Flood Risk Assessment of the Existing Suburban Drainage System in Lagundi, Mexico, Pampanga

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Abstract: - This research assesses the suburban drainage system in Lagundi, Mexico, Pampanga, focusing on the relationship between drainage and flooding. The study gathers rainfall data, drainage system blueprint, and municipality CLUP, and analyzes it using hydrologic and hydraulic methods. The study uses software like ArcGIS, HEC-HMS, and SWMM to simulate water flow and evaluate the drainage system's capability. The flood hazard map is a valuable resource for the community and LGUs in Lagundi, Mexico.

Key Words: — *Flood Hazard Map, Flood Risk Assessment, Suburban Drainage System.*

I. INTRODUCTION

Brown [1] stated "The Philippines is the Most Storm-Exposed Country on Earth", in 2013. Typhoons frequently hit the Philippine Area of Responsibility (PAR), with 20 tropical cyclones on average per year [2]. This series result in heavy rainfall, leading to flooding. The World Bank's data shows a rise from 2529.66 mm in 2020 to 2826.17 mm in 2021, primarily due to flood-prone areas [3].

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Flooding in the Philippines is primarily experienced in urban settings, with lower elevations being particularly affected. The intensity and frequency of storms significantly impact inundation. However, infrastructures like drainage channels in cities, such as underground and exposed systems, help control waterways and reduce floods. These systems collect excess water from private and public properties and redirect it to large bodies of water or predetermined basins for water retention. While many municipalities and towns in the Philippines are well-equipped to mitigate heavy rainfall effects, many regions still face severe consequences from rainstorms, particularly flooding.

The Philippines, a tropical country in the western Pacific Ocean receives frequent rainfall. According to PAGASA [4] , the country experiences wet and dry seasons, with frequent flooding in Region III, Central Luzon, particularly in Pampanga province.

Calipusan and Salas [5] (2017) stated that Mexico, Pampanga faces challenges due to its low elevation and four major rivers: Betis River, Abacan River, Mexico River, Bungang Guinto River, and Mexico River. These rivers are geographically inherent and susceptible to flooding, but significant waterways ensure water flow through the municipality.

Lagundi Village in Mexico, Pampanga, faces flooding due to moderate to heavy rain, despite a drainage system in place, causing inconvenience and typhoon-related issues. Also, from the statement in the Official Gazette [6] (2016), the village was covered in floodwaters of one to two feet in level that lasted for several weeks.

A study of Sohn, et al., [7] (2020) found that 92% of flood damage costs can be retained if there is an established drainage system or storage-based facilities.

The researcher's aim was to assess the rainfall in Lagundi, Mexico, Pampanga and determine if the existing drainage system can handle this amount. At the end of the study, the researchers' goal is to create a flood hazard map that is important in flood risk management and risk reduction.

The intent of this research is to assess the existing drainage system in Lagundi, Mexico, Pampanga and to investigate the flood risks associated with it.

The specific objectives are as follows: (1) to perform the hydrologic assessment in Lagundi, Mexico, Pampanga through HEC-HMS software, (2) to assess the efficiency of the drainage system in Lagundi, Mexico, Pampanga through SWMM, and; (3) to create a flood hazard map with 100 years return period.

II. REVIEW OF RELATED LITERATURE

Kittipongvises, et al. [8] published "AHP-GIS Analysis for Flood Hazard Assessment of the Communities near the World Heritage Site in Ayutthaya Island, Thailand. International Journal of Disaster Risk Reduction" in 2020. It is said that tropical storms cause severe flooding, posing danger to lives and property, affecting around one billion people in flood-prone areas. According to Duan, et al. [9] in 2015, climate change increases extreme floods' frequency, magnitude, and seasonality, causing severe effects and increasing risks in extreme hydrological events.

According to the [8] climate model, Global climate change is causing a 187% increase in flood probability by 2050 due to increasing rainfall and extreme precipitation events. This leads to increased urban flooding unless measures are taken to reduce its impacts.

As shown by Feng et al. [10] in 2021. Another factor that contributes to flooding is urbanization. Urbanization increases impervious land, reducing hydrological response time and increasing flooding hazards, leading to faster peak runoff and discharge times.

As per the conclusion reached by the report of Galloway et al. [11] it was shown that urban floods increase due to suburban development, inadequate infrastructure, inadequate drainage systems, and disorganized watershed management.

There are many ways to control or avoid flooding; one of them is a drainage system. In the research of S. Islam and A. Islam [12] in the year 2021, it is stated that a drainage channel is crucial for community sustainability, directing rainwater to basins, and must be engineered to prevent failure and maintain efficiency even during heavy rain.

In the study of Sarminingsih [13] (2019), it is said that a study collects channel measurement, drainage system, inundation, rain station maps, site maps, and land use to calculate water movement.

As mentioned earlier [12], it states that drainage system malfunctions impact cleanliness and public health by disrupting flow, causing stagnation, low self-cleansing velocity, and insufficient gradient.

A proper flood risk assessment requires operative modeling and a systematic approach, including hazard mapping to identify areas prone to severe flooding and assess water levels.

Demir V. et al. [14] published "Flood Hazard Mapping by Using Geographic Information System and Hydraulic Model: Mert River, Samsun, Turkey" (2015), have noted that flooding, a major natural disaster worldwide, causes hundreds of deaths and billions of dollars in property and infrastructure losses. Accurate flood damage maps can help avoid and mitigate these risks.

According to the study of Panigrahi B., (2016) [15], The Hydrologic Modeling System (HEC-HMS) is a US Army Corps software designes to simulate precipitation and runoff effects in various geographic contexts. It includes rainfall to runoff and open-channel routing. It utilizes event-based hydrological modeling for direct and depth of runoff, base-flow, and channel-related route procedures, based on data availability, suitability, and researcher recommendations.

In the study of Thakur B. et al. (2017) [16], precipitation is the primary source of runoff and flooding, influenced by factors like land use, soil type, evaporation, and storage. HEC-HMS models rainfall runoff events.

US-EPA, [17] (2023) has shown another software that the researchers would be using is the Storm Water Management Model, or SWMM, which is a modeling software that is used for water and sanitation. The free software, SWMM, is available online and is used to test water runoff quality and quantity in urban areas. SWMM is primarily used for single-event or long-term simulations, updating input data, running simulations, and assessing outcomes using various tools, such as color-coded maps, statistical frequency analyses, and time series graphs.

Stated in the study of Palaka, R. et al. [18] (2021) that the primary goal is to design stormwater drainage systems that can remove flood water without flooding low-lying areas. The study involves GPS land surveying, identifying road networks and drainage systems, leveling, and catchment delineation. The software ArcGIS helps in determining drainage flow direction and elevations, ultimately improving the drainage system. The software ArcGIS (Geographic Information System) would be utilized in the process of completing this thesis. Demirci, A. [19] (as cited in Korucu, 2012) have stated that GIS data, or Geographic Information Systems, analyzes Earth's properties and human traits through data collection, presenting results in a database with accurate coordinates and graphs, charts, and maps.

In the study of Gacu et al. [20] (2022), The GIS aids in assessing flood risk through a standardized evaluation process, ensuring comparability and accuracy by merging unique data and establishing national criteria.

Drainage systems are crucial in communities to prevent flooding and transfer excess water to nearby basins. Proper design and implementation of drainage systems are essential for both residents and the environment. Digital era programs have made it easier to test the efficiency of drainage systems, saving time and money on costly repairs.

III. METHODOLOGY

According to Streefkerk [21] (2019), inductive reasoning seeks to work out a theory, while deductive reasoning's goal is to test a theory that already exists. Since the researchers plan is to assess the current drainage system in Lagundi, Mexico, it is then concluded that this study falls under deductive research. Quantitative research was utilized in this study and was non-experimental. In the study of Creswell [22] (2014), quantitative research methods entail gathering, evaluating, interpreting, and documenting study data. The aim of this research is to utilize the gathered data and make use of it in the software to simulate the existing drainage system in Lagundi, Mexico, Pampanga.The data collection process in this study is based on the stormwater modeling and management procedures of Kuang (as cited in Eslamian, 2014) [23]. Modeling of stormwater was used to identify the direction of flow, rates of flow, elevations of water, pollutants, and concentrations of contaminants at a specific location both while and after a storm occurrence.

For the accomplishment of the analysis in the study, rainfall data is required. Rainfall is the most typical type of precipitation in which water droplets fall to the ground, according to Supriya [24] (2022). This has a significant impact on the earth's water resources and the ecological cycle. In the Philippines, rainfall is the most important factor considered by hydrologists to determine the possible threats of flooding. In this study, the Rainfall Intensity Duration Frequency, or RIDF, is the primary data needed by the proponents. To have this information, a request letter to a PAGASA station in Quezon City was sent. To calculate the runoff, the study area's typical rainfall amount was necessary. That value was then inputted into the software used, and through that, the researchers were able to determine if the current drainage system is still capable of accommodating that measure. And if it can still be transported to the drainage basin.

One of the vital pieces of data needed in this study is the blueprint of the drainage system in the area.To be permitted to have a copy of the drainage plan in every *sitios* of Lagundi, attendants of the Engineering Office of the municipality of Mexico, Pampanga, required the proponents to send a formal letter to the Municipal Mayor and addressed it to the Acting Municipal Engineer of the town. The same procedure was followed for the blueprint of the drainage system along the main road, and the request letter was addressed to the Regional Director of the Department of Public Works and Highways, or DPWH. The information in the blueprint like the materials, dimensions, elevation, and section view of the drainage system were used in this study. For those other places where the drainage is made by the residents, the researchers conducted an actual measurement of these channels. To determine the length of these waterways, Google Maps was utilized. To be permitted to have a copy of the drainage plan in every *sitios* of Lagundi, attendants of the Engineering Office of the municipality of Mexico, Pampanga, required the proponents to send a formal letter to the Municipal Mayor and addressed it to the Acting Municipal Engineer of the town. The same procedure was followed for the blueprint of the drainage system along the main road, and the request letter was addressed to the Regional Director of the Department of Public Works and Highways, or DPWH.

The information in the blueprint like the materials, dimensions, elevation, and section view of the drainage system were used in this study. For those other places where the drainage is made by the residents, the researchers conducted an actual measurement of these channels. To determine the length of these waterways, Google Maps was utilized. This information can be collected from the mandated CLUP of the municipality. To have a copy of this, the researchers were advised by the Municipal Planning and Development Coordinator Office's representative to download the soft copy from the municipality's official website for better access.

An actual onsite observation was performed on the current state of the drainage system. The observed info needed are the fills or sediments, particularly sand and other debris, that may occupy some parts of the channels of the drainage system in the barangay. To obtain these, the researchers considered each of the sections of the drainage system and executed manual measurements to determine the volume of the fills or sediments.

To measure the sediment depth in the catch basin, the researchers observed the procedures of the Public Works Department [25]. The first procedure to be done was to remove the manhole cover and identify the sump depth by using a rod. To do this, dip the rod into the water and sediment until it reaches the catch basin's bottom; the water level will then be visible for measurement. In typical circumstances, the water level must be parallel to the outflow pipe. The researchers ensured that the rod contacted the top of the sediment by dipping it into the water. The chalk is used to indicate its location in relation to a fixed point in the catch basin, and that is Position 1. Mark the rod with reference to the same stationary point as in item 1 above after inserting the rod through the water and sediment until it touches the bottom of the catch basin, and that is Position 2. The difference between the two marks is the sediment depth. The water mark left on the rod is the sump depth.

However, in this study, the removal of the manhole cover, especially on the areas where drainage is covered, was not executed due to the requirement of manpower and machine power for this procedure because most covers are fixed. Instead, the researchers inserted the rod into the hole of these covers.

The data analysis and evaluation in this study are divided into three parts. The first part is hydrological characteristics analysis, which includes the calculation of runoff due to rain using the rational method. The rational method is based on the assumption that a given precipitation intensity is evenly distributed over the region and that the most distant part of the basin has valid rainfall over a period of time, known as the time of concentration, Tc, to arrive at the basin outlet. The relationship for peak runoff rate Qp is expressed as follows:

$$Q_p = \frac{1}{3.6}CIA = 0.278CIA$$

where Q_p is the peak discharge for a given rainfall intensity in $\frac{m^3}{s}$, C is the coefficient of runoff, I is the intensity of rainfall in $\frac{mm}{hr}$, and A is the area of the catchment in km^2.

In this study, the Rational method is used because it is when the peak flow is thought to happen when the watershed is providing runoff, therefore soil is impervious.

The runoff coefficient explains how local land use, soil storage, and infiltration conditions relate to rainfall and runoff. These values are from the United States Department of Agriculture, U.S. Soil Conservation Service. Technical Release 55: Urban Hydrology for Small Watersheds.

Table.1. Runoff Coefficient C for the Study Area

Land Use	Runoff Coefficient C_i
Business (Downtown area)	0.9
Suburban residence	0.60
Concrete pavements	0.85
Unimproved area	0.20

Catchments in urban areas are composed of different surface areas. Considering that, a composite analysis must be used to determine the runoff coefficient. It is calculated based on the formula:

$$\bar{C} = \frac{\sum_{i=1}^{n} C_i A_i}{A_{total}}$$

where C_i is the runoff coefficient value for a specific land use, A_i is the catchment size of the specific land use, and;A_{total} is the summation of the sizes of the catchments of all land use types.

Rainfall Intensity (I)

An indicator of rainfall intensity is measured by how much rain falls over time. The cumulative depth of the water layer that covers the ground serves as a gauge for rain's strength. The intensity of rainfall is acquired by using the formula below. Tc.

$$I = \frac{d_{max}}{Tc}$$

where I is the rainfall intensity, Tc is the time concentration, and d_{max} actual rainfall depth in a given time duration which is computed through interpolation.

Time of Concentration (T_c)

The most commonly used formula for determining the time of concentration is provided by Kirpich (1940) wherein the equation is expressed as;

$$T_C = 0.01947L^{0.77}s^{-0.385}$$

where Tc is the time of concentration in minutes, L is the maximum length of travel of water in meters, s is the slope of the drainage basin in which H is the difference between the most remote point of the basin and its outlet in meters.

The second part is hydraulic analysis, which is flood and drainage system channel modeling; these are performed through HEC-HMS and SWMM, respectively.

The drainage system is composed of rectangular channels made out of concrete of different sizes. Upon the analysis of the capacity of the drainage channels, the inundation in the area will be determined. Rainwater is typically collected in an urban area by sheet flow, pipes, and creeks and brought downstream. A chezy formula is frequently utilized to determine the collecting system capacity for both pipelines and open channels:

$$V = C\sqrt{RS}$$
$$Q = AC\sqrt{RS}$$

where v is the velocity in $\frac{m}{s}$, n is the dimensionless Manning's roughness coefficient, Q is the discharge of the volumetric flow, $R = \frac{A}{P}$ is the hydraulic radius obtained in m, where A is the cross-sectional area of the channel and P is the wetted perimeter of the channel, $S = \frac{hf}{L}$ is the dimensionless slope of the energy grade line, L is the length of the channel, C is the chezy coefficient wherein it can be solve in SI units by using the Manning formula $C = \frac{1}{n}R^{\frac{1}{6}}$.

The drainage system channel was accumulated by the DPWH and LGU. Unfortunately, the blueprint of the existing drainage on the main road was not available. Instead, they provided the typical cross-section that is similar to that drainage channel. The researchers then used the provided data and verified the dimensions through actual observation. To get the geographic information, like the elevation, Google Earth Pro was utilized. Google Earth Pro is a software that allows users to stimulate, assess, visualize and create geospatial data.

HEC-HMS and SWMM were utilized for the simulation through hydrologic and hydraulic modeling in the study. HEC-HMS version 4.10 was used in flood routing to know how rainfall occurring upstream of a city will change as it approaches the city. In comparison, SWMM version 5.2.3 was employed to determine the direction of flow of the runoff and locate the sections on each channel where an overflow might occur.

The last part is the flood hazard mapping. Data outputs from the previous phases are then applied in ARC-GIS to create the product of the assessment, which is the flood hazard map.

In creating flood hazard maps, several types of information are required. Information on the areas prone to flooding is required to create flood maps. Information on the population and their residences, social infrastructure, including schools and hospitals, transportation infrastructure, industrial sites, agricultural land, protected areas, and other kinds of assets and natural features are all included in this. To make the actual flood hazard map, a significant quantity of input data is needed, including spatial data such as information on land usage, digital terrain models, river cross sections, hydrological data, and meteorological data, and operational rules information. To model how flooding spreads across the landscape, hydrological and hydrodynamic models are fed with this information. Modeling is done for hypothetical flood events with low, medium, and high probabilities, such as floods that only happen once every 1000, 100, 10, or 20 years, according to statistics (Fischer & Stanchev, 2022) [26].

In this paper, the researchers aimed to illustrate a flood hazard map with 100 years return period. The 100-year reign return period aims to present the efficacy of the drainage system in the study area. This flood hazard is the product of the analysis made in HEC-HMS and SWMM but is rendered using ARC-GIS.

IV. RESULTS AND DISCUSSION

4.1 Part I - Hydrological Characteristics Analysis

Before the actual hydrologic analysis takes place, several inputs are acquired. The collected information from the mandated CLUP of the municipality is presented in Table 2. In the given CLUP, the existing land use of barangay Lagundi is in 2017.

Table.2. Area of Existing Land Use of Barangay Lagundi in 2017

Land Use	Size (ha)
Agricultural	62.31
Commercial	43.45
Buffer/ Greenbelt	4.25
Industrial	3.50
Infrastructure	17.07
Institutional	0.48
Residential	63.55
Socialized Housing Zones	2.37
Total Area:	**196.98**

Since the study area is composed of different land uses, the runoff coefficient value to be used was computed through composite analysis. Commercial, industrial, and institutional land use were categorized under business or downtown areas. Residential and socialized housing zones fall on suburban residences. Infrastructures are the horizontal facilities that serve transportation, like roads, which are made out of concrete pavements. Agricultural and buffer/greenbelts areas were classified as part of the unimproved areas. The area and coefficient of each land use, along with their runoff coefficients, were presented in Table 3.

$$\underline{C} = \frac{\sum_{i=1}^{n} C_i A_i}{A_{total}} = \frac{110.0605}{196.98} = 0.56$$

In computing the peak discharge, 100-year rain return period was used. The return period, often referred to as the "reccurence interval", assesses the likelihood of any events occurring in one year. These events include natural disasters like floods (Saksena, n.d.) [27].

Table.3: Composite Analysis of the Runoff Coefficient and Land Use Area

Land use	Runoff Coefficient Ci	Area (ha)	Ci x A (ha)
Business (Downtown area)	0.9	47.43	42. 687
Suburban residence	0.60	65.92	39.552
Concrete pavements	0.85	17.07	14.509
Unimproved area	0.20	66.56	13.312
			Σ Ci x A=110.0605

The importance of the structure determines the return period for highway drainage design. Highways and other regional transportation infrastructure, including culverts, typically have return periods ranging from 25 to 100 years (Ponce, 2008) [28]. Since the study area has highway drainage, a 100-year rain return period was used in this research to ensure the maximum functionality of the drainage system.

Barangay Lagundi stretches along Jose Abad Santos Avenue, locally known as JASA. It also consists of three sitios, namely Troso, Bulaklak, and Paroba, that are found straight from the corners of the main road. Drainage systems on the main road and in Sitio Bulaklak were constructed under the supervision of DPWH, while in Sitio Troso they were made by the residents only. Unfortunately, Sitio Paroba has no drainage system at all.

Table.4. Computed Extreme Values (in mm) of Precipitation based on 100 years return period

Time Duration (mins)	30	48.670	60
Rainfall Depth (mm)	102.5	x	153.8

$$d_{max} = \frac{30 - 48.670}{30 - 60} = \frac{102.5 - x}{102.5 - 153.8}$$

$$d_{max} = 134.4257\ mm$$

The rainfall intensity was calculated using the given formula below:

$$I = \frac{d_{max}}{Tc} = (\frac{134.4257mm}{48.670mins}) \text{ x } \frac{60mins}{1hrs} = 165.718 \frac{mm}{hr}$$

The peak discharge, Q_p was calculated using the below equation:

$$Q_p = \frac{1}{3.6} CIA = \frac{1}{3.6}(0.56)(165.718 \frac{mm}{hr})(1.9698km^2) = \mathbf{50.778 \frac{m^3}{s}}$$

The sediments inside the channel were subtracted from the actual depth. After acquiring the dimensions, each channel was cut based on their elevations. Sewers are made from concrete in normal condition and have manholes and inlets, the manning's constant used was $n = 0.015$. The n value or roughness coefficient is based on the Manning's n for open channels. Thereafter, the minimum velocity and minimum discharge capacity can be determined.

The flood analysis is based on the unsteady flow conditions. The peak discharge data from a 100-year rain. From the results of the manual computations, the flow rate of the actual runoff compared to the flow rate capacity of the drainage channels, the drainage cannot accommodate the volume of water. The manual computations show that as the velocity of flow increases, there is also an increase in the discharge capacity.

The quantified values for the runoff's peak discharge and discharge capacity of the channels were then used for the actual hydraulic analysis. They were inputs that are interpreted in the software through modeling the inundation and the functioning of the drainage system in Barangay Lagundi.

4.2 Part II - Hydraulic Analysis

The hydraulic analysis was performed through HEC-HMS and SWMM.

The first simulation was done using HEC-HMS version 4.10 with steady flow simulation. The elevation of the area is obtained through layers of GIS data and formed a Digital Elevation Model or DEM. This DEM has a range of 6.5m to 9.5m elevation, the peak discharge is $50.778 \frac{m^3}{s}$.

Figure 1 is the result of the simulation using HEC-HMS. The inundation is represented in gradations of color. As the shade darkens, the depth of the inundation rises.

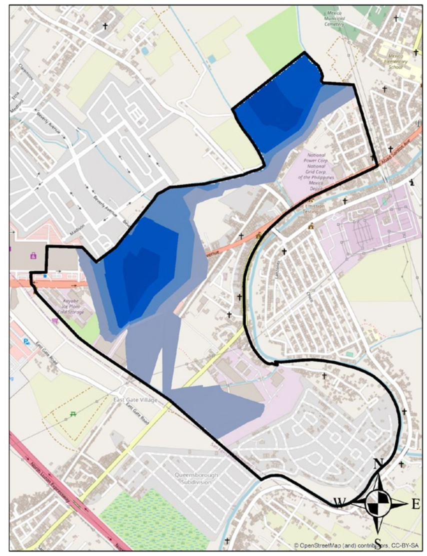

Fig.1. Simulation Result of 100-year rain return period in HEC-HMS

Storm Water Management Model was used to simulate the water flow of the drainage in the study area. SWMM can replicate rainfall, runoff, evaporation, infiltration, and the connection of groundwater to roots, roadways, grassy areas, rain gardens, ditches and pipes. It is also used to make a simple hydrological model.

The map of the study area was used as a basis to determine the subcatchments, the drainage line in the main road, the sitios, and the catch basin where the water would go. Inserting the map would make it easier to determine the areas affected by the water flow; it serves as an actual representation and helps in figuring out which part of the study area is most affected.

To run a simulation using the software SWMM, first identify the subcatchments in the study area. A subcatchment in the network represents the physical area from which a manhole or other inflow node collects water. In this process, researchers have identified five subcatchments, which are the Sitio Troso, whereas Sitio Bulaklak and the Main Road are divided into two. Afterward, the junction nodes are identified. The junction nodes are usually located at the ends of each drainage. These junction nodes would be used to identify the route of the drainage system. Subsequently, determine the outfall node, also known as the catch basin, where the excess water will be disposed of.

A conduit link is used to connect the junction nodes in the direction of the water flow going to the outfall node. After determining all the required attributes, the rain gauge can be added. Under the rain gauge, input the rainfall intensity in its property according to the year of return period. After completing all the procedures and entering all inputs, the simulation can be done.

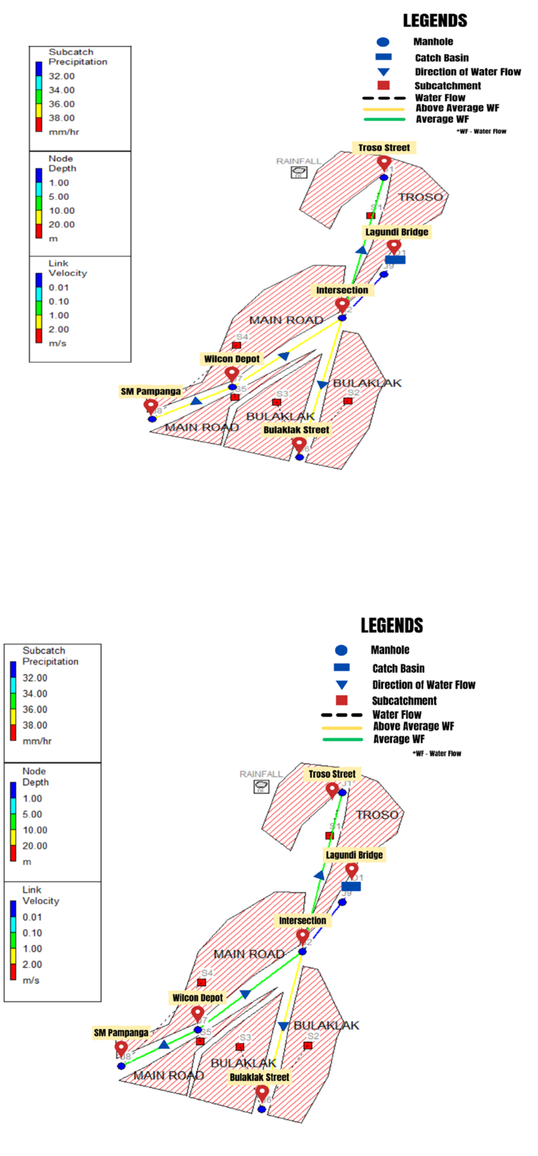

Fig.2. SWMM Simulation Result

After running the simulation, the researchers now can identify the places where the water increases, as shown in Figure 2. The conduit links which represent the drainage in the study area, were colored as a representation of the water flow: blue as low, light blue as below average, green as average, yellow as above average and red as high level of water. It is found out that the characteristics of the inundation depend on the speed of the flow. As the velocity increases, the inundation heightens.

According to the software SWMM, using 100-year return period, there would be a height increase in water level of the drainage located in the main road, particularly in the route from SM to Sitio Troso. There would be an increase in the drainage in the street of Sitio Bulaklak as well. Whereas the water level in the street of Sitio Troso would remain average. Over time, the water accumulation in the drainage located on the main road would decrease to average, the water level in Sitio Troso would remain average, and Sitio Bulaklak would retain its high-water level.

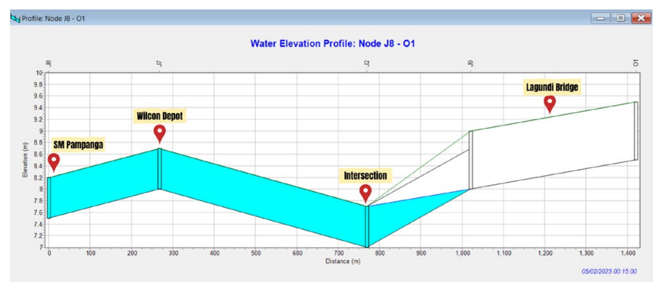

Fig.3. Water Flow Result from Main Road to Catch Basin

Water flows were visualized as shown in Figure 3 using the software SWMM. The system observed an overflow directed from the road of SM Pampanga going to Wilcon Depot up to the portion where the Sitios and the Main Road intersect. From the intersected point, the water level decreased and did not flow through the catch basin, which is the Lagundi Bridge.

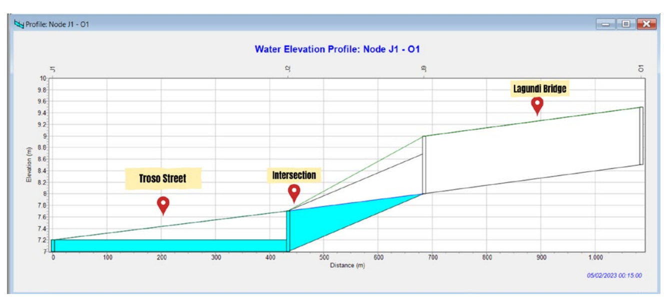

Fig.4. Water Flow Result from Troso to Catch Basin

Observing the water flow from Sitio Troso to Lagundi Bridge using the same process from the Main Road represented by

Figure 4. Upon observation, the researchers noticed that there was not much change in the flow of water in the drainage of Sitio Troso. But there was an increase in the part where the main road and the sitios intersect, where the water flows through from both sitio Troso and the main road. Similar to the Main Road, the water did not go straight to the catch basin, which is the Lagundi Bridge.

Using the same process from the previous simulation, the sitio Bulaklak water flow simulation was visualized as seen in Figure 5. There was an overflow at the end of sitio Bulaklak, but it decreased as it went to the main road, which was because of the change in elevation of the street. Just like in the sitio Troso, there was also an increase in the part where the main road and Sitios intersect, and the water did not go straight to the basin.

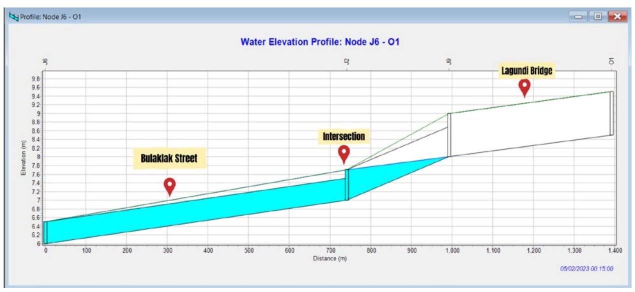

Fig.5. Water Flow Result from Bulaklak to Catch Basin

There are two reasons as to why the water does not flow directly to the catch basin. First, the elevation is high in the location of the catch basin as compared to the other parts of the roads, more specifically at the part of Lagundi that is near the basin, which is the Ningnangan. Second, the drainage was cut off at that particular part of the road, which ended the flow of the water at that point, which causes inundation since the water has nowhere to go.

4.3 Part III - Flood Hazard Mapping

The final part of the study presents the output of the hydrologic and hydraulic assessment: the flood hazard map in Barangay Lagundi with a 100-year return period.

In Figure 6, a flood hazard map is illustrated. The area enclosed is Barangay Lagundi; it is shaded with green, yellow, and red colors. These colors represent the susceptibility of inundation in the area if the quantity of rain exceeds of a 100-year rain return period: green there indicates a low vulnerability, which means the area is at a higher elevation; yellow indicates a moderate vulnerability; and red indicates a high susceptibility because the area is at a lower elevation.

This flood hazard map created will be presented to the officials in Barangay Lagundi for use by the LGU and the residents, as it aids primarily in disaster readiness and risk management in the barangay. With the use of this flood hazard map, the LGU can improve the response time when flooding occurs as it points out the hazardous area on the map, and through this, they can make an efficient route based on it when an emergency occurs. This can also be distributed to citizens or posted on the barangay hall, as it provides information that can raise awareness about the flood-prone areas. This can also help in planning as it indicates high-flood-risk areas that the entrepreneurs and investors should avoid. In the branch of civil engineering, this flood hazard map can be considered when designing structures that can mitigate the floods, like drainage systems.

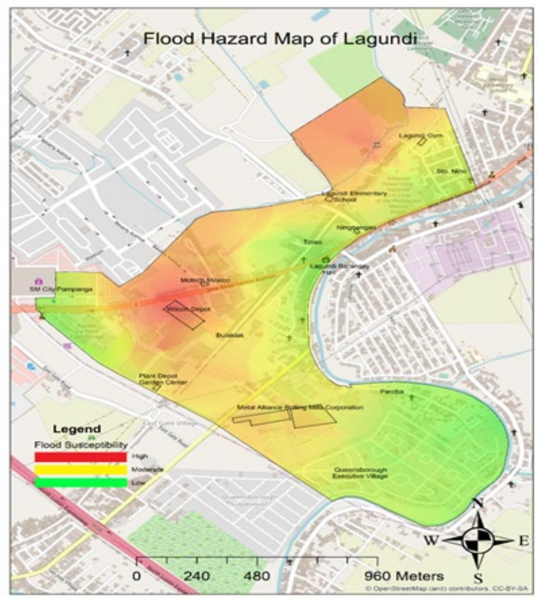

Fig.6. Flood Hazard Map of Lagundi, Mexico, Pampanga with 100 years return period

V. CONCLUSION

Lagundi, Mexico, Pampanga, is a suburban area that is composed of different land uses. The area of Lagundi is divided into 66.56 hectares of rural land, which is 34% of the total, and 130.42 hectares urban land, which is 66% of the area. Some areas are still in rural settings, but most of them have been developed into urban areas. The study area has a drainage system that the citizens rely on; some are man-made, but other areas do not have any at all.

Based on the flood mapping simulated in HEC-HMS, the inundation can be concluded in the areas in Lagundi that are located at lower elevations, especially on parts in the Main Road, Troso, and Bulaklak. In addition, according to the results of the simulation of the existing drainage system loaded with the peak runoff discharge amount, the inundation can be reduced, but it is still not enough to cater to the flood. Some areas can still experience flooding.

In the simulation of the drainage system, the inundation was concluded to be due to the sizes of the channels of the drainage system, the lack of these waterways, and urbanization. The small dimensions of the drainage system mean a small volume of water can be transported. Another reason is the insufficiency of these kinds of facilities that control the sewage water in the catch basin in the area. Urbanization also has an impact on the incidence of flooding. As situated in the simulations, it is revealed that most areas that experience flooding are the developed areas. There is a need to normalize the flow of water; therefore, redesigning the drainage to sustain rapid urbanization is highly recommended.

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