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Design Proposal of a Coastal Bridge as an Access Route for an Efficient Local Travel in Barangay Malusac, Sasmuan, Pampanga

Jertrude P. Salunga[1], Jacob V. Ramos[2], Kate Catherine O. Ramos[3], Sonny Vic P. Razon[4], Khian D. Rivera[5], Aldrich Mitchel M. Santos[6], Jafet C. Culala[7], Raul O. Duya[8]

[1]*Department of Civil Engineering, Don Honorio Ventura State University, Bacolor, Pampanga, Philippines*
Email: slngjrtrdprz@gmail.com
[2]*Department of Civil Engineering, Don Honorio Ventura State University, Bacolor, Pampanga, Philippines*
Email: ramosjacob103@gmail.com
[3]*Department of Civil Engineering, Don Honorio Ventura State University, Bacolor, Pampanga, Philippines*
Email: ramoskcatherine@gmail.com,
[4]*Department of Civil Engineering, Don Honorio Ventura State University, Bacolor, Pampanga, Philippines*
Email: sonnyvicrazon@gmail.com
[5]*Department of Civil Engineering, Don Honorio Ventura State University, Bacolor, Pampanga, Philippines*
Email: khiandrivera@gmail.com
[6]*Department of Civil Engineering, Don Honorio Ventura State University, Bacolor, Pampanga, Philippines*
Email: aldrichmitchelsantos10@gmail.com

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Abstract:
The study addresses the critical transportation challenges faced by Barangay Malusac, a coastal community in Sasmuan, Pampanga, due to the lack of infrastructure connecting it to nearby towns. The current reliance on water transportation is inefficient and unreliable, limiting access to essential services like healthcare, education, and emergency response. To improve local transportation and connectivity, the study proposes a sustainable coastal bridge design. Using a mixed-method approach, including surveys of 333 residents and interviews with municipal engineers, the findings highlight the urgent need for improved infrastructure. Advanced tools such as QGIS, HEC-HMS, HEC-RAS, and MIDAS Civil were used for comprehensive analysis and design. The proposed bridge, adhering to relevant design guidelines and standards, features a 20-meter span, 7.32-meter width, two lanes, and sidewalks, ensuring structural integrity and safety. This bridge aims to enhance the quality of life in Barangay Malusac by providing reliable transportation and better access to essential services.

Keywords **—Coastal Community, Coastal Bridge, Travel Patterns, HEC-HMS, HEC-RAS, QGIS, MIDAS Civil.**

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I. INTRODUCTION

Human existence depends heavily on transportation, which is an essential component that makes it easier to obtain necessities and contributes significantly in several aspects of daily life. It is the key facilitator for people to access essential services including jobs, healthcare, and education. Efficient transport is also essential for promoting recreational activities and improving general wellbeing. Besides personal use, transport is essential to businesses as it facilitates the flow of goods and services that are necessary for long-term economic viability. Furthermore, in order to preserve and enhance public services, governments depend on strong transportation networks. A well-functioning transportation system is essential for the overall advancement and well-being of societies.

The term "coastal communities" refers to areas that are situated directly above the surface waters and are typically found along lakeshores, riverbeds, mangrove swamps, estuaries, and seacoasts [1]. Transportation in coastal areas holds unique challenges and significance due to the proximity to water bodies and the dynamic nature of coastal environments. Coastal areas rely on water transportation to travel within the community, which can limit the movement of people in that area.

A bridge can significantly alleviate the transportation limitations in coastal areas by providing a direct and efficient pathway between two points. This infrastructure reduces the reliance on water transportation, leading to a significant decrease in travel time for the people in the community traveling in and out of the area, making travel more accessible and convenient. It provides a reliable and secure means of transportation, improving safety in the movement of people and goods between coastal communities.

The United Nations created 17 world development goals called the Sustainable Development Goals. The Sustainable Development Goals (SDGs) are a set of 17 global goals adopted by all United Nations Member States in 2015 as part of the 2030 Agenda for Sustainable Development. The Sustainable Development Goals (SDGs) aim to transform the world. They serve as a call to action to end poverty and injustice, save the environment, and guarantee the well-being, fairness, and prosperity of all people. Ensuring that nobody is left behind is crucial [2]. The SDGs are designed to address a range of global challenges and promote sustainable development across economic, social, and environmental dimensions. They aim to improve the well-being of people and the planet by tackling issues such as poverty, hunger, health, education, gender equality, clean water, sanitation, affordable and clean energy, decent work, industry and innovation, reduced inequalities, sustainable cities, responsible consumption and production, climate action, life below water, life on land, peace, justice, and strong institutions.

Ensuring inclusive, safe, resilient, and sustainable cities and human settlements is the focus of Sustainable Cities and Communities, Goal 11 of the Sustainable Development Goals (SDGs) [3]. Affordable housing, environmentally friendly transport, inclusive urbanization, cultural heritage preservation, disaster risk reduction, environmental impact reduction, public space accessibility for all, integrated development planning, mitigating and adapting to climate change, and assistance for countries that are less developed are just a few of the issues it covers. The objective is to make sure that cities support social and environmental sustainability, and resilience to hazards like disasters and climate change, in addition to improving the quality of life for all citizens.

This chapter provides a comprehensive review of previous research and studies that are pertinent to the current study. It also explores the study's background, presents the problem statement, outlines the objectives, and discusses the overall significance of the research.

A. Background of the Study

Developing society needs to embrace improvements that can possibly help arise in every aspect in that particular area. According to One Ocean Organization, the Philippines is one big coastal community of more than 70 million people. The country boasts a coastline that spans over 18,000 kilometers, encompassing coastal waters spanning 266,000 square kilometers in area. Seventy percent of its more than 1,500 municipalities are located in the coastal area, which is home to millions of people for whom the sea is an ordinary, but often little understood, fact of life.

Sasmuan covers a land area of 91.80 square kilometers or 35.44 square miles, accounting for 4.59% of Pampanga's total area. According to the 2020 Census, its population was 29,076, constituting 1.19% of Pampanga's total population and 0.23% of the Central Luzon region's overall population. Using these statistics, the population density can be calculated as 317 residents per square kilometer or 820 residents per square mile.

Sasmuan, a fourth-class municipality located in the coastal province of Pampanga, is situated in the southern part of the province, sharing its coastline with the municipalities of Macabebe and Lubao, making it one of the three coastal municipalities in the province along Manila Bay. To the north, Sasmuan is bordered by Guagua and Minalin, to the east by Macabebe, to the west by Lubao, and to the south by Manila Bay. The majority of Sasmuan's land area consists of fish ponds, streams, and rivers. A notable feature of Sasmuan is the predominance of fish ponds within its land area. These fish ponds are used for aquaculture and play a vital role in the local economy, contributing to the production of various seafoods. Sasmuan is also recognized as an agricultural town, with rice and fish being the primary products of the region. Agriculture, including both rice farming and fishing, plays a role in the livelihoods of the local residents [42].

Sasmuan, Pampanga consists of 12 barangays. Five of them, Sebitanan, Malusac, Mabuanbuan, Batang 1st, and Batang 2nd, were located at the end of the main municipality. They are the most affected places surrounding rivers in their locations. Each barangay needs water transportation in order to get or land in their target place. According to PhilAtlas in the 2020 census, almost 22% of the entire population in the Municipality of Sasmuan lived and were affected in those said barangays. Majority of the municipality is used for aquaculture (76%) while only a minor portion is built-up with residential, commercial, institutional, and other buildings (2%). Waterways, which include rivers and creeks, make up 12% of total area while mangrove areas which line the waterways make up only 1% of the municipality's total land area.

According to the Comprehensive Land and Water Use Plan of Municipality of Sasmuan, Pampanga, the topography of the municipality is primarily plain and flat, with an elevation approximately 6 meters above the towns mean sea level. It has two kinds of soil type, which is the Hydrosol and La Paz Silt Loam. Hydrosol is a form of soil that is usually grey or greenish-grey in color and is saturated with water over a long period of time. On the other hand, La Paz Silt Loam has a greyish color because to its prolonged saturation with water.

Fig. 1 Drone Shot of Barangay Malusac, Sasmuan, Pampanga

Malusac is a barangay located in the municipality of Sasmuan, situated in the province of Pampanga. According to the 2020 Census, its population was recorded at 2,461, constituting 8.46% of the total population of Sasmuan. Notably, Malusac serves as the initial barangay where coastal communities begin within the municipality of Sasmuan, Pampanga.

Until now, aside from water transportation, there are no other shorter routes for the communities from coastal areas. It's been an ongoing issue for how many decades. According to Engr. Guillermo Reafort Angeles, municipal engineer of Sasmuan, the travel time from Barangay Malusac to Sasmuan Town Proper is almost two hours.

Coastal bridges are important assets in coastal communities, improving transportation efficiency and connection. These constructions have various benefits, including decreasing traffic congestion by giving alternate routes to coastal regions and drastically lowering travel times by providing direct crossings over bodies of water. Furthermore, coastal bridges can encourage economic growth by enhancing company access to clients and attracting visitors more effectively. They also play an important role in improving emergency response times during natural catastrophes, encouraging development in formerly isolated coastal areas, and limiting environmental effects via intelligent design and decreased disruption to sensitive ecosystems.

B. Review of Related Studies

B.1. Modes of Transportation and Travel Patterns

Transport modes are the systems that enable both mobility of passenger and freight. They can be divided into three basic types; air, land for road, rail, and, pipelines and water for shipping [4]. The mode of transportation plays a crucial role in various aspects of modern society, affecting individuals, businesses, and the overall economy. Identifying and understanding the modes of transportation in a community is crucial for several reasons, as it provides valuable information for planning, development, and overall improvement of the community.

It has been demonstrated that limited transport opportunities hinder social inclusion and accessibility in modern society, particularly for those who reside in rural and less populated areas. The need for and willingness to engage in regular relationships and activities is the same for people living in rural and urban areas, but the lack of good transportation options in rural areas has a significant impact on how households organize transportation and what places and activities they can access [5]. Limited transportation options can make it more difficult to access necessities like healthcare, education, and work opportunities in rural and less populous places. Accessing schools, jobs, and medical services may be difficult for the residents, which could have an impact on their general well-being and standard of living.

Understanding the travel patterns or travel behavior of a population is fundamental in comprehending and evaluating the transportation needs of a community. It also provides valuable information for transportation planning, infrastructure development, and overall well-being of the community. Planning for a more effective traffic system that meets the need for human mobility requires in-depth understanding of travel patterns. The majority of this knowledge is derived from traffic models that are based on relatively small samples of data gathered through traffic counts and travel surveys [6].

Identifying travel patterns is a crucial factor in assessing the special structure and connectivity of road networks. Investigating travel patterns is therefore important for traffic control, urban planning, and improvement of transportation system's operational efficiency [7]. Analysis of travel patterns is essential for maintaining the operational efficiency of the transportation system. Transportation authorities are able to strategically engage in infrastructure development by having a thorough awareness of people's movements between different zones and destinations.

B.2. Bridge

Bridges are critical infrastructure that play an important role in society that offers numerous benefits and contributes to various aspects of human life, economic development, and the functioning of communities. The bridge takes a special role because of its function that can connect two different places, crossing valleys, rivers, lakes, and cliffs. Bridges are needed on transportation infrastructure because they connect different points that are usually inaccessible [8]. It can also serve as evacuation routes during natural disasters and emergencies, ensuring the safety of the residents. This can also facilitate the swift deployment of emergency services. Bridges shorten commute times, improving the efficiency and convenience of daily travel. They make it simpler for residents to access jobs, education, and other services.

A bridge is a structure that spans between supports to carry vertical loads, including the weight of people, vehicles, or other loads that must be transferred between two points. The fundamental design of a bridge includes two supports holding up a beam, wherein the supports must have sufficient strength to uphold the structure, and the span between them must be sturdy enough to carry the loads. Furthermore, major bridges are funded by public money, which is why they should be designed with the public's interest in mind. Bridges should prioritize efficiency, economy, and safety. Efficiency entails minimizing the materials used while maximizing performance. Economy involves reducing construction costs while maintaining efficiency. Moreover, bridges should be safe to protect lives, sustain economic activities, and prevent events that could affect both people and the environment [9].

Bridge developments should examine chances for regeneration of surrounding land, creation of new public spaces, and use of lighting to create safe, open places beneath bridges in addition to boosting connectivity and supporting active travel. Elevated bridges provide unique observation platforms, encouraging people to appreciate the environment and engage with it. Consultation and involvement are required for bridge projects to have a beneficial societal impact. When determining the cost of bridge construction, cost vs value is an important factor to consider. A bridge's worth to its users or occupants might assist decide its affordability. New mechanisms for identifying, capturing, and evaluating broader social effects are being created, making it simpler to fund more ambitious project aims [10].

Highway bridges are crucial for society, but they can be seriously damaged by natural disasters, such as earthquakes, hurricanes, and floods. This article introduces an integrated framework for assessing their long-term resilience and damage potential. When disasters strike, these bridges can disrupt transportation and hinder rescues, leading to significant societal and financial losses. Therefore, evaluating bridge vulnerability and recovery potential during such events becomes imperative for improved emergency response and recovery efforts. One essential element in rebounding from extreme events is resilience, which measures a structure's ability to recover. This study employs a renewal process model to compute the anticipated long-term resilience and potential damage, taking into account a variety of hazard characteristics. By doing so, it offers valuable insights into enhancing the preparedness, design, and maintenance of critical infrastructure systems facing the ever-present threat of multiple natural disasters [11].

Beyond simply enhancing transportation connections, bridge projects help communities in several ways on the social and environmental fronts. To provide these advantages, engineers must use a people-centered approach to planning and design. The rebuilt Pooley Bridge in England, for example, emphasizes the citizens' sentimental relationship to the older, 250-year-old stone bridge by symbolizing the community's reliance on the passage. The cost of bridge projects that seek to alter society will not necessarily be higher than initiatives that only work to construct the bridge. Ideas for enhancing lives and livelihoods can be explored by seeing bridges as services rather than as systems or buildings. Better transportation options can open up more opportunities for employment and education, develop new economic hubs, and rebalance the expansion of the economy. Pedestrian and bicycle bridges promote people of all ages to travel by foot or bicycle, enhancing the general well-being of the community [11].

Essential infrastructures such as bridges are designed to provide a long-lasting and intergenerational functionality. In those cases, sustainability becomes of paramount importance when the infrastructure is exposed to aggressive environments, which can jeopardize their durability and lead to significant maintenance demands. The assessment of sustainability is however often complex and uncertain. Choices made based on the optimality of a design in only some of the sustainability pillars will lead to erroneous conclusions. The use of concrete with silica fume has resulted in a sustainability performance of 46.3% better than conventional concrete designs [12].

The construction of bridges has environmental implications both during the building process and after completion. Materials such as steel and concrete, essential for bridge construction, require energy for manufacturing and transportation, leading to the production of dust, carbon dioxide, and noise—contributors to climate change. To reduce these environmental impacts, it is crucial to design and construct bridges in a sustainable manner. Using sustainable materials and adopting green designs in bridge construction can enhance the longevity of bridges, reducing the necessity for extensive maintenance. This not only diminishes the environmental effects of bridge construction globally but also lowers the costs and time associated with ongoing maintenance and repairs [13].

B.3. Coastal Bridges

Coastal bridges have been around for centuries, but their design and construction have evolved significantly over time. The earliest coastal bridges were simple wooden structures that were often destroyed by storms and tides. As engineering techniques improved, so did the durability and strength of coastal bridges. Today, coastal bridges are some of the most impressive and challenging engineering feats in the world. The first coastal bridges were built in ancient Greece and Rome. These bridges were typically made of wood and stone and were often quite short. They were used to cross small rivers and streams, but they were not strong enough to withstand the harsh conditions of the open ocean [14].

In the Middle Ages, coastal bridges became more sophisticated. Engineers began to use arches and buttresses to make their bridges stronger and more durable. They also began to build longer bridges, which allowed them to cross larger bodies of water. The Industrial Revolution led to a dramatic increase in the construction of coastal bridges. New materials, such as steel and concrete, made it possible to build bridges that were stronger, longer, and more durable than ever before. Coastal bridges also became more complex, as engineers developed new techniques to protect them from the forces of nature [15].

Building coastal bridges is a challenging task, due to the harsh conditions of the marine environment. Coastal bridges must be able to withstand the effects of waves, tides, storms, and salt water corrosion. Engineers must also consider the impact of climate change, as rising sea levels and more extreme weather events are putting additional strain on coastal infrastructure [16].

The Philippines' bridge-building history mirrors its evolution, shaped by colonial influences. Early Spanish bridges, built with wood, may have been basic, but they connected regions. The Americans brought concrete and steel, enabling grander bridges and a national road network. Post-war marvels like the record-setting San Juanico Bridge and the unique Shell Helix Bridge with its spiral design stand out. Today, the Philippines boasts a diverse collection of coastal bridges, from arches to suspension to cable-stayed, vital for transportation, the economy, and even disaster relief [17].

Despite their significance, coastal bridges in the Philippines face challenges, particularly from natural disasters such as typhoons, earthquakes, and landslides. Additionally, the impact of climate change, including rising sea levels, poses an ongoing threat, necessitating careful planning and adaptation measures. However, with a commitment to infrastructure investment from the government, there is optimism for the future of coastal bridges in the Philippines. Ongoing and planned projects aim to enhance transportation systems, spur economic development, and strengthen social cohesion, highlighting a positive trajectory for the role of bridges in the country's growth and resilience [18].

In the Philippines, coastal bridges are lifelines, stitching islands, provinces, and communities together. They're vital for business, daily commutes, and tourism, pumping life into local and regional economies. A single day's closure of Manila's major bridges can cost ₱10 billion, a DOT study shows. Socially, they connect people to schools, hospitals, emergency services, fostering unity. Typhoon Yolanda's devastation exposed how isolation grows when bridges fall, cutting off access to critical care. They're also evacuation routes and conduits for disaster relief, as seen after Typhoon Haiyan. But typhoons, earthquakes, and landslides threaten these crucial links. Superstorms like Yolanda batter foundations and rip apart structures, while tremors like the 1990 Luzon earthquake can crack their very core. Even landslides can cause catastrophic collapses. This vulnerability demands proactive measures and resilient infrastructure to protect these vital lifelines and weather the inevitable storms [19].

Coastal bridges stand as indispensable components of the Philippine transportation infrastructure, providing critical connections between islands, provinces, and municipalities. Their multifaceted roles include facilitating transportation for goods and people, fostering economic growth, promoting social cohesion, aiding in emergency response efforts, and contributing to tourism and recreation. These bridges play a pivotal part in enhancing the lives of Filipinos by providing access to essential services, employment opportunities, and markets [20].

Safeguarding coastal bridges is paramount for the well-being of the Philippines. By protecting these vital structures through investments in maintenance, upgrades, and resiliency measures, the country can ensure continued economic development, social integration, and effective response to emergencies. Preserving and enhancing coastal bridges is an investment in the resilience and sustainability of the nation's infrastructure, supporting the well-being and prosperity of its coastal communities [21].

Coastal bridges are a type of infrastructure that connects land areas separated by rivers, bays, or other coastal water bodies. It serves as a critical transportation link that supports the movement of people, goods, and services while providing access to coastal regions. Coastal bridges are important infrastructures that not only connect communities, and facilitate trades which contribute significantly to the local and regional economy, but also serve as an emergency access to facilitate post-disaster rescues [22]. Coastal bridges are exposed to water at all times, which can lead to corrosion of its structural components. These are often made of corrosion- resistant materials, such as stainless steel or specially coated steel to avoid the effects of saltwater corrosion. These bridges are also designed to be able to withstand environmental conditions associated with coastal areas, including exposure to saltwater, storms, and potential erosions.

The field of coastal bridge design has seen significant progress thanks to advancements in construction technologies and materials. Researchers have been investigating the application of cutting-edge materials like fiber-reinforced polymers and innovative construction techniques such as prefabricated bridge elements. These advancements offer multiple benefits, including improved efficiency and enhanced durability of coastal bridges [23]. By incorporating these innovations, bridge projects can achieve higher levels of performance and longevity while also potentially reducing construction timelines and costs.

Numerous studies offer valuable insights by examining successful case studies of coastal bridge projects. These case studies encompass a variety of bridge types, such as cable-stayed, arch, and bascule bridges. They provide a comprehensive understanding of how different bridge designs influence various aspects, including local travel convenience, economic development, and the overall well-being of the community [24]. Analyzing these real-world examples not only highlights the effectiveness of diverse bridge designs but also serves as a source of inspiration and best practices for future coastal bridge projects, ensuring they meet the multifaceted needs of the communities they serve.

B.4. Coastal Communities

Coastal communities without bridges can face several employment-related challenges due to their limited access to economic opportunities. These challenges can significantly affect the livelihoods and well-being of the community. According to [25], one of the main causes of poverty in developing communities is a lack of effective infrastructure on transportation. In some communities, safe passage of rivers is often nonexistent, or bridges may be in poor condition. Coastal communities without bridges may struggle when it comes to access to employment which provides residents limited job opportunities. These communities may experience higher unemployment rates, as job seekers are limited only to local opportunities. Residents rely only on traditional sectors such as fishing, agriculture, or small-scale local industries. Commuting also poses a problem for the residents of coastal communities as they only rely on boats or finding alternate routes, which can be time-consuming, expensive, and physically demanding.

The success of coastal bridge projects hinges on actively involving the local community. It's vital to engage community members in the design process to understand and address their unique needs and preferences. Research emphasizes this involvement, highlighting that aligning the bridge design with what the community requires leads to better outcomes and greater acceptance of the infrastructure within the community [26]. Community engagement helps to ensure that the bridge design meets the needs of the community. Coastal bridges can have a significant impact on the communities they serve, both in terms of transportation and recreation. By engaging with community members early in the design process, project planners can learn about the community's priorities and concerns. This information can then be used to develop a bridge design that is both functional and meets the needs of the community. Ultimately, community engagement fosters a sense of ownership, enhances the effectiveness of the bridge, and contributes to the overall success of the project.

Coastal communities in the Philippines, home to over 70 million people, play a crucial role in global trade, tourism, agriculture, aquaculture, and fishing. However, overfishing, over-exploitation, and pollution are straining these resources, causing habitat loss, water quality issues, and marine life degradation. Mangrove forests are being converted into mangrove resorts, reducing natural habitats for fish, shellfish, and crustaceans. The limits of sustainable fishing have been reached or exceeded in many areas [27].

Furthermore, a lack of bridges stifles prospective development in remote coastal locations, restricting residential and commercial expansion options. This isolation, in turn, creates a scarcity of work prospects and stifles economic growth. As large road networks are required across delicate coastal ecosystems, the environmental impact of deficient bridges becomes more obvious, interrupting wildlife habitats and contributing to ecological deterioration. In essence, the lack of bridges in coastal locations causes a chain reaction of interrelated problems ranging from transportation inefficiencies and economic constraints to degraded emergency response capabilities and negative environmental consequences [28].

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B.5. Hydraulic/Hydrologic Analysis

The method of studying and comprehending the behavior of fluids, usually water within a system or structure is called hydraulic analysis. It involves applying the principles of fluid mechanics to predict the behavior of fluids in various situations. Numerous disciplines and situations, such as engineering, environmental science, and urban planning, use hydraulic analysis. Hydraulic analysis is crucial for system design, optimization, and management in complicated urban water distribution systems, which represent significant infrastructure. The process of determining the nodal pressure head and pipe flow rate hydraulic parameters under steady-state conditions is known as hydraulic analysis [29].

Hydraulic analysis is a method used by engineers to evaluate the performance of current hydraulic systems. This involves studying factors like pressure distribution, flow rates, and possible bottlenecks in order to identify problematic areas and troubleshoot problems. The depth of flow, flow velocity, and forces from flowing water on a surface or at hydraulic structures are all determined by hydraulic analysis. These investigations are essential to the hydraulic analysis and design of structures [30].

To measure the volumetric flow rate of water draining from a watershed, or drainage area, over time, hydrologic analysis is performed. The characteristics of a watershed, such as its size, land cover, antecedent moisture, and steepness, as well as the presence of water, such as the intensity and duration of a precipitation event or dam management, determine how much water flows from it [30].

The hydrological analysis model can help in estimating the extent of the flood, locating the sources of runoff pollution, and forecasting the impact of geomorphological changes on runoff. Numerous sectors and areas, including road design, forestry, agriculture, and disaster prediction, use it widely in regional planning [31]. Hydrologic analysis is a tool used by engineers to develop water-related infrastructure, including stormwater management facilities, irrigation systems, dams, and reservoirs. Determining the capacity and effectiveness of these buildings requires an understanding of the hydrological characteristics of the area.

B.6. Quantum Geographic Information System (QGIS)

A visual presentation is a tool for effectively conveying information to diverse audiences. Mapping stands as a prominent example of visual information, and the Quantum Geographic Information System (QGIS) is one of many mapping programs available. QGIS enables users to create, visualize, and analyze geospatial data. It provides a wide range of functionalities, such as using plug-ins and downloading maps and other online resources necessary for completing a particular task. This software offers a user-friendly interface that supports various data formats, such as shapefiles. [32]

Gandaki, a province in Nepal, is rich in water resources, including rivers and lakes. The analysis of watersheds within this region is crucial for effective management, planning, and sustainable utilization of these resources. Quantum Geographic Information System (QGIS) is the primary tool employed for conducting morphometric analysis of watersheds in Gandaki Province, utilizing the Digital Elevation Model (DEM) obtained from NASA-Earth data. This provided some of the morphometric watershed parameters including the drainage area and density, slope, flow length, and rainfall patterns. When establishing infrastructure projects in those watersheds, these findings can be reviewed. Additionally, when officials from local governments are formulating policies pertaining to infrastructure, energy, water resources, and irrigation, these findings serve as valuable references. [33]

B.7. Hydrologic Engineering Center-Hydrologic Modeling System (HEC-HMS)

HEC-HMS (Hydrologic Engineering Center – Hydrologic Modeling System) model was developed by the US Army Corps of Engineers (Feldman, 2000) that could be used for many hydrological simulations [34]. The HEC-HMS model can be applied to analyze urban flooding, flood frequency, flood warning system planning, reservoir spillway capacity, stream restoration, etc.

Parameter estimation on a regional scale at least may be possible to switch over to watershed models like the HEC-HMS and take advantage of the high-speed computer programs than spreadsheet exercises [35]. The HEC-HMS contains four main components. 1) An analytical model to calculate overland flow runoff as well as channel routing, 2) an advanced graphical user interface illustrating hydrologic system components with interactive features, 3) a system for storing and managing data, specifically large, time variable data sets, and 4) a means for displaying and reporting model outputs [36].

B.8. Hydrologic Engineering Center-River Analysis System (HEC-RAS)

The utilization of the Hydrologic Engineering Center – River Analysis System (HEC-RAS) in the development of the Marikina River Flood Model represents a significant advancement in flood management strategies. The model was strategically configured to integrate real-time 10-minute water level data sourced from the Enhanced Flood Control and Operation Warning System (EFCOS) monitoring stations along the Marikina River, thereby enhancing its accuracy and reliability. Automation scripts were ingeniously employed to streamline the conversion of water level time series data into a compatible format for seamless integration with the HEC-RAS model. Moreover, an innovative automation script was devised to execute the entire modeling workflow autonomously, eliminating the need for manual intervention in crucial tasks such as assigning initial and boundary conditions, defining simulation parameters, conducting model computations, and generating flood extent and depth outputs. Notably, the generated outputs are promptly disseminated to the public through the Project NOAH (Nationwide Operational Assessment of Hazards) website, enabling near real-time visualization of flood extents along the Marikina River, thus empowering communities with vital information for informed decision-making and disaster preparedness. This integration of advanced technological tools, including Geographic Information System (GIS) and Light Detection and Ranging (LiDAR) technology, underscores the comprehensive approach adopted in preparing the model geometry, ensuring a precise representation of the river system's morphology and dynamics [37].

In the computation of river flow using HEC-RAS, the accurate assignment of surface roughness coefficients to channel cross-sections is paramount, as it directly influences the model's reliability and precision [38]. However, to effectively utilize the HEC-RAS model, input files must conform to the HEC-Data Storage System (DSS) format, a specialized database system tailored for water resource applications [37]. Designed to efficiently store various types of data, particularly large blocks of data such as time-series data, HECDSS serves as a robust platform for managing the intricate datasets required for hydraulic modeling and analysis. By leveraging HECDSS, users can seamlessly organize, access, and manipulate critical data inputs within the HEC-RAS framework, facilitating the accurate representation of hydraulic parameters and enhancing the model's computational efficiency and effectiveness.

The development process of the HEC-RAS flood model, coupled with a hydrologic model based on HEC HMS for flood forecasting, follows a meticulous series of steps to ensure accuracy and reliability. Initially, the hydraulic model construction adheres to five key stages outlined by the US Army Corps of Engineers (USACE) HEC-RAS River Analysis System User's Manual (2016). This includes initializing a new project, inputting geometric and flow data, defining boundary conditions, conducting hydraulic calculations, and finally, analyzing and presenting the results. However, preceding these steps, data pre-processing is conducted utilizing HEC GeoRAS within a Geographic Information System (GIS) environment. This involves the analysis of a Digital Elevation Model (DEM) to generate a comprehensive river hydraulic model. Additionally, bank lines and stream center lines are meticulously digitized using a combination of Google Earth imagery and GIS tools. Moreover, an assessment of stream bank properties is performed to accurately estimate Manning's roughness coefficients for each river reach and station, laying the foundation for precise hydraulic modeling and flood forecasting capabilities [39].

B.9. MIDAS Civil

MIDAS Civil is a software tool predominantly employed in civil and structural engineering for analysis and design purposes. Developed by Midas IT, it serves as a Finite Element Analysis (FEA) solution tailored for bridge analysis and design. MIDAS Civil streamlines the process of bridge modeling and analysis, offering a seamless integration of extensive pre- and post-processing functionalities with a highly efficient solver. Additionally, it provides straightforward tools for adjusting parameters, facilitating parametric analysis and enabling the creation of designs that are both resourceful and economical [40]. In contrast to conventional methods of structural analysis, MIDAS Civil offers a straightforward approach where all internal forces within a standard component can be readily accessed. This is achieved by constructing a model and incorporating relevant loads and constraints. MIDAS Civil is particularly suited for analyzing hydraulic structures that require enhanced seismic resilience [41].

C. Synthesis

Transport modes are systems that allow passengers and freight to move around. They are classified into three categories: air, land for road, rail, and pipelines and water for shipping [2]. The mode of transportation has a significant impact on many facets of modern life, impacting individuals, corporations, and the broader economy. People living in rural and urban areas have the same need and willingness to engage in regular relationships and activities, but the lack of good transportation options in rural areas has a significant impact on how households organize transportation and what places and activities they can access [3]. Identifying travel patterns is critical in determining the unique structure and interconnectedness of road networks. Investigating travel patterns is thus critical for traffic control, urban planning, and increasing the operational efficiency of the transportation system [5].

Bridges are essential for transportation infrastructure because they link previously inaccessible places [6]. Better transportation alternatives may increase job and educational possibilities, create new economic hubs, and rebalance the economy's growth. These bridges play a critical role in improving Filipinos' lives by giving access to crucial services, job opportunities, and markets [18]. The safety of coastal bridges is critical to the Philippines' well-being. By investing in maintenance, renovations, and resiliency measures, the country can assure long-term economic development, social integration, and effective disaster response. Coastal bridges are critical pieces of infrastructure that connect land regions divided by rivers, bays, or bodies of water, facilitating transit, trade, and emergency access while also contributing to local economies and disaster relief efforts. [20].

Coastal communities without bridges face employment challenges due to limited economic opportunities, affecting their livelihoods and well-being. Lack of transportation infrastructure, unsafe river passage, and poor bridge condition contribute to poverty and higher unemployment rates in these communities [23]. The success of coastal bridge projects hinges on actively involving the local community. It's vital to engage community members in the design process to understand and address their unique needs and preferences [24]. Community engagement is crucial in designing coastal bridges, as it helps understand the community's priorities and concerns. This early involvement fosters a sense of ownership, enhances the bridge's effectiveness, and contributes to the project's overall success. The absence of bridges in remote coastal areas hinders development, economic growth, and wildlife habitats. This isolation leads to a scarcity of work prospects and ecological deterioration. The lack of bridges leads to transportation inefficiencies, economic constraints, degraded emergency response capabilities, and negative environmental consequences. [26].

II. METHODOLOGY

A. *Methodological Framework*

This chapter outlines the methodological framework and the specific research methods employed in the study. It covers aspects such as the research design, selection of the study location and respondents, the research instrument used, the process of data collection, and the statistical methods applied for data analysis.

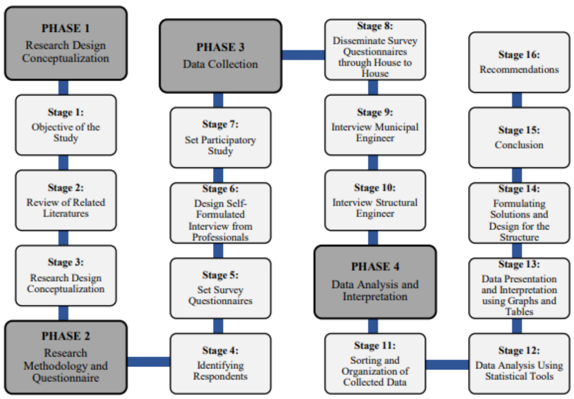


Fig. 2 Methodological Framework

The figure above illustrates the methodological framework of the study which consists of four (4) phases namely; Phase 1 - Research Design Conceptualization, Phase 2 - Research Methodology and Questionnaire Design, Phase 3 - Data Collection, and Phase 4 - Data Analysis and Interpretation. Respective phases consist of individual stages which are further discussed in the following sections of this chapter.

B. *Research Design*

A mixed-method approach was used, combining both qualitative and quantitative methods in addressing the objective of the study effectively. An exploratory and descriptive research method was also used with the aim of exploring the existing transportation challenges in the area and providing a detailed description of the proposed coastal bridge design in Sasmuan, Pampanga. The exploratory method primarily focused for a deeper understanding of the issues, while the descriptive method resulted in a comprehensive account of the bridge design. This method utilized interview and survey questionnaires which gave information to obtain the objectives of this study which included in assessing the current mode of transportation and travel patterns in Sasmuan, Pampanga to identify the existing problems and challenges and provide a design of sustainable design of coastal bridge that will improve the local transportation in the community.

The municipality of Sasmuan, Pampanga comprises 12 barangays. Five of these barangays, namely Malusac, Sebitanan, Mabuanbuan, Batang 1st, and Batang 2nd, are situated at the periphery of the main municipality. Barangay Malusac has been specifically chosen as the primary research locale, as it represents the initial barangay where coastal communities begin in the municipality of Sasmuan, Pampanga.

The municipality of Sasmuan has initiated a comprehensive development plan to construct an access road aimed at enhancing connectivity across various areas in Pampanga. One of the starting points for this access road is Sasmuan Dike Road, while the endpoint, where the roads will converge, is near Barangay Malusac. In line with this, this research will focus on designing a bridge that will start at the access road's endpoint and end at Barangay Malusac, directly linking the barangay to the road network.

The researchers employed systematic sampling, a method based on probability, to select respondents. This approach involved randomly selecting community members at fixed intervals predetermined by the researchers. The sampling interval, calculated by dividing the community population by the estimated sample size, determined the selection pattern. This sampling technique was supported by Cochran's sample size formula to determine the sample size of the study area. Cochran's formula was considered to be particularly relevant in situations involving large populations. According to the 2020 Cencus, the total population of the Barangay Malusac is 2,461, which is relatively high to get a sample size. In line with this, Cochran's formula was used in solving the sample size for the traffic survey that was conducted which is the Household Interview Survey (HIS).

The required return sample size using this formula is 385. Since the sample size exceeds 5% of the population (2,461*.05=123), Cochran's correction formula was used to calculate the final sample size.

The researchers utilized both interviews and survey questionnaire. The interviews were conducted with the municipal engineers and experts in infrastructures development to gather their insights, perspectives, and, challenges faced, and potential solutions for a sustainable design. Since this research aims to evaluate the current transportation patterns in Sasmuan, Pampanga, identify issues, and understand the community's transportation needs. The researchers formulated fixed set of questions that was convenient for the respondents. The researchers used survey questionnaires distributed to the local community in the coastal areas of Sasmuan, including residents and frequent travelers, to understand their experiences, needs, and preferences related to having a coastal bridge.

The researchers conducted a Household Interview Survey (HIS) to collect data on travel behavior patterns and characteristics of the Barangay Malusac, Sasmuan, Pampanga. HIS is aimed to understand travel behaviors of individuals, and their activities, depending on age and socio-economic characteristics. This included the demographic survey and self-formulated survey questionnaire to assess the socio-economic characteristics and travel behaviors of the residents in addition to the perceived barriers in transportation, among residents of Barangay Malusac, Sasmuan, Pampanga. The survey questionnaire approach utilized as it guarantees the advantage of achieving objectivity, measurability, and collection of large amounts of data in a limited span of time. The questionnaire was designed based from the variables utilized in the review of related literature, survey questionnaires from the previous studies of DTCB (2011). Further modification of the survey questionnaires was performed to complement and obtain the necessary data for the study.

The researchers gathered data through direct, face-to-face interactions to acquire first-hand information from respondents. The corroborated self-formulated survey questionnaires were distributed to individuals who are willing and capable of participating. Before administering the survey questionnaire, the respondents were informed about the purpose of the study and the significance of their response to the research study. To uphold confidentiality in line with Republic Act No. 10173, the Data Privacy Act of 2021, the collected data were treated with the utmost confidentiality. Upon completion, the questionnaires were compiled in a Spreadsheet File for sorting and organization before undergoing further data analysis. Additionally, researchers closely observed participants' statements about difficulties and problems encountered in their primary mode of transportation to provide a comprehensive evaluation of the issues. The data gathered from the survey that were conducted by the researchers were analyzed and presented systematically through different statistical approach.

The researcher utilized the following software: QGIS, HEC-HMS, and HEC-RAS, to generate and analyze the flow of water in streams, rivers, and channels. This software can be used for flood forecasting and management by predicting streamflow and flood levels in rivers and streams. The data generated informed the design process of the bridge, determining factors such as size, span length, and pier height. This ensures that the designed bridge can accommodate anticipated flood depth and flow velocity during peak discharge events.

The study area was divided into four analysis zones: Zone 1 includes the Barangay Malusac, Zone 2 includes the Sasmuan Town Proper, Zone 3 includes the Guagua, Pampanga, and Zone 4 includes the Lubao Bamboo Hub & Eco Park, which is the area taken into consideration. It is considered that every movement into and out of a zone starts and ends at a single point within the zone. This site served as a representation of the focal point of transportation activity. The socioeconomic variables that are currently available for the traffic demand model's calibration and application constrained the sort of traffic zone system that was selected for this study. The zonal structure was created to guarantee that areas with comparable traits are represented. Whenever it was practical to do thus, zones were established to represent areas that might be considered to be generally uniform in terms of factors like population, land use, income, employment, or accessibility.

C. Data Analysis

The data were collected and organized using a spreadsheet. Categorical variables were filtered through the application of frequency distribution, describing the percentage of observations for each data point or data point grouping. This method is effective in expressing the relative frequency of survey responses and other data.

To prevent any oversight or duplication of data, the researchers identified the maximum and minimum values. After coding and double-checking the data, Descriptive Statistics was generated. The assessment and evaluation of other data involved the use of frequency distribution, percentages, mean scores, and percentage ranking. The results were presented in tables, bar graphs, or pie charts based on the percentage frequency distributions obtained from the survey questionnaire.

As stated by [37], hydrological calculations ascertain the elevation, speed, and discharge capacity of floodwaters. According to the Section 3.2 of Design Guidelines, Criteria and Standards: Volume 5 - Bridge Design, 2015, the hydrologic analysis for determining the design discharge, crucial for calculating the maximum flood level in bridge design, involves several steps. These include catchment delineation, analysis of design rainfall, and the selection and application of appropriate hydrological analysis techniques.

According to [37], hydraulic calculations establish the quantity that facilitates the design of an appropriately sized bridge, ensuring an effective flow of water without posing threats to surrounding objects or adjacent areas. Section 3.3 of Design Guidelines, Criteria and Standards: Volume 5 - Bridge Design, 2015, offers a comprehensive overview of essential factors in the hydraulic design of bridges. This includes site inspections, crucial design considerations, bridge hydraulics, computer modeling, examination of afflux and its impact on surrounding areas, downstream influences, constriction ratio concerning obstruction to the waterway, and considerations related to scour.

D. Design of Bridge

To design coastal bridge, the researchers employed MIDAS Civil, a software tool predominantly employed in civil and structural engineering for analysis and design purposes.

The design of the substructure of the bridge was based on the Design Guidelines, Criteria and Standards: Volume 5 - Bridge Design (2015), and the DPWH Guide Specifications for LRFD Bridge Seismic Design Specifications, 1st Edition, 2013. Substructures such as abutment and pier provide support for bridges. Abutments specifically supporting the ends of a bridge or the extreme ends of a multi-span superstructure. It typically holds or provide support for the road approach embankments, often featuring wing walls to retain the approach. Piers play a crucial role in transmitting the load of the superstructure to the supporting ground, serving as intermediate supports between abutments. These may experience various loads, including those from streams, collisions, and impacts. Designing substructures for bridges over rivers requires the consideration of river forces and scour.

If the ground conditions suggest a potential risk of river washout for bridge abutments across rivers, even with scour protection, they should be designed as piers. Furthermore, the abutments must be designed to withstand earth pressures from the bridge approach embankment in the event of river bank erosion up to the abutment's centerline and the usual river bed level.

In river crossings with fast stream flow and debris are present, it is advisable to used piers with solid shafts. The foundation can either be a spread footing or a pile type. However, it is essential to note that long solid shaft piers may exhibit poor seismic performance, and therefore, they are recommended to be avoided. For standard bridges without debris-related concerns in river crossings, piers with two columns can be utilized. The foundation options for these piers include both spread footing and pile types.

The design requirements for the bridge location and alignment were also based on the Design Guidelines, Criteria and Standards: Volume 5 – Bridge Design (2015). The selection of the bridge location must take into account the assessed river morphology to minimize the risk of damage to abutments or the entire bridge resulting from river channel movements. Bridges situated in harsh environments, such as an exposed marine setting, may necessitate additional considerations for corrosion protection to meet the intended design life.

The arrangement of bridge spans should account for the need to meet navigational clearance requirements and minimize interference with flood flow. Generally, piers should be positioned parallel to the direction of the river current during flood stages. The selection of spans should ensure that piers are located to avoid issues such as scour, debris blockage, or constriction. To address debris concerns, adequate provisions should be made by increasing span lengths and vertical clearances, selecting appropriate pier types, and utilizing debris deflectors.

The vertical clearance between either the Design Flood Level (DFL) or the Maximum Flood Level (MFL) and the soffit or the lowest member of the bridge superstructure must not be less than 1.50 m for bridges spanning rivers with debris and 1.00 m for other bridges. In coastal environments, sufficient freeboard should be incorporated to prevent wave impact on the bridge superstructure, considering the combined effects of high tide, storm surge, and the design wave.

In the design of bridges, it is essential to incorporate effective bridge deck drainage systems. These systems are designed to efficiently channel runoff from the bridge deck, directing it towards the bridge abutments, and ultimately discharging it into existing stormwater drainage systems or outlets in the absence of such systems. The bridge deck drainage should ensure the drainage of both the bridge deck itself and the adjoining roadway, extending to the ends of the abutment wingwalls. A smooth transition in drainage should be established to integrate with the drainage of the adjacent road.

A desirable minimum bridge span length can be estimated using the equation established by a design standard by the Ministry of Construction in Japan

$$L=20+0.005Q$$

Where:

L = desirable minimum bridge span length (m)

Q = discharge (m3/s)

The minimum width of bridges shall be in accordance with Table 6.1.3-1 of Design Guidelines, Criteria and Standards: Volume 5 - Bridge Design (2015

Table 6.1.3-1 Clear Width of a Bridge

No Lanes	Mininimum Width Roadway
1 Lane	4.00 m
2 Lanes	7.32 m
More than 2 lanes	Refer to Highway Design Requirements

Fig. 3 Clear Width of Bridge

The normal spans range of prestressed concrete bridges are listed in Table 6.3.3-1 of Design Guidelines, Criteria and Standards: Volume 5 - Bridge Design (2015) and applies only to standard beam type bridges.

Table 6.3.3-1 Span Range for Prestressed Concrete Bridges

Form of Construction	Span Range
Channel beams	11.0 m to 14.0 m.
Tee beams	15.0 m to 18.0 m
*I-beams	21.0 m to 30.0 m
Box girders	Over 30.0 m
Hollow (voided) slab	15.0 m to 30.0 m

Fig. 4 Span Range for Prestressed Concrete Bridges

Table 6.4-1 of Design Guidelines, Criteria and Standards: Volume 5 - Bridge Design (2015) shows the recommended number of girders for different number of lanes.

Table 6.4-1 Number of Girders in Relation to Number of Lanes

No. o f Lanes	Min. Roadway Width (m)	Min. No. of Girders
1 lane	4.00	3 girders
2 lanes	6.70	4 girders (rural)
2 lanes	7.30	4 girders (urban)
More than 2 lanes	variable	not less than 6 girders

Fig. 5 Number of Girders in Relation to Number of Lanes

III. RESULTS AND DISCUSSION

This chapter presents the findings, discussion, and analysis of data obtained by the researchers during the process of conducting the research's methods outlined in the preceding chapter.

A. Household Interview Survey

Researchers distributed survey questionnaires to 333 participants for data collection using the Household Interview Survey (HIS). Through face-to-face interviews, the researchers gathered information on participants' socio-demographic profiles, household characteristics, travel patterns, primary modes of transportation, perceived barriers to transportation, and recommendations for improving transportation systems, including infrastructure and services in their community.

The Household Interview Survey (HIS) was effectively conducted by distributing survey questionnaires in the study area through home visits. The following data were collected through the HIS:

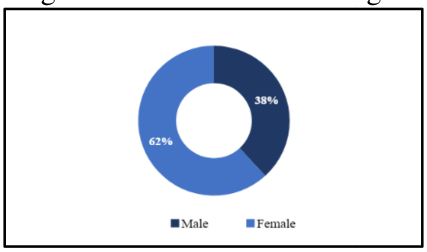


Fig. 6 Population by Gender

Figure 6 illustrates the demographic distribution by gender, indicating that 62% of the surveyed population consists of females, with males comprising 38%. These percentages were derived from a systematic random sampling method conducted at the survey site.

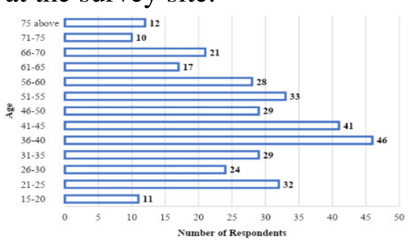


Fig. 7 Population by Age

Figure 7 presents a detailed breakdown of the population according to different age brackets. It reveals that the largest group falls within the age range of 36-40, with 46 individuals. Following this, the age groups of 41-45 and 51-55 are also significant, each comprising 41 and 33 individuals, respectively. Conversely, the age brackets of 71-75 and 75 and above have the fewest individuals, with 10 and 12 respectively. Overall, this data provides useful insights into the age distribution of the studied sample, which numbered 333 people.

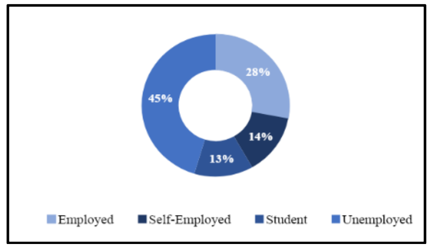


Fig. 8 Occupation of the Respondents

Figure 8 depicts the respondents' occupational status as a percentage of the total surveyed population. Among the surveyed individuals, 93 are employed, which accounts for approximately 28% of the total. Additionally, 46 individuals identify as self-employed, representing around 14% of the surveyed population. Furthermore, there are 43 students, making up roughly 13% of the total. Notably, the largest group comprises 151 unemployed individuals, accounting for approximately 45% of the surveyed population. This breakdown sheds light on the distribution of employment statuses among the surveyed population, indicating the proportions of individuals in each occupational category and emphasizing the rate of unemployment among respondents.

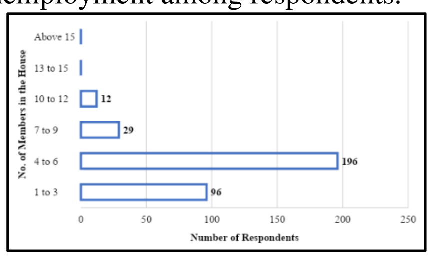


Fig. 9 No. of Members in the House

Figure 9 shows the distribution of household sizes throughout the studied population. The findings indicate that the majority of households, 196 in total, have 4 to 6 individuals. In addition, homes with 1 to 3 individuals are the next most common, accounting for 96 cases. There are also 29 homes with 7 to 9 members, with 12 with 10 to 12 individuals. However, no households with 13 to 15 or more than 15 individuals were found in the survey population. Overall, this breakdown of 333 houses provides useful insights on the average composition of households in the examined population, highlighting the significant number of medium-sized households and the rarity of bigger ones.

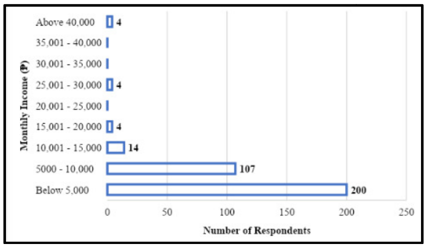


Fig. 10 Monthly Income

Figure 10 provides the monthly income distribution in the interrogated population. According to the data, 200 people earn less than ₱5,000 per month, making up the largest group. Following this, there are 107 persons earning between ₱5,000 and ₱10,000 monthly. The number of individuals reduces substantially as income levels climb, with only a few earning more than ₱15,000. There are 14 individuals earning between ₱10,001 to ₱15,000, with just 4 individuals in each income category of ₱15,001 to ₱20,000, ₱25,001 to ₱30,000, and over ₱40,000. Notably, no individuals fall into the income ranges of ₱20,001 to ₱25,000, ₱30,001 to ₱35,000, and ₱35,001 to ₱40,000. Overall, this distribution highlights the high number of lower-income earners in the studied population, with a significant scarcity of persons earning higher earnings.

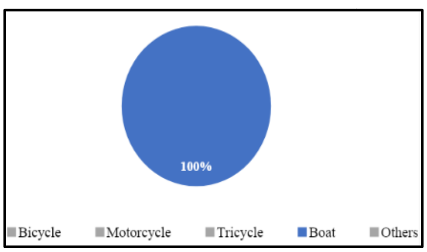


Fig. 11 Primary Mode of Transportation

Figure 11 highlights the primary mode of transportation within the surveyed population of 333 individuals. Remarkably, boats emerge as the exclusive mode of transport for all respondents, representing 100% of the total. There are no instances of bicycle, motorcycle, tricycle, or any other mode of transportation reported among the surveyed population. This data underscores the singular reliance on boats as the primary means of transportation within this community, highlighting the unique geographical or cultural context where boats play a central role in facilitating mobility and transportation needs.

Table 1. Respondents' Ratings and Assessment on the Different Aspects of Transportation in Barangay Malusac, Sasmuan, Pampanga

Indicator	Weighted Mean	Verbal Interpretation
Sidewalks	2.33	Needs Improvement
Parking	2.26	Needs Improvement
Condition of Streets	3.53	Very Good
Traffic Congestion	3.88	Very Good
Overall Ease of Travel	3.58	Very Good

Table 1 displays the evaluation of the respondents regarding the aspect of transportation in Barangay Malusac in terms of the quality and serviceability of the sidewalks, parking, conditions of streets, traffic congestion, and overall ease of travel in the study area. The result for the quality and serviceability of the sidewalks in the study area has a computed mean of 2.33. It means that sidewalks are somewhat walk-friendly and safe, but still needs improvement. In addition, the condition and functionality of the parking in the locality has a computed mean of 2.26. This signifies that parking is somehow organized but there are not enough parking areas, and it needs improvement. Furthermore, the conditions of streets in the vicinity of Barangay Malusac reveals that it is “Very Good” with a computed mean of 3.53. It indicates that the roads are in a satisfactory condition. Moreover, the computed mean of 3.88 indicates that the traffic congestion in the area is considered "Very Good". It implies that the flow of mobilization is satisfactory.

Lastly, the evaluation of individuals surveyed on the transportation aspect of Barangay Malusac, specifically on the overall ease of travel in the locality revealed that travelling back and forth is easy and convenient. The computed weighted mean of 3.58 indicates that the overall ease of travel in the area is considered "Very Good".

Table 2. Respondents' Ratings and Assessment on How Well the Transportation System Meets their Travel Needs

Indicator	Weighted Mean	Verbal Interpretation
Traveling by Foot	2.00	Needs Improvement
Traveling by Land	1.98	Needs Improvement
Traveling by Water	4.45	Excellent

Table 2 presents the respondents' ratings and assessment of how well the transportation system meets their travel needs across different modes of transportation. Travelling by foot has a weighted mean of 2.00 which indicates that they are perceived as needing improvement. It implies that walking is quite a bit not feasible and unsafe. Likewise, travelling by land signifies as it needs improvement with a weighted mean of 1.98. This indicates that utilizing land-based vehicles is slightly expensive, unsafe, and vehicles are rarely available. In contrast, travelling by water stands out with a notably high weighted mean score of 4.45, suggesting an excellent rating.

Overall, while there is a perceived need for improvement in the modes of transportation involving land travel and foot travel, the transportation system, particularly in terms of water travel, is highly regarded and meets the respondents' travel needs exceptionally well.

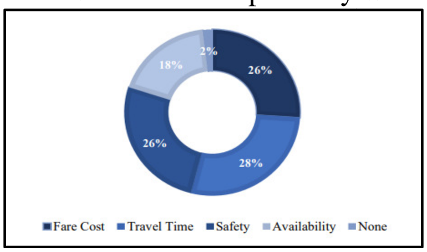


Fig. 12 Barriers that Affect Transport

Figure 12 provides a detailed overview of the perceived barriers affecting transportation within the surveyed population. Approximately 26% of respondents consider fare cost as a significant barrier to transportation. Similarly, around 28% of respondents express concerns about travel time. Safety is also a notable concern, with 26% of respondents citing it as a barrier. Availability is mentioned by a smaller proportion of respondents, with 18% perceiving it as a barrier to transportation. Conversely, a small minority of respondents, approximately 2% of the total, do not identify any barriers affecting their transportation experience.

This breakdown offers valuable insights into the varied perceptions of transportation barriers within the surveyed population, highlighting the significant number of concerns about travel time, fare cost, and safety, while also acknowledging the smaller proportion of people who cite availability as a barrier and those who do not perceive any barriers at all.

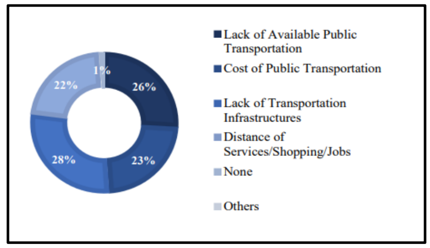


Fig. 13 Barriers that Burden the Population

Figure 13 presents data on the barriers burdening the population within the surveyed area. Approximately 26% of respondents perceive the lack of available public transportation as a burden on the population. Similarly, around 23% of respondents identify the cost of public transportation as a significant concern. The lack of transportation infrastructures is cited by the highest proportion of respondents, with approximately 28% perceiving it as a burden. Additionally, the distance of services/shopping/jobs is seen as a significant barrier by approximately 22% of respondents. Interestingly, a small minority of respondents, approximately 1% of the total, do not perceive any barriers affecting the population. Furthermore, no respondents cite "others" as a barrier.

The result provides useful insights into the diverse challenges related to transportation accessibility, infrastructure, and cost in the studied area, illustrating the varying degrees of concern among the population.

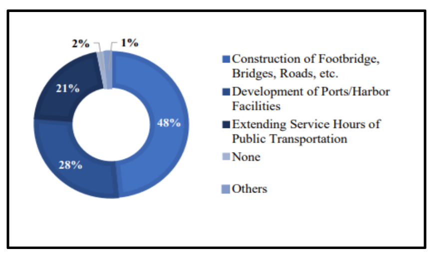


Fig. 14 Types of Improvement in the Community

Figure 14 illustrates a detailed breakdown of the types of improvement desired within the community. About 48% of respondents express a desire for the construction of footbridges, bridges, roads, etc., suggesting a significant need for infrastructural development. Similarly, around 28% of respondents prioritize the development of ports/harbor facilities, indicating the importance of enhancing maritime infrastructure. Additionally, approximately 21% of respondents advocate for extending service hours of public transportation, highlighting the significance of improving transportation accessibility. Interestingly, a small minority of respondents, around 2% of the total do not express a desire for any specific improvement. Furthermore, representing about 1% of the total, suggest other improvements.

The findings reveal helpful insights into the diverse priorities and needs within the community, reflecting the varying degrees of emphasis placed on different types of improvements.

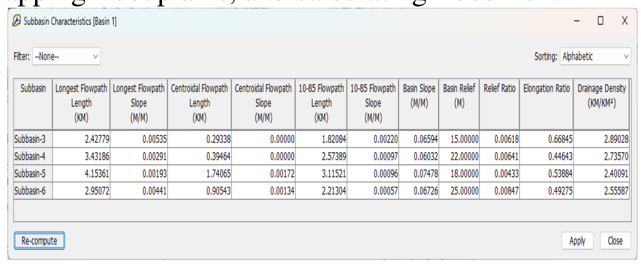
In conclusion, the data from Figure 14 indicates that a significant portion of the surveyed population (approximately 48%) express a desire for the construction of footbridges, bridges, and roads within their community, suggesting a substantial need for infrastructural development to address transportation challenges. Additionally, when considering the barriers highlighted in Figures 12 and 13, such as concerns about travel time, lack of available public transportation, and the distance of essential services, it becomes apparent that building bridges could indeed benefit the community by improving accessibility and connectivity. Therefore, it is evident that the community expressed interest in infrastructural enhancements, along with the prevailing transportation difficulties, highlights the importance of constructing bridges to ease

B. Hydrologic Analysis

Hydrological simulations serve as vital tools for understanding and managing water resources in a variety of situations. Among these simulations, the Hydrologic Engineering Center's Hydrologic Modeling System (HEC-HMS) is notable for its dependability and flexibility. It gives engineers and academics a solid foundation for modeling and assessing watershed responses to precipitation and other hydrological phenomena.

In this work, the HEC-HMS model was used to simulate various return periods ranging from one to hundred years. Return periods are the average time between occurrences of a specific magnitude of a hydrological event, such as peak discharge. By performing simulations for several return times, engineers can analyze the probable severity of catastrophic occurrences and build infrastructure appropriately.

The major goal of these simulations was to calculate the peak discharge, measured in cubic meters per second (m3/s), for each return time. Peak discharge is the greatest flow rate experienced in a river or stream over a certain time period, and it is frequently related with flood occurrences. Understanding peak discharge across varied return times is critical for building hydraulic structures, mapping floodplains, and calculating flood risk.


Subbasin Characteristics [Basin 1]

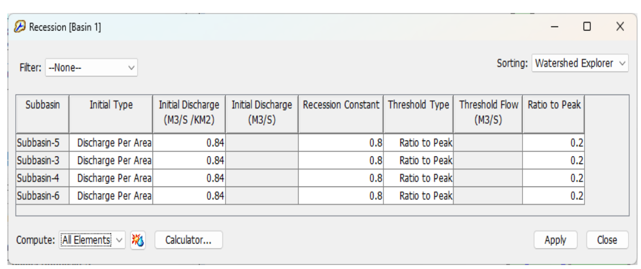
Filter: --None-- Sorting: Alphabetic

Subbasin	Longest Flowpath Length (KM)	Longest Flowpath Slope (M/M)	Centroidal Flowpath Length (KM)	Centroidal Flowpath Slope (M/M)	10-85 Flowpath Length (KM)	10-85 Flowpath Slope (M/M)	Basin Slope (M/M)	Basin Relief (M)	Relief Ratio	Elongation Ratio	Drainage Density (KM/KM²)
Subbasin-3	2.42779	0.00535	0.29338	0.00000	1.82084	0.00220	0.06594	15.00000	0.00618	0.66845	2.89028
Subbasin-4	3.43186	0.00291	0.39464	0.00000	2.57389	0.00097	0.06032	22.00000	0.00641	0.44643	2.73570
Subbasin-5	4.15361	0.00193	1.74065	0.00172	3.11521	0.00096	0.07478	18.00000	0.00433	0.53884	2.40091
Subbasin-6	2.95072	0.00441	0.90543	0.00134	2.21304	0.00057	0.06726	25.00000	0.00847	0.49275	2.55587

Re-compute Apply Close

Fig. 15 Sub basin Characteristics

Figure 15 shows the longest flow path extends from the sub basin outlet to the most hydraulically remote point upstream. The longest flow path is significant in that it is typically used to determine the time of concentration for a watershed. A sub basin is a single-outflow element in basin models that is used to calculate outflow using meteorological data. It can simulate different catchment sizes and incorporate canopy and surface components for interception and evapotranspiration. The total length of the watercourse, measured from the downstream end of each sub-basin to its upstream boundary, sums up to 12.96392 km. Furthermore, the total length from the downstream end of each sub-basin to an intersection on the stream perpendicular to the centroid of the sub-basin is recorded as 3.3335 km.


Recession [Basin 1]

Filter: --None-- Sorting: Watershed Explorer

Subbasin	Initial Type	Initial Discharge (M3/S /KM2)	Initial Discharge (M3/S)	Recession Constant	Threshold Type	Threshold Flow (M3/S)	Ratio to Peak
Subbasin-5	Discharge Per Area	0.84		0.8	Ratio to Peak		0.2
Subbasin-3	Discharge Per Area	0.84		0.8	Ratio to Peak		0.2
Subbasin-4	Discharge Per Area	0.84		0.8	Ratio to Peak		0.2
Subbasin-6	Discharge Per Area	0.84		0.8	Ratio to Peak		0.2

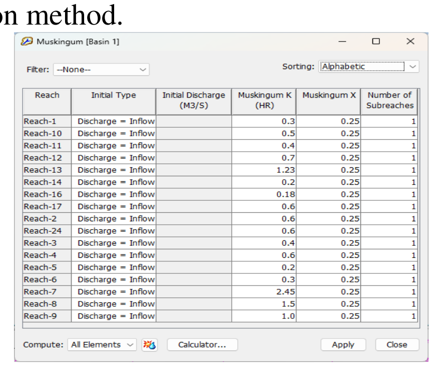
Compute: All Elements Calculator... Apply Close

Fig. 16Calibrated Parameters for Recession Method

In addition to providing important data for baseflowmodeling, the calibrated parameters displayed in Figure 25 also shows the behavior of water in watershed. Each sub-basins have a baseline initial discharge rate per unit area of 0.84 m3/s /km2, indicating the initial rate at which water flows from the watershed. This parameter, which shows the initial water input to streamflow before accounting for other influences like rainfall or runoff, is an important measure of the hydrological characteristics of the watershed.

A fixed value of 0.8 for the recession constant for all sub-basins significantly affects how quickly baseflow subsides after rain. A recession constant of 0.8 indicates a moderate decrease in baseflow following rainfall occurrences. This parameter determines how long and how much baseflow contributes to streamflow during periods of drought by reflecting the river's ability to hold and gradually release water over time.

The fixed ratio to peak value, set uniformly at 0.2 for all sub-basins, shows that baseflow accounts for approximately 20% of total streamflow during droughts. This emphasizes the significance of baseflow in maintaining streamflow, especially in periods of low rainfall. The researchers were able to create precise models of baseflowbehavior by utilizing these calibrated parameters in the recession method.


Muskingum [Basin 1]

Filter: --None--   Sorting: Alphabetic

Reach	Initial Type	Initial Discharge (M3/S)	Muskingum K (HR)	Muskingum X	Number of Subreaches
Reach-1	Discharge = Inflow		0.3	0.25	1
Reach-10	Discharge = Inflow		0.5	0.25	1
Reach-11	Discharge = Inflow		0.4	0.25	1
Reach-12	Discharge = Inflow		0.7	0.25	1
Reach-13	Discharge = Inflow		1.23	0.25	1
Reach-14	Discharge = Inflow		0.2	0.25	1
Reach-16	Discharge = Inflow		0.18	0.25	1
Reach-17	Discharge = Inflow		0.6	0.25	1
Reach-2	Discharge = Inflow		0.6	0.25	1
Reach-24	Discharge = Inflow		0.6	0.25	1
Reach-3	Discharge = Inflow		0.4	0.25	1
Reach-4	Discharge = Inflow		0.6	0.25	1
Reach-5	Discharge = Inflow		0.2	0.25	1
Reach-6	Discharge = Inflow		0.3	0.25	1
Reach-7	Discharge = Inflow		2.45	0.25	1
Reach-8	Discharge = Inflow		1.5	0.25	1
Reach-9	Discharge = Inflow		1.0	0.25	1

Compute: All Elements   Calculator...   Apply   Close

Fig. 17Calibrated Parameters for Muskingum

Figure 17 shows the calibrated parameters that are relevant to the Muskingum method, which is used for routing modeling in Basin 1. This approach divides the watershed into seventeen (17) spans in order to define different parts.

The Muskingum K parameter, which represents the duration of transit across each of the 17 reaches, can be estimated by analyzing hydrograph data, comparing flow lengths, and using regression equations. In addition, the process time can be calculated by dividing the reach length by the flood wave velocity, using techniques such as Manning's Equation and Kleitz-Seddon Law. The Muskingum X parameter is a dimensionless coefficient that represents the maximum attenuation of a flow. It ranges from 0.0 to 0.5. The initial estimation for this value is 0.25, however it is further refined during model calibration for most applications.

When the value is set to 0, the amount of storage available is exclusively determined by the outflow, leading to the highest level of attenuation. In contrast, when the value is set to 0.5, equal importance is given to both the inflow and outflow, resulting in no reduction of the inflow hydrograph. The slower flow of water within the system allows for a quicker response to changes in upstream circumstances, hence improving the accuracy of anticipating hydrological events like floods by minimizing disruptions.

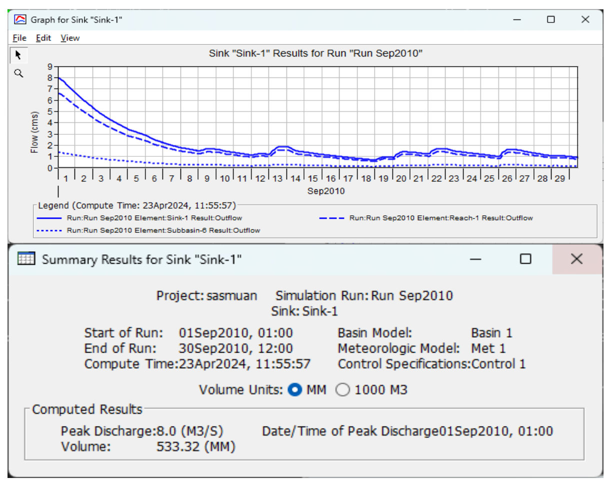


Fig. 18Flood Hydrograph of the Calibration

The calibration approach of the HEC-HMS model includes using data from the Pampanga Rainfall Station during Typhoon Inday, with a particular focus on the maximum 24-hour rainfall rate, which was measured at 2.54 meters. The purpose of this calibration initiative was to attain an accurate representation of actual hydrological conditions within the model.

Figure 18 illustrates the hydrograph produced by the model, which showed a maximum discharge of

8.0 m3/s during the calibration process. Remarkably, in the HEC- RAS software, this maximum flow rate precisely aligned with a depth of 2.54 meters. The effectiveness of the calibration process was demonstrated by the model's capacity to accurately reproduce the recorded depth at the Pampanga Rainfall Station, which coincided with the beginning of Typhoon Inday.

The model's capacity to effectively simulate the hydrological response to the recorded rainfall event was confirmed by the agreement between the projected depth of 2.54 meters and the observed depth from the rainfall station. Moreover, the model's precision in depicting the complex dynamics of the watershed was confirmed by the agreement between the simulated and observed data.

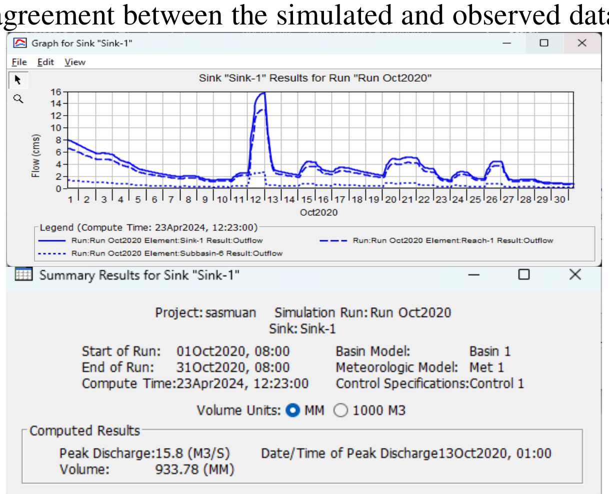


Fig. 19Flood Hydrograph of the River based on 100 Year Return Period

The analysis conducted for the 100-year return period determined that Sink 1, located within the watershed, had a maximum flow rate of 15.8 cubic meters per second. Statistically, it the probability of this event happening in a single year was 1%.

Nevertheless, the potential consequences of such an occurrence could be substantial due to the significant quantity of water involved. The peak discharge of 15.8 m3/s in this situation was important for bridge building, particularly in establishing the depth of debris flow and the discharge required for design purposes.

Using this data, it was feasible to ensure that the bridge was sufficiently built to endure and alleviate the impacts of periodic flash floods in the river, thus protecting local residents and their means of living. Figure 19 illustrates the flood hydrograph for Sink 1 that corresponds to the specified return period.

C. Hydraulic Analysis

Hydraulic analysis is essential for determining the necessary height for the design of bridge in Malusac. Hydrologic Engineering Center's River Analysis System (HEC-RAS) was the software used for the said analysis. HEC-RAS is a widely utilized software tool in hydraulic engineering and river modeling, providing a comprehensive set of features to assist engineers in designing, managing, and evaluating hydraulic systems and water- related infrastructure.

For this study, HEC-RAS 1D steady flow analysis was utilized, enabling the modeling and simulation of steady-state flow conditions in rivers, channels, and other open-channel systems. Data obtained from HEC-HMS, such as peak discharge, was utilized to model and ascertain the hydraulic depth of the river.

	River Station	Frctn (n/K)	n #1
1	1144	n	0.07

Fig. 20Manning's Roughness Coefficient for Calibration Model

According to the DPWH Design Guidelines, Criteria, and Standards Volume 3 for Water Engineering Projects, natural channels such as rivers with heavy brush on banks generally have Manning's Roughness Coefficients ranging from 0.05 to 0.07. The selection of the appropriate Manning's n value for this study was guided by on-site observations. Consequently, a Manning's n value of 0.07 was employed for the main channel, left overbank, and right overbank of the river.

Cross Section Output
File Type Options Help
River: River 1 Profile: Calibrated Peak
Reach Reach 1 RS: 1144 Plan: Plan 01
Plan: Plan 01 River 1 Reach 1 RS: 1144 Profile: Calibrated Peak

		Element	Left OB	Channel	Right OB
E.G. Elev (m)	2.61	Wt. n-Val.	0.070	0.070	0.070
Vel Head (m)	0.00	Reach Len. (m)	68.80	68.90	69.60
W.S. Elev (m)	2.61	Flow Area (m2)	106.73	227.48	156.68
Crit W.S. (m)		Area (m2)	106.73	227.48	156.68
E.G. Slope (m/m)	0.000000	Flow (m3/s)	1.71	3.79	2.50
Q Total (m3/s)	8.00	Top Width (m)	42.10	89.60	63.10
Top Width (m)	194.80	Avg. Vel. (m/s)	0.02	0.02	0.02
Vel Total (m/s)	0.02	Hydr. Depth (m)	2.54	2.54	2.48
Max Chl Dpth (m)	2.58	Conv. (m3/s)	2726.0	6047.6	3999.1
Conv. Total (m3/s)	12772.7	Wetted Per. (m)	44.65	89.60	65.61
Length Wtd. (m)	69.10	Shear (N/m2)	0.01	0.01	0.01
Min Ch El (m)	0.03	Stream Power (N/m s)	0.00	0.00	0.00
Alpha	1.00	Cum Volume (1000 m3)	150.09	248.59	152.70
Frctn Loss (m)	0.00	Cum SA (1000 m2)	59.29	97.36	60.34
C & E Loss (m)	0.00				

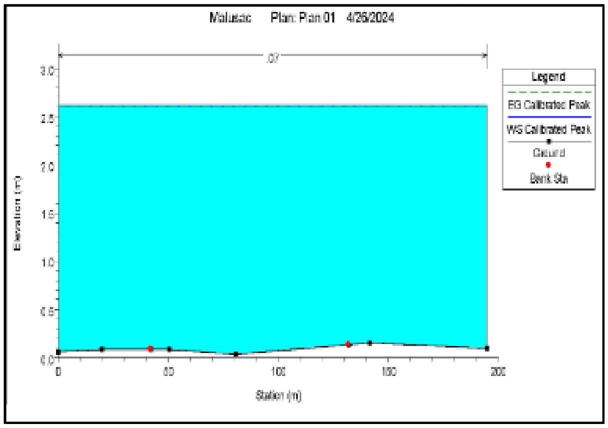
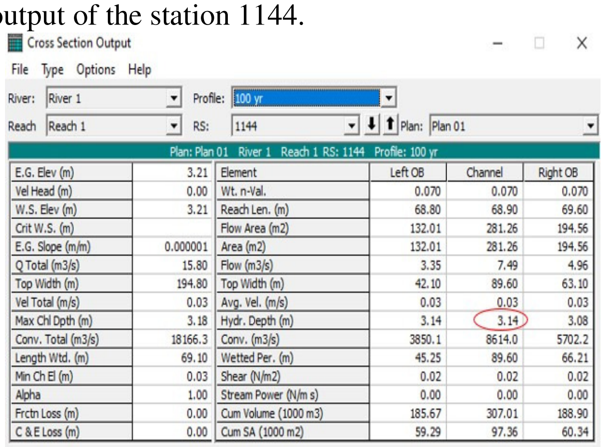


Fig. 21Cross Section Output of Calibrated Peak Discharge

The calibrated peak discharge of 8 m3/s acquired in HEC-HMS was used to calculate the hydraulic depth at the station 1144. The HEC-RAS simulation of 1D steady flow analysis revealed that the hydraulic depth during the discharge of 8 m3/s is 2.54 meters. Figure 21 shows the cross-sectional output of the station 1144.



E.G. Elev (m)	3.21	Element	Left OB	Channel	Right OB
Vel Head (m)	0.00	Wt. n-Val.	0.070	0.070	0.070
W.S. Elev (m)	3.21	Reach Len. (m)	68.80	68.90	69.60
Crit W.S. (m)		Flow Area (m2)	132.01	281.26	194.56
E.G. Slope (m/m)	0.000001	Area (m2)	132.01	281.26	194.56
Q Total (m3/s)	15.80	Flow (m3/s)	3.35	7.49	4.96
Top Width (m)	194.80	Top Width (m)	42.10	89.60	63.10
Vel Total (m/s)	0.03	Avg. Vel. (m/s)	0.03	0.03	0.03
Max Chl Dpth (m)	3.18	Hydr. Depth (m)	3.14	3.14	3.08
Conv. Total (m3/s)	18166.3	Conv. (m3/s)	3850.1	8614.0	5702.2
Length Wtd. (m)	69.10	Wetted Per. (m)	45.25	89.60	66.21
Min Ch El (m)	0.03	Shear (N/m2)	0.02	0.02	0.02
Alpha	1.00	Stream Power (N/m s)	0.00	0.00	0.00
Frctn Loss (m)	0.00	Cum Volume (1000 m3)	185.67	307.01	188.90
C & E Loss (m)	0.00	Cum SA (1000 m2)	59.29	97.36	60.34

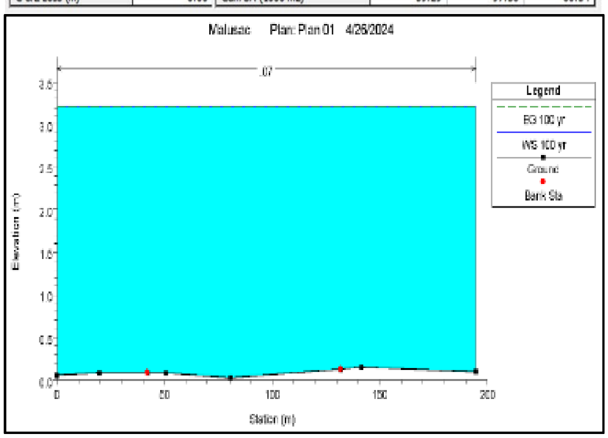


Fig. 22Cross Section Output of 100 Year Return Period Discharge

Figure 22 illustrates the cross-sectional output and hydraulic depth at station 1144 during the 100-year return period discharge of 15.8 m3/s from HEC-HMS. The calculated hydraulic depth of 3.14 m will serve as guide for the design of the bridge specifically for the height of piers that will be used.

D. Bridge Design

This section provides the result of the final design of the coastal bridge, which comprises the superstructure and substructure of the bridge, excluding the foundation, piles, abutments, and approach structures. It also includes the beam diagram of the coastal bridge.

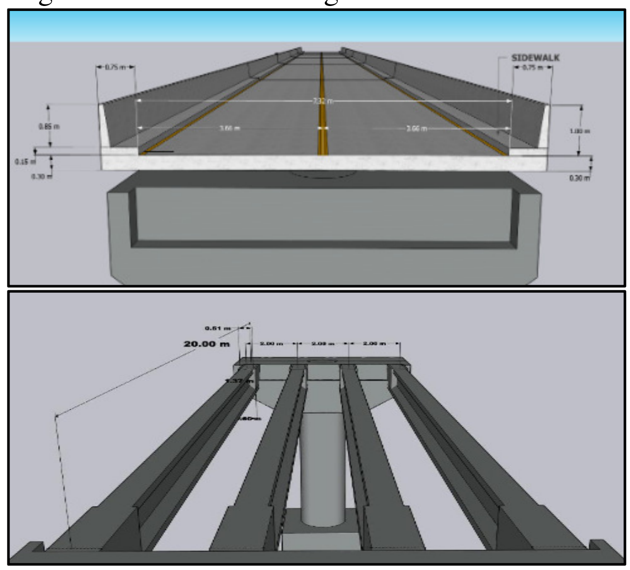


Fig. 23Bridge Cross Section

The bridge considered for design has a span length of 20 m (c/c pier distance) with no skew and a total width of 7.32 m. The bridge superstructure consists of 4 AASHTO Type IV beams spaced 2 m center to center designed to act compositely with 0.30 m thick cast in place concrete deck as shown in figure 23. The bridge consists two lanes with a clear width of 7.32 m in accordance with Table 6.1.3-1 of Design Guidelines, Criteria and Standards: Volume 5 - Bridge Design (2015) shown in figure 3. The bridge considered has sidewalks of 0.75 m. The bridge cross section is shown in figure 23.

Table 3. Material Properties

Cast in Place Slab	
Thickness, t_s	0.30 m
Concrete Strength at 28 days, f_c’	27.6 MPa
Concrete Unit Weight	23.5 kN/m^3
Precast Beams	

AASHTO Type IV	
Concrete Strength at release, f_c'	27.6 MPa
Concrete Strength at 28 days, f_c'	35.4 MPa
Concrete Unit Weight	23.5 kN/m^3
Span Length (c/c Piers)	20 m
Pretensioning Strands	
Number of Strands	7 wire low relaxation
Diameter of One Strand	12 mm
Area of One Strand	113.097 mm^2
Ultimate Stress, f_{pu}	1861.584 MPa
Yield Strength, $f_{py} = 0.9f_{pu}$	1675.426 MPa
Stress Limits for Prestressing Strands:	
Before Transfer, $f_{pi} \leq 0.75f_{pu}$	1396.188 MPa
At Service Limit State (After All Losses) $f_{pe} \leq 0.80f_{py}$	1340.341 MPa
Modulus of Elasticity, E_p	200 GPa

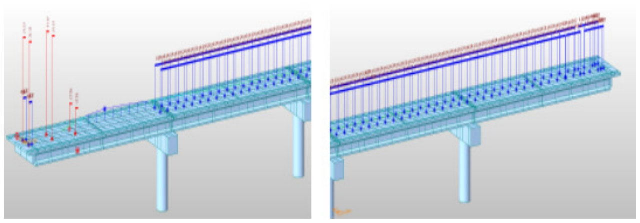


Fig. 24Maximum Moving Load Tracer for Beam Stress

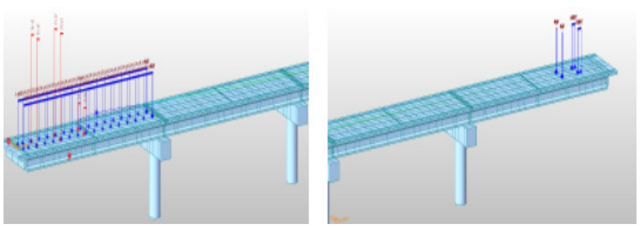


Fig. 25Minimum Moving Load Tracer for Beam Stress

Figures 24 and 25 show the Moving Load Tracer applied on the design bridge. Moving Load Tracer graphically display the vehicle loading condition that results in the maximum and minimum effect. It shows the position of the maximum and minimum applied loads on the bridge with a value of 71.17 kN, 17.79 kN, and 4.67 kN/m. The type of load use for the moving load is called HL-93 which is a type of theoretical vehicular loading proposed by AASHTO in 1993. It is used as the design loading for highway structures in USA and other countries where AASHTO code is followed.

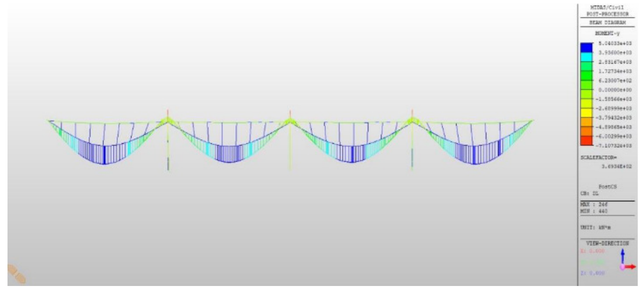


Fig. 26Beam Diagram of Dead Load

Figure 26 illustrates the beam diagram of the dead load. The bridge has a maximum positive bending moment of 5.040×103 kiloNewton meter (kN-m) on midspan. Its maximum negative moment falls on its supports with -7.107×103 kN-m.

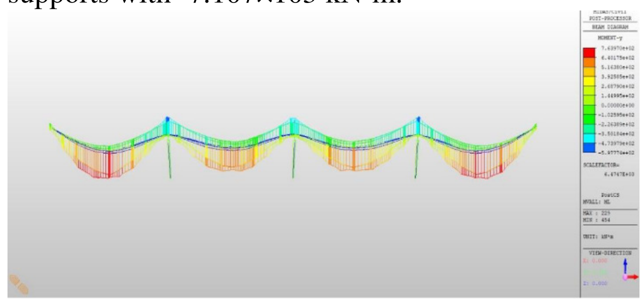


Fig. 27Beam Diagram of Moving Load

Figure 27 show the beam diagram of the moving loads. The bridge has a maximum positive bending moment of 7.640×102 kN-m on midspan. Its maximum negative moment falls on its supports with -5.978×102 kN-m.

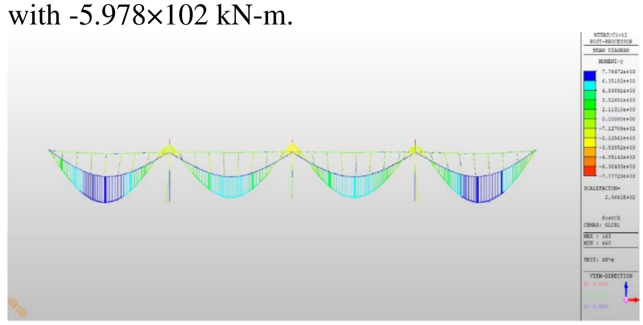
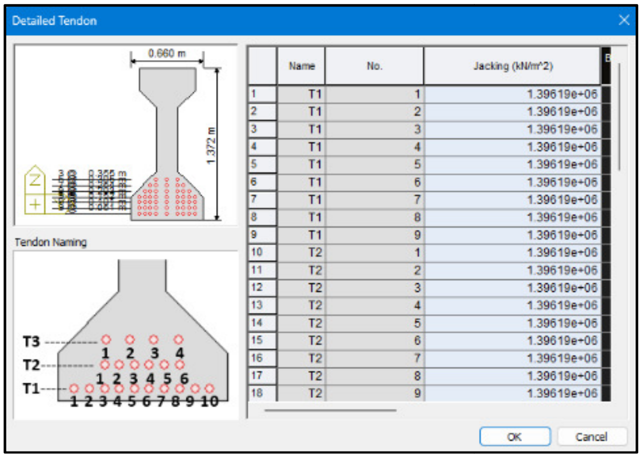


Fig. 28Beam Diagram of Maximum Load Combination

Figure 28 depicts the beam diagram of the maximum load combination. The bridge has a maximum positive bending moment of 7.765×103 kN-m on midspan. Its maximum negative moment falls on its supports with -7.777×103 kN-m.



	Name	No.	Jacking (kN/m^2)
1	T1	1	1.39619e+06
2	T1	2	1.39619e+06
3	T1	3	1.39619e+06
4	T1	4	1.39619e+06
5	T1	5	1.39619e+06
6	T1	6	1.39619e+06
7	T1	7	1.39619e+06
8	T1	8	1.39619e+06
9	T1	9	1.39619e+06
10	T2	1	1.39619e+06
11	T2	2	1.39619e+06
12	T2	3	1.39619e+06
13	T2	4	1.39619e+06
14	T2	5	1.39619e+06
15	T2	6	1.39619e+06
16	T2	7	1.39619e+06
17	T2	8	1.39619e+06
18	T2	9	1.39619e+06

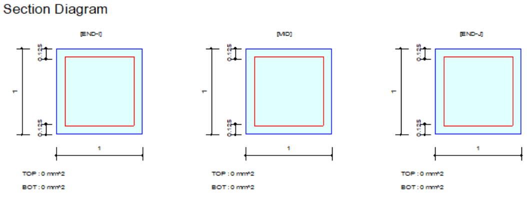
Fig. 29Cross Section Design of Tendon in Each Girder

Figure 29 depicts the placement of each prestressing tendon strands in each girder. The tension in each strand has a value of 1.39619×106. The first row consists of 3 strands has a spacing 0.355m. The second row of strands consists of 5 tendons spaced at 0.305m. The third row has 7 tendons spaced at 0.254. The fourth row has 9 tendons spaced at 0.202m. The last three rows were spaced at 0.152m, 0.101m and 0.051.

1. Design Information

Design Code : AASHTO-LRFD17
Unit System : N, mm
Material Data : fc = 0, fy = 0, fys = 0 MPa
Beam Span : 1000 mm
Section Property : GirderWizRectangle_8 (No : 8)

2. Section Diagram



3. Bending Moment Capacity

	END-I	MID	END-J
Negative Moment (Mu)	0.00	0.00	0.00
(-) Load Combination No.	2+	2+	2+
Factored Strength (Mr)	0.00	0.00	0.00
Check Ratio (Mu/Mr)	0.0000	0.0000	0.0000
Positive Moment (Mu)	0.00	0.00	0.00
(+) Load Combination No.	2+	2+	2+
Factored Strength (Mr)	0.00	0.00	0.00
Check Ratio (Mu/Mr)	0.0000	0.0000	0.0000
Required Top As	0.0000	0.0000	0.0000
Required Bot As	0.0000	0.0000	0.0000

4. Shear Capacity

	END-I	MID	END-J
Load Combination No.	2+	2+	2+
Factored Shear Force (Vu)	0.00	0.00	0.00
Shear Strength by Conc.(phiV)	0.62	0.62	0.62
Shear Strength by Rebar.(phiVs)	4.27	4.27	4.27
Required Shear Reinf. (Av)	0.5547	0.5547	0.5547
Required Stirrups Spacing	2.0-#3 @0	2.0-#3 @0	2.0-#3 @0
Check Ratio	0.0000	0.0000	0.0000
Required long. rebar	*****	*****	*****

5. Torsion Capacity

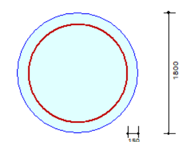
	END-I	MID	END-J
Load Combination No.	2+	2+	2+
Factored Torsion (Tu)	0.00	0.00	0.00
Torsion Resistance (Tn)	268797849.82	268797849.82	268797849.82
Required Stirrups Spacing	0.00	0.00	0.00
Check Ratio	0.0000	0.0000	0.0000
Required long. rebar	*****	*****	*****

Fig. 30Cross Section Details and Design of Pier Cap

Figure 30 shows the design information, the section diagram, bending moment capacity, shear capacity, and torsion capacity of the pier cap.

Design Condition

Design Code AASHTO-LRFD17
Unit System N, mm
Member Number 443 (PM), 457 (Shear)
Material Data fc = 27.579, fy = 275.79, fys = 275.79 MPa
Column Height 8000 mm
Section Property COLUMN (No : 6)
Rebar Pattern Total Rebar Area Ast = 76340.7 mm^2 (Rhost = 0.0300)



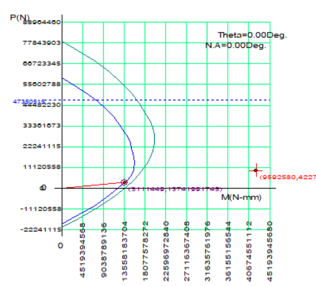
Applied Loads

Load Combination 6+ AT (J) Point
Pu = 9.6e+06 N, Mcy = 4.2e+10, Mcz = 6.1e+05, Mc = 4.2e+10 N-mm

Axial Forces and Moments Capacity Check

Concentric Max. Axial Load	Pr-max	= 4.7e+07 N	
Axial Load Ratio	Pu/Pr	= 9.6e+06 / 3.1e+06	= 3.083 > 1.000 .... N.G
Moment Ratio	Mcy/Mry	= 4.2e+10 / 1.4e+10	= 3.076 > 1.000 .... N.G
	Mcz/Mrz	= 6.1e+05 / 2.1e+05	= 2.938 > 1.000 .... N.G
	Mc/Mr	= 4.2e+10 / 1.4e+10	= 3.076 > 1.000 .... N.G

P-M Interaction Diagram



Pr(N)	Mr(N-mm)
59188144.33	0.00
46932209.93	7684930512.82
38307652.78	11320557984.02
30481425.55	13662347380.20
24201915.79	14926435650.64
20085054.50	15313377809.27
17136034.17	15633662701.54
[illegible]	15769063073.73
11316805.54	15725189573.93
6928193.01	15200723357.11
308507.15	12489980299.03
-9197501.63	7090098579.27
-18948627.80	0.00

Shear Force Capacity Check

Applied Shear Force	Vu	= 6.4e+06 N (Load Combination 6+)	
Shear Strength by Conc	phiV	= 1.3e+06 N	
Shear Strength by Rebar	phiVs	= 5.4e+06 N (10.-#5 @150)	
Shear Ratio	Vu/Vr	= 6.4e+06 / 6.7e+06	= 0.966 < 1.000 .... O.K

Fig. 31Cross Section Details and Design of Pier Column

Figure 31 shows the design information, the section diagram, bending moment capacity, shear capacity, and torsion capacity of the pier (column).

IV. CONCLUSIONS

A. Household Interview Survey Conclusion

The Community-Based Assessment carried out in Malusac, Sasmuan serves as a crucial tool for gathering data on various aspects of the transportation system within the study area, including its current status, usage patterns, and anticipated future utilization. This study concludes that by examining travel patterns and characteristics, as well as analyzing existing transportation systems provided valuable insights into the current state and future needs of the community.

Based on the analyzed findings, the drawn conclusions are as follows:

1. A significant portion of the population resides below the poverty threshold, earning monthly incomes of less than P5000. This circumstance is largely attributable to the high unemployment rate among the 151 respondents, resulting in lower monthly earnings.
2. The primary concerns for respondents in using their main mode of transportation are related to travel time, fare expenses, and safety. These factors significantly impact their monthly budget, time allocation for travel, and perceived risks. Consequently, a notable portion of the population in the study area does not possess any form of personal vehicle and depends entirely on public transportation for their daily commuting due to financial constraints preventing them from purchasing their own vehicles.
3. Boats are the primary public transportation mode that are available in the area.
4. Boats emerge as the exclusive mode of transport for all the respondents. However, the safety of using this mode of transportation is the residents' major concern.
5. Sidewalks and Parking in the area are also an area of concern since they were rated as 'Needs Improvement' by the respondents. Given that Malusac is a coastal community, its development is slower than the most of the community in Sasmuan.
6. The majority of 28% of survey respondents identified 'lack of transportation infrastructure' as a barrier that affects the general population. It is supported by the ideas and improvements that respondents believe would help their community the most, with a majority of respondents answering "construction of footbridges, bridges, roads, etc." accounting for 48% of all survey responses. The respondents feel that a transportation infrastructure must be established or developed in their research area in order to improve their transportation system and increase their mobility.

B. Hydrologic and Hydraulic Analysis

The calibration approach employed for the HEC-HMS model, utilizing data from the Pampanga Rainfall Station during Typhoon Inday and focusing on the maximum 24-hour rainfall rate of 2.54 meters, aimed to achieve an accurate representation of real hydrological conditions. The effectiveness of the calibration was evident through the model's ability to precisely reproduce the recorded depth at the rainfall station, aligning with the onset of Typhoon Inday. Furthermore, the model's capacity to simulate the hydrological response to the rainfall event was validated by the agreement between the projected and observed depth. Additionally, the model demonstrated precision in depicting the watershed's complex dynamics, as evidenced by the agreement between simulated and observed data. This underscores the reliability and utility of the calibrated HEC-HMS model in accurately assessing and predicting hydrological phenomena.

In analyzing the 100-year return period, sink 1 in the watershed exhibited a peak flow rate of 15.8 cubic meters per second, with a 1% probability of occurrence annually. Despite its rarity, the potential consequences of such an event are significant due to the large volume of water involved. Understanding the peak discharge was essential for bridge construction, aiding in determining debris flow depth and design discharge requirements. By leveraging this data, the bridge could be engineered to withstand periodic flash floods, ensuring the safety of residents and their livelihoods. The calculated hydraulic depth of 3.14 m will serve as guide for the design of the bridge specifically for the height of piers that will be used.

C. Bridge Design

The bridge design features a 20-meter span length and 7.32-meter total width, with four AASHTO Type IV beams spaced at 2-meter intervals supporting a 0.30-meter-thick concrete deck. It accommodates two lanes with a clear width of 7.32 meters and 0.75-meter-wide sidewalks, adhering to design guidelines. It identifies the maximum and minimum applied loads on the bridge, which are 71.17 kN, 17.79 kN, and 4.67 kN/m, using the HL-93 moving load type. The beam diagram indicates a maximum positive bending moment of 7.765×103 kN-m at midspan and a maximum negative moment of -7.777×103 kN-m at the supports. These specifications ensure structural integrity and compliance with safety standards.

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