ISSN No:-2456-2165

Republic of the Philippines Commission on Higher Education
DON HONORIO VENTURA STATE UNIVERSITY
Villa de Bacolor, Pampanga

Proposed Extension of Drainage System in Sto. Rosario, Mexico, Pampanga

A Thesis Proposal Presented to
The Faculty of the Civil Engineering DepartmentDon Honorio Ventura State University

In partial fulfillment of the requirement for the Degree ofBachelor of Science in Civil Engineering

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APPROVAL SHEET

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ISSN No:-2456-2165

ACKNOWLEDGEMENT

The researchers would like to appreciate and thank **Engr. Jafet C. Culala** for being the adviser of the research entitled "Proposed Extension Of Drainage Systemfor Sto. Rosario, Mexico, Pampanga". Acknowledged the insights and guidance on what are the better things that will be good in our research. He is an essential part of our success inthis research.

Furthermore, we would also like to thank our research coordinator**, Engr. Juanita Carmelita Zoleta** for giving us the opportunity to finish this research. Her efforts gaveus knowledge and understanding of each chapter, as well as the things that we need to know during the presentation of the research.

Our thanks and appreciations to our dearest dean and chairperson of College of Engineering, **Engr. Jun P. Flores** and **Engr. Irene R. Roque**. We thank them for their endless supports and guidance in publishing and finishing this research.

We would also want to thank our **lecturers** and **panelists** for their comments, assessments, and evaluations, which helped us enhance our research work. The researchers would also like to thank our parents who are always there to provide support in our studies. Their hard work greatly supported us in accomplishing the research.

As well as **Ourselves**, who gave our very best to express the ideas that greatly contributed to the progress of the research. This research gave us the opportunity to appreciate the works of a Civil Engineer which is a great experience in our career.

And above all, to our **Almighty God**, for giving us the strength and wisdom to do this thesis, we are fortunate to gratefully acknowledge Him for the good health and well- being that we received to complete it.

ABSTRACT

The Philippines is one of the most tropical countries in the world. Many typhoons enter the country annually, and so do the light rains. In a specific area in Sto. Rosario Highway in Pampanga, flooding is always evident. No matter the intensity of the rain, theflooding causes inconvenience to the people who use the road. It hinders the transportation system.

The researchers focused on proposing a drainage system that can minimize the longevity of flooding. The length of the proposed extension of drainage system is about 750 meters. The researchers used the Rational Method since it is applicable to the study. The researchers identified 5 catchment areas. The drainage system withdrawal point will be on the two rivers that cover the barangay from point to point.

The researchers found that there is no existing drainage within 750 meters of length, there is a huge difference in elevation especially in the catchment areas, and there is an available space wider than the layout of DPWH. The proposed extension of drainage system followed guidelines, and provisions, and is dependent on rainfall intensity duration. The proposed extension of drainage system will help the Barangay to be a better and more habitable place to live.

Keywords:- *Drainage System, Flooding, Catchment Areas, Rainfall, and Elevation.*

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CHAPTER ONE
THE PROBLEM AND REVIEW OF RELATED LITERATURE AND STUDIES

- *Introduction*

The Philippines being a third country is a country that is continuously developing. This is visible in urban cities and even in rural areas. Along with an improvement in urbanization, the population also rises. The Philippines is a country that is highly exposed tosuch natural phenomena that posed a greater threat to the public. One of these is becoming ahome for some typhoons trying to cross over the major seas. Making drainage systems, dams, reservoirs, and such water containment is helpful to mitigate flooding. Building the given infrastructures lessens the floodwater over an area (Sahnan, 2017).

Typhoon is one of the natural disasters that hit our country an average of 20 times per year. The Philippines is located in the Pacific Typhoon Belt making rain a common season throughout the calendar. Based on prior events, the effects of this disaster have causeddevastating situations, leaving many people homeless, damage to buildings and other structures, and a threat to public safety. This is where the drainage system plays a big role, especially during times of crisis.

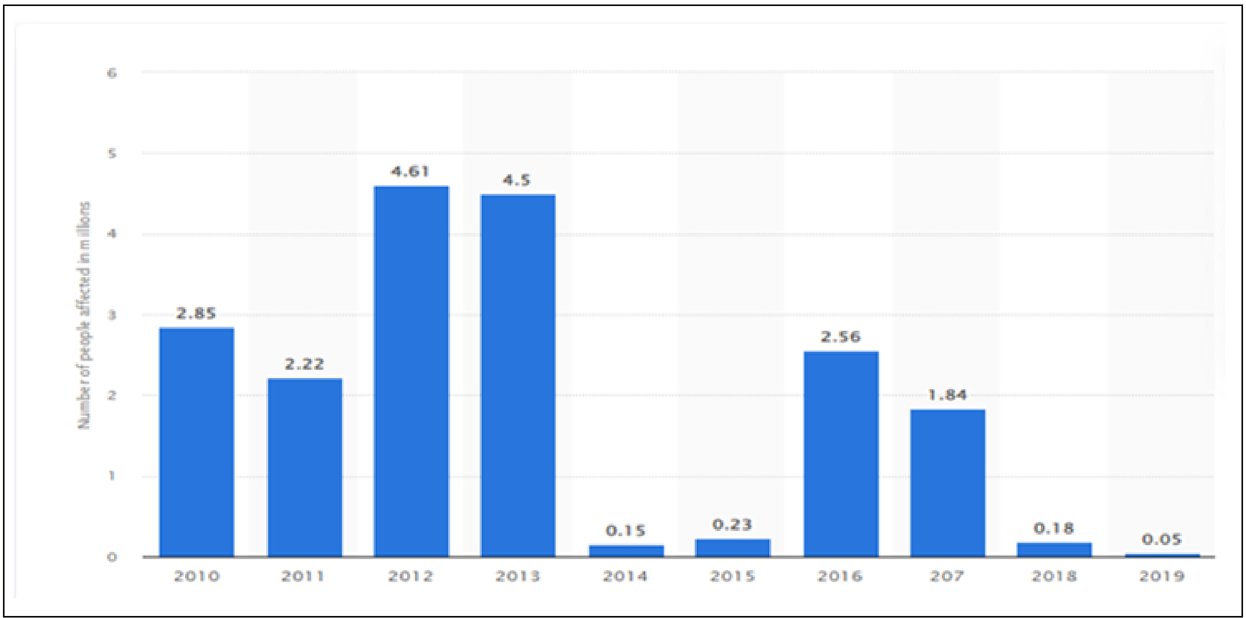

Fig 1 Number of People Affected by Flood in the Philippines from 2010 to 2019.

Flooding occurs when the rate of rainfall in low-lying areas and metropolitan settings exceeds the capacity of the ground to absorb it. Flooding usually happens when there hasbeen an extended amount of rain over several days when there has been a brief period of strong rain, or when a debris blockage has caused a river or stream to overflow into the nearby region. Flooding can also happen when a levee or other water-controlling structure, like dams and reservoirs, fails.

This study introduces a drainage system that focuses on mitigating the existence of flooding and providing a better drivable road for the residents and passersby. This givenstudy will give light and better disaster management from the wider community and also its local government. Individuals will see a drainage system that is working and fit the community's needs.

The community and government itself should promote a good neighborhood, participate in good cause projects, and be oriented on such pre-measurements regarding actions that they needed to do incase of disaster. Being prepared means being one step ahead of what is bound to happen, even the unimaginable. Prevention is truly always far better than cure, it can save a million lives and any livelihoods during a disaster. It can also help the community's coordination and practice response during the given event. Attention should be paid to the community both during and after a disaster in order to save lives and not just to increase readiness to respond to a disaster (Torani, 2019).

- *Background of the Study*

Flooding is a common situation in our country that should not be treated normally just because it is a common situation. It simply produces more threats to the greater community especially in life, structure health, and even to the transportation system. A drainage system is one of the structures built by humans to mitigate and control the level of availablefloodwater in any given pathway. It plays a big role in any given event, especially in preparation. Given the situation is light rain, it is expected that the road is clear and drivable. If the situation escalates to the point that drainage is filled completely, the local government and community have available time to respond knowing the level of water isn't high.

One of the most significant purposes of building drainage is to delay the floodwater level's rising speed. It is an excellent structure built to reduce water visibility within the road and also lessen exposure to such diseases. Drainage is a self-sustaining structure given that it has a reliable outlet. Building drainage system for barangay or roads exposed to flooding is a big help for the environment, and community and an aid for the government's response.

It's possible to approach the subject of disasters, especially those needing emergency response options, from the viewpoint of the drainage system center itself. It was used in many different businesses, especially those that needed a lot of disaster management.

Typhoons cause serious disasters in a number of Philippine cities. It develops over the Pacific Northwest, not far from our country. It may even put our lives in peril while exposing our fellow countrymen to such danger. Each year, the Philippines is struck by abouttwenty typhoons that can always be a threat, especially to areas that are not prepared for the situation.

Aid from the local government including its engineers can be a big help in preparationfor a given disaster. Assuring that the structure is overly-fit over what the current situation demands is a great help, especially for future adjustments. Informing the higher positions andaddressing the current problem will surely help alleviate the situation and be ahead of any possible unwanted events.

Flooding is common in tropical countries as a result of storm surges and excessive rainfall. The "flood" is a natural calamity brought on by a tropical cyclone, and the government works nonstop to lessen the damage. Additionally, the natural calamity caused enormous economic damage and annually claimed a large number of lives. Agribusiness, transportation, communication and even building structures to locations where exposure to flooding is one of many factors affected by flooding. Due to the inadequate resourcesavailable to address the phenomenon, the government barely managed to prevent this type of distress (Pour, 2020).

- *Study Area*

The researchers will focus on the proposal for a extension drainage system in Barangay Sto. Rosario Highway, Mexico, Pampanga. It is a main highway road part of Jose Abad Santos Avenue. It is approximately situated at 15.06907, 120.73231, on the island of Luzon. According to the Comprehensive Land use Plan of Mexico, Sto. Rosario is one of the most frequently inundated barangays that results in flooding. It causes direct damage to the road, such as road destruction, as the continuous rain harms the road. Mexico is prone to flooding due to the level of elevation of its neighboring barangays. Being prone to flooding,it is only righteous to build a drainage system. The Philippines, according to PAGASA,is susceptible to tropical cyclones due to its geographic location, which often results in heavyrainfall and flooding over wide areas.

According to the Municipal Disaster Risk Reduction and Management Council of Mexico, Pampanga (2019), Sto. Rosario is part of Cluster A which means the area is prone toflooding at a higher rate. Following that information, MDRRMC stated that floodwater is stagnant in certain areas, this only explains that there are available catchment areas. Citizens of the said area blamed the situation for the lack of action of its government unit about the situation. As of the moment of writing, the authorities in the area have no budget for it even though a number of sites have taken the position. As per MDRRMC, approximately only 577 families are living here.

Fig 2 Aerial View of the Study Area

ISSN No:-2456-2165

Fig 3 Actual Photo of the Study Area

➢ *Review of Related Literature*

- *Review of Related Literature on Flooding*

Floods are a particular kind of natural catastrophe that occurs when an excessive amount of water submerges normally dry areas. The need for such measures is a decision that shouldn't be taken for granted by the authorities. Its importance is visible, especially throughout the years when our country experienced super typhoons. According to Miguez (2017), Urban drainage management is a flood risk management strategy that increases city resilience, or the ability to continue operating even in potentially dangerous future situations,in response to this growing risk.

Damage from these floods may be direct or indirect. There are two types of damage: direct and indirect. Direct damages include death, injury, and property damage. Cars, infrastructure, and crop and animal damage. Indirect harm is used to describe societalupheaval, psychological pain, and distorted patterns of good production and consumption (Munawar, 2018).

It exists primarily because of road elevations, the road's position, the dam's failure, and the drainage system around it. As claimed by Fernandes (2022), floods create economic and societal damages of millions of dollars. Simply flooding constitutes such dangers in life that are either during flooding or post-flood situation. Making an area less habitable especially for its current residence.

According to Kulp (2019), continuous flooding in the area may result ina lesser population as the residents of it will surely find the place unhabitable. Threat to health and safety is one of the things not overlooked by residents. The longer existence of wet roads is also being considered as it indicates the possibility of any physical accidents that may occur in the area.

- *Review of Related Literature on Drainage System*

Structural and nonstructural are the two categories of flood control measures. Non- structural solutions, which have traditionally been a crucial component of managing flood risk, include private precaution, spatial planning regulation, increasing responsibility for flood-prone areas, and insurance arrangements. Structural measures are considered for highlydensely populated areas where they build levees, berms, floodwalls, large sewer conduits, and dikes (Bubeck, 2017).

Flooding poses a significant risk to roadways among the natural disasters that endanger transportation infrastructure because it interferes with their operation, efficiency, and safety. It is expected to prioritize main road highways as a greater number of vehicles jammed over these roads. Engineers should install long-term, durable, and convenient master plansfor flood control measures on roads (Pedrozo-Acuña, 2017).

Reconstruction of transportation structures is also a way to reduce flooding. Raising the flood embankment level is one method for containing floodplains around reservoirs and rivers. By doing this, a greater freshet level can be reached above the main riverbed, which will limit the flood (Kłosowski et al., 2018).

As stated by Byrne et al. (2017), conventional highway drainages are built to control runoff for the safety of the traffic on the road and the preservation of the road pavement fromwater damage. These drainages should be constructed cost-effectively in order to attain such goals mentioned. Traditionally, highway drainages are designed to remove water from driving lanes by directing it to the outside shoulders, which it is infiltrated or discharges to surface water.

Drainage systems are vital to an area in driving away excess water to reduce floods at an acceptable limit. To avoid flood disruptions and damages, long-term changes in hydrological regimes particularly in surface flooding routes and characteristics may also leadto changes in land use and drainage systems (Zhou et al., 2019).

According to Sohn et al. (2020), there are three types of drainage systems which are; storage, conveyance, and infiltration-based facilities. In creating a new drainage system, it should be based on the effectiveness of the drainage system, it should vary depending on the type of facility and the surrounding environment. Moreover, the storage-based drainage system is the most effective in mitigating floods, and utilizing storage-based facilities can reduce flood damage costs by 92%.

Some of the issues that we encounter in the present are the poor management of drainage systems. According to the study conducted by Alejo (2018), poor drainage systems may lead to house flooding, destruction of buildings, roads, and gutters, and a steady increasein illness and other harmful substances. These harmful substances will harm the health of the public. It is necessary to eliminate or reduce them as much as possible, especially in public places.

The Philippines is also one of the countries that have drainage issues. As stated by Alcantara (2019), floods may not just be due to the severity of monsoon rains and typhoons; it is also due to the poor community drainage and overloaded river channels caused by rapid urbanization. Therefore, we can say that as the population increases, there are always issues regarding the floods and drainage systems in the area.

The study byRai et al. (2019) includes the Morphometric Study of the VarunaRiver basin in India. Their study indicates that the Varuna River shows a very classic drainage texture. The bifurcation ratio of the Varuna River is 3.92 which means that the river is normal and can be part of a drainage network based on its geomorphology. Having a lower bifurcation ratio means that the drainage basin has an underlying uniform material. Drainage density is helpful in the interpretation of the hydrological data of the Varuna River. The Varuna River has moderate drainage density which is an indication of permeable material, vegetative cover, and moderate to low relief and can be an outlet for the drainage.

Over the previous few decades, metropolitan areas have grown and become denser. At the same time, urban drainage networks are falling behind in terms of development and upgrading, especially in light of the expected consequences of climate change. According to Wu et. Al. (2018), inundation is becoming more likely. Inundation is an excessive number of persons exceeding the capacity a certain area can only accommodate. Therefore, it is now critical to focus on reducing urban flood risk and enhancing urban flood resistance. Wu et. Al(2018) added that number of people equates to a much larger acquisition of waste and destruction. These include the road pavements being driven by a much number of vehicles and drainage systems with blockage from the trash.

An area serviced by a drainage system has a greater factor of water runoff response than either an unaffected area or development type. It is vital to include the role of a drainagesystem in evaluating the ever-changing state of flooding. Carrying rainwater away from the highway has a purpose. It is appropriate in regions with a lot of rainfall. This style of drainage system intercepts and diverts water off the road surface to prevent precipitation intrusion (EL-Nwsany, 2019).

In line with Zevenbergen et al. (2018), drainage should be maintained and improvedas the climate varies. Thus, a critical factor to consider in our generation is the worsening state of our climate where rains are somehow heavier. Therefore, the ratio of time and population in our generation requires much focus on the systems that might affect the public.

The flow that each leg of the storm sewer system ought to carry, must be determined before construction can begin. Events involving rainfall are statistically predictable. As a result, some storms will develop that will overwhelm the system, regardless of the return period chosen as a foundation for design. A crucial component of the collection system is its physical design. The overall volume of runoff and peak flow size will rise as temporary storm drainage in growing urban areas improves while lowering flood risks in the area served. Water that has permeated the ground may surface as springs or from an unidentified or concealed source. Groundwater flow and reservoir discharge together make up dry water flow (Ortiz, 2020).

➢ *Statement of the Problem*

This study sought to answer the subsequent questions:

- Are there any catchment areas within the area?
- Does the current drainage system available work effectively?
- Is an extension of the drainage system possible for Sto. Rosario?
- What will be the total cost for the proposed extension of drainage system?

➢ *Objectives of the Study*

- *General Objectives*

In this study, the main objective is to reduce the flooding at Sto. Rosario Highway by improving its drainage system.

- *Specific Objectives*

✓ To minimize the longevity of flooding.
✓ To propose extension of drainage system.

➢ *Significance of the Study*

Whenever it rains, flooding is evident at Sto. Rosario's Highway. A typhoon, low- pressure area, southwest monsoon, or even light rains can result in flooding. It causesinconvenience to the community as flooding remains for days and with no way out.

The researchers will focus on providing a extension drainage system in Sto. Rosario Highway. The proposed study will help the community, civil engineering students, and Local Government Units. It will also be beneficial for future researchers because the study may become their reference and be improved with the data available. Furthermore, the study will be beneficial in the following ways:

- *Community* -

The result of the study may contribute to the improvement of the drainage system as it will serve its functions. It will become accessible and raise awareness for its purpose.

- *Civil Engineering Student* -

The research may present a valuable reference for civil engineering students in exploring more about the connections between structural and hydrology.

- *Local Government Unit* -

The result of this study will help the Local Government Unit in identifying the current situation of the barangay as well as minimizing the workload available.

- *Future Researchers* -

This research will be a useful reference and serves as guidance for theresearchers who would plan to make any related study precisely the flooding and drainage system.

➢ *Scope and Limitation of the Study* -

The study primarily focuses on the adaptation of the existing drainage system and reducing the longevity of flooding along the Sto. Rosario Highway. The beneficiaries of the study will be composed of the local government unit, civil engineering students, and the residents of this area. The findings of the study will help the road in Sto. Rosario Highway inreducing flooding and ensuring an effective drainage system in the area.

The health, traffic plans, and the pricing of the materials for the proposed extension of the drainage system would not be included in the study due to financial limits and time constraints.

➢ *Definition of Terms*

- *Drainage System* - A system of channels or drainage for removing excess water.
- *Elevation* - The height that anything is elevated above a visual reference, particularly themean sea level.
- *Embankment* – A stone or earthen mound constructed to support a road or to hold backwater.
- *Epidemic* – Spreading quickly and widely by infection and simultaneously affecting a largenumber of people in a location or population.
- *Flood* – A flood that overflows onto typically dry terrain.
- *Flood Control* – A practice of (engineering) trying to regulate rivers with dams and otherstructures to reduce the likelihood of flooding
- *Freshet* – A massive increase in stream level or overflow produced by a storm
- *Gastroenteritis Outbreak* – Occurs when two or more people in the same institution sufferthe unexpected start of vomiting or diarrhea at the same time.
- *Grey Infrastructure* – Refers to the historic and traditional infrastructure, such as storagetanks or sewage pipes.
- *Hypothetical Data* – *I*ncorporating or relying on a proposed theory or idea.

- *Hypothetical Tests* – This is a statistical procedure whereby an analyst verifies a population parameter assumption. The type of data used and the purpose of the research will determine the methodology the analyst uses.
- *Infrastructures* – A supporting framework or foundation, particularly for a group or system.
- *Low-Pressure Area* – A region having a lower air pressure and counterclockwise-moving winds
- *Macroscopic* – Large enough for the unaided eye to see or examine.
- *Maritime* – In or connected to sea navigation or commerce.
- *Mental Health* – It affects cognition, perceptions, and attitude.
- *Monsoon Rai***ns** –A change in wind patterns that frequently brings to a very wet or very dry season.
- *Preventive Measures* – Defines any reasonable actions that are performed by anyone in reaction to an occurrence to mitigate or prevent loss or damage or to clean up the environment.
- *Rapid Urbanization* – The rate at which residents move from rural to urban areas.
- *River Channels* – Is used to describe the portion of a river's habitat that is riverward of the mean high water mark.
- *Safeguards* – A measure of safety.
- *Sewer System* – Facility with a network of sewers to remove both liquid and solid waste.
- *Southwest Monsoon* – Large-scale wind system that affects many climate zones and changesdirection seasonally.

ISSN No:-2456-2165

CHAPTER TWO
METHODOLOGY

This chapter presents the research method which contains the research design, procedures, and analysis that aids the objectives of the study. It encompasses different materials, preparations, instruments, parameters, and provisions that were used in designing adrainage system.

➢ *Methodological Framework*

Time of arrival will always be the top priority of every individual to meet all their basic needs. The flood in the Sto. Rosario Highway causes inconvenience to the drivers, passengers, and community. The study's methodological framework will show the general procedure in the process of formulating solutions to reduce the flood in the area.

The researchers looked for possible ways to help reduce the flooding in the area. The results were analyzed and the researchers determined if the proposed solutions will remove the certainty of flooding in the area.

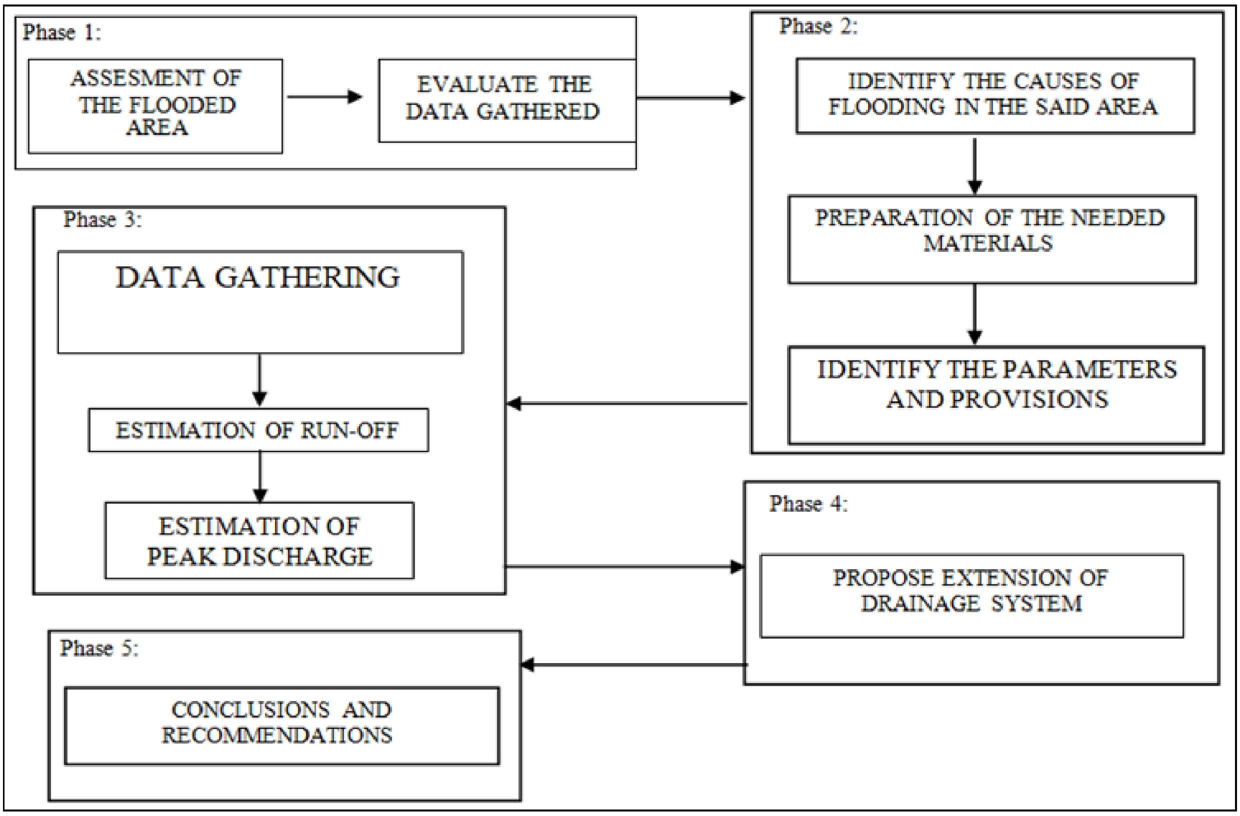

Fig 4 Methodological Framework

- *phase 1*

The researchers assessed the flooded area, and based on the assessment the researchers evaluated the data gathered. They evaluated the measurements, elevations, andcurrent status of the drainage system.

- *phase 2*

The researchers identified the problems that caused flooding in the area and preparedthe materials needed for the study. They also identified the parameters and provisions in accordance with NSCP 2015.

- *phase 3*

The third phase is about data gathering, the researchers estimated the runoff and peakdischarge in the study area.

- *phase 4*

The researchers proposed extension of drainage system based on the result of theprevious phases as well as the testing of the proposed extension of drainage system.

- *phase 5*

The researchers gave conclusions and recommendations regarding the possibleimprovement of the study.

➢ *Preparations of Materials*

The following are the materials, tools, equipment, and software needed for theproposed extension of drainage system.

➢ *Tools and Equipment*

The following listed are the tools and equipment that were used in the study for the preparation of designing a drainage system:

- *Tape Measure*

Tape Measure, often known as a measuring tape, is a flexible ruler that is used to measure length or distance. It was to be used to measure the depths and heights of the currentdrainage system.

Fig 5 Tape Measure

- *Level with Tripod*

A surveyor's level is a tool used in surveying to determine the height of distant places with respect to a reference point (a point for which the height above sea level is accurately known). It is made up of a telescope that is equipped with a spirit level and is usually set on atripod. It was used to identify the measurements of cut and fill.

Fig 6 Level with Tripod

- *Road Inspection Signage*

A road inspection sign denotes a vehicle traveling slowly and checking the road as temporary mobile work. It was used to notify the commuters, drivers, and passersby thatthere is an ongoing road inspection within the area.

Fig7 Road Inspection Signage

- *Drone*

A drone was used for the aerial view of the drainage system. It was also used to determine thetotal length of the drainage system from starting point up to the endpoint.

Fig 8 Drone

➢ *Softwares*

- *AutoCAD*

AutoCAD is a computer-aided design software program created by Autodesk (hence the name AutoCAD). It enables you to draw and edit digital 2D and 3D designs faster and more readily than you could by hand. It was used to outline and create the plan for the proposed extension of drainage systemwhile maintaining accuracy with the measurements.

Fig 9 AutoCAD

- *Google Earth Pro*

The researchers used google earth pro in order to measure the distance between the starting point and the ending point of the proposed extension of drainage system. It was also usedto identify the discharge point to its surrounding river, the Abacan River and SapangBalen. Furthermore, google maps served as a reference for the illustration of the catchment areas used inthe study.

Fig 10 Google Earth Pro

➢ *Data Sources*

In this research, gathered data will primarily come from two sources which arePrimary and Secondary sources.

- *Sources*

✓ *Layout Plans*

TheDepartment of Public Works and Highways will be a big aid in this study especially the available data they have. Philippine Atmospheric, Geophysical, andAstronomical Services Administration or also known as PAGASA, has valuable data regarding runoffs.

✓ *Site-Investigation*

The researcher's exposure to the given area is considered as a primary source.

It also includes photographs captured within the time of finishing this research.

➢ *Design Parameters*

The sciences of hydrology were used to build drainage infrastructure, which is vital in identifying the past year's rainfall activity within the area.

- *Hydrology*

The nearest PAGASA monitoring station's Rainfall Intensity-Duration- Frequency (RIDF) can be used as a basis for hydraulic calculations. The Researcher has the obligation to obtain and secure such hydrologic information to be utilized in his design. Considerations must also be made in light of the recent extreme weather changes, which may be attributable to climate change.

➢ *Location*

The researchers identified the starting point and end point of the drainage system. The researchers will then identify if the current system is viable for an extension for the barangay.The researcher identified the elevations through the use of the materials listed above. Measurement of the area of the available land was also identified through the use of Google Maps.

➢ *Design Procedure*

The following is the complete procedure that includes the guidelines, provisions, and parameters of a drainage system.

➢ *Inspection Stage*

The researchers went to Sto. Rosario Highway to inspect and do all the measuring procedures. Using all the tools and equipment given, the researchers can already specify the measurements needed for a proposed extension of drainage system. Road elevation will also be observed as it considers the geographical features of the said area. Measurements will then be considered as data that was used for the next stage.

➢ *Estimating Runoff*

Any drainage project is scaled based on the likelihood of an estimated peak discharge occurring during the installation's design life. In addition to the intensity and length of a peakrainfall event, it is also taken into account and is typically dependent on the life of the road, traffic, and the implications of failure. Frequency intervals of 50 to 100 years are common for primary highways such as the Sto. Rosario Highway.

The proportion of rainfall that eventually becomes stream flow is dependent on the following factors:

- **The drainage area's size.** The volume of runoff increases with the size of the region. To apply runoff calculations and charts, an estimate of the basin area is required.
- **Topography.** The volume of runoff rises with the steepness of the slope. Although average slope, basin elevation, and aspect are not commonly requested in most runoff calculations and charts, they might give useful information when improving a design.

The risk of failure over the design life must be indicated in order to incorporate this knowledge into the design. By determining an acceptable degree of risk, the intended level ofsuccess (or failure) with road drainage systems must be stated.

Table 1 Flood Recurrence Interval (years) in Relation to Design Life and Probability of Failure.

Design Life (years)	**Chance of Failure (%)**						
	10	**20**	**30**	**40**	**50**	**60**	**70**
	recurrence interval (years)						
5	48	23	15	10	8	6	5
10	95	45	29	20	15	11	9
15	100+	68	43	30	22	17	13
20	100+	90	57	40	229	22	17
25	200+	100+	71	49	37	28	21
30	200+	100+	85	59	44	33	25
40	300+	100+	100+	79	58	44	34
50	400+	200+	100+	98	73	55	42

- *Estimating Discharge*

Estimating the discharge, the formula that will be used is Manning's Formula:

$$\mathbf{Q = n\text{-}1\ A\ x\ R^{2/3}\ x\ S^{1/2}}$$

Where:

Q = discharge (m3/s)

A = cross-sectional area of the stream (m²)

R = hydraulic radius (m), (area/wetted perimeter of the channel)

S = slope of the water surface

n = roughness coefficient of the channel.

Table 2 Manning's n for Natural Stream Channels (surface width at flood stage less than 30 m).

Natural stream channels	**n**
1. Fairly regular section:	
Some grass and weeds, little or no brush	0.030 – 0.035
Dense growth of weeds, depth of flow materially greater than weed height	0.035 – 0.050
Some weeds, light brush on banks	0.050 – 0.070
Some weeds, heavy brush on banks	0.060 – 0.080
Some weeds, dense willows on banks	0.010 – 0.020
For trees within a channel, with branches submerged at a high stage, increaseabove values by	0.010 – 0.020
2. Irregular sections, with pools, slight channel meander; increase values givenabove by	0.010 – 0.020
3. Mountain streams, no vegetation in channel, banks usually steep, trees andbrush along banks submerged at high stage:	
Bottom of gravel, cobbles, and a few boulders	0.040 – 0.050
Bottom of cobbles with large boulders	0.050 – 0.070

- *Nscp Provision*

All the dimensions will be in line with the provisions of section 302.6 of the NSCP 2015.

- No proposed fills are greater than 3 m in maximum depth.
- No proposed finish cut or fill slope faces have a vertical height in excess of3 m.
- No existing slope faces steeper than 1 unit vertical in 10 units horizontal (10%slope) have a vertical height in excess of 3m.

- *Designing Stage*

At this stage, the researchers will use AutoCAD in order to identify the appropriate measurements of the proposed extension of drainage system. Measurements were accurately outlined within the software and provided the most efficient section.

ISSN No:-2456-2165

CHAPTER THREE
RESULTS AND DISCUSSION

➢ *Assessment*

The starting and end point of the proposed extension of drainage system was determined by simply identifying where the available space for the drainage system was. Visible at first 78.20 meters from the known spillway bridge of Mexico is the absence of the drainage that runs down further into the next barangay. The area is known where floodwater's existence is relativelyhigh.

➢ *Plan and Profile*

This is the current layout plan for Sto. Rosario, Mexico. As of 2023, the proposed widening section has already been used, making each way have an additional lane. The portion left for drainage is still available for further implementation of a project.

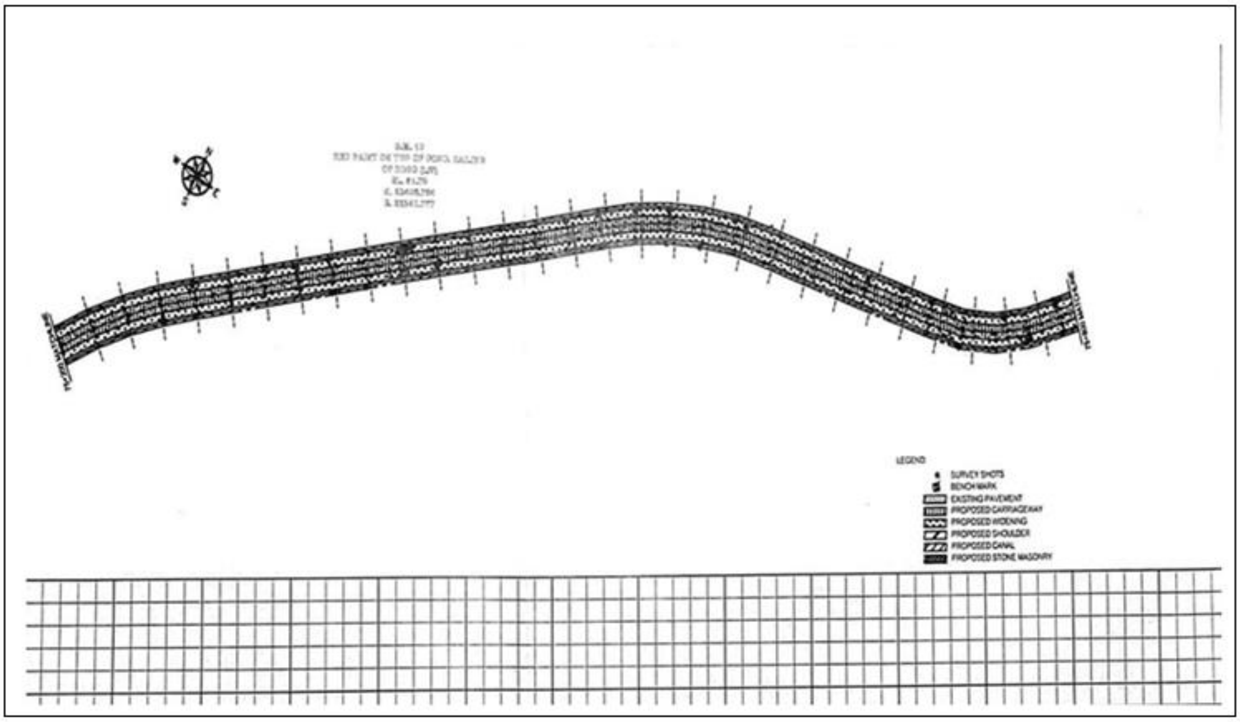

Fig 11 Plan and Profile

➢ *Measurements*

The researchers measured the area for the proposed extension of drainage system. The length is said to be 780 meters ranging from the starting point (Figure 12) to the end (Figure 13). The starting point is located 78.20 meters from the bridge since there is no existing drainage nearthe said area. The length travels from Sto. Rosario up to San Pablo, both in Mexico, Pampanga.

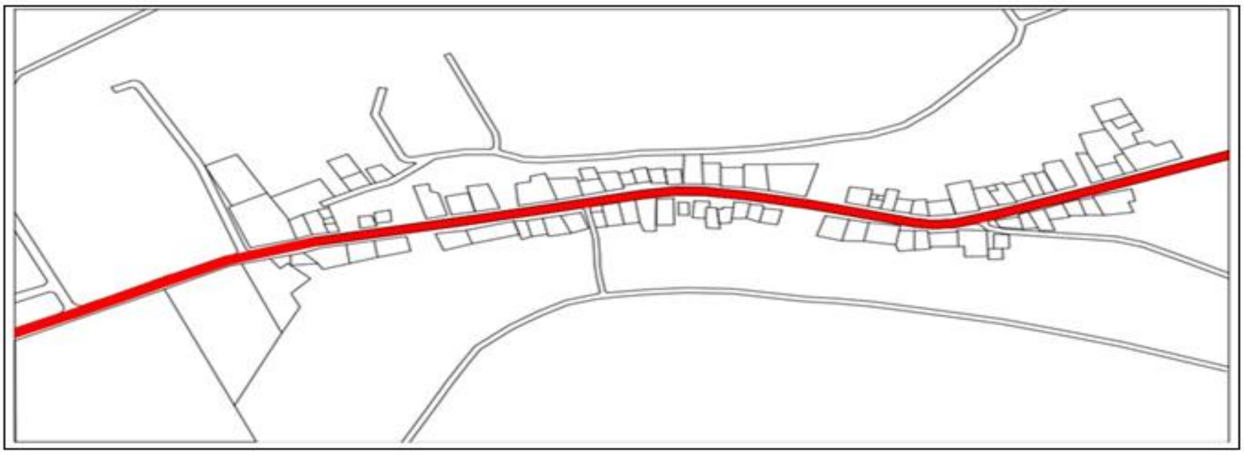

Fig 12 Drawn Aerial View

Fig 13 BM1

Fig 14 TP 8

- *Land Use*

Sto. Rosario, Mexico, Pampanga is a barangay that is crossed by thousands of drivers and passengers traveling Jose Abad Santos Avenue. The following table shows the division of land inBarangay Sto. Rosario, Mexico:

Table 3 Land used in Sto. Rosario

Agri	**Agi lnd**	**Com**	**Buffer/ Gbelt**	**Ind**	**Infra**	**Inst**	**Parks**	**Res**	**SHZ**	**Water**	**Cem**
40.7	1.39	0.35	6.76	0.29	5.87	0.92	1.41	21.79	2.42	14.09	0.00

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➢ *Rainfall Data*

- *Rainfall Intensity - Duration Frequency Analysis Data*

EQUIVALENT AVERAGE INTENSITY (in mm/hr) OF COMPUTED EXTREME VALUES

Return Period (yrs)	5 mins	10 mins	15 mins	20 mins	30 mins	45 mins	60 mins	80 mins	100 mins	120 mins	150 mins	3 hrs	6 hrs	12 hrs	24 hrs
	5	10	15	20	30	45	60	80	100	120	150	3	6	12	24
2	154.8	118.2	101.6	88.2	74.6	56.9	45.7	39.0	34.1	30.2	26.7	23.7	15.8	10.7	6.8
5	189.6	142.8	120.8	107.1	89.2	68.5	55.3	47.6	42.1	37.3	33.3	29.7	20.2	13.9	8.9
10	212.4	159.0	133.2	119.7	98.8	76.3	61.7	53.2	47.4	42.0	37.7	33.7	23.1	16.0	10.3
15	225.6	168.0	140.4	126.6	104.4	80.7	65.2	56.4	50.4	44.6	40.2	35.9	24.8	17.2	11.1
20	235.2	174.6	145.6	131.7	108.2	83.7	67.7	58.6	52.5	46.5	41.9	37.5	25.9	18.1	11.7
25	241.2	179.4	149.6	135.3	111.2	86.0	69.7	60.3	54.1	47.9	43.3	38.7	26.8	18.7	12.1
50	262.8	195.0	161.2	147.0	120.2	92.8	75.6	65.6	59.0	52.3	47.4	42.4	29.5	20.7	13.4
100	284.4	210.0	173.2	158.7	129.4	100.4	81.5	70.9	64.0	56.7	51.4	46.2	32.2	22.7	14.7

Fig 15 RIDF of Porac, Pampanga from DOST-PAGASA

The 20-year return period with varying values in minutes, which is frequently used as a design requirement for infrastructure and flood management projects, is depicted in the picture above. It aids in choosing the proper safety precautions and design requirements for safeguardingagainst flooding.

➢ *Profile Leveling*

The image below illustrates the turning points identified during the field surveyconducted in Sto. Rosario, Mexico.

Fig 16 Sto. Rosario, Mexico Plot Layout

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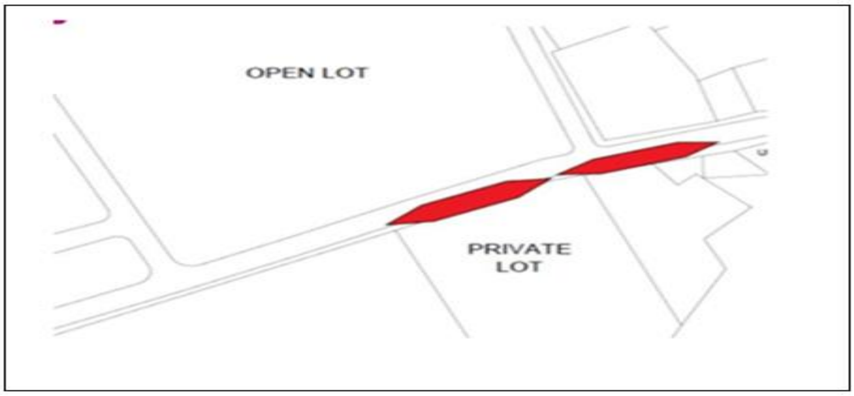
The tabulated results from surveying are as follows:

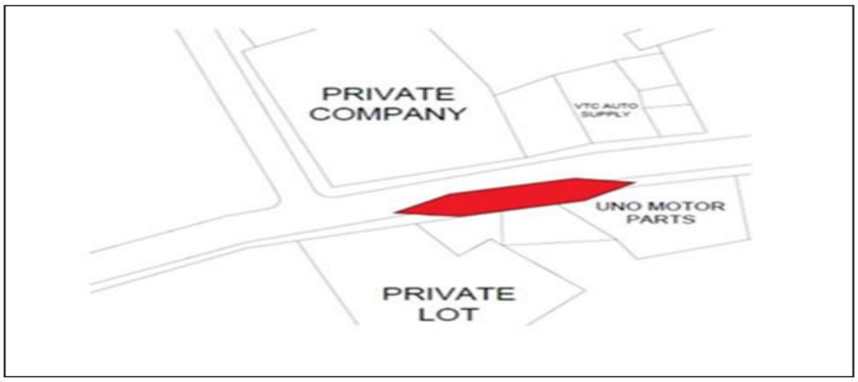
Table 4 Surveying Results

STA	BS	HI	FS	ELEVATION
BM	0.785	100.785	1.628	100.000 99.157
TP1	1.267	100.424	1.322	99.102
TP2	1.141	100.243	1.116	99.127
TP3	1.443	100.723	1.584	99.139
TP4	1.431	100.570	1.455	99.115
TP5	1.163	100.278	1.156	99.122
TP6	1.288	100.410	1.282	99.128
TP7	1.477	100.605	1.469	99.136
TP8	1.502	100.638	1.495	99.143

By analyzing the depicted profile leveling figure of Sto. Rosario, it becomes clear that the village is located in a region characterized by relatively low altitude. The first catchment areawas located between TP1 and TP2. Not far from it, the second catchment area was located between TP3 and TP4. Further analysis shows the slope elevation from Google Earth Pro. Additional info from the Municipal Government of Mexico proves the idea that the area is located at low elevations compared to its neighboring barangays. The outcomes of this comparison provide valid reasons to support the utilization of Google Earth and profile leveling as valuable instruments for analyzing geographical data and conducting surveys of land.The catchment areas designated in this research are as follows:



Catchment Area 1



Catchment Area 2

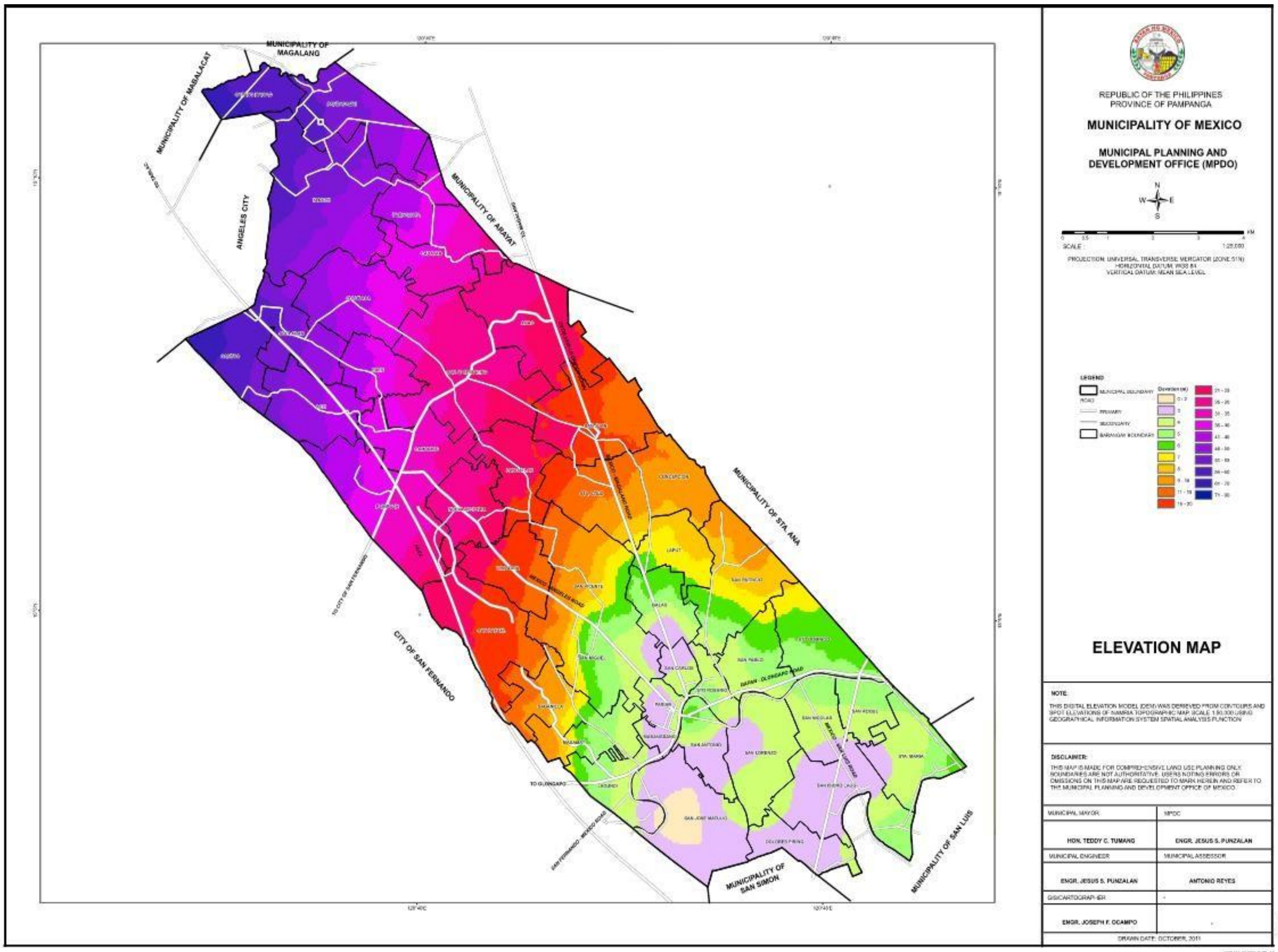


Fig 17 Map Elevation of Mexico

- *Slope Elevation*

Fig 18 Slope Elevation with Catchment Area 1

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Fig 19 Slope Elevation with Catchment Area 2

➢ *Drainage System Design*

- *Design Calculations*

The Rational Method is the most commonly used method for determining the peak flows from small drainages under an area of 300 acres. Estimating runoff in small drainage systems with a considerable proportion of impervious surfaces, this method provides the most precise results.

Considering the formulas,

$$Q = \frac{1}{3.6}CIA; \quad \frac{1}{n}AR^{\frac{2}{3}}S^{\frac{1}{2}}$$

The drainage surface area is used to denote the area and is measured horizontally. It comprises all the area of land bounded by drainage lines. The area is in terms of kilometers, which is the entirety of Barangay Sto Rosario, Mexico. According to the Municipal of Mexico, the total land area of the barangay is 959,999.3274m^2, or 237.221acres when converted to acres.The value satisfies the requirement that the maximum area should be less than 300 acres.

Therefore, the Rational Method is applicable.

The ratio of runoff to rainfall is represented by the runoff coefficient. It depicts the interplay of different factors that includes infiltration, antecedent moisture, ground cover, groundslopes, and soil types, as well as the storage of water in surface depressions. Moreover, the coefficient may change depending on the seasonal conditions. Values will be average to easily simplify the determination of the coefficients. Dividing the summation of the products of the subareas and their coefficients by the total area will give you the composite coefficient for the drainage:

$$\underline{C} = \frac{(C_1 \times A_1) + (C_2 \times A_2) + (C_n \times A_n)}{\sum A}$$

Data from many buildings, both individually and collectively, have been acquired.

Researchers manually calculated the areas of the roads and areas with various land uses in order to arrive at the following results:

Table 5 Calculated Area and Runoff Coefficient Per Land use

LAND USE	AREA (㎡)	RUNOFF COEFFICIENT
ROOF	575, 450.38 ㎡	.90
GRASS SHOULDER	14, 824.56 ㎡	.25
DRIVES AND WALKS	172, 652.087 ㎡	.75
UNIMPROVED AREAS	207,072.30 ㎡	.10

Solving for $\underline{C}$:

$(C_1 \times A_1)$= (575, 450.380.90) = 517,905.342
$(C_2 \times A_2)$= (14,824,.56x.25) = 3, 706. 14
$(C_3 \times A_3)$= (172,652.0870x.75) = 129, 489. 0652
$(C_4 \times A_4)$= (207,072.30x.10) = 20,707. 23
$(C_1 \times A_1) + (C_2 \times A_2) + (C_n \times \;)$

$$\underline{C} = \frac{(C_1 \times A_1) + (C_2 \times A_2) + (C_n \times A_n)}{\sum A}$$

$$\underline{C} = \frac{517{,}905.342 + 3{,}706.14 + 129{,}489.0652 + 20{,}707.23}{959{,}999.3274}$$

$$\underline{C} = 0.6998$$

I indicate rainfall severity. Rainfall duration and design storm recurrence interval are related to rainfall intensity. Using rainfall intensity at a duration equal to the time concentration Tc, the peak flow in the Rational Method can be solved.

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

To determine the value of *I*, solve for T_c by the formula;

$$T_c = 0.01947 L^{0.77} S^{-0.385}$$

L is dependent on the length of reach, or the maximum length of the flow of water. On the other hand, the slope S is the difference in elevation divided by the ***L.***

$$S = \frac{H}{L}$$

➢ *Solving for H and L:*

- CA_1

L =106.87m

H = 99.139 - 99.102

=0.037 m.

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- CA_2

L =89.63m
H = 99.127 - 99.102
=0.025 m.

- *Solving for S:*

$$S = \frac{H}{L}$$

s_1 = 0.000346

s_2 = 0.00279

Substituting to:

$Tc = 0.01947 L^{0.77} S^{-0.385}$

Solving for Tc :

Tc_1 = $0.01947\ (106.87)^{0.77} (0.000346)^{-0.385}$
= 15.277 minutes or 0.2546 hours.

Tc_1 = $0.01947\ (89.63)^{0.77} (0.000279)^{-0.385}$

= 14.494 minutes or 0.2416 hours.

Frequently, estimates are used to determine rainfall frequency values for durations less than one hour because direct measurements are not readily available in a convenient format for compiling annual partial duration series. To estimate rainfall frequency data for short durations,average ratios of rainfall amount for 5, 10, 15, and 30 minutes compared to 1-hour amounts are used. These ratios have been computed from records of hundreds of station years and are listed below.

Table 6 Duration and Ratio

Duration (minutes)	5	10	15	30
Ratio (n minutes to 60 minutes)	0.29	0.45	0.57	0.79

d_{max} is attainable by using interpolation and since the $P_{20}$is already available, interpolate valuesof P_{20} = 67.7 and arrive at this:

Table 7 Time Duration and the Calculated Rainfall Depth

Time duration (mins)	5	10	15	20	25	30	40	60
Rainfall Depth (mm)	19.63	30.47	38.59	43.33	48.74	53.48	58.22	67.7

Once T_c has been established for various catchment areas, the value of d_{max} can be determinedthrough interpolation of the rainfall depth values listed in the table above, taking into account their corresponding T_c values.

$$dmaxCA1 = \frac{15.277 - 20}{x - 45.9} = \frac{30 - 20}{54.1 - 43.9}$$

$$= 41.0825\text{ mm}$$

$$dmaxCA2 = \frac{14.494 - 20}{x - 45.9} = \frac{30 - 20}{54.1 - 43.9}$$

$$= 40.2839\text{mm}$$

The formula for rainfall intensity provides the I for each catchment area.

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

- *Solving for I :*

I_{CA1} = 41.0825 / 0.2546 = 161.3620 mm/hr

I_{CA2} = 40.2839 / 0.2416 = 166.7380 mm/ hr

$Ac1$ = $0.000768 km^2$

$Ac2$ = $0.001332\ km^2$

Peak discharge will be calculated using the formula below:

$$Q = \frac{1}{3.6} CIA$$

$$Q_{CA1} = \left(\frac{1}{3.6}\right)(0.6998)(161.3620)(0.000768)$$
$$= 0.0240 \frac{m^3}{s}$$

$$Q_{CA2} = \left(\frac{1}{3.6}\right)(0.6998)(166.7380)(0.01187)$$
$$= 0.38473 \frac{m^3}{s}$$

$$D = \frac{Volume}{Time}$$

$$0.38473 = \frac{Volume}{14.494 \min \times 60}$$

Volume = 334. 577 m^3 is the ideal volume

Dimension of the Drainage is 0.9m x 0.9m x 750m

= 750 x 0.9 x 0.9

= 607. 5 m^3 is the actual volume607.5 m^3> 334. 577 m^3

Therefore, Safe

Through this, the individual discharges per catchment area are determined. Using the Manning's equation $Q = \frac{1}{n} AR^{\frac{2}{3}} S^{\frac{1}{2}}$ (using Manning's Roughness Coefficient as 0.012), it can be n solved by equating the discharge Q.

Results are the following:

Table 8 Discharge of Catchment Areas

CATCHMENT AREAS	C	H (m)	L(m)	S	Tc(mins)	Tc(hrs)	dmax	I	Ac	Q
CA1	.0.6998	0.037	106.87	0.000346	15.277	0.2546	41.0825	161.3620	0.000768	0.0240
CA2	.0.6998	0.025	89.63	0.00279	14.494	0.2416	40.2839	166.7380	0.001332	0.38473

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➢ *Designing*

Flooding has been a major problem for the residents of Sto. Rosario for more than a decade and experiencing it despite light rains. The main source of flooding is the absence of drainage systems within the barangay. The drainage system of the neighboring barangay is thefollowing layout below. It is redrawn for better visuals. The existing drainage system is 130cm wide and its height is 115cm and it will extend for the next 750 meters along the Sto. Rosario road.

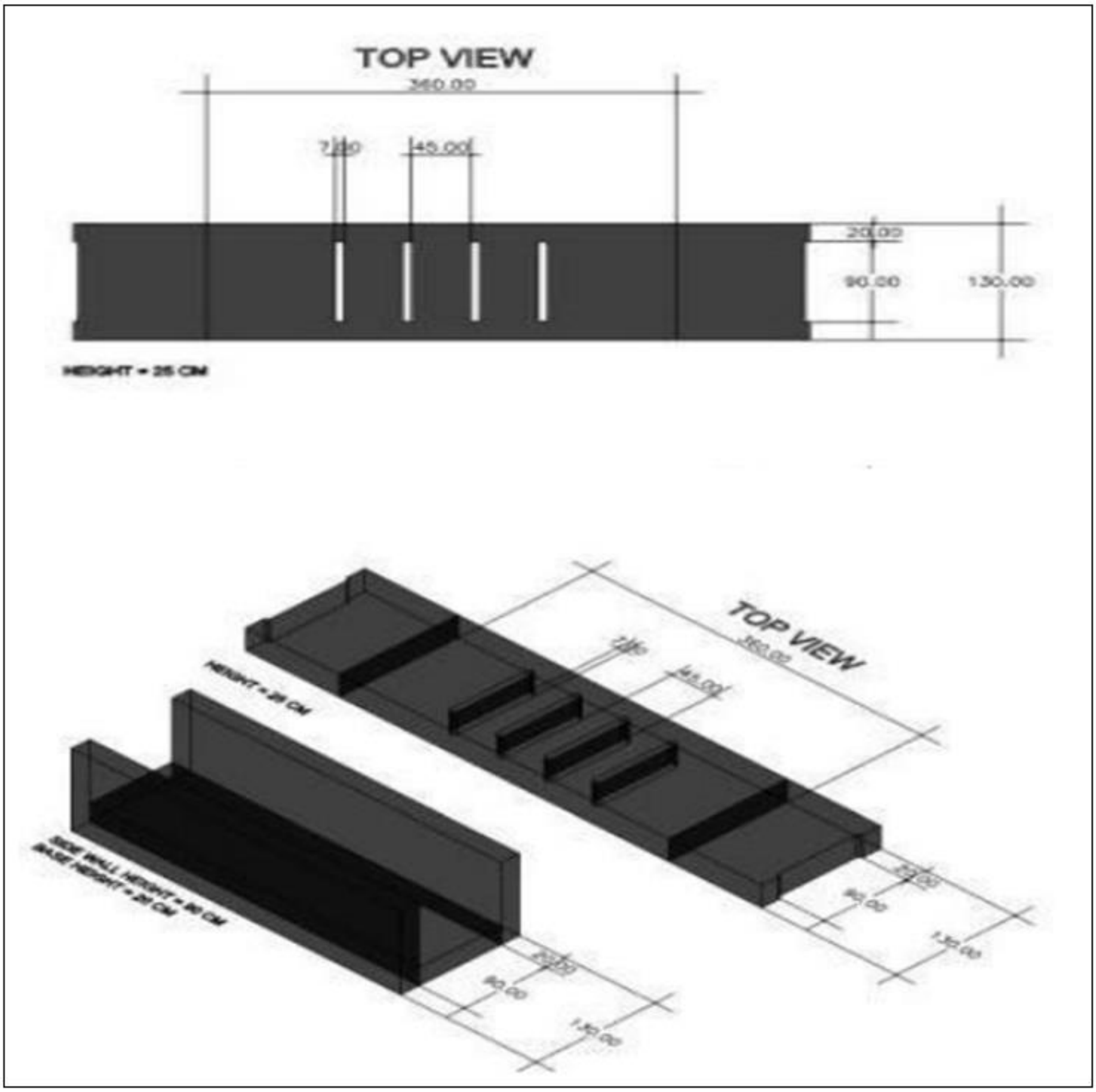

Fig 20 Proposed Extension of Drainage System

➢ *Outlet*

Considering the information obtained, the Sto. Rosario Highway is prone to flooding because it has low runoff and no established drainage system. The researchers came to the conclusion that the drainage system in San Pablo may be adapted to extend to Sto. Rosario. Given that the barangay is situated between two rivers which are the Abacan and SapangBalenrivers, these two rivers will serve as the flooding outlets.

Fig 21 Top View of the Location of Drainage System and the Nearest River

➢ *Narrative*

The Drainage system of the neighboring barangay is found at the following dimensions: 750 cm x 130 cm x 115 cm. The walls are in 20 cm thick for both sides. The base is 20 cm thick from the ground to the visible surface. The cover of the drainage is removable and has a provided manhole that can fit 980 cm. The cover is 25 cm in thicknessand with holes each measuring 7 cm in diameter with a rectangular shape 90 cm length between 2 semi-circular hole.

➢ *Evaluation*

The researchers calculated the total discharge in barangay Sto.Rosario. Based on the findings, the researchers were able to assess if the current drainage system could handle the water flow properly. It was found out that the current drainage system was able to control thewater's discharge or flow rate. This finding implies that the current infrastructure was capable of managing the amount of water during typical rainstorm events without leading to serious flooding.

CHAPTER FOUR
CONCLUSIONS AND RECOMMENDATIONS

➢ *Summary*

The purpose of this study is to provide an extension of the drainage system for the residents and passersby of the highway road in Sto. Rosario, Mexico, Pampanga. The proposed extension of the drainage system will be helpful to minimize the longer existence of flooding throughout the area and will provide wider space for its user. To attain the given objective, given factors were considered such; as rainfall accumulation, categorization of the barangay, profile leveling, parameters, and provision of a drainage system and discharge value There is no existing drainage prior to the first station up to the last station. To ensure protection against flooding, the frequency of rainfall intensity and duration was used to determine whether the current drainage system should be retained for design purposes or if a new system should be suggested. The area was also located at a lower elevation. The study used the Rational Method, a popular technique for calculating peak flows from small drainages with considerable impervious regions, to decide on the proper drainage system design. Overall, the findings provide a thorough and comprehensive evaluation of the study area and come up with a proposed extension of the drainage system.

➢ *Conclusion*

Barangay Sto. Rosario, Mexico, Pampanga has a total land area of 915, 759.13 m^2. It wasidentified that 780 meters from the designated first station have no existing drainage system. The researchers also identified 2 catchment areas that locate where flooding normally exists. It was determined that the floodwater will remain for days and is only waiting to dry up. The proposed extension of the drainage system is adequate and fit for the current needs of the barangay. The adoption of the proposed design will contribute in reducing the consequences and enhancing the town's situation.

➢ *Recommendation*

- *Road Reconstruction*

✓ Procurement of the damaged roads.
✓ Elevating Roads to aid the eradication of Catchment Areas.
✓ Providing a walkway for residents.
✓ Better visibility of partitions and available land for future improvements.

- *Setting a Minimum Setback Requirement*

✓ Establishing a mandatory setback for future building and infrastructure development
✓ Providing wider space.
✓ Making the 2 lanes possible for driving, minimizing the possibility of traffic jams.

- *For Future Researchers*

✓ Render the proposed extension of the drainage system in known software.
✓ Create a miniature to visualize the concept in life.
✓ Provide more architectural styles that may fit the design.

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ISSN No:-2456-2165

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APPENDIX (Last letter applicable)

DOCUMENTATIONS

Rainfall Intensity Duration-Frequency Analysis Data

Republic of the Philippines
Department of Science and Technology
PHILIPPINE ATMOSPHERIC, GEOPHYSICAL AND ASTRONOMICAL SERVICES ADMINISTRATION (PAGASA)
FLOOD FORECASTING BRANCH
WFFC, BIR Road, Quezon City 1100 Tel. No. 928-27-54/926-50-60 Fax. 929-40-65
Webpage: http://pagasa.dost.gov.ph

RAINFALL INTENSITY - DURATION FREQUENCY ANALYSIS DATA

for

STA. CRUZ, PORAC, PAMPANGA

Based on 17 years of record

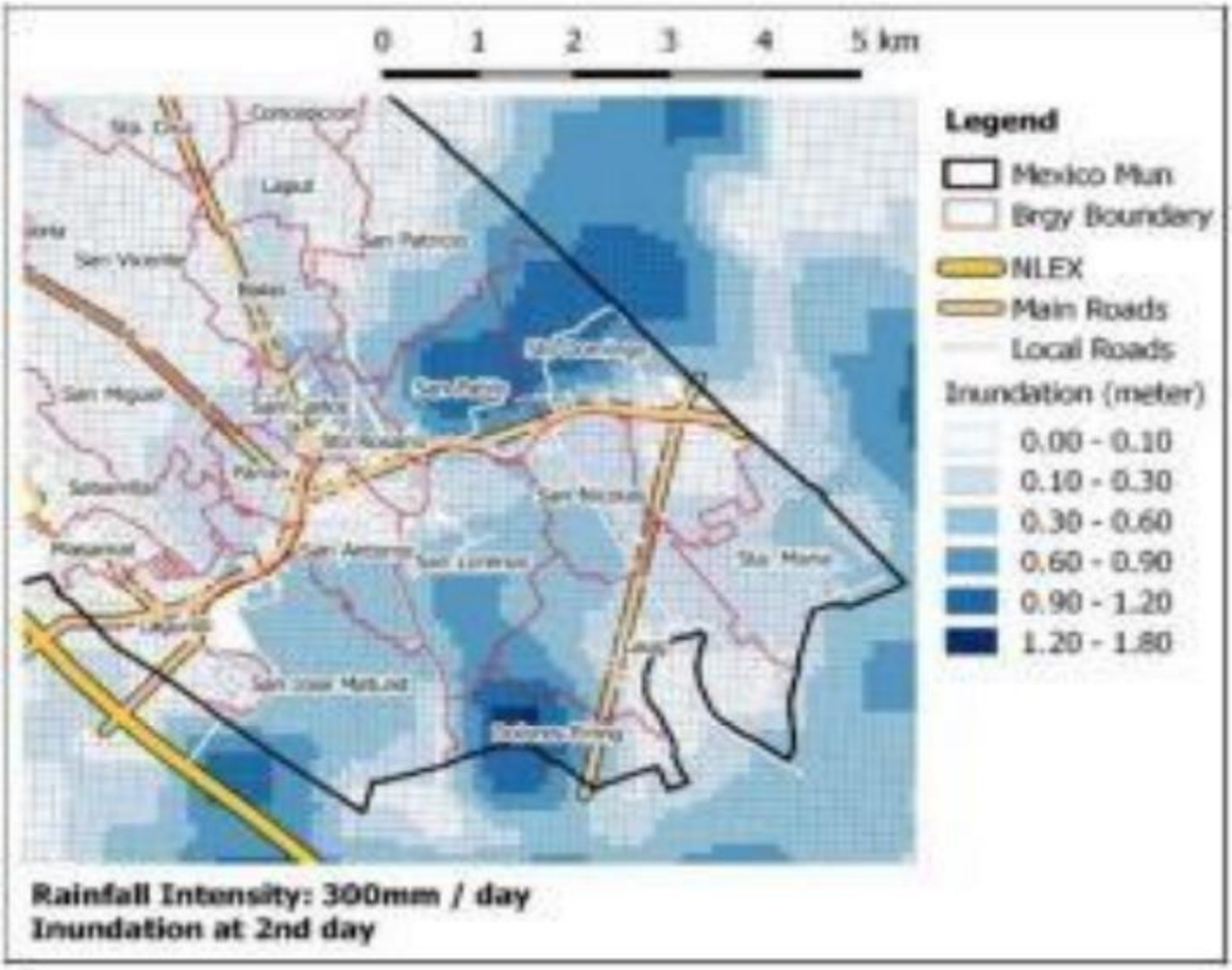
COMPUTED EXTREME (in mm) OF PRECIPITATION

Return Period (yrs)	5 mins	10 mins	15 mins	20 mins	30 mins	45 mins	60 mins	80 mins	100 mins	120 mins	150 mins	3 hrs	6 hrs	12 hrs	24 hrs
2	12.9	19.7	25.4	29.4	37.3	42.7	45.7	52.0	56.9	60.3	66.8	71.0	94.7	128.1	164.2
5	15.8	23.8	30.2	35.7	44.6	51.4	55.3	63.4	70.2	74.5	83.3	89.1	121.1	166.7	214.6
10	17.7	26.5	33.3	39.9	49.4	57.2	61.7	70.9	79.0	83.9	94.3	101.0	138.6	192.3	248.0
15	18.8	28.0	35.1	42.2	52.2	60.5	65.2	75.2	84.0	89.2	100.5	107.8	148.5	206.8	266.9
20	19.6	29.1	36.4	43.9	54.1	62.8	67.7	78.1	87.5	92.9	104.8	112.5	155.4	216.9	280.1
25	20.1	29.9	37.4	45.1	55.6	64.5	69.7	80.4	90.1	95.8	108.2	116.1	160.7	224.7	290.2
50	21.9	32.5	40.3	49.0	60.1	69.6	75.6	87.5	98.4	104.6	118.4	127.3	177.2	248.6	321.5
100	23.7	35.0	43.3	52.9	64.7	75.3	81.5	94.5	106.6	113.3	128.6	138.5	193.4	272.5	352.6

EQUIVALENT AVERAGE INTENSITY (in mm/hr) OF COMPUTED EXTREME VALUES

Return Period (yrs)	5 mins	10 mins	15 mins	20 mins	30 mins	45 mins	60 mins	80 mins	100 mins	120 mins	150 mins	3 hrs	6 hrs	12 hrs	24 hrs
	5	10	15	20	30	45	60	80	100	120	150	3	6	12	24
2	154.8	118.2	101.6	88.2	74.6	56.9	45.7	39.0	34.1	30.2	26.7	23.7	15.8	10.7	6.8
5	189.6	142.8	120.8	107.1	89.2	68.5	55.3	47.6	42.1	37.3	33.3	29.7	20.2	13.9	8.9
10	212.4	159.0	133.2	119.7	98.8	76.3	61.7	53.2	47.4	42.0	37.7	33.7	23.1	16.0	10.3
15	225.6	168.0	140.4	126.6	104.4	80.7	65.2	56.4	50.4	44.6	40.2	35.9	24.8	17.2	11.1
20	235.2	174.6	145.6	131.7	108.2	83.7	67.7	58.6	52.5	46.5	41.9	37.5	25.9	18.1	11.7
25	241.2	179.4	149.6	135.3	111.2	86.0	69.7	60.3	54.1	47.9	43.3	38.7	26.8	18.7	12.1
50	262.8	195.0	161.2	147.0	120.2	92.8	75.6	65.6	59.0	52.3	47.4	42.4	29.5	20.7	13.4
100	284.4	210.0	173.2	158.7	129.4	100.4	81.5	70.9	64.0	56.7	51.4	46.2	32.2	22.7	14.7

Range of Flood Depth in Frequently Inundated Barangays (Based on EFDC Simulation)



ISSN No:-2456-2165

Table 1-3. *Area (ha) of Existent Land Use (2017) per Barangay*

Brgy Name	Agri	Agri-Ind	Com	Buffer/ Gbelt	Ind	Infra	Inst	Parks, Rec	Res	SHZ	Water	Cem
Acli	237.23	5.79	5.75	8.06	0.07	11.86	0.24	0.00	5.67	5.80	0.71	0.00
Anao	384.75	0.00	0.71	8.95	0.00	9.54	2.81	5.98	39.38	0.00	4.50	5.77
Balas	127.77	0.00	0.23	4.61	0.00	3.74	0.45	2.80	23.87	0.00	25.07	0.00
Buenavista	165.61	5.88	0.00	2.62	0.00	1.81	0.31	0.00	10.99	0.00	5.43	0.00
Camuning	186.87	1.08	0.27	4.03	1.28	12.84	0.82	0.00	41.55	1.62	0.76	0.00
Cauayan	269.24	3.26	0.00	13.01	0.00	3.31	0.71	0.00	11.67	0.00	9.05	0.00
Concepcion	182.64	0.00	0.01	9.08	0.00	4.01	0.35	0.00	11.23	0.00	17.91	0.00
Culubasa	321.32	0.00	0.08	7.09	0.00	11.64	0.77	0.00	16.32	0.00	12.50	0.00
Divisoria	175.32	0.00	0.10	4.18	0.00	8.70	1.30	0.00	42.07	0.00	7.28	0.00
Dolores Piring	127.05	0.00	0.81	1.51	0.85	1.99	0.53	0.00	13.88	0.00	21.31	0.00
Eden	151.86	0.00	1.56	5.07	0.00	2.69	0.56	0.00	8.08	0.00	2.80	0.00
Gandus	184.93	5.81	0.00	1.61	7.89	5.36	0.03	0.00	13.04	0.00	0.18	0.00
Lagundi	62.31	0.00	43.45	4.25	3.50	17.07	0.48	0.00	63.55	2.37	3.81	0.00
Laput	148.75	0.00	0.15	5.32	0.95	4.53	0.46	0.08	14.14	0.00	19.03	0.00
Masamat	13.14	0.00	0.02	-0.33	0.14	15.09	0.49	0.00	87.12	0.00	0.61	0.00
Nueva Victoria	137.39	5.34	0.12	0.37	0.00	16.51	2.21	0.00	75.42	0.00	9.51	0.00
Pandacaqui	198.44	0.31	2.73	6.03	7.60	33.00	7.21	3.68	49.79	56.20	1.70	0.00
Pangatian	213.21	2.48	0.08	2.98	0.00	2.68	2.25	0.05	19.36	0.00	5.34	0.00
Panipuan	269.23	3.23	2.29	12.15	11.84	50.77	0.63	0.00	121.99	4.13	7.64	0.00
Parian	38.64	0.00	2.30	1.60	0.22	4.29	1.87	6.44	29.88	0.00	3.63	6.34
Sabanilla	98.57	0.05	0.03	2.91	0.00	27.91	0.78	37.58	100.98	18.64	4.57	0.00
San Antonio	94.99	0.21	2.24	2.12	0.00	7.03	1.86	0.00	42.10	0.00	14.30	0.00
San Carlos	40.54	0.00	0.66	1.89	0.00	2.86	2.76	4.20	18.18	0.00	3.32	4.20
San Isidro Laug	315.15	3.75	0.86	3.01	3.70	6.60	1.06	0.00	27.82	0.00	28.97	0.00
San Jose Malino	527.44	0.79	7.12	6.94	13.78	35.36	1.51	3.74	54.72	0.00	20.79	1.95
San Jose Matulid	343.55	0.00	0.00	9.67	0.00	20.12	1.10	0.00	39.47	0.00	15.95	0.00
San Juan	330.06	0.58	0.27	3.00	0.00	11.32	5.23	0.00	33.17	1.24	13.12	0.00
San Lorenzo	260.60	0.00	0.00	2.78	0.00	3.02	1.11	0.07	20.16	0.00	24.23	0.00
San Miguel	231.43	4.70	0.44	3.10	0.00	8.34	0.85	0.00	44.11	0.00	9.59	0.00
San Nicolas	130.35	2.55	0.00	0.16	4.88	2.53	0.21	0.00	17.67	0.00	25.07	0.00
San Pablo	142.36	0.00	2.40	4.39	3.19	5.63	0.32	1.29	17.03	0.00	34.18	0.00
San Patricio	264.64	0.00	0.00	5.92	0.00	5.40	0.59	0.00	35.40	0.00	52.69	0.00
San Rafael	165.89	0.01	0.00	8.97	0.00	50.73	0.12	26.54	125.80	13.21	6.35	4.43
San Roque	108.90	1.63	0.45	0.32	8.09	2.46	0.11	0.00	9.19	0.00	7.84	0.00
San Vicente	406.81	0.00	0.08	9.06	0.00	5.45	1.82	0.13	32.29	0.00	6.25	0.00
SapangMaisac	64.43	0.23	1.69	5.92	0.00	14.61	0.55	2.27	45.87	27.08	1.82	2.27
Sta. Cruz	262.01	0.00	0.05	3.60	0.00	6.37	0.88	0.98	37.99	0.00	16.49	0.00
Sta. Maria	233.29	2.74	0.16	-0.01	0.00	4.20	0.73	0.00	21.41	0.00	12.61	0.00
Sto Cristo	18.15	0.00	2.85	0.68	0.00	2.46	2.96	0.55	15.41	0.00	0.93	0.50
Sto Domingo	97.10	2.52	1.82	5.38	0.00	9.43	3.12	3.42	23.56	0.00	133.84	3.35
Sto Rosario	40.70	1.39	0.35	6.76	0.29	5.87	0.92	1.41	21.79	2.42	14.09	0.00
Suclaban	219.29	0.00	0.59	5.50	20.75	15.82	0.70	0.00	7.80	0.00	2.36	0.00
Tangle	535.05	24.24	0.00	14.50	1.30	18.10	3.27	5.82	69.35	4.43	15.54	0.00
TOTAL	8,527.00	78.55	82.72	208.78	90.32	493.05	57.04	107.03	1,560.27	137.14	623.67	28.81

Table 3-1. List of 43 Barangays in Mexico, Pampanga

North Area	Area (ha)	South Area	Area (ha)
1. Acli	281.18	23. Laput	193.40
2. Anao	462.39	24. Laug	390.92
3. Buenavista	192.65	25. Masamat	116.28
4. Camuning	251.12	26. Sto. Cristo (Masangsang)	44.50
5. Cawayan	310.25	27. Nueva Victoria	246.86
6. Culubasa	369.71	28. Parian	95.22
7. Eden	172.64	29. Sabanilla	292.03
8. Gandus	218.84	30. San Antonio	164.85
9. Pandacaqui	366.68	31. San Carlos	78.60
10. San Jose Malino	674.13	32. San Jose Matulid	429.88
11. Sapang Maisac	166.74	33. San Lorenzo	311.97
12. Pangatian	248.44	34. San Nicolas	183.42
13. Panipuan	483.89	35. San Roque	138.98
14. San Juan	398.00	36. San Pablo	210.78
15. Sta. Cruz	328.38	37. San Patricio	364.64
16. Suclaban	272.81	38. San Rafael	402.05
17. Tangle	691.62	39. San Miguel	302.56
18. Balas	188.54	40. San Vicente	461.90
19. Concepcion	225.24	41. Sta. Maria	275.12
20. Divisoria	238.94	42. Sto. Domingo	283.52
21. Dolores Piring	167.93	43. Sto. Rosario	96.00
22. Lagundi	200.79	**TOTAL**	**11,994.38**

Republic of the Philippines
Commission on Higher Education
DON HONORIO VENTURA STATE UNIVERSITY
Villa de Bacolor, Pampanga

RECEIVED 16 MAY 2023

May 16, 2023

To whom it may concern,

Good day, we are graduating Civil Engineering students from Don Honorio Ventura State University - Main Campus, and one of our curriculum requirements is to create a drainage design as our thesis. The proposed field of study is under Water Resources and Traffic Engineering. Our research is about extending the drainage system from San Pablo, Mexico through Sto. Rosario, Mexico, Pampanga. Our objective is to create an environment free from floodwaters. The selected project study will be along Jose Abad Santos Highway in Sto. Rosario, Mexico, Pampanga.

We would like to request permission to conduct the study within Sto. Rosario, Mexico, Pampanga, specifically on the roads and bridges within the area. The study will involve data gathering, and site inspections.

Rest assured that we will take the necessary precautions to ensure that our study will not cause any disruption to the community. We will coordinate with the local authorities and secure the necessary permits before conducting any activity within the area.

Your cooperation and support will be greatly appreciated. Thank you for your time and consideration.

Yours truly,

Aaron John Isidro
Edward Harold P. Marin
Jeremy Louis D. Marin
Melvin L. Marin

Ralph Jared C. Matias
Rhon Joseph M. Monsanto
Darwin M. Suba

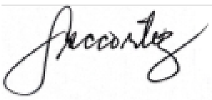
ISSN No:-2456-2165

MMARIAN'S CERTIFICATE

This is to certify that the undersigned has reviewed all the pages of the study titled **"Proposed Extension Of Drainage System InSto. Rosario, Mexico, Pampanga"** byAaron John Isidro, Edward Harold P. Marin, Jeremy Louis D. Marin, Melvin L. Marin, Ralph Jared C. Matias, Rhon Joseph M. Monsanto, and Darwin M. Suba., aligned with the set of structural rules that govern the composition of sentences, phrases, and words in the English language.

Signed this 7th day of June in the year of our Lord, 2023, at Don Honorio Ventura StateUniversity- Villa de Bacolor, Pampanga.

Signed:



LEILA C. CORTEZ,MAEd
Grammarian

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GRADUATE SCHOOL RESEARCH LABORATORY

Certificate of Plagiarism Scan

This certifies that the thesis entitled

"Proposed Extension of Drainage System in Sto. Rosario, Mexico, Pampanga"

By
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Marin, Edward Harold P.
Marin, Jeremy Louis D
Marin, Melvin L.
Matias, Ralph Jared C.
Monsanto, Rhon Joseph M
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BACHELOR OF SCIENCE IN CIVIL ENGINEERING MAJOR IN STRUCTURAL ENGINEERING

Scanned and reviewed by the Graduate School Research Laboratoryon June 10, 2023.

CHARLIE K. P PADILLA, MIT
Plagiarism and Grammar Review Coordinator

PGR-00424-21i23
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