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Optimizing Culvert Design for Creek Overflow Management: Determining the Optimal Structural Solution

Amor Judith A. CABANESAS[1], Derick Aldrin L. ESTEBAN[2], Alelie Joy C. ALEJO[3], Kevin Lester L. MABALAY[4]

[1,2.3,4] Instructor, Nueva Ecija University of Science and Technology,
Sumacab Este, Cabanatuan City, Nueva Ecija, Philippines

ABSTRACT: Flooding caused by creek overflow poses significant risks to communities, particularly in flood-prone areas with inadequate drainage infrastructure. This study examines the discharge capacity of Labni Creek in Brgy. Las Piñas, Peñaranda, Nueva Ecija, to identify appropriate engineering interventions for flood mitigation. Site inspections and hydraulic analysis revealed that the existing reinforced concrete pipe culvert is insufficient, with a discharge capacity of only 3.78 cubic meters per second, compared to the creek's peak discharge of 89.8 cubic meters per second. The study also identified sediment accumulation, minimal vegetation, and the absence of flood control structures as key contributors to overflow. Using Manning's and Rational Formulas, alternative structural solutions were evaluated, with a two-barrel box culvert emerging as the most effective design. This proposed structure meets AASHTO and DPWH standards, ensuring improved water flow management and reducing flood risks. The findings highlight the need for immediate intervention, including dredging, vegetation management, and upgraded culvert design, to enhance the creek's resilience and safeguard surrounding communities from recurring flooding.

KEYWORDS: Flood Mitigation, Community Resilience, Engineering Intervention, Nueva Ecija, Disaster Management

I. INTRODUCTION

Flooding is a global environmental crisis with wide-reaching impacts on human rights, economies, and sustainable development. Climate change, urbanization, and poor infrastructure have intensified flood risks worldwide, especially in flood-prone regions like the Philippines. This tropical nation faces frequent and severe flooding due to its vulnerability to typhoons, monsoons, and storm surges. Human activities, such as deforestation and improper waste management, further exacerbate these risks by reducing land permeability and clogging drainage systems. Addressing flood resilience is crucial for achieving several Sustainable Development Goals (SDGs), which emphasize the need for climate action and sustainable infrastructure to protect communities and ecosystems.

In the Philippines, the Ambisyon Natin 2040 vision aims for a resilient and peaceful life for all Filipinos by 2040, promoting both structural and non-structural flood management. While urban areas like Metro Manila benefit from substantial investments, such as the Pasig-Marikina River Channel Improvement Project, rural areas often receive insufficient resources for effective flood control. This disparity leaves rural communities, such as Peñaranda in Nueva Ecija, vulnerable to severe flooding, particularly along Labni Creek, where outdated infrastructure exacerbates flooding during heavy rains. Bridging this gap requires equitable resource allocation and comprehensive flood resilience strategies to protect all communities, supporting the country's broader development goals.

II. OBJECTIVES

A. General Objective

To develop an engineering intervention that mitigates flood risks caused by the overflowing creek at Brgy. Las Piñas, Peñaranda, Nueva Ecija.

B. Specific Objective

1. Assess the discharge capacity of the existing pipe culvert bridge at the creek.
2. Identify suitable flood mitigation measures for managing the creek overflow.
3. Determine and recommend appropriate flood mitigation structures that can accommodate a higher discharge capacity than the current infrastructure, thus preventing creek overflow and subsequent flooding.

III. METHODOLOGY

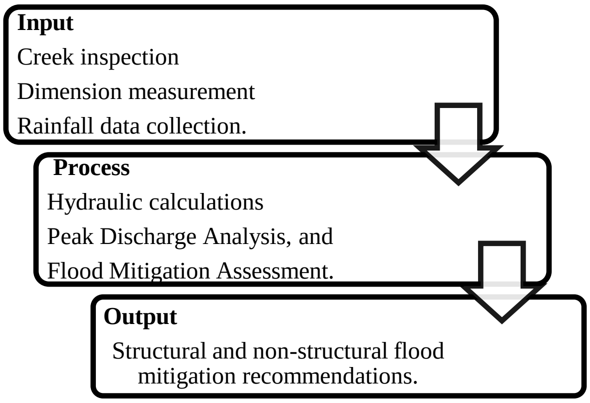

Figure III-I. Research Flow

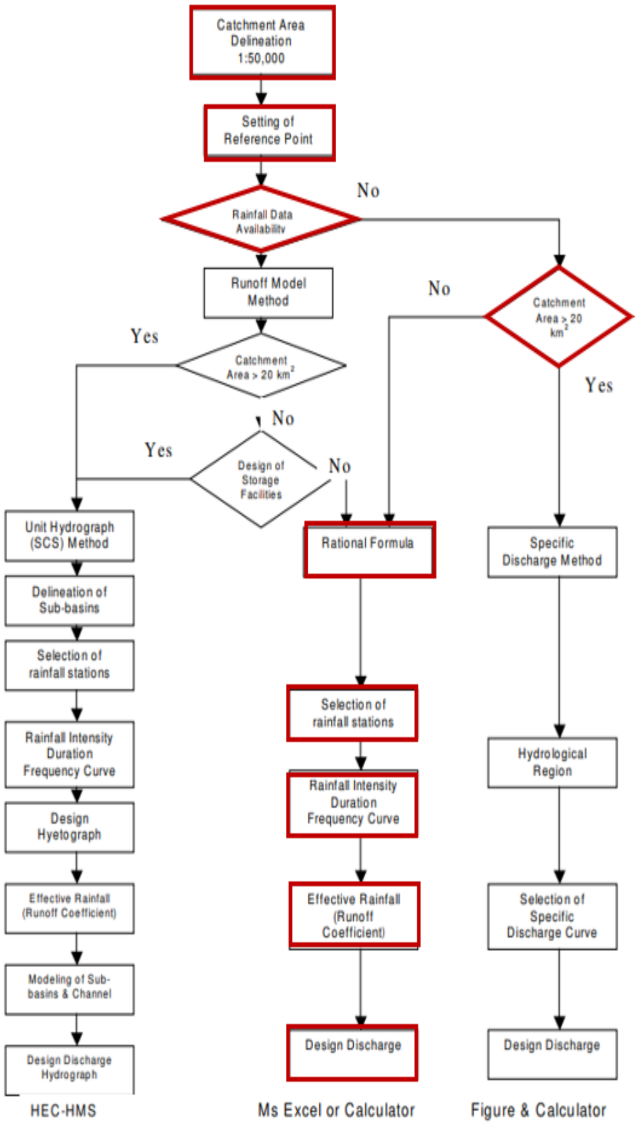

Figure III-II Procedure in The Determination of The Design Discharge

This research employed a quantitative descriptive design it is focused specifically on flooding caused by the overflow of Labni Creek, which had been exacerbated by the creek's inadequate discharge capacity and the accumulation of sediment and debris. Covering a 50-meter stretch of the creek, the research excluded other sources of flooding and socio-economic considerations, limiting its scope to technical solutions.

Data collection involved physical surveys to measure the creek's dimensions, rainfall data from PAGASA to determine intensity, Google Earth for catchment area mapping, and site investigation forms to document observations. The discharge capacity of the existing pipe culvert was calculated using Manning's Formula, while the creek's peak discharge was determined using the Rational Formula. These values were compared to assess the adequacy of the existing infrastructure. Creek characteristics, including land use, vegetation, and sediment composition, were analyzed at 2.5-meter intervals along the 50-meter stretch. Flow conditions were evaluated for both dry and wet seasons.

The study identified and analyzed non-structural and structural flood mitigation measures tailored to the creek's specific conditions. These measures were evaluated to ensure effective water management and address the recurring flooding issues. The analysis provided the foundation for developing solutions aimed at enhancing flood resilience within the community.

IV. RESULTS AND DISCUSSION

The physical characteristics of Labni Creek, including depth, width, and flow conditions, were analyzed to determine the factors contributing to overflow. Measurements indicated significant variations in depth along the creek, with shallower sections near the existing structure at Sta. 0+000, where overflow frequently occurs due to limited water-carrying capacity. These variations in depth suggest potential bottlenecks that restrict the natural flow of water, especially during heavy rainfall.

Site inspection revealed that the creek lacks flood control structures, making it more susceptible to uncontrolled water flow and erosion. Additionally, the creek bed is primarily composed of silt, which reduces permeability and increases sediment accumulation over time, further affecting its capacity to handle large volumes of water. The presence of silt also indicates a tendency for sediment transport, which can lead to blockages and increased flood risks.

Vegetation coverage along the creek was found to be minimal, with 81% of the area having little vegetation. This lack of vegetation influences flow resistance and sediment transport, as plant roots help stabilize soil and reduce erosion. Without sufficient vegetation, the banks of the creek are more prone to degradation, contributing to sediment buildup that obstructs water flow. These findings highlight the need for strategic interventions such as dredging, vegetation management, and improved flood control structures to enhance the creek's ability to manage excess water efficiently.

Table IV-1 Physical Dimension of the Creek

STATION	DEPTH (cm)	TOP WIDTH (cm)	BOTTOM WIDTH (cm)
Sta . 0+000.0	114.30	220.98	149.75
Sta. 0+002.5	101.60	391.16	175.03
Sta. 0+005.0	116.84	518.16	403.87
Sta. 0+007.5	127.00	1,128.04	1,102.03
Sta. 0+010.0	134.62	1,047.24	1,023.89
Sta. 0+012.5	154.94	903.26	810.54
Sta. 0+015.0	180.34	878.84	792.30
Sta. 0+017.5	182.88	797.56	715.21
Sta. 0+020.0	190.50	797.56	679.82
Sta. 0+022.5	243.84	955.04	636.40
Sta. 0+025.0	248.93	944.88	696.23
Sta. 0+027.5	271.78	873.76	692.56
Sta. 0+030.0	284.48	873.76	649.27
Sta. 0+032.5	289.56	861.06	638.00
Sta. 0+035.0	287.02	810.26	638.00
Sta. 0+037.5	276.86	810.26	582.09
Sta. 0+040.0	266.70	749.30	569.25
Sta. 0+042.5	271.78	779.78	555.00
Sta. 0+045.0	279.40	840.74	473.20
Sta. 0+047.5	294.64	779.78	638.82
Sta. 0+050.0	302.26	871.22	762.46

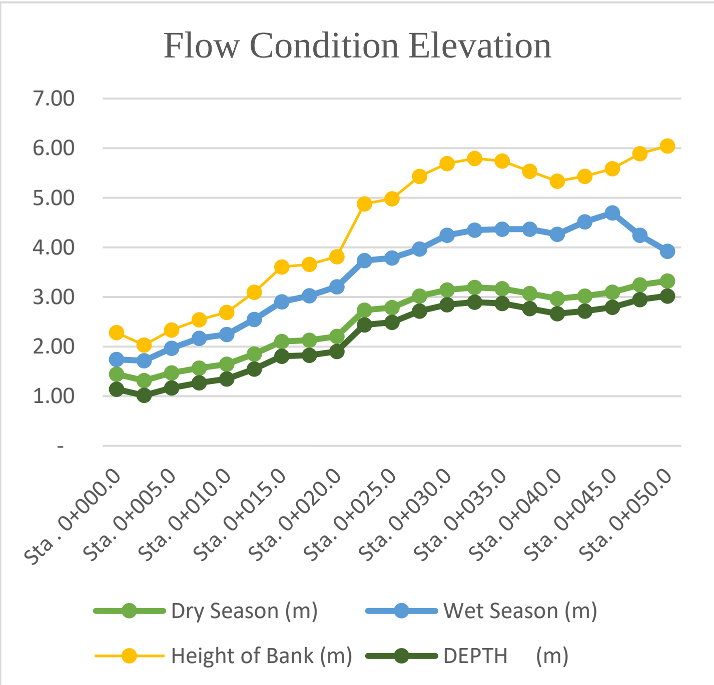

Figure IV-I Flow Condition and Elevation

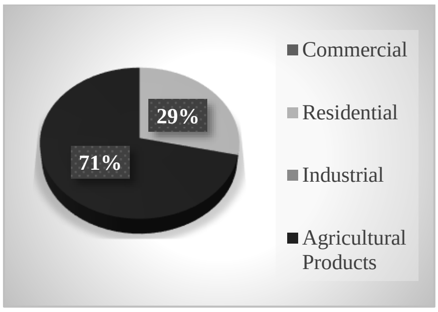

Figure IV-II Land use in the 50m stretch of the Creek

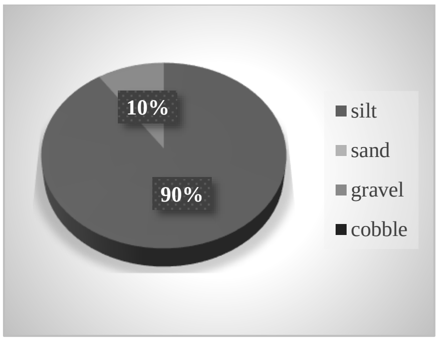

Figure IV-III Type of Soil in the Creek Bed

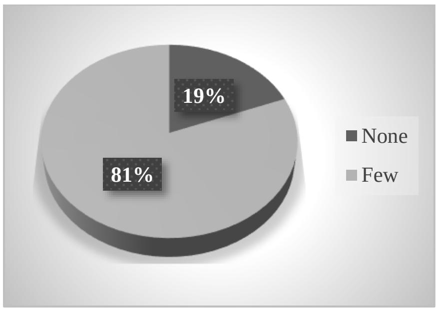

Figure IV-IV Vegetation in the Creek

Hydraulic analysis of the existing reinforced concrete pipe culvert, using Manning’s formula, confirmed that its discharge capacity of 3.78 cubic meters per second is insufficient compared to the creek's peak discharge of 89.8 cubic meters per second. The flow condition analysis showed that during the wet season, water levels frequently exceed the hydraulic elevation of the pipe culvert, causing flooding that takes 12 to 14 hours to subside.

Figure IV-IV Existing Pipe Culvert Bridge

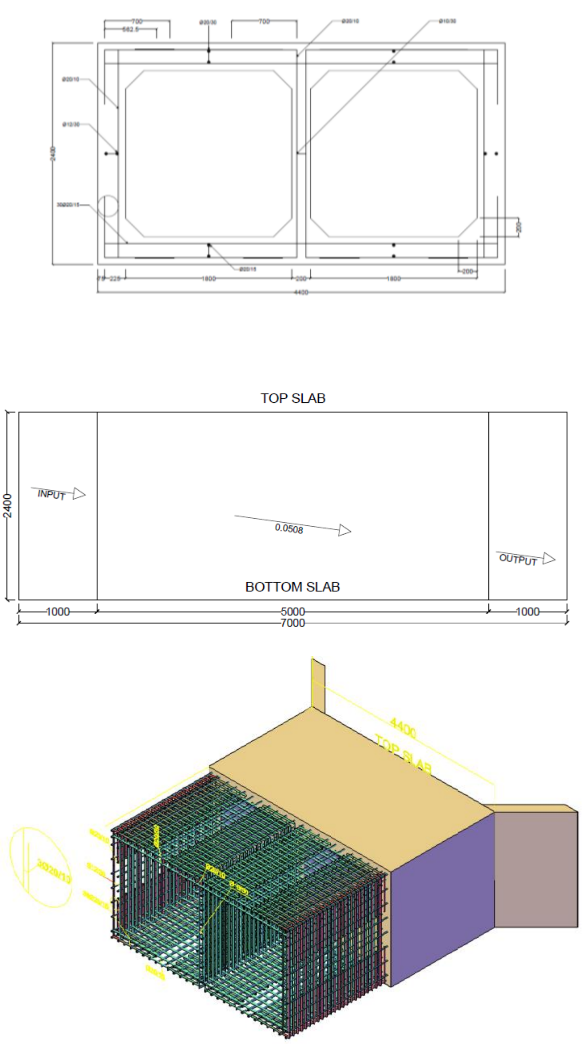

Figure IV-V Plan of Proposed Culvert

A comparison of hydraulic designs between pipe culverts and box culverts demonstrated that a box culvert can achieve a significantly higher discharge capacity. The most economical section was determined based on engineering calculations, leading to the recommendation of a two-barrel box culvert as an optimal solution. Load analysis and structural design computations confirmed that this design meets AASHTO and DPWH standards for effective flood management.

CONCLUSIONS

The discharge capacity analysis of the existing pipe culvert bridge unveiled its inadequacy, with a capacity of 3.78 cubic meters per second falling significantly short of the creek's peak discharge capacity of 89.8 cubic meters per second. This deficiency underscores the urgent need for enhanced infrastructure to manage the creek's flow effectively. Furthermore, the physical inspection conducted at Labni creek highlighted the presence of substantial obstructions caused by accumulated sediment and debris. These obstructions exacerbate flood risks during heavy rainfall events, emphasizing the necessity for immediate action. Dredging and Vegetation management emerged as a suitable flood mitigation measure to address these obstructions, restore the creek's flow capacity and enhance natural vegetation along watercourse to stabilize banks and absorb water. Another reason of dredging operation is to address the size of the existing structure, as the culvert’s dimensions are such that debris tends to accumulate at the approach of the pipe before it reaches the structure necessitating the removal of these obstructions. Dredging of a creek refers to the process of removing sediment, debris, or other material from the bottom of the creek bed using specialized equipment such as dredgers, excavators, or suction devices. This process is typically done to deepen the creek, improve navigation, restore aquatic habitats, prevent flooding, or maintain water quality. Lastly, the study identified a two-barrel box culvert as the most appropriate flood mitigation structure for the creek, capable of accommodating higher discharge capacity while adhering to AASHTO standards. This design approach aligns with the rigorous protocols established by the DPWH, ensuring the structural integrity and effectiveness of the mitigation efforts.

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