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Evaluating Soil and Flood Conditions for Economical Flood Control of the Minanga River in Casiguran, Aurora

Rona Mae Q. Gabogen, Alvin M. Concepcion, Zimran Paul M. Lazaro, Mary Jane T. Curitana, Donna Fe A. Baylon, Jhun M. Jacinto

School of Engineering, Aurora State College of Technology

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ABSTRACT

Natural disasters like floods have the power to obliterate people, things, and buildings. However, numerous flood mitigation strategies were developed to lessen their effects or to stop floods from destroying buildings, lives, and property. And many factors, including the flood and soil conditions, the cost, duration, and availability of the materials to be utilized in the structure, should not be overlooked while implementing flood mitigation measures. This would assist in determining the most cost-effective method of flood management for a particular area. In addition, the current study is focused on the Minanga River in Casiguran, Aurora. By assessing the soil and flood conditions, the cost and duration of construction, and the availability of materials, it was determined that concrete slope protection is the most cost-effective flood control solution for the area of interest. This is said to be the case because the soil is clayey and prone to shifting and spreading, necessitating the construction of a pile foundation to anchor the structure and provide concrete slope protection. The location requires this type of flood control, which can be relied upon to last long and far from failure based on the considerations that were examined, despite the estimates that the researchers' work revealed to be that concrete slope protection is the costliest and longest length of construction.

Indexterms: Economical Flood Control, Evaluation, Flood Condition, Soil Analysis

INTRODUCTION

With some estimates placing 60% of its geographical area and 74% of its population as subject to multiple dangers, including floods, cyclones, droughts, earthquakes, tsunamis, and landslides, the Philippines are highly susceptible to calamities brought on by natural disasters. As a result of powerful storms and lots of rain, the nation is quite vulnerable to flooding. Land-use changes like logging and urbanization increase flooding hazards [37]. Moreover, according to various estimates, Asia has seen the most flood damage of any continent, accounting for 50% of all fatalities in the final quarter of the 20th century [19]. Therefore, it is essential to be aware of how flooding might affect all facets of life. Therefore, effective flood management is essential in preventing and reducing the effects of this natural occurrence. Furthermore, one of the flood management strategies used is building flood control, which aids in regulating water flow and prevents it from destroying properties and taking lives.

Moreover, flood control has always been a crucial issue for our society. Even though dwelling near rivers, lakes, and coastal locations gave people access to reliable harvests, vital trade routes, and transit routes, water has also posed a threat to destroy those settlements in a matter of hours [44]. However, the risk is not eliminated by flood control systems. If the design water levels exceed, flooding could happen. These structures can enhance danger by creating a false sense of security and promoting settlements or economic activity in dangerous places if improperly planned, designed, built, operated, or maintained [12].

Furthermore, there are some instances when a structure may fail or break because of some factors. One of the factors that may cause this failure is the need for more analysis of the location where that is subject to construction. When it comes to construction undertakings, the area of occupancy is equally as important as the

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structure to construct. For a successful construction project, the structure must be aesthetically and technically compatible with the surrounding area; therefore, site research is essential [49].

More so, various analyses are necessary to determine the state of a particular area. Before building flood control, an evaluation of the flood and the soil is a must. The analysis would facilitate the design of a more effective structure to lessen the effects of the flood on the region and a more costly maintenance of the structure.

As a result, this study aims to investigate the viability of a flood control method that will successfully cut down on flooding along the Minanga River in Casiguran, Aurora and will be economical for the community when it comes in funding and building the said structure. In line with this, according to the partial observations in the Minanga River, Casiguran, Aurora, one factor that contributes to flooding in the area is the continuous rainfall and that it is in a low-lying area. According to the residents who experience the flood, since it is the only route to the town, it prohibits light vehicles from passing through. When the river's water level rises above its average level, wide range of area from it are flooded. This problem limits them from acquiring things they need at the market throughout the storm or flooding.

Furthermore, for the study to be possible, the researchers would be conducting an on-site examination and collect data through interviews with the residents of Barangay Marikit in Casiguran, Aurora, regarding the flooding conditions in the area to determine how risky the flood they were experiencing. The interview consists of the profile of the respondents regarding their age and length of residency in Barangay Marikit. Also, this includes the potential cause and effect of flood to assess its vulnerability. In addition, the researchers would be acquiring an existing data from the PAGASA to know the rainfall amount experienced by Casiguran, Aurora, for the past ten years. Moreover, they would be conducting a soil test in the Quality Assurance Laboratory of DPWH Baler, Aurora to know the strength, properties, and classification of the soil in the Minanga River in Casiguran, Aurora.

Furthermore, the study analyzes five types of flood control which are levees, dredging, gabion, riprap, and concrete slope protection, as these types of flood control were seen to be suitable for the area based on the partial observations. The flood controls being examined would have a total length of 100 meters for its estimation. However, this study will not provide the detailed structural design of the flood control. This study will only help in determining the type of flood control for the area regarding the analysis conducted. Also, this study will not construct the most economical flood control to be analyzed. This study will recommend primary investigations and considerations before planning and building flood control in the Minanga River in Casiguran, Aurora.

Thus, this study aims to analyze the type of flood control that is economically suitable for the Minanga River in Casiguran, Aurora.

LITERATURE REVIEW

This literature study seeks out articles published between 2012 and 2023 that cover topics including the value of understanding flood information, various flood management measures, the significance of soil analysis, and various types of soil analysis. Table 1 show the methodological process used to locate and choose the essential papers for this study. This literature review's primary objective is to identify and connect to the following research questions:

Research Questions:

1. What is the condition of the area in terms of the;
    - Flooding Condition
    - Soil Condition

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2. How do these conditions affect the decision on the type of flood control for the Minanga River in Casiguran, Aurora?

3. What is the most economical flood control for the Minanga River in Casiguran, Aurora, based on the following?

    - Availability of Materials
    - Construction Duration
    - Cost of Construction

Table 1. Literature Review Process Furthermore, this literature review further discussed the necessary information that is used in this study.

Analysis of Feasible Flood Control: A Literature Review	
Articles	Number of Articles
What is Flood and Flood Control?	7
Flooding information	20
Types of Flood Control	9
What are Soil Analysis and its importance?	8
Types of Soil Analysis	12
Total	56

Different Types of Flood Control

For our society, flood control has always been an essential element. Since settling near rivers, lakes, and coastal locations gave people access to reliable harvests, vital trade routes, and transit routes, water has also posed a threat to destroy those settlements in a matter of hours [40]. And flood control has different types with different characteristics and purpose.

Levee

A levee is a "man-made structure, usually an earthen embankment, designed and constructed by sound engineering practices to contain, control, or divert the flow of water to protect from temporary flooding." A levee system is a "flood protection system which consists of a levee or levees, and associated structures, such as closure and drainage devices, which are constructed and operated by sound engineering practices" [16].

Dredging

Dredging has many different purposes, such as navigation, environmental cleanup, flood control, and the placement of structures (e.g., foundations, pipelines, and tunnels). These activities may produce significant amounts of waste that must eliminate. Dredging is to obtain materials, such as those needed for beach nourishment or reclamation. Sand, silt, clay, gravel, coral, rock, boulders, and peat are suitable for dredging [14].

Gabion

Gabions are wire-stone elements in the shape of hexagons or cuboids made of wire mesh with double or triple twisting. It is filled with local stone or quarry and used for retaining walls, sea walls, mechanically stabilized earth MSE walls, hydraulic works, and channels lining or revetments. The primary function of a gabion retaining wall is to allow for lateral movement of soil or rock to control active earth pressure and to resist the

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transverse load in the case of gravity retaining walls, which are supported and stabilized by their weight. To improve, double or triple twisting should be applied to the hexagonal and rectangular GI wire mesh used in gabion walls [17].

Riprap

Rock fragments collected along seashore comprise a riprap [29]. A numerically based technique is applied to determine a size selection formula for the riprap stone portion of the apron that serves as erosion protection for wing-wall abutments. Various simulation series takes place with a specified mean riprap diameter for abutments located in straight and curved channels with or without a floodplain. It helps to estimate the maximum bed shear stress over the riprap apron and the maximum (critical) Froude number at which riprap stones will resist shear failure by the flow [26].

Concrete Slope Protection

Concrete Slope Protection shall consist of furnishing and placing concrete slope protection, including all necessary excavation, a bed course, and reinforced concrete to the required thickness and extent to protect against erosion [34].

The concrete slope protection on a steel sheet pile foundation with reinforced concrete pile caps helps to prevent accidents, collapse, and landslides [9].

Cause and Effect of Flood

Cause of Flood

Flooding is a natural occurrence that can harm various aspects of existence. Moreover, inundation may be because of various factors. Here are some common causes of flooding in a given area.

Table 2. Causes of Flood

Causes of Flooding	Citations
Frequent and Heavy Rainfall	[11] [12] [17]
Disposal of Garbage (Biodegradable and Non-biodegradable)	[14] [21] [24]
Sand Composition of River	[7] [8] [29]
Waste Water from surrounding Residential	[18] [22] [31]
Utilization of Heavy Machinery	[3] [13] [23]

Effect of Flood

Flooding can have several immediate effects, including the death of people, the devastation of buildings and infrastructure, and the loss of livestock and crops. Disrupting vital infrastructure (such as power plants, highways, hospitals, and more) and communication networks, for instance, can have long-term effects on social and economic activity. It is crucial to ensure consistency in assessing damages to manage flood risk. Flood risk frequently entails assessing only the national economic losses brought on by floods and coastal erosion rather than the financial losses suffered by affected individuals and organizations, and however severe those losses may be. This analysis could help to create a flood management plan that will stop those losses and damages caused by floods as this influence the man-built structure [57].

In addition, as most people know, the immediate effects of flooding include loss of life, property damage, agricultural destruction, livestock loss, and worsening health conditions due to waterborne diseases. As communication connections and infrastructure such as power plants, roads, and bridges are damaged and

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disrupted, some economic activities may halt, people should abandon their homes, and everyday life is in a mess.

Soil Analysis

Soil testing involves evaluating the soil's condition and bearing capacity. A geotechnical expert examines soil samples to ascertain the soil's characteristics, composition, and reactivity. In addition, soil testing can be conducted anywhere, depending on the geographical structure of the earth's surface that is required to accomplish the testing's purpose. As we may know, soil testing is necessary before agriculture and building construction [54].

Furthermore, the primary purpose of soil testing is to determine the bearing capacity. The soil must be capable of supporting the building's weight. Moreover, soil testing is a crucial phase before beginning construction. Without soil testing, the structure will be subject to unknown dangers, and the result could be fatal. Soil testing includes Moisture Test, Proctor's Compaction Test, Atterberg Limit Test, Soil Classification Method and Bearing Capacity Test [54].

Moreover, as these tests were conducted, the type of soil will be known. There are three primary soil classifications: clay, sand, and silt. In general, clay soil requires a deeper foundation and readily absorbs water. A moderate amount of sand as a component of loamy soil has beneficial properties, but it tends to migrate and expand. The silt soil type allows water to disperse nicely and has a high level of aeration, whereas uncompact sand is susceptible to erosion.

In line with this, some clays are typically quite firm. These clays will not move excessively, so erosion is not a concern. However, they are only sometimes strong enough to support a hefty concrete slab. Other clays will be significantly softer. In certain instances, these will resemble grit. Therefore, placing a concrete slab on these clays is impossible because the slab would shift and descend [53]. Moreover, the most common deep foundation used for flood control is a sheet pile foundation, and it can withstand soft soil types such as clay [1].

METHODOLOGY

This study gathered and analysed data using a mixed-method design, qualitative and quantitative. The qualitative approach is necessary since this study involved interviews and observation. The researchers will be able to comprehend the flood situation in the Minanga River in Casiguran, Aurora, as a result. However, due to the soil testing and structure estimation that the researchers conducted, the quantitative technique is necessary because of some computations necessary for the experiment.

The procedure for gathering and analyzing data to develop the most economical flood control for the Minanga River in Casiguran, Aurora, is in the figure below.

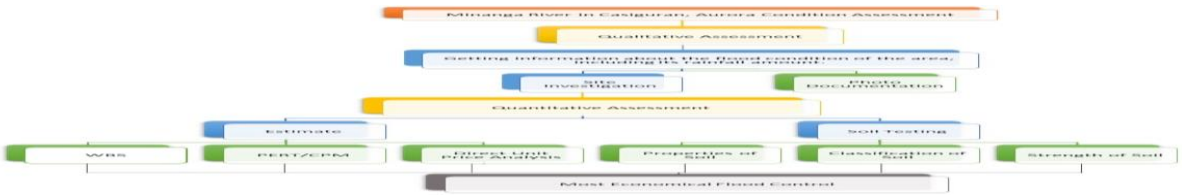

Figure 1. Process Flowchart

Furthermore, to achieve the objectives of this study, which is to know the vulnerability of flooding in Barangay Marikit, Casiguran, Aurora used a self-made research questionnaire. It is a printed questionnaire written in English with Tagalog translation for more accessible communication—the first part of the questionnaire concerns the respondents' profile. The second part is a yes-no question examining the causes of flooding in Marikit. Lastly, 3-point Likert-type questions determined the perceived effects and level of flood impact of flooding in the community.

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Moreover, in soil testing conducted by the researchers, soil samples were from two separate locations: the upper stream and the lower stream. The researchers gathered four different holes where every hole that have two samples labeled as 1-meter and 2-meter samples. The soil samples were from the natural grade line, which is not saturated with water. And the **s**ediment was analyzed in the laboratory of DPWH Quality Assurance Section for the evaluation.

DISCUSSION

Flooding Condition

It is essential to understand the flood risk and the severity of the disaster. There are three flood classifications including minor, moderate, and significant inundation. Minor flooding refers to the flooding of low-lying areas adjacent to waterways. It is possible for minor roads to be closed and low-level structures to be submerged. It can affect backyards, subfloor structures, and bicycle and pedestrian paths. For moderate flooding, the inundated area is significantly larger. It may be necessary to evacuate flood-affected areas and remove stock if significant roads are inundated by flood and certain buildings are affected above the first floor. In addition to being extremely hazardous, significant flooding can result in the widespread inundation of rural and urban areas. It is probable that properties and towns will disappear and that all roads will be closed. People in flood-affected areas may be required to evacuate, and utility services may be interrupted [45].

The researchers were able to determine the full extent of the flooding's impact on the residents and properties of Barangay Marikit, Casiguran, Aurora by conducting an interview with the residents who were most affected. Based on the responses of the residents to the researchers' inquiries, the flood in their area was moderately severe which affects a lot of people.

Soil Condition

As soil analysis is necessary before constructing a structure, it is essential. Testing the soil at a construction site helps determine the nature and characteristics of the soil present. This analysis includes the material's composition, strength, Density, water content, and other properties that can affect the construction process and the integrity of the infrastructure. In addition, the results of a soil test can reveal whether the soil is appropriate for the proposed construction. For instance, if the soil is too weak, unstable, or compressible, it may not be able to support the weight of the infrastructure or may contribute to the settlement, resulting in structural damage [4].

The researcher's soil test results are presented in Table 3, which provides insight into the soil's characteristics and strength in the Minanga River in Casiguran, Aurora.

Table 3. Soil Condition

Soil Sample	Soil Classifications (AASHTO)	Soil Type (CBR Test)		
Upper Stream	20 meter	1 meter	A-4(Silty Soil)	Sandy Clay
		2 meter	A-4(Silty Soil)	Clay
	40 meter	1 meter	A-4(Silty Soil)	Clay
		2 meter	A-1-b(Stone fragments, gravel and sand)	Well graded sand
Lower Stream	20 meter	1 meter	A-6(Clayey Soil)	Clay
		2 meter	A-7(Clayey Soil)	Clay
	40 meter	1 meter	A-4(Silty Soil)	Sandy Clay
		2 meter	A-4(Silty Soil)	Sandy Clay

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Construction Details

The cost and duration of construction for a 100-meter flood control length, as well as the foundation used for each form of flood control, are detailed in Table 4. The data presented in this table was regarded to be the basis for the estimations and articles collected by the researchers from the websites. Regarding the availability of materials for each form of flood control, they were determined to be available in the region.

Table 4.Construction Details

Types of Flood Control	Construction Cost	Construction Schedule	Foundation Type
Levee	P2,737,298.48	65 CD	None
Dredging	P2,550,955.73	103 CD	None
Gabion	P6,619,680.15	117 CD	Rock Embedment
Riprap	P4,078,135.26	107 CD	Concrete
Concrete Slope Protection	P12,176,049.26	123 CD	Sheet Pile

Research Gaps

Various essential techniques and engineering evaluations determine the most efficient and effective flood control system. However, decision-making should be according to the local and actual situation, which is a tremendous challenge for implementing such a type of Flood Control.

Table 5. Challenges in the Analysis of Economical Flood Control

NO.	CHALLENGES	CITATION
1	Reliability of flooding effects within the area	[3],[5],[11],[12],13]
2	Reliability of soil analysis to the study	[2],[4],[8],[32]
3	Process of selecting the most economical flood control for the area	[17],[28],[29],[35],[44]

In order to optimize the opportunities presented by the analysis of the most cost-effective flood control for the area of interest, it is crucial to establish the reliability of the conditions that require evaluation. In order to facilitate a more comprehensive understanding of the effect of flooding on the area, it is necessary to interview the residents. Can the soil analysis be relied upon to determine the most cost-effective flood control solution for the region? In order to reduce future maintenance expenses and construct a high-quality structure, it is crucial to consider the impact of processes such as construction, soil type, flood impacts, and the compatibility of flood control with these conditions.

CONCLUSION

The following conclusions are reached based on the research's findings and the information acquired by the researchers:

- Due to the Brgy. Marikit, Casiguran, Aurora's moderate risk. Although it is determined that flooding has a moderate impact on the community and its inhabitants, immediate action is still required. Because of the community's exposure to damage to people, property, and live cattle. Therefore, it must be fixed immediately to prevent more severe damage.

- Knowing the soil and flood conditions in Brgy. Marikit, Casiguran, Aurora, as well as the Minanga River in Casiguran, Aurora, led to the discovery of the most cost-effective flood management for the aforementioned location. If the soil and flood conditions for the area conflict with the flood control for

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the location, it will not be helpful and economical regardless of the cost, duration, and availability of materials.

- Since the soil in the Minanga River was discovered to be clayey, it has been suggested in some studies that a pile foundation be used to stabilize the project. This study came to the conclusion that concrete slope protection with a sheet pile as the base is the most practical and cost-effective flood management for the Minanga River in Casiguran, Aurora. This is because it is said that although it took the longest and most money to construct, it won't quickly crumble when a flood occurs nearby. With this reason construction and maintenance will be of less compare to other four types of flood control discussed earlier.

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