickly and runs smoothly", obtained a mean of 3.70 which translates verbal description "Strongly Agree" supported by 273 out of 384 respondents with a percentage of 71.09%.

Item number 3 which states "The icons and buttons in the application are easy to recognize and use", obtained a mean of 3.72 which translates verbal description "Strongly Agree" supported by 282 out of 384 respondents with a percentage of 73.44%. Item number 4 which states "The instructions and labels in the application are clear and concise", obtained a mean of 3.56 which translates verbal description "Strongly Agree" supported by 219 out of 384 respondents with a percentage of 57.03%. Item number 5 which states "The application responds quickly to the user's actions", obtained a weighted mean of 3.64 which translates verbal description "Strongly Agree" supported by 247 out of 384 respondents with a percentage of 64.32%.

Table III. User Friendly

User Friendly	Mean	Description
1. The application provides clear instructions and guidance throughout the process	2.99	Agree
2. The application load quickly and runs smoothly	3.70	Strongly Agree
3. The icons and buttons in the application are easy to recognize and use	3.72	Strongly Agree
4. The instructions and labels in the application are clear and concise	3.56	Strongly Agree
5. The application responds quickly to the user's actions	3.64	Strongly Agree
General Mean	3.52	Strongly Agree

Usefulness

—Table IV presented the reaction of the people in the application Usefulness. Item number 1 which states "The application helps you achieve the user's goals efficiently", obtained a mean of 3.46 which translates verbal description "Agree" supported by 201 out of 384 respondents with a percentage of 52.34%. Item number 2 which states "The application provides features that the user finds useful", obtained a mean of 3.39 which translates verbal description "Strongly Agree" supported by 270 out of 384 respondents with a percentage of 70.31%. Item number 3 which states "The application provides all the features and functionally that the user needs", obtained a mean of 3.69 which translates verbal description "Strongly Agree" supported by 273 out of 384 respondents with a percentage of 71.09%.

Table IV. Usefulness

Usefulness	Mean	Description
1. The application helps you achieve the user's goals efficiently	3.46	Strongly Agree
2. The application provides features that the user finds useful	3.39	Strongly Agree
3. The application provides all the features and functionally that the user needs	3.69	Strongly Agree
General Mean	3.51	Strongly Agree

Accessibility

—Table V presented the reaction of the people to the application Accessibility. Item number 1 which states

"The application loads quickly," obtained a mean of 3.55 which translates the verbal description "Strongly Agree" supported by 214 out of 384 respondents with a percentage of 55.73. Item number 2 which states "There were no issues or errors experienced while using the application," obtained a mean of 3.60 which translates verbal description "Strongly Agree" supported by 230 out of 384 respondents with a percentage of 59.90%. Item number 3 which states "The buttons and controls within the application are easy to find and use," obtained a mean of 3.27 which translates verbal description "Strongly Agree" supported by 224 out of 384 respondents with a percentage of 58.33%. Item number 4 which states "The application can be navigated easily," obtained a mean of 3.67 which translates the verbal description "Strongly Agree" supported by 261 out of 384 respondents with a percentage of 67.97%.

Table V. Accessibility

Accessibility	Mean	Description
The application loads quickly	3.55	Strongly Agree
There were no issues or errors experienced while using the application	3.60	Strongly Agree
The buttons and controls within the application are easy to find and use	3.27	Strongly Agree
The Application can be navigated easily	3.67	Strongly Agree
General Mean	3.52	Strongly Agree

The Application Serves a Purpose

—Table VI presented the reaction of the people if the application Serves a Purpose. Item number 1 which states "The application provides information of flood caused by low to moderate rainfall", obtained a mean of 3.57 which translates verbal description "Strongly Agree" supported by 220 out of 384 respondents with a percentage of 57.29%. Item number 2 which states "The application shows expected level of flood caused by low to moderate rainfall", obtained a mean of 3.76 which translates verbal description "Strongly Agree" supported by 287 out of 384 respondents with a percentage of 74.74%. Item number 3 which states "The application can help the user prepare for the expected low to moderate rainfall", obtained a mean of 3.75 which translates verbal description "Strongly Agree" supported by 291 out of 384 respondents with a percentage of 75.78%. Item number 4 which states "The application can help provide information towards flood risk reduction and management", obtained a mean of 3.43 which translates verbal description "Strongly Agree" supported by 287 out of 384 respondents with a percentage of 74.74%.

Table VI. The Application Serves a Purpose

The Application Serves a Purpose	Mean	Description
The application provides information of flood caused by low to moderate rainfall	3.57	Strongly Agree
The application shows expected level of flood caused by low to moderate rainfall	3.76	Strongly Agree
The application can help the user prepare for the expected low to moderate rainfall	3.75	Strongly Agree
The application can help provide information towards flood risk reduction and management	3.43	Strongly Agree
General Mean	3.63	Strongly Agree

Based on data gathered, the following are determined, the application is Aesthetically Pleasing, User friendly, Useful, Accessible, and The Application Serves a Purpose based on the result of their survey which is all of the gathered aspects general mean is strongly agree.

IV. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

This chapter presents the summary, conclusions and recommendation for the study

4.1 Summary

The study was able to produce an application about Flood Level identification map using Geographic Information System (GIS) in Guagua, Pampanga. The Flood Level Overview of Guagua (FLO-G) application was designed using JSON and Java application software that provide users with information about flood-prone areas and potential flood risks in a given geographic location. The application depicts the possibility of flooding in various places as well as the estimated severity and effect of a flood event using a wide variety of data sources and techniques.

The use of the flood map application can assist people and organizations in making educated choices regarding the placement of infrastructures such as homes, companies, and roads as well as how they should prepare for expected flooding scenarios. The application is capable of helping in preventing unnecessary development in areas susceptible to floods while encouraging the use of flood-resistant construction techniques by detecting places that are at high risk of flooding.

All of the objectives in this study were accomplished, it includes the following:

Developed flood map using an open-source Geographic information system (GIS) software and a flood map application software using a java-based application software development platform that can be accessed through an offline mobile application;

Conducted a pilot testing of Flo G with selected respondents that evaluated and assessed the performance, usability, and effectiveness of the flood map application software;

Carried out a Feedback survey, the evaluation focused on the overall usefulness of the flood map application software. The assessment encompassed its aesthetics, user-friendliness, usefulness, and accessibility

4.2 Conclusions

The following research findings can be concluded from the development and implementation of a flood map application:

1. Improved flood solution: By giving emergency responders and leaders reliable data on flood conditions, they can successfully organize and implement a response to the flood event, which may reduce damage to infrastructure and danger to people.
2. More effective flood management: Flood Level Overview of Guagua (FLOG) application can also be used for establishing long-term flood management plans, such as the positioning of flood control infrastructure or zoning regulations that seek to prevent development in areas prone to flooding.
3. Increased public safety: Those who live in flood-prone areas can be more prepared for flooding calamities as well as prevent harm to themselves and their property through improved flood information and response capabilities.

Overall, the Flood Level Overview of Guagua (FLO-G) application is a technology that has the ability to enhance flood response and management while enhancing safety for residents of flood-prone areas.

4.3 Recommendations

The map produced in this study is from a Geographic Information System (GIS) application based from historical data collected.

- For the application

For future replication of this study, further improvements must be made.

1. The collected data should be updated because improved and additional data become available.
2. Adding data based on high rainfall intensity because this study is only based on low to moderate risk.
3. Enhance the application by having real time data.

4. The application can display real time data when connected through internet.
5. The application can be improved by adding zoom in and zoom out effect on the map to make the maps more interactive.
6. The flood map can also improve by adding different language or translation language.

For future researchers,

1. For a more comprehensive map flood, modeling software such as HEC-HMS and HEC-RAS can be used.
2. The application produced cannot be used by other cities or municipalities. Nonetheless, the method used in producing the application can be adapted as long as the necessary data are available. As for the application additional maps can be added to provide more information that can help the residents.
3. Incorporate, community engagement to collaborate with the chosen community.
4. Explore more functions of GIS to add more data that can be added on the application.

ACKNOWLEDGMENT

First, we would like to entirely give the honor of appreciation to God, who guided and helped us make the entire study. He gave us the strength and wisdom to finish our work, even when we encountered discouragement.

We want to express our sincere gratitude to Engr. Inla Diana C. Salonga, who served as our adviser throughout the process of writing our study. Her expert guidance and unwavering support have been instrumental in helping us complete our work, and we appreciate her willingness to address any questions or concerns we had along the way.

To Engr. John Vincent Tongol, our thesis coordinator, guided and helped us prepare, check, and validate every detail of our study.

To Dean Engr. Jun P Flores, Chairperson Engr. Irene R. Roque and to the civil engineering faculty providing a remarkable academic environment and providing us necessary tools to conduct our research. Their knowledge and unwavering commitment have played a pivotal role in influencing our viewpoints and motivating our academic endeavors their efforts in fostering excellence within us are sincerely appreciated.

To our parents, who gave their full support and encouragement in completing the project, and to appreciate them, who enormously upheld us from the earliest starting point of our study until the end, they also helped us to conquer our limitations.

We express our sincere gratitude to the participants who have provided us with honest feedback, both in terms of criticism and praise, as their cooperation has been invaluable in shaping and improving our work.

REFERENCES

[1] Weather-related disasters increase over past 50 years, causing more damage but fewer deaths. (2021, September 9). World Meteorological Organization. https://public.wmo.int/en/media/press-release/weather-related-disasters-increase-over-past-50-years-causing-more-damage-fewer (Monjardin et al., 2019).

[2] Monjardin, C. E., Cabundocan, C., Ignacio, C., & Tesnado, C. J. (2019). Impact of Climate Change on the Frequency and Severity of Floods in the Pasig-Marikina River Basin. E3S Web of Conferences, 117, 00005. https://doi.org/10.1051/e3sconf/201911700005

[3] Banks, J.C., Camp, J. V., Abkowitz, M. D., (2014). Adaptation planning for floods: a review of available tools. Natural Hazards, 70(2), pp. 1327– 1337.https://citation-needed.springer.com/v2/references/10.1007/s11069-013- 0876-7?format=refman&flavour=citation

[4] Komolafe, A. A., Adegboyega, S. A.-A., & Akinluyi, F. O. (2015). A review of Flood Risk Analysis in Nigeria. American Journal of Environmental Sciences, 11(3), 157–166. https://doi.org/10.3844/ajessp.2015.157.166

[5] M. Viana, C., Abrantes, P., & Rocha, J. (2019). Introductory Chapter: Geographic Information Systems and Science. IntechOpen. doi: 10.5772/intechopen.86121

[6] [8] Rincón, D., Khan, U., & Armenakis, C. (2018). Flood Risk Mapping Using GIS and Multi-Criteria Analysis: A Greater Toronto Area Case Study. Geosciences, 8(8), 275. https://doi.org/10.3390/geosciences8080275

[7] Hagos, Y., Andualem, T. G., Yibeltal, M., & Mengie, M. A. (2022). Flood hazard assessment and mapping using GIS integrated with multi-criteria decision analysis in upper Awash River basin, Ethiopia. Applied Water Science, 12(7). https://doi.org/10.1007/s13201-022-01674-8

[8] A. Lagmay, A. M., 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, 59, 13–23. https://doi.org/10.1016/j.jes.2017.03.014

[9] Lagmay, A. M. F., Agaton, R. P., Bahala, M. A. C., Briones, J. B. L. T., Cabacaba, K. M. C., Caro, C. V. C., Dasallas, L. L., Gonzalo, L. A. L., Ladiero, C. N., Lapidez, J. P., Mungcal, M. T. F., Puno, J. V. R., Ramos, M. M. A. C., Santiago, J., Suarez, J. K., & Tablazon, J. P. (2015). Devastating storm surges of Typhoon Haiyan. International Journal of Disaster Risk Reduction, 11, 1–12. https://doi.org/10.1016/j.ijdrr.2014.10.006

[10] Philippines hit by over half a billion dollars in damages from Typhoon Rai; farming and fishing hardest hit - Philippines. (2022b, January 10). ReliefWeb. https://reliefweb.int/report/philippines/philippines-hit-over-half-billion-dollars-damages-typhoon-rai-farming-and-fishing

[11] Flora, I. O. (2021). Pampanga Agri Damage Reaches p118m; 96 villages remain flooded. SUNSTAR. Retrieved December 10, 2022, from https://www.sunstar.com.ph/article/1902346/pampanga/local-news/pampangaagri-damage-reaches-p118m-96-villages-remainflooded#:~:text=DAMAGE%20from%20flooding%20brought%20by,local%20government%20units%20remain%20flooded.

[12] Hoeppe, P. (2016). Trends in weather related disasters – consequences for insurers and Society. Weather and Climate Extremes, 11, 70–79. https://doi.org/10.1016/j.wace.2015.10.002

[13] Watson, R. (2015). Quantitative research. Nursing Standard, 29(31), 44–48. https://doi.org/10.7748/ns.29.31.44.e8681 (Bhandari, P. (2022). What Is Deductive Reasoning? | Explanation & Examples. Scribbr. https://www.scribbr.com/methodology/deductive-reasoning/

[14] Bhandari, P. (2022). What Is Deductive Reasoning? | Explanation & Examples. Scribbr. https://www.scribbr.com/methodology/deductive-reasoning/

[15] Mukherji, P., & Albon, D. (2022). Research Methods in Early Childhood: An Introductory Guide. SAGE.vol. 24, no. 2, pp. 379–393, Jun. 2015, doi: 10.1080/10618600.2014.901225.