Enhancing Flood Resilience in San Guillermo Village, Tinajero, Bacolor, Pampanga, Philippines: Evaluation of Current Drainage Design and Recommendation of The Provision of Cistern Tank with Pumping System

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Abstract: - Flooding is a problem that requires prompt attention as it endangers the health and safety of the general public, harms homes and businesses, and interrupts transportation and other important services. The physical and mental health of people can be negatively impacted by flooding in a variety of ways. Populations living in flood-prone locations may experience repeated flooding occurrences given predictions that both the frequency and severity of flooding events will continue to rise in the future. It is one of the most catastrophic natural disasters to hit the Philippines. San Guillermo Village, the study area for this research situated in Barangay Tinajero, Bacolor, Pampanga, has been consistently inundated with severe flooding. As a result, identifying a viable solution that will provide relief to the affected residents from the disastrous consequences of such flooding is paramount such as assessing the factors that contribute to flooding in the study area. The hydraulic performance of the existing storm drainage system design was assessed using Manning's equation and Rational Method, and a suitable drainage system design was proposed, including the installation of appropriately sized pipes to improve the system's performance. In addition, this study recommended suitable strategies to mitigate the effects of flooding in the area, such as the provision of a cistern tank with a pumping system. A more detailed calculation of the cistern tank's capacity and size was also conducted to ensure optimal water storage and usage. Overall, these recommendations aim to address the issue of flooding in the study area and to provide effective and sustainable solutions for the benefit of the affected residents.

Key Words: — ***Flooding, Drainage System, Manning's Equation, Rational Method, Cistern Tank, Pumping System.***

I. INTRODUCTION

The Philippines is a disaster hotspot given its location in a region where climate and geophysical storms are prevalent.

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According to the official website of PAGASA, more tropical cyclones (TC) than anywhere else in the world are making landfall in the Philippine Area of Responsibility (PAR). Approximately 8 to 9 of the 20 TCs that pass through this area on average each year also cross the Philippines. Nearly 70% of all typhoons develop during the peak of the typhoon season, which lasts from July through October. The country will unavoidably endure natural disasters such as tropical storms, tsunamis, earthquakes, and volcanic eruptions. These natural disasters cause significant property damage as well as the loss of life. It is anticipated that damage to infrastructure and fatalities will continue and even increase with continuous development and population growth in hazard-prone areas unless the appropriate measures are immediately implemented (Lagmay et al., 2017).

Flooding stands out as one of the most devastating natural disasters that occur in the Philippines. The occurrence of flood risk is influenced by both natural and anthropogenic variables, prompting a deeper comprehension of its geographic extent. Take into consideration the occurring climate change that increases the frequency, magnitude, and seasonality of catastrophic events like floods (Danumah et al., 2016). The majority of people are caught unprepared by the unpredictable rain showers that the Philippine archipelago experiences. Despite these changes in pattern, particularly in low-elevation regions, a multitude of vehicles cannot travel on the roadway due to flooding (Cabrera & Lee 2020). The frequency and size of floods, as well as the concentration of people and economic activity, have all intensified the impact of floods leading to significant harm, including the loss of life, property, and livelihood. (Shrestha et al., 2014). As a result, concurrent flood hazards that are significant to urban flood risk management may occur more frequently in the future (Danumah et al., 2016). Although the government conducted a flood control program and employed new flood equipment, it appears that these measures were unable to resolve the issue. (Ganiron Jr, 2016). Flooding caused by the accumulation of rainwater in low-lying areas is a widespread phenomenon observed across numerous regions globally. When heavy rainfall occurs in areas with low elevation, the excess water has nowhere to go and can quickly overwhelm the natural drainage systems. This can lead to flooding, which can cause damage to homes and businesses, disrupt transportation and other essential services, and even pose a threat to public health and safety.

The impact of rainwater flood due to low elevation can be particularly severe in urban areas, where concrete and other impervious surfaces prevent the water from soaking into the ground. Instead, the water flows over the surface, picking up pollutants and debris along the way. This can contaminate drinking water supplies, create breeding grounds for disease-carrying pests, and even cause buildings and other structures to collapse.

One of the places that experiences severe flooding is San Guillermo Village located at Barangay Tinajero, Bacolor, Pampanga. During the Super Typhoon Karding, the village experienced flooding that is two feet high due to heavy rains which causes evacuation of the residents. (MDRRMO-Bacolor, 2022).

According to the Office of the Municipal Engineer and the official report of the Municipal Disaster Risk Reduction and Management Office (MDRRMO) of the Municipality of Bacolor, flooding in San Guillermo Village lasts from 3 to 5 days. It is also evident that the elevation of the road leading to the village is decreasing based on the naked eye. Rainwater flooding due to low elevation is a serious concern, but by taking the right steps, it is possible to reduce the impact of flooding on communities and protect people and property from harm.

According to H.M.Ranghunath (2006) in Melese Chanies 2011 thesis, urban flooding is particular in that it occurs as a result of inadequate drainage systems within urbanized regions. Nearly all of the precipitation needs to be transferred to surface water or the sewage system because there isn't much open land that can be used to store water. Flooding can be triggered by intense rainfall when the capacity of the city's sewage system and drainage canals falls short in effectively managing the excessive precipitation.

Flood control methods are implemented with the primary objective of mitigating the adverse consequences caused by flooding. These techniques aim to minimize or even prevent the detrimental impacts of floodwaters, including but not limited to property damage, infrastructure loss, loss of human lives, and economic disruption. By leveraging effective flood control methods, communities can better prepare for and respond to flood events, thereby reducing the risk of catastrophic outcomes and enhancing the overall resilience of the region (Ghayar et al.,2020).

In the Philippines, installing cistern tanks with pumping equipment might help reduce flooding in local communities. In metropolitan settings, especially in low-lying neighborhoods that are prone to flooding, underground cistern tanks can successfully store rainwater and greatly minimize flooding (Dimaiwat et al., 2019). The study emphasizes how this strategy might aid in reducing floods during rainy seasons and minimize water resource pollution, which can result in a number of waterborne illnesses.

The possibility of rainwater collection devices, particularly cistern tanks, to alleviate the issues of floods in the Philippines. In metropolitan locations, where typical stormwater management systems are difficult to deploy due to high population density and a lack of open space, the study claims that rainwater collecting is an efficient way to reduce floods. According to the study, coupling cistern tanks with a pumping system can assist in releasing flood water that has been stored into nearby bodies of water or other storage tanks, successfully reducing flood damage and protecting the community's infrastructure (Flores et al., 2017)

A pumping system for flood water disposal can be a valuable tool for managing to flood and protecting communities from harm. By removing excess water from low-lying areas and safely disposing of it at higher elevations, a pumping system can help to reduce the risk of damage and improve public safety.

There are several advantages to using a pumping system for flood water disposal. One of the most significant benefits is that it can prevent damage to homes and businesses, as well as other important infrastructure. By removing excess water from flood-prone areas, a pumping system can help to protect buildings, roads, and other structures from being damaged by flooding.

Cistern tanks with a pumping system can be an effective flood mitigation solution by lowering the volume of stormwater runoff during high rainfall events and minimizing flood damage in metropolitan areas. Excess rainwater can be collected and stored in cistern tanks, then pumped out when necessary to prevent floods. This technique can improve urban resilience to flooding while simultaneously supporting sustainable water management practices. By examining the performance of cistern tanks with a pumping system and identifying the major aspects that contribute to their success, urban planners and policymakers may make educated judgments about incorporating this flood prevention approach into urban planning and design.

Cistern tanks with a pumping system are gaining prominence as a viable technique for minimizing the devastating impacts of floods in urban areas. According to M. M. Hasan, M. A. Akbar, and M. A. Hossain (2014), multiple factors such as the size of the cistern tank, pump capacity, rainfall intensity, and even the type of pump utilized all have an impact on system performance. A higher tank size, for example, can enhance the system's storage capacity, allowing for the storage of a larger volume of rainwater during severe rainfall events. Meanwhile, a larger capacity pump can quickly move water from the cistern tank to a drainage system or other waterways. These elements can have a substantial impact on the system's effectiveness in reducing flood damage. Furthermore, the incorporation of a pumping system allows for greater flexibility and control over the water held in the cistern tank, allowing urban planners to better manage water supplies in their particular locations.

II. Methodology

This chapter comes out with the data gathering and field surveying for identifying the location of the lowest point of the village. The aim of this study is to help mitigate the flooding at San Guillermo Village, Barangay Tinajero, Bacolor, Pampanga. The researchers aim to obtain answers to these questions (1) What are the causes of flooding at San Guillermo Village, Barangay Tinajero, Bacolor, Pampanga? (2) What methods must be implemented to mitigate flooding at San Guillermo Village, Barangay Tinajero, Bacolor, Pampanga? (3) Does the current drainage system work effectively? (4) What is the present state or condition of the drainage system in San Guillermo Village?

A mixed-method design combining quantitative and qualitative methods will be used in this study. Qualitative method which entails the systematic collection and analysis of numerical data in order to measure and describe variables, and test hypotheses through statistical analysis. Using quantitative methods to gather objective and precise data that can be analyzed using statistical tools to identify patterns, relationships, and trends within the data. That will base predictions on solid empirical data and draw trustworthy findings. Quantitative approaches can also offer an organized and exacting approach to research, enabling the use of standardized practices that can be repeated and applied to bigger populations. In the end, applying a quantitative approach offers a solid and objective means of comprehending complex events and making decisions that are supported by solid information.

In obtaining the data necessary for the study, the researchers have adopted the Analysis Method because it allows the researcher to gather data from existing documents, such as reports, memos, and other written materials. This method can provide valuable insights into a topic and support or refute research hypotheses, making it a useful tool for conducting a thorough investigation. Numerical data was also utilized in this study, which involved conducting field surveying and measuring the areas of the catchment based on their land use. Additionally, the study utilized various mathematical formulas to perform necessary computations. These methods allowed the research team to obtain precise and accurate numerical data, which was essential in achieving the objectives of the study.

For this study, information and data collection were obtained via two sources which include: Primary and secondary sources.

2.1 Primary sources

2.1.1 Administering of Interviews

Interviews for specialists such as civil engineer, a master plumber and a concerned body like the head of municipality, the municipal engineer and government agencies concerning the most likely causes, effect of water drainage challenges of the drainage systems in the chosen locations.

2.1.2 Study Area Observations

To accurately represent existing drainage conditions, this study will use photographic documentation of several drainage conditions in the study area.

2.2 Secondary Sources

Other secondary sources of information that will be used include books, journals, manuals, conference proceedings, etc. Both quantitative and qualitative techniques in data collection and analysis will be utilized as main instruments.

The primary focus of this thesis will be the performance assessment of the drainage systems within San Guillermo Village. As a result, the data obtained will be critically analyzed in accordance with the results from interviews, official reviews and record data.

The final data will be provided in a suitable format such as tabular, graphical, and will include a summary and recommendations for the problem that the study identified.

The main steps that are used to address the objectives of this study are;

2.3 Delineate watershed

- Applying hydrological or mathematical equation to determine peak runoff Estimation of Time of concentration
- Estimation of Rainfall Intensity by using Tc (Time of Concentration) and RIDF
- Estimation of weighted runoff coefficient based on land use composition, and its percent of area coverage, soil type and permeability.
- Estimation of peak discharge by using rational method

Estimation of hydraulic parameters by using Manning's equation for existing, proposed and fixing the size of drainage structures.

The final step is to solve the problem of the locale based on the analysis and by recommending possible mitigation measures.

The materials used for this research are:

- Profile Levelling to obtain hydrological and physical parameters and spatial information of the catchments of the study area.
- Google Earth Software to verify watersheds and divides of catchments of the study area.
- Measuring tape.
- Hydrological data

The research locale for this study was San Guillermo Village, located in Bacolor, Pampanga. This area was chosen due to its susceptibility to flooding within the municipality, making it a particularly vulnerable location. Additionally, San Guillermo Village is densely populated and has numerous settlements, making it a crucial research site for investigating effective flood mitigation strategies in such settings. The choice of San Guillermo Village as the research locale provides a valuable opportunity to study and develop practical flood mitigation strategies that can help protect the community from the adverse effects of flooding.

Data Gathering is the process of acquiring and analyzing information about a study in a suitable, methodical way that enables one to answer to stated research questions, hypotheses, and outcome evaluations. It is essential to ensure that the data are gathered properly and precisely. Regardless of the research topic or preference for categorizing data as either quantitative or qualitative, accurate data collection is essential to maintaining the standard of the study.

A mixed-methods strategy will be used in this study to integrate quantitative and qualitative methods. The quantitative approach entails the collection and statistical analysis of numerical data to measure variables, test hypotheses, and spot trends. Utilizing quantitative techniques will yield accurate and objective data that will allow for trustworthy forecasts and conclusions. Quantitative techniques also offer a structured and repeatable research methodology that may be used with bigger populations. In the end, this strategy guarantees a thorough and impartial comprehension of complicated events and makes it easier to make wise decisions based on solid facts.

In the qualitative component of this study, conducting interviews with experts who have the essential knowledge, such as civil engineers, architects, and master plumbers, is suitable and necessary. As these experts can provide a wealth of knowledge and experience regarding the evaluation of drainage systems and the implementation of flood-resistant infrastructure, the insights gained from such interviews would prove instrumental in informing the development and execution of the study in question. The rigor, thoroughness, and practical applicability of the study's findings and suggestions may therefore be significantly improved by the inclusion of interviews with such specialists.

Collecting data from various government agencies with authorization, such as the Local Government Unit (LGU), PAG-ASA, National Housing Authority (NHA) and Municipality of Bacolor is a crucial part and also serves as one of the foundations for the completion of this study. The collected data from LGU and the Municipality of Bacolor includes necessary information regarding the study area such as maps. In PAG-ASA, the recorded rainfall within the rain gauge stations around the area while in the National Housing Authority, the existing dimensions of the drainage and Department of Public Works and Highways (DPWH) for the guidelines for the design standards which will be used for the designing of the drainage system.

The collected data were subjected to a rigorous analysis process that involved utilizing both tabular and descriptive methods. The tabular method involved organizing the data into tables and presenting it in a systematic and logical manner to aid in easy comprehension and interpretation. On the other hand, the descriptive method was used to compare the results and to identify patterns, trends, and relationships between variables. This approach enabled a comprehensive understanding of the data, highlighting key insights and providing meaningful interpretations of the results. By utilizing these analysis techniques, the study was able to derive valuable findings and contribute to the existing body of knowledge in the field.

III. Results And Discussion

Existing drainage facilities located in San Guillermo Village are classified as closed drainage lines, which are made of concrete pipe conduit. The sizes of the conduits are 450mm and 600mm. The 600mm conduits are found along the lowest elevation of the area where the undeveloped outfall is located, while the 450mm conduits are located along the remaining roads in San Guillermo Village.

In terms of effectiveness and quality, the drainage service in the area can be deemed deficient. The San Guillermo Village's stormwater drainage system is currently inefficient, which causes design, construction, and management issues. Therefore, it is essential to carefully construct the stormwater drainage master plan.

The main challenges of the current drainage system are:

- Drainage systems are not well connected
- Ponds or other spaces are not properly allocated to accommodate overflow of flooding
- Most of existing drainage ditches have been silted by sand and other rubbish materials
- Inefficient drainage outfall

Numerous issues with the existing drainage system lead to waterlogging and floods. Poor connection between drainage components, a lack of ponds to store excess water, siltation of drainage ditches, and ineffective drainage outfall are some of these issues. Damage to infrastructure, including houses, companies, and infrastructure, may occur from these problems. To increase the drainage system's efficacy and resilience, it is imperative that these issues be addressed.

IV. Summary Of Findings

The findings provide a comprehensive analysis of several factors that affect the drainage system in San Guillermo Village. The evaluation includes the assessment of existing drainage design, accumulation of rainfall data, hydrological modeling, survey results, and provision of drainage system design. Based on the assessment, it was found that the drainage facilities in the village are inefficient due to various issues, including silted drainage ditches, insufficient culvert size for drainage and undeveloped drainage outfall. To ensure proper protection against flooding, the study utilized rainfall intensity-duration frequency analysis data to identify suitable design standards and safety measures. Also, the field survey results revealed that the village is located in an area with a low elevation, making it more susceptible to flooding. To determine the appropriate design of the drainage system, the study employed the Rational Method, a widely used approach for estimating peak flows from small drainages with significant impervious areas. Overall, the results provide a detailed and insightful analysis of the drainage system in San Guillermo Village, which can be useful for identifying appropriate measures to improve the current drainage infrastructure.

V. Conclusion

San Guillermo Village is prone to flooding due to its low elevation, which makes it susceptible to water runoff. After conducting a thorough analysis of the available data, it has been determined that the existing drainage system is inadequate to handle the amount of water runoff in the area. Specifically, the size of the current drainage pipe is insufficient to accommodate the water runoff, which contributes to the frequent flooding that forces residents to evacuate during heavy rain and typhoons. The insufficiency of the drainage system exacerbates the impact of natural disasters, causing severe damage to infrastructure, properties, and health of the people in the village. The implementation of the proposed design will help to minimize these effects and improve the water management in the village. An underground rainwater cistern tank can serve as a promising solution to minimize flooding in areas that are prone to water runoff. This system is designed to collect and dispose of rainwater, which would otherwise contribute to water runoff and aggravate flooding. By collecting the amount of water runoff in an underground rainwater cistern tank and transporting it to the nearest creek, the flood in low-lying areas such as San Guillermo Village can be mitigated.

Flooding issues at San Guillermo village can be minimized by installation of a pumping system that pumps rainfall from an underground cistern tank to a nearby creek that is located at higher elevation. The system works by moving rainwater collected in the cistern from the village to a creek at a higher elevation, helping to safeguard infrastructure and property against flood damage. The community and the environment may be negatively impacted by soil erosion and waterlogging, which can be reduced with the aid of this technology. To ensure the system's effectiveness and dependability, it is vital to make sure it is well-designed and maintained.

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