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Run-Off Analysis for a State University: An Input to Drainage System Design and Management Plan for Don Honorio Ventura State University (Main Campus), Pampanga, Philippines

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Abstract:

Don Honorio Ventura State University is considered as one of the oldest vocational schools in Far East Asia, having been established since 1861. Throughout the years, the university has developed various infrastructures and evolved to become what it is today. However, the university seems to suffer from floodwater accumulation despite the university's improvements. These situations would cause an inconvenience to the DHVSU community, hindering various university activities in the process.This study focused on conducting a run-off analysis utilizing Rational Method at DHVSU Main Campus, both at the main lot and extension lot of the university. This was accomplished to develop a drainage system design that can reduce the run-off accumulation inside of the university. A management plan was also crafted to help maintain the efficiency of the proposed drainage system design.It was concluded that the existing outfall cross-section can accommodate the flooding that the current storms would produce. However, it was surveyed that the university has lower elevations at the center of both lots compared to its perimeter. Because of this, the surface run-off from these storms accumulates inside the university with nowhere to discharge to. A drainage design and management plan was proposed to properly discharge the accumulated floodwater, while following guidelines and provisions to achieve proper efficiency and durability.

Keywords — **Drainage System, Run-off, Elevation, Perimeter, Discharge, Channel.**

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I. THE PROBLEM AND A REVIEW OF RELATED LIRERATURE AND SUDIES

1.1 Introduction

A significant change to average weather conditions over several decades or longer, such as a noticeable increase in temperature, dryness, or precipitation, is called climate change. Climate change has significant impacts in the Philippines. The country is highly vulnerable to climate-related hazards such as typhoons and heavy rainfalls and urban flooding [1]-[2]. Typhoons have become more intense and prevalent because of climate change, leaving various institutions under floodwaters [3].

Due to this reason, precipitation frequency and intensity are subject to vary due to climate change and the quantity of water evaporating into the atmosphere rises with warmer waters. More severe precipitation, such as heavier rains, can be produced when more moisture-laden air flows over land or converges into a storm system [4]. In this case, the Philippines is one of the most typhoon-prone areas in the world, which experiences 19–20 typhoons on average per year, with 7–9 of them making landfall [5].

Additionally,as urban areas develop, the amount of impervious surfaces, such as roads, sidewalks, and buildings, increases. It is generally believed that urbanization leads to an increase in imperviousness, a decrease in green areas, and a reduction in soil infiltration capacity [6]. Due to climate change and urbanization, schools, which are places for learning, are not spared especially during disasters such as typhoons or simple low pressure areas (LPAs), causing pluvial flooding in the area

Solutions to the flood problems can be categorized into two forms of flood control measures: Structural and Non-structural measures [7]. Structural measures are any type of physical structures that reduces or avoids flood hazards such as floodwalls, levees, and dams. Non-structural measures instead use practices, knowledge, or agreements to reduce the risks and impacts of flooding such as catchment flood modelling and early warning systems. Apart from these flood controls, drainage systems are also important in minimizing surface runoff in urbanized environments, making it critical in modelling urban floods for scientific research or forecasting practices [8].

1.2 Literature Review

1.2.1 Drainage System

A building's drainage system is an essential component wherein it is necessary to control groundwater, rainfall, and wastewater flow to maintain the lifetime and appropriate operation of the building. It averts numerous water-borne health risks, flooding, and water damage [9]. The excess water that flows through a clearly defined channel is known as the drainage system. This method is done to prevent the collection of water-formed pools under residential grounds or on roadways. Drainage systems' primary function nowadays is to quickly dispose of wastewater [10].

Much of the system's longevity can be attributed to the materials used in channel drain construction [11]. In certain places, there are open and closed drains. Closed drains create a complex underground network. It may be acceptable to use open drains in some situations. But any location with a body of water attracts a variety of microorganisms that cause sickness [12].

1.2.2 Factors to Consider for Drainage System Designs

It is critical to understand the water movement, surface characteristics, the slope of the soil,and flood prone areas. These are all important when it comes to designing an efficient drainage system. By understanding these fundamental factors,a drainage system can be constructed that can efficiently manage water flow, minimize the risk of flooding, and ensure the overall lifespan of the structure. These can all be done by analysing the flow of water, features of the soil, and flood zones [13].

Failures on the drainage system design could significantly lower the anticipated levels of flood protection services in cities and have detrimental effects, including property damage, loss of life, and damage to vital infrastructure [14]. Thus, it is becoming more and more clear that urban drainage systems (UDSs) must become more resilient in order to maximize their capacity to both minimize the consequent flooding consequences during unforeseen or exceptional loading conditions that result in system failure and to maintain acceptable levels of flood protection service in the cities they serve [15].

1.2.3 Drainage System Management Plan

A project management plan is a legal document that specifies how the project is executed and includes information on its scope, objectives, budget, schedule, and outcomes. Since it keeps the project on schedule, it is essential to its success [16]. It provides an overview of the project's value proposition, methods of execution, materials, communication tools and protocols, risks, stakeholders (as well as their roles), and deliverables. An executive summary, team and Gantt charts, a risk assessment, and more details for resource management and communication are all included in the documents [17].

A drainage plan offers a secure and efficient means of managing stormwater runoff, preventing water damage to a structure's foundation and structural elements. Designing a drainage plan for an establishment requires carefully considering both the surrounding environment and the property's location. Before beginning a demolition and rebuild project, a drainage plan is an essential phase in the process. It guarantees that every facet of the project is taken carefully right from the start, assisting in averting future problems. So that other labourers can easily recognize the drainage system, the plan will clearly describe where it needs to be installed [18].

Regularly performing routine maintenance might lessen the requirement for reactive maintenance. It contributes to the optimal functioning of machinery and assets, which reduces failure rates and increases profitability, productivity, and safety [19]. Regular drainage system inspections would identify any damage, blockages, or damage. It makes it possible to resolve problems quickly before they get worse. Additionally, clean and clear the gutters, downspouts, and drain covers frequently to avoid clogging water flow with debris, leaves, and other obstacles. It guarantees the effectiveness of drainage and helps avoid blockages. Lastly, ensure that the drainage system is installed appropriately, with the proper grading, pipe size, and slope to allow water to flow. Installation properly reduces the possibility of water build-up and other drainage issues [20].

1.2.4 Drainage Design and Analysis Methods

There are two commonly used methods which are the Curve Number (CN) Method and the Rational Method. These are utilized in order to design a proper and efficient drainage system design and management plan. Although these both use a rainfall event and catchment area to calculate the peak run-off rate, the difference is that CN Method uses the moisture condition of soils while Rational Method uses the amount of run-off a type of surface would flow through [21]-[22]. Additionally, the Rational Method is limited to only smaller plots of land of about 0.8km2 while the CN Method can be applied to larger areas [23]. Despite this however, Rational Method was utilized instead as it is a more empirical and simpler approach focusing on calculating peak run-off rate and where the university is under the 0.8km2 limit, while CN Method is a more comprehensive analysis requiring additional input parameters compared to Rational Method.

In calculating the peak run-off rate using the Rational Method however, Time of Concentration (Tc) will be needed to determine one of the method’s parameters, which is the rainfall intensity. Tc is calculated by analysing the topography of a certain watershed or catchment area to determine the maximum water travel length and average slope of the area [24]. These two parameters can be identified by conducting a topographical survey of that certain area. There are two types of topographical surveying, these are profile levelling surveys and differential levelling surveys. Profile levelling is used to establish changes in elevation along a line, such as drains, roads, fences, and retaining walls. It provides a side view or cross-sectional view of the earth's surface and is commonly used for routes like sidewalks, streets, and utilities. The primary purpose of profile surveys is to determine the slope between points, depths of trenches, and other applications [25]. On the other hand, differential levelling is used to directly measure elevation differences between points. It is commonly used in various applications such as tidal measurements, connecting to GPS way-points, and determining the natural stability of the land. Differential levelling uses the vertical distance difference between two points to transfer an elevation from one point to another [26].

Following a complete survey, a contour map and zoning map can be developed. The contour map depicts run-off flow while the zoning map determines the surface area characteristics. Zoning maps aids in identifying various land uses, allowing for more accurate use of the rational method to estimate peak discharges for specific areas. Understanding the land use features of zoning maps allow hydrologists to conduct more exact calculations using the rational method, resulting in better-informed decisions in hydraulic design and stormwater management [27]. Contour maps are important when conducting a run-off analysis since these help in identifying drainage zones, shows the slope of the land, and providing a visual representation of the area’s topography. These can also be combined with various geographical data, providing a more comprehensive understanding of the elements influencing run-off and possible impacts on the movement of water [28]-[29].

Lastly, AutoCAD is a computer-aided software (CAD) used to model structures and is used for general construction developed by Autodesk. This is incorporated in the study when it is necessary to produce a new drainage system design that will accommodate the amount of stormwater flowing in the system. Google Earth Pro is utilized to determine elevations from various parts of the university and to determine the length and change in elevation of two points.

1.3 Background of the Study

The main campus of Don Honorio Ventura State University in Cabambangan, Bacolor, was experiencing problems managing the run-off accumulating inside the university which would then affect the effectiveness of its drainage system, requiring an extensive analysis of the university’s drainage system. During heavy rains in recent years, the university has experienced more frequent stagnant floodwater accumulation, forcing the university to suspend classes and creating safety concerns for the DHVSU community This issue affected the physical infrastructures inside the university and the overall functionality and safety of the university’s environment.

In order to resolve the specific issue, a full run-off analysis was required. The university also planned to address these issues by developing and implementing a comprehensive drainage system design and management strategy to reduce flooding hazards on the campus. This study gave important insights into the university's run-off patterns allowing for the development of a tailored drainage system that efficiently managed water flow and reducing flooding hazards.

1.4 Objectives

The general objective of this study is to conduct a run-off analysis of DHVSU’s drainage system utilizing the Rational Method equation to calculate the peak run-off rate based on the contour map, zoning map, and the design recurrence interval of DHVSU. Moreover, a drainage system proposal design was crafted together with the formulated drainage management plan to ensure both the effectiveness and sustainability of the proposed systems.

Specifically, the study looked into the following:

- To conduct a run-off analysis of DHVSU and determine the peak run-off rate using the Rational Method.
- To provide a drainage system design proposal for DHVSU utilizing Manning’s Equation.
- To craft a drainage management plan including the regular inspection and maintenance schedule.

1.5 Conceptual Framework

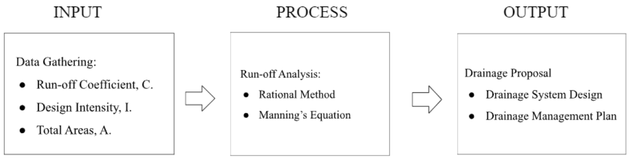
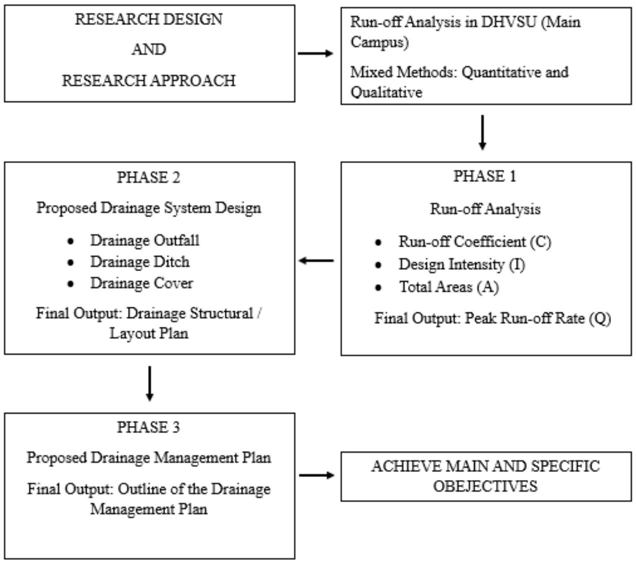


Fig. 1 Conceptual Framework

The diagram emphasizes the aim of the study, which was to gather information about the university, specifically to survey the DHVSU area and examine its flooding history. Next is to analyse the contour map and zone map of DHVSU, and to determine the design recurrence interval to be used. Lastly, a run-off analysis was conducted to determine the peak run-off rate using Rational Method and to develop a proposed drainage system design and management plan for DHVSU.

II. METHODOLOGY

2.1 Methodological Framework



2.2 Fig. 2 Methodological Framework

This study employed a mixed-method approach, integrating both quantitative and qualitative approaches across three sequential phases to comprehensively evaluate and address the university's drainage system.

The study aimed to perform a thorough investigation of the drainage system at the main campus of DHVSU. It concentrated on determining the peak run-off rate that would flow through the university and the areas where it would accumulate through simulation. A modified drainage design and layout of DHVSU was designed to accommodate the total amount of water that would flow through while also providing drainage maintenance plans to prevent further complications. The study follows a structured three-phase approach in analyzing the run-off dynamics in DHVSU's main campus drainage system.

2.3 Research Locale

The school's existing drainage system design was built back in 2010 according to the layout provided by the Office of Physical Plan and Facility (OPPF). Although the existing drainage system is properly designed, runoff in the system still overflows and causes flooding. The recent flooding in the school was experienced in the first week of September 2023 due to continuous rains brought by Typhoon Hanna (Haikui) [30]. The impacts of flooding in the school caused the suspension and disruption of classes: the absence of the students due to inaccessibility and difficulty of transportation.

2.4 Data Analysis

The data analysis of the study contained three phases: the development of the contour map and zone map of DHVSU, the identified design recurrence interval and run-off analysis results, and lastly, a proposed drainage system design and management plan for DHVSU. These steps were followed to form a systematized and efficient analysis of the collected data.

PHASE I - Run-off Analysis

A. Run-off Coefficient, C

The data analysis of the study contained three phases: the development of the contour map and zone map of DHVSU, the identified design recurrence interval and run-off analysis results, and lastly, a proposed drainage system design and management plan for DHVSU.

The equation below shows the formula to calculate the overall coefficient to be used in the Rational Method. The equation was developed by using Varignon's Theorem and by inputting the areas of the three surface characteristics, the corresponding run-off coefficients, and the total area of the university.

$$C_T = \frac{A_1C_1 + A_2C_2 + A_3C_3}{A_T}$$

Eq. 1 Total Coefficient Equation using Varignon's Theorem

B. Design Intensity, i

- **DHVSU Contour Map and Time of Concentration (Tc)**

A field survey or field investigation in DHVSU was conducted to develop the contour map and zone map of the university. Specifically, a profile levelling survey was conducted as it was the suitable method to determine the run-off flow route and surface elevation. Using various surveying tools that the university provided, such as the level tool with a tripod and levelling rod, elevations of the site were gathered to develop the contour map. After analysing the Contour Map of the university, the Time of Concentration was needed, as shown by the equation below, to determine the rainfall intensity that would be used. This equation is the most widely used Time of Concentration formula from Kirpich during 1940.

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

Eq. 2 Time of Concentration Formula

Where:
Tc = Time of Concentration (min)
L = Maximum Water Travel Length (m)
H = Difference in Elevation (m)
s = Drainage Basin Slope (H/L)

- **Design Recurrence Interval and Maximum Rainfall Depth (dmax)**

First, the history of flooding inside the university was determined by analysing the Flooding Incident Reports provided by the Bacolor MDRRMO and acquiring the design rainfall that was used. The Daily Precipitation Observation from PAGASA was also analysed to compare depth of rainfall from the selected rainfall design to the rainfall depth from the RIDF curve. After comparing the rainfall depths that were analysed, a chosen return period was used as the design recurrence interval. The maximum rainfall depth was calculated by using linear interpolation and inputting the rainfall depth and rainfall duration from the RIDF curve and flooding history analysis.

- **Calculated Design Intensity (dmax/Tc)**

After acquiring the calculated time of concentration and maximum rainfall depth, the last section of the Phase 2 can be conducted. The design intensity can be calculated using the acquired parameters, which was then used to calculate the peak run-off rate using the Rational Method. The equation shows the formula to calculate the rainfall intensity or design intensity that was used in designing the drainage system design.

$$i = \frac{d_{max}}{T_C}$$

Eq. 3 Rainfall Intensity Formula

Where:
i = Rainfall Intensity (mm/hr)
dmax = Maximum Depth of Rainfall (mm)
Tc = Time of Concentration (hr)

C. Total Area,A

Lastly, the total area was needed as the last parameter in calculating the peak run-off rate. The DHVSU area was divided into two lots, the main lot and extension lot of the campus. The two lot areas were calculated during the development of the zone map of the university. These areas were determined by measuring the lot dimensions from the site development plan of DHVSU using AutoCAD.

D. Peak Run-off Rate, Q

The rational method predicts the peak run-off rate that would flow through an area, and the method served as the basis for the run-off analysis.

Data from the contour map, zoning map, and the rainfall intensity from the chosen rainfall design scenario were used to calculate the peak run-off rate flowing through the university. After analysing the peak run-off rate, it was used for the drainage system design section. Below is the Rational Method equation to calculate the maximum run-off rate that would flow through DHVSU.

$$\boldsymbol{Q = \frac{1}{3.6} CiA}$$

Eq. 4Rational Method Formula

Where:
Q = Maximum Run-off Rate (m^3/s)
i = Average Rainfall Intensity (mm/hr)
C = Run-off Coefficient
A = Drainage Area (km^2)

PHASE II - Drainage System Design

Based on the calculated peak run-off rate from the run-off analysis, a drainage system can be designed. This design accommodated the chosen design recurrence interval and the current contour and zone map of DHVSU. The Manning's Equation below was utilized to calculate the cross-sectional area of the Most Efficient Section (MES) of a drainage channel. After designing the MES drainage system design, the MES design was compared to the existing drainage system of the university and the standard design of a drainage system. The three designs were compared to determine which design governed and used as the proposed drainage system design.

$$\boldsymbol{Q = A\frac{1}{n} R^{2/3} S^{1/2}}$$

Eq. 5 Manning's Equation on Open Channel Flow

Where:
Q = Flow Rate (m3/s)
A = Cross-sectional Area (m2)
n = Surface Roughness
R = Hydraulic Radius (m), (A/P)
P = Wetted Perimeter (m)
S = Slope of the Energy Grade Line

PHASE III - Drainage System Design

Various related literature was considered in formulating the management plan for the proposed drainage system design for the university. The proposed management plan focused on mitigating the run-off accumulation at DHVSU and increasing the efficiency of the proposed drainage system design. The management plan also included a schedule of the regular inspection and the maintenance procedures for the proposed system design.

III. RESULTS AND DISCUSSION

3.1 Run-off Analysis (Phase I)

As stated previously, Rational Method was utilized in conducting the run-off analysis at DHVSU. To achieve this, three parameters were needed and these were the overall run-off coefficient, the design intensity, and the total area of the main lot and extension lot of DHVSU.

3.1.1. Run-off Coefficient, C

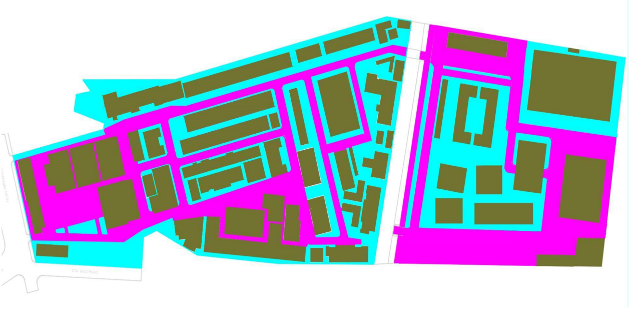


Fig. 3 DHVSU Zone Map

There were three distinct surface characteristics that were considered based on observations which are the asphalt and concrete (pink), the roof of the buildings (green), and soil lawns (blue). The building roofs, lawn soils, and asphalt or concrete were measured using AutoCAD and calculating the areas based on the dimensions from the site development plan provided by the OPPF.

TABLE I
UTILIZED RUN-OFF COEFFICIENTS

Soil Characteristic	Asphalt & Concrete	Building Roofs	Soil Lawns
Coefficients	0.95	0.95	0.17

By using the calculated areas from the zone map, an equation can be developed to calculate the overall run-off coefficient of the university by using Varignon's Theorem as shown. By inputting these values, an overall coefficient of 0.653 and 0.644 can be calculated for the main campus lot and extension lot of the university.

$$C_{Main} = 0.653 \quad C_{Ext.} = 0.644$$

Eq. 6 Calculated Total Run-off Coefficient

3.1.2. Design Intensity, i

- **Time of Concentration (Tc) Results**

  On the main and extension lot of the university, a maximum water travel length of 260m and 240m was measured respectively, following the where the run-off would flow. Tc for the main lot and extension lot respectively can be seen below.

$$Tc_{Main} = 14.591min \quad Tc_{Ext.} = 17.371min$$

Eq. 7 Calculated Time of Concentration

- **Maximum Rainfall Depth (dmax) Results**

  A Maximum Rainfall Depth (dmax) of Tc_{Main}=0.243hrs and Tc_{Ext}=0.289hrs was determined by utilizing the 2 year RIDF curve. This was accomplished through linear interpolation of the calculated rainfall depths for the 2-year interval return period.

$$dmax_{Main} = 34.401mm \quad dmax_{Ext.} = 34.938mm$$

Eq. 8 Calculated Maximum Rainfall Depth

- **Design Intensity (i) Results**

  It was identified that a rainfall intensity of 141.465mm/hr and 118.822mm/hr occurred on the main lot and extension lot of the university.

$$i_{Main} = 141.465mm/hr \quad i_{Ext.} = 118.822mm/hr$$

Eq. 9 Calculated Maximum Rainfall Depth

3.1.3. Total Area, A

TABLE III
MAIN LOT AREAS AND EXTENSION LOT AREAS

Soil Characteristics	Main Lot Areas (m^2)	Extension Lot Areas (m^2)
Asphalt & Concrete	**8719.15**	**6517.66**
Building Roofs	**20324.39**	**11757.73**
Soil Lawns	**17841.01**	**11815.74**
Total	**46884.54**	**30091.13**

By calculating the summation of the three surface areas, a total area of 46884.54m2 and 30091.13m2 was calculated for the main lot and extensions lot of DHVSU.

3.1.4. Peak Run-off Rate, Q

It was determined that a peak run-off rate of 1.203m3/s and 0.639m3/s can be calculated for the main lot and extension lot of DHVSU, based on the calculated design parameters.

$$Q_{Main} = 1.203m^3/s \quad Q_{Ext.} = 0.639m^3/s$$

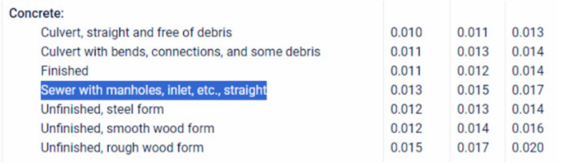
Eq. 10 Calculated Peak Run-off Rate due to STY. Karding

However, according to the DPWH Design Guidelines, Criteria and Standards, a minimum of a 5-year rainfall interval was used for roadside ditches and inlets based on the figure below. During the designing of the MES drainage system, the peak run-off rate from the main campus lot was utilized to provide an MES drainage design that would accommodate both the main campus lot and extension lot of DHVSU.

$$Q_{Main} = 1.588m^3/s \quad Q_{Ext.} = 0.856m^3/s$$

Eq. 11 Calculated Peak Run-off Rate from a 5-year Interval Storm

3.2 Drainage System Design (Phase II)



Concrete:			
Culvert, straight and free of debris	0.010	0.011	0.013
Culvert with bends, connections, and some debris	0.011	0.013	0.014
Finished	0.011	0.012	0.014
Sewer with manholes, inlet, etc., straight	0.013	0.015	0.017
Unfinished, steel form	0.012	0.013	0.014
Unfinished, smooth wood form	0.012	0.014	0.016
Unfinished, rough wood form	0.015	0.017	0.020

Fig. 4 Manning's Roughness Coefficient

3.2.1 Drainage Ditch and Cover Design

In this section, Manning's Equation was utilized since the formula is used for open channels which is similar to the DHVSU drainage system. The slope that is used is 2% since it is the minimum and recommended slope to achieve good flow of water [31].

There were two types of drainages that were observed at DHVSU, these are drainages located within the roads and drainages located beside the roads which can be seen at the figure below respectively. Some parts of the drainage system inside the university are located on the sidewalks while some parts are situated on the road itself. DHVSU's roads have a width of 5m to 6m and according to the Federal Highway Administration [32], a minimum width for a single lane would be about 2.7m.

$$D_{Main}(WithinRoads) = 0.575m \approx 0.600m$$
$$D_{Ext.}(WithinRoads) = 0.716m \approx 0.750m$$
$$D_{Main}(BesideRoads) = 0.360m \approx 0.400m$$
$$D_{Ext.}(BesideRoads) = 0.438m \approx 0.450m$$

Eq. 12 Calculated MES Drainage System Depth

With this information, the drainage width used for the MES design is 0.85m based on the DHVSU drainage system design that are situated on its roads. The 0.85m drainage width was calculated to make sure that the design width does not exceed the 5m width of the road while also adhering to the minimum lane width of 2.7m. Additionally, the drainage design width for beside the roads remained as 0.7m, without the walls, to avoid damages to nearby structures such as the roads, buildings, or sidewalks. The drainage wall thickness was 150mm and the slab or drainage cover thickness is 200mm within roads and 150mm beside the roads since these are the minimum specifications [33]-[35]. Additionally, other countries use a minimum roadside drain depth of 0.5m below the surface where it was used as the minimum depth for the MES design [36].

This investigation involved a comparative analysis of the three drainage designs sourced from different entities: the DPWH, DHVSU, and for the MES of drainage design within roads and beside roads respectively. The table below shows the details of each of the three drainage system designs where the yellow and green highlighted details were used for the final proposed drainage system design for drainages within roads and beside roads respectively at DHVSU. The dimensions highlighted in blue however are the drainage dimensions that was utilized on both proposed designs.

TABLE III
COMPARISON OF THE DHVSU, DPWH, MES DRAINAGE DESIGNS

Designs	DHVSU	DPWH	MES (Within)	MES (Beside)
Removable Cover	0.50m x 1.00m	0.50m x 1.20m	0.50m x 1.15m	0.50m x 1.00m
Fixed Cover	2.00m x 1.00m	2.10m x 1.20m	2.10m x 1.15m	2.10m x 1.00m
Cover Thickness	0.15m	0.20m	0.20m	0.15m
Drainage Wall Thickness	0.15m	0.15m	0.15m	0.15m
Drainage Width	0.70m	0.90m	0.85m	0.70m
Drainage Depth	1.00m	0.85m	0.60m	0.75m
Fixed Cover Long. Bars	7-12mm⌀ Bars	7-12mm⌀ Bars	7-12mm⌀ Bars	7-12mm⌀ Bars
Fixed Cover Trans. Bars	15-16mm⌀ Bars	11-16mm⌀ Bars	16-16mm⌀ Bars	16-16mm⌀ Bars
Removable Cover Long. Bars	7-12mm⌀ Bars	7-12mm⌀ Bars	7-12mm⌀ Bars	7-12mm⌀ Bars
Removable Cover Trans. Bars	4-16mm⌀ Bars	3-16mm⌀ Bars	4-16mm⌀ Bars	4-16mm⌀ Bars
Drainage Hor. Bars	16mm⌀ Bars @ 0.15m O.C.	16mm⌀ Bars @ 0.20m O.C.	16mm⌀ Bars @ 0.15m O.C.	16mm⌀ Bars @ 0.15m O.C.
Drainage U. Bars	12mm⌀ Bars @	12mm⌀ Bars @	12mm⌀ Bars @	12mm⌀ Bars @

	0.20m O.C.	0.20m O.C.	0.20m O.C.	0.20m O.C.

Based on the results of the analysis, the drainage design with a minimum cross-section of 0.70m x 0.85m and 0.85m x 0.85m took priority with a wall thickness of 0.15m for drainages within roads and drainages beside roads respectively. The drainage depth varies from 0.85m to 1.00m. The design has a drainage cover thickness of 0.15m and 0.20m and with three removable concrete drainage covers of 0.50m width spaced with a 2.10m fixed cover for drainages within roads and beside roads respectively. The channel of the proposed drainage system design has a slope of 2% along its channel bed. The reinforcements from the DHVSU drainage design were adapted for the proposed design as it provided higher strength compared to the other three designs.

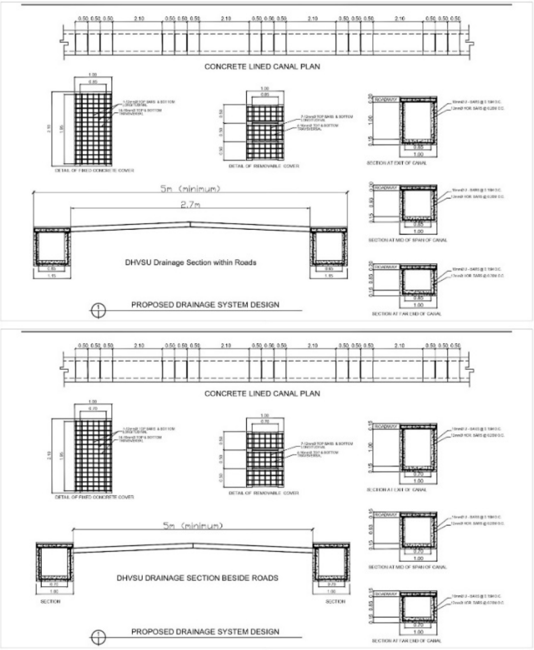


Fig. 6 Proposed Drainage Design at DHVSU Within Roads & Beside Roads Respectively

3.2.2 *Establishing New Drainage Outfalls*

However, based on the drainage system design comparison, the maximum depth of the outfall remained unchanged, meaning that it should be able to withstand the surface run-off from super typhoon Karding or typhoon Hanna. Additionally, based on the contour map of DHVSU, the university acts as its own catch basin where run-off is unable to flow out of the university without manually pumping out the floodwater. Based on these analyses, the run-off from these storms would flow towards the centre of both main and extension lots, specifically at the southern part of the university, similar to the study of Eusebio et al. [37]. That is why this design proposes new outfall locations at the university.

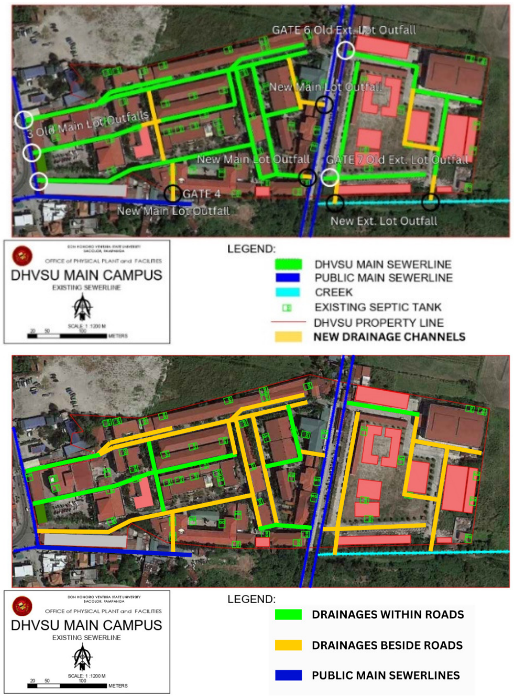


Fig. 7 Proposed DHVSU Drainage Layout Plan

Though it was not shown on the DHVSU drainage system layout plan, there is a drainage channel at the southern part of the main campus lot near Gate 4 where the new outfall can be placed based on observation. Similarly, to the extension lot, an outfall can be placed near Gate 7 flowing towards the creek, as seen from the DHVSU drainage layout plan, where the stormwater run-off could be discharged out of the extension lot. The new channels and outfalls were based on the existing DHVSU layout plan and from the contour map of DHVSU, where run-off would potentially accumulate in the middle of both the main campus lot and extension lot.

3.3 Drainage Management Plan (Phase III)

The Proposed Drainage Management Plan for Don Honorio Ventura State University focuses on the efficiency and capability of the DHVSU drainage system.Below are the tables of the plan's checklist schedule to be done for the proposed drainage system design.

TABLE IV
DHVSU MANAGEMENT PLAN CHECKLIST

QUARTERLY TASKS	
Thorough Drainage System Inspection:	
	Inspect drainage system, including underground pipes, culverts, and open channels.
	Document any issues and prioritize repairs.
Clear Blocked Drains	
	Use high-pressure water jetting or vacuum equipment to clear stubborn blockages.
Inspect Stormwater Management Facilities:	
	Check green infrastructure facilities like permeable pavement, rain gardens.
	Remove accumulated sediment and debris.
Review Maintenance Records:	
	Review past maintenance activities and inspections.
	Identify recurring issues or areas needing special attention.
Training and Education:	
	Provide training on drainage system maintenance best practices and safety procedures to staff.

ANNUAL TASKS	
Comprehensive System Assessment:	
	Conduct a detailed assessment of the entire drainage system.
	Identify structural deficiencies and areas needing upgrades.
	Develop a prioritized plan for infrastructure improvements.
Inspect Underground Infrastructure:	
	Assess condition of underground channels.
	Schedule repairs as necessary.
Review Emergency Response Plan:	
	Review and update emergency response plan for drainage-related incidents.
	Ensure all staff are aware of their roles and responsibilities.
Coordinate with External Agencies:	
	Coordinate with local authorities and environmental agencies.
	Ensure compliance with regulations and coordinate efforts for flood prevention and stormwater management.
Community Engagement:	
	Engage with university community to raise awareness about drainage system maintenance importance.
	Solicit feedback on drainage issues experienced on campus.

MONTHLY TASKS	
Inspect Drainage Inlets and outlets:	
	Check for debris or blockages.
	Remove any accumulated debris.
Inspect the Channel:	
	Look for signs of damage (cracks, corrosion)
	Schedule repairs if necessary.
Check Grates and Covers:	
	Ensure grates and covers are securely in place.
	Repair or replace damaged grates or covers.
Inspect Slopes and Erosion Control Measures:	
	Examine slopes for erosion signs.
	Inspect erosion control measures (blankets, silt fences).

The flooding problem at Don Honorio Ventura State University (DHVSU) isn't just because it's in a low-lying area. The drainage systems outside the university, which are connected to it, might also be a big part of the problem. According to the engineers at OPPF, they expected that water from outside drainages would flow towards the university which can be seen on the figures below.

Fig. 12 DHVSU Drainage Outfalls

That is why whenever DHVSU suffers from flooding, instead of using the drainage system, the university would manually pump out the floodwater that accumulated inside DHVSU. Additionally, it was observed, as seen from the figures below, that some of the outfalls had solid wastes, which could be one of the reasons why the flood water cannot flow out from DHVSU. Other factors such as the nearby neighbourhoods might have poor drainage, which makes it hard for water to flow away properly. When it rains, water collects and floods the area. To fix this, it's important to improve the drainage systems both at DHVSU and in the surrounding areas. This way, the water can be managed better and the risk of flooding will be reduced.

IV. SUMMARY, CONCLUSIONS, AND RECOMMENDATION

4.1 Summary

The objective of this study was to propose Don Honorio Ventura State University (DHVSU) at Cabambangan, Bacolor with a drainage system design and management plan. The suggested drainage system design and management plan offered an effective way to discharge flood water outside of DHVSU and helped to reduce the length of time that flooding occurs throughout the university. The elevation of DHVSU, the surface characteristics of the institution, the rainfall history of the research locale, hydraulic and hydrological principles, and RIDF parameters were among the aspects taken into consideration to achieve the provided objectives.

The Rainfall Intensity Duration Frequency curve of San Fernando City was used to assess if the current drainage system should be retained for design purposes or if a new system should be suggested to ensure protection against flooding. In addition, the university's altitude was lower than that of its surroundings. To determine the appropriate drainage system design, the study employed the Rational Method formula, which is a widely used equation for predicting peak run-off flows from small drainages with significant impervious portions. Overall, the results offered a full and comprehensive assessment of the research area and produced a proposed drainage system design and management plan that can accommodate the ever-changing climate.

4.2 Conclusions

It was identified from conducting a profile levelling survey that the elevation of the university was lower compared to its surrounding community. It was also identified that DHVSU acts as its own catchment area due to its low elevation, where a peak run-off rate of 1.203m3/s can flow inside of the university but a 1.588m3/s was used as it was the minimum design flood for roadside drainages. It was determined from the surface characteristics of the university that the floodwater would remain for a prolonged period of time if it is not removed manually.

Based on the results of the analysis, the drainage design with a minimum cross-section of 0.70m x 0.85m and 0.85m x 0.85m took priority with a wall thickness of 0.15m for drainages within roads and drainages beside roads respectively. The drainage depth varies from 0.85m to 1.00m. The design has a drainage cover thickness of 0.15m and 0.20m and with three removable concrete drainage covers of 0.50m width spaced with a 2.10m fixed cover for drainages within roads and beside roads respectively. The channel of the proposed drainage system design has a slope of 2% along its channel bed.

The proposed drainage system design and management plan of the DHVSU drainage system would be adequate to accommodate the frequent downpours of the current and following years. The adoption of this proposal contributes to reducing various consequences due to flooding such as delayed school activities, school property damage, and possible health hazards towards the DHVSU community. This proposal helps the overall situation of the university when it comes to flooding, especially during the rainy seasons and from the rising rainfall intensities due to climate change

4.3 Recommendations

There are various areas that need to be addressed for future studies. One of the areas needed to be addressed is to survey the true elevation of the university since the surveyed elevations from the contour map are from an assumed benchmark of 100m. Determining the true elevation of the university could help compare its altitude compared to various areas such as the surrounding communities of DHVSU. Still on the topic of the university’s elevation, according to the results from the profile levelling survey, it was observed that the university acts as its own catchment area where run-off would accumulate inside the university. It is due to this reason that it is recommended to focus on this aspect of the university on developing a solution to DHVSU's problem due to flooding.

Another thing to consider is how the zone map was developed since it was developed from an outdated site development plan of the university. Various buildings are not laid out on the provided site development plan such as the Cafe Honorio building and the university swimming pool for example. Because of this, the zoning map and the calculation of the surface characteristic coefficient used in the rational method may not be up-to-date to the current layout of the university. That is why it is recommended to acquire the updated site development plan of DHVSU or to manually survey the surface areas of the university.

To further understand the flooding situation of the university and to provide other possible solutions, it is recommended to survey the surrounding community of DHVSU such as its elevation and drainage system. This is done to further understand why the run-off stays inside the university and to determine the reason on what prevents the run-off from flowing from the university drainage system to the public main sewer lines outside DHVSU.

Lastly, the total amount of materials and costing used could be considered in designing the proposed drainage system in the future. This study only focused on calculating the drainage dimensions and reinforcement details to accommodate the amount of run-off that would flow inside the university. It is recommended to conduct an analysis of the proposed drainage system design to determine the amount of materials that can be used and the total cost of the project.. By accomplishing these, the strength and durability of the proposed design can be improved, prolonging the overall life span of the drainage system.

The study focused only on the design of the DHVSU drainage system, specifically the dimensions of the university's drainage system. Another way to prevent surface run-off accumulation inside DHVSU is by implementing various ways to increase the groundwater infiltration of the university. This is done by designing various flood control structures such as roof gardens and permeable asphalt and concrete that would help improve infiltration inside of the university.

REFERENCES

[1] "How is climate change affecting the Philippines?," The Climate Reality Project, Jan. 19, 2016. https://www.climaterealityproject.org/blog/how-climate-change-affecting-philippines

[2] FutureLearn, "Everything you need to know about climate change in the Philippines - FutureLearn," FutureLearn, Aug. 18, 2021. https://www.futurelearn.com/info/futurelearn-international/climate-change-philippines

[3] B. Bernal, "'We have to do something': Philippine schools, students grapple with floods as climate change forces them to adapt," *CNA*, Dec. 11, 2023. [Online]. Available: https://www.channelnewsasia.com/asia/philippines-riverside-community-schools-students-flooding-climate-change-sea-levels-3979616

[4] "Climate change indicators: Heavy precipitation | US EPA," US EPA, Nov. 02, 2023. https://www.epa.gov/climate-indicators/climate-change-indicators-heavy-precipitation#:~:text=Warmer%20oceans%20increase%20the%20amount,heavier%20rain%20and%20snow%20storms.

[5] FutureLearn, "Everything you need to know about climate change in the Philippines - FutureLearn," FutureLearn, Aug. 18, 2021. https://www.futurelearn.com/info/futurelearn-international/climate-change-philippines

[6] L. Cheng et al., "Impacts of urbanization on watershed water balances across the conterminous United States," Water Resources Research, vol. 56, no. 7, Jun. 2020, doi: 10.1029/2019wr026574.

[7] Northern Territory Government, "Flood mitigation measures," Department of Infrastructure, Planning and Logistics, Jun. 06, 2018. https://dipl.nt.gov.au/lands-and-planning/flood-mitigation/flood-mitigation-measures

[8] W. Sohn, S. D. Brody, J. Kim, and M.-H. Li, "How effective are drainage systems in mitigating flood losses?," Cities, vol. 107, p. 102917, Dec. 2020, doi: 10.1016/j.cities.2020.102917.

[9] Testbook, "Drainage system in Building - Definition, types, and benefits," Testbook, Aug. 03, 2023. https://testbook.com/civil-engineering/drainage-system-in-building

[10] Testbook, "Drainage system: Learn definition, types, open and closed system," Testbook, May 23, 2023. https://testbook.com/chemistry/drainage-systems

[11] Chris.Brafford, "Everything You Need To Know About Channel Drains," ABT Inc., Apr. 10, 2023. https://abtdrains.com/everything-you-need-to-know-about-channel-drains/

[12] Admin, "Drainage system - Open drain, closed drain, importance, uses," BYJUS, Jul. 18, 2022. https://byjus.com/chemistry/drainage-systems/

[13] The Uni Tutor, "Study on drainage system design," The Uni Tutor, n.d. [Online]. Availabe: https://www.theunitutor.com/study-drainage-system-design/

[14] "Summary for policymakers," in Cambridge University Press eBooks, 2015, pp. 1–32. doi: 10.1017/cbo9781107415379.003.

[15] D. Butler, R. Farmani, G. Fu, S. Ward, K. Diao, and M. Imani, "A new approach to urban water management: Safe and sure," Procedia

Engineering, vol. 89, pp. 347–354, Jan. 2014, doi: 10.1016/j.proeng.2014.11.198.

[16] M. Nediger, "What is a Project Management Plan and How to Create One - Venngage," *Venngage*, Apr. 25, 2024. https://venngage.com/blog/project-management-plan/

[17] A. Rudder, "What is a project management plan and how to create one," *Forbes Advisor*, Aug. 01, 2023. [Online]. Available: https://www.forbes.com/advisor/business/project-management-plan/

[18] Carl, "The importance of having a drainage plan for your new home," *Yeti Civil Products*, Mar. 09, 2023. https://yeticivil.com.au/all-articles/the-importance-of-having-a-drainage-plan-for-your-new-home/#:~:text=A%20drainage%20plan%20will%20help%20to%20prevent%20water%20damage%20to,plan%20for%20your%20new%20home.

[19] Fiix, "What is Routine Maintenance? | Fiix," *Fiix*, Mar. 27, 2023. https://fiixsoftware.com/glossary/routine-maintenance/#:~:text=Regular%20routine%20maintenance%20can%20reduce,higher%20profitability%2C%20and%20improved%20safety.

[20] P. Tyrrell, "Drainage Maintenance Guide (Preventive & scheduling)," FieldInsight, Jun. 02, 2023. https://www.fieldinsight.com/blog/drainage-maintenance-guide-preventive-scheduling/#:~:text=Regular%20Inspections%3A%20Conduct%20routine%20inspections,issues%20promptly%20before%20they%20worsen.

[21] "Curve number." https://www.hec.usace.army.mil/confluence/rasdocs/ras1dtechref/latest/overview-of-optional-capabilities/modeling-precipitation-and-infiltration/curve-number

[22] "Rational Method Runoff Coefficient - CivilWeb Drainage Design spreadsheets," CivilWeb Spreadsheets, Mar. 03, 2019. https://civilweb-spreadsheets.com/drainage-design-spreadsheets/runoff-and-rainfall-intensity-calculator-spreadsheet/rational-method-runoff-coefficient/

[23] "Hydraulic Design Manual: Rational Method." https://onlinemanuals.txdot.gov/TxDOTOnlineManuals/TxDOTManuals/hyd/rational_method.htm

[24] "VICAIRE - Module 1A - Chapter 2." https://echo2.epfl.ch/VICAIRE/mod_1a/chapt_2/text.htm

[25] "Profile leveling - Agricultural Engineering - Progressive Gardening," Progressive Gardening, Dec. 17, 2023. https://www.progressivegardening.com/agricultural-engineering-2/profile-leveling.html

[26] C. E. Views, "Uses of the leveling and principles of differential leveling," Civil Engineering Views, May 04, 2023. https://civilengineeringviews.com/uses-of-the-leveling-and-principles-of-differential-leveling/

[27] "Hydraulic Design Manual: Rational Method." http://onlinemanuals.txdot.gov/TxDOTOnlineManuals/TxDOTManuals/hyd/rational_method.htm

[28] The Editors of Encyclopaedia Britannica, "Contour mapping | Topography, Elevation, Relief," Encyclopedia Britannica, Jul. 20, 1998. https://www.britannica.com/science/contour-mapping

[29] "What is a Contour - Contour Definition." https://www.caliper.com/glossary/what-is-a-contour-map.htm

[30] NDRRMC. Situational Report for Southwest Monsoon enhanced by TC GORING and HANNA . SitRep No. 08 for Southwest Monsoon enhanced by TCs GORING and HANNA. 2023.

[31] UpCodes, "Slope of horizontal Drainage piping | UPCodes," UpCodes. https://up.codes/s/slope-of-horizontal-drainage-piping

[32] "Roadway widths for Low-Traffic Volume Roads - FHWA-RD-94-023." https://www.fhwa.dot.gov/publications/research/safety/humanfac/94023.cfm

[33] Sidewalk Safety, Inc., "How Thick Should a Concrete Sidewalk Be? Tips from Sidewalk Safety Inc. - Sidewalk Safety, Inc.," Sidewalk Safety, Inc., Jan. 08, 2024. https://sidewalksafetyinc.com/how-thick-should-a-concrete-sidewalk-be-tips-from-sidewalk-safety-inc/

[34] F. Fuchs and P. Sion, "RURAL ROADS IN CEMENT CONCRETE: a TECHNIQUE THAT CAN BE ADAPTED TO DEVELOPING REGIONS." https://trid.trb.org/view/288191

[35] "Open channel systems." https://www.stormwatercenter.net/Manual_Builder/Performance%20Criteria/Open%20Channels.htm#:~:text=for%20data%20on%20erosive%20velocities,be%20steeper%20than%202%3A1.

[36] "4. Components of road drainage system - ROADEX Network," ROADEX Network, Apr. 15, 2024. https://www.roadex.org/e-learning/lessons/drainage-of-low-volume-roads/components-of-road-drainage-system/

[37] M. V. I. S. Eusebio et al., "Underground Electrical System with Solar-powered Photovoltaic Panels and Water Drainage System for DHVTSU Main Campus." Philippines: DHVSU, 2017.