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Proposed design of The Existing Dike Along Sitio Delta, Consuelo, Macabebe, Pampanga

Justice Zimer Y. Bernarte
justicezimerbernarte@gmail.com
Don Honorio Ventura State University, Bacolor, Philippines

Maynard P. Buan
maynardpanganbuan08@gmail.com
Don Honorio Ventura State University, Bacolor, Philippines

Karlfred Ivan I. Condes
karlfredivancondes@gmail.com
Don Honorio Ventura State University, Bacolor, Philippines

Gerold Roy B. Cortez
cortezgeroldroy@gmail.com
Don Honorio Ventura State University, Bacolor,

Kenneth M. Isip
kennethisip112@gmail.com
Don Honorio Ventura State University, Bacolor, Philippines

Adrian L. Ronquillo
adrianronquillo082@gmail.com
Don Honorio Ventura State University, Bacolor, Philippines

Ivan M. Sandajan
ivansandajan0@gmail.com
Don Honorio Ventura State University, Bacolor, Philippines

John Vincent G. Tongol
jgtongol.13@gmail.com
Don Honorio Ventura State University, Bacolor, Philippines

Miriam B. Villanueva
mbvillanueva.dhvsu.edu.ph
Don Honorio Ventura State University, Bacolor, Philippines

ABSTRACT

Dikes are structures that prevent overflow to the inland ground and must be built on a continuing basis to protect flood-prone areas. To have a long service life, dikes must be built according to design standards, and failure to do so my result in the structure failing. Failure on some parts of Consuelo Dike motivated the researchers to come up with the study. The present project study aimed to propose a redesign of the dike along Sitio Delta, Consuelo, Macabebe, Pampanga. Before determining the parameters needed in designing, the researchers identified first the causes of failure of the dike through the gathered or collected data from the respondents' observations and experiences. Then, researchers assessed the present condition of the existing dike through site analysis and actual observation. The data collection procedure was carried out by obtaining secondary data from the Municipality of Macabebe and Department of Public Works and Highways (DPWH). This includes the result of soil sample tests, past maximum flood levels, river profiling, geotechnical investigations, and other tests made regarding the dike. The findings of the study helped the residents of Barangay Consuelo deal with the consequences of dike failure. The findings provided useful data to the Local Government Unit of Macabebe,

Pampanga, which can be used as a reference and guide to the development of the existing Consuelo Dike design. Researchers may use the findings to identify additional areas of concern and recommend appropriate interventions.

Keywords: Dike, Slope Protection, Surcharge Load, Traffic Loading, GEO 5, Concrete Slope Protection, Revetment, Flood Protecting Structures

1. INTRODUCTION

Disaster includes all geophysical, meteorological, and climate events including earthquakes, volcanic activity, landslides, drought, wildfires, storms, and flooding. According to Covington (2021), an average of 6,800 natural disasters strike the planet each year. Disaster brings a huge devastation that affects the environment as well as a lot of vulnerable groups resulting for it to be a worldwide concern. According to the Office for the Coordination of Humanitarian Affairs (OCHA), Asia was the most severely impacted in the year 2021, suffering 40% of all disaster events and accounting for 49% of the total number of deaths and 66% of the total number of people affected.

During its monsoon season (June to September), India experienced a series of deadly floods that claimed 1,282 lives. In July, the Henan Flood in China was particularly severe, resulting in 352 deaths, 14.5 million people affected and a cost of 16.5 billion US$. In the same month, the Nuristan Floods in Afghanistan resulted in 260 fatalities. In July, the Central European floods and subsequent landslides resulted in 40 billion US$ of economic costs in Germany alone and stood as the second most costly disaster (OCHA, 2022).

According to the World Bank Climate Change Knowledge Portal (2021), 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 is highly susceptible to calamities caused by natural disasters. The nation has experienced 565 similar catastrophes since 1990, which have resulted in 70,000 fatalities and $23 billion damages.

In Central Luzon, the onslaught of severe Tropical Storm (TS) Florita affected at least 264 families or 947 people. According to the information provided by the Department of Social Welfare and Developments (DSWD) Region 3 Field Office, flooding caused by heavy rains forced 31 barangays in 12 municipalities in the provinces of Aurora, Tarlac, Zambales, and Bataan to evacuate. A total of 843 people from Zambales, 73 from Aurora, 23 from Bataan, and 8 from Tarlac made up the total number of displaced people (Tecson, 2022).

In research from the University of the Assumption (UA) - School of Business and Public Administration (SBPA) entitled "Geo-hazard Mapping of the Province of Pampanga: A Reference for Disaster Preparedness Panorama", it has been discovered that 39% of the 2,340,355 Pampanguenos living in areas that are severely vulnerable to floods as of 2010 resided there. Further research revealed that the Municipality of Arayat is especially susceptible to landslides because of its proximity to Mt. Arayat. In addition, because of their steep and mountainous terrain, the Municipalities of Floridablanca, Porac, and Mabalacat have landslide susceptibility ranging from extremely low to very high. However, a few barangays in the municipalities of Masantol, Lubao, Sasmuan, and Macabebe, which are listed as being in the province's coastal communities, are particularly susceptible and vulnerable to storm surges.

According to OCHA (2022), in 2021, a total of 432 catastrophic events were recorded, which is considerably higher than the average of 357 annual catastrophic events for 2001 - 2020. Floods dominated these events, with 223 occurrences, up from an average of 163 annual flood occurrences recorded across the 2001 – 2020 period. The degree of the inundation that towns, groups, or people experience during a flood event does not solely dictate how it affects them. Depending on their inherent vulnerabilities, different persons are affected differently by flooding. Every community is unique, and individuals within each community have varying capacities, experiences, and limitations that have an impact on how well they can avoid, prepare for, and deal with flooding (Flood Resilience Portal, 2022). This is one of the reasons why constructing safe, effective, efficient, and helpful flood protection, particularly dikes, is important.

A dike is an embankment constructed to prevent floodwaters from flowing onto land behind it along a riverbank or coastal shoreline. It is usually made of compacted earth and has flood boxes, gates, and pumps to help control the water level on the landward side of the dike. It is frequently designed to withstand a certain amount of flooding. Dikes are typically designed to defend against a specified level of flooding and to maintain the effectiveness, dikes need to be inspected, maintained, and upgraded (Dikes and Related Works, 2020).

According to Lopez E. (2022), a dike was built at Barangay Consuelo in 1970 to 1980's to protect its community particularly from sea waves. When a region is surrounded by water, its location is critical, especially in terms of flooding and the rapid depletion or collapse of the land that supports households and the populace's livelihood. The dike was constructed as a soil at the bottom and asphalt at the top. It was constructed with a specific objective in mind. The most frequent natural disaster in Macabebe, Pampanga that affects people and its surroundings is flood because it is a low - lying area. That is the reason why a dike was built to the municipality: in order to reduce the negative impacts of the flood. Since this is the only road constructed in the region, it also functions as a transportation hub for moving people and goods between barangays. The movement of people and goods over time and space is made safe, effective, dependable, and sustainable. But because of the failure of the existing dike at Sitio Delta, Consuelo, Macabebe, Pampanga, the risks of floods have increased.

The researchers conducted this study because they found it as one of the major problems at Consuelo, Macabebe, Pampanga. Since this town is known as one of the low-lying areas in Pampanga, this area is prone to flooding. So, researchers saw an opportunity and gathered more data on the subject and developed this topic.

The Consuelo Dike in Sitio Delta that protects residents of Barangay Consuelo from floods, strong waves, and potential high floods is gradually deteriorating. Failure of dike has a number of negative effects on the daily lives of those who live nearby. Researchers decided to solve this problem by means of a new and improved proposed design of the existing dike along Sitio Delta, Barangay Consuelo, Macabebe, Pampanga with a length of 200 meters that will benefit the residents.

2. BACKGROUND OF THE STUDY

Dikes protect both the land and the community from upland erosion and surge flooding, which is especially important in low-lying areas like Macabebe, Pampanga, specifically Sitio Delta, Barangay Consuelo, which is surrounded by the sea. To ensure adequate safety, particularly against flooding, assessment and propose of a redesign dike with slope protection in terms of acceptable flooding probabilities, in accordance with recently established risk-informed safety standards must be considered (Jonkman et al, 2018).

Slope instability is one of the primary failure mechanisms that can result in dike breaching and subsequent flooding. A probabilistic slope stability analysis, for example, can be used to estimate the reliability of a dike slope. This type of analysis explicitly and quantitatively considers uncertainty in geologic, ground, and geotechnical models (M.G. van der Krogt et al, 2021). The dominant factors determining slope stability reliability are soil properties, which are uncertain due to spatial variability, measurement errors, and pore water pressures.

The paper was structured as follows: First, the researchers identified the causes of failures of the existing dike system. Then, researchers analyzed the soil properties, voids, and other factors that influence dike structure using the collected or gathered data from the Local Government Unit of Macabebe and DPWH. Lastly, researchers proposed a feasible strategy for incorporating the construction of a new design of the dike that has a length of 200 meters. The paper concluded with a discussion of how the approach can be applied in practice and what future developments would be beneficial.

3. STUDY AREA

Figure-1: Actual Condition of the Sitio Delta, Consuelo Dike

Macabebe is located in the southern part of Pampanga. It is bounded to the north by the municipalities of Minalin, Guagua and Apalit; to the east by the municipalities of Calumpit and Hagonoy in Bulacan; to the west by the municipality of Sasmuan; and to the south by the municipality of Masantol and Manila Bay. According to a Spanish Augustinian friar, Fray Manuel Diaz Toledano, Macabebe was founded in 1575 resulted to be the oldest municipality in the province of Pampanga. It was considered as the first-class municipality which is politically subdivided into 25 barangays. In addition, Macabebe is geographically situated and connected along the shores or banks of Rio Grande de Pampanga, also known as Pampanga River.

Five puroks made up Barangay Consuelo, including Sitio Delta, which serves as the barangay's extension. This Sitio is divided into Tora-Tora and Delta, which are both located next to the Pampanga River. The Consuelo Dike at Sitio Delta, which protects the residents of Barangay Consuelo from floods, strong waves, and potential high floods, is progressively deteriorating over time. Because the aforementioned dike is an earth-fill dike and is surrounded by water, erosion occurs frequently and causes damage, particularly on its side. If the erosion persists and is not stopped right away, a serious issue could result, such as the dike breaking entirely.

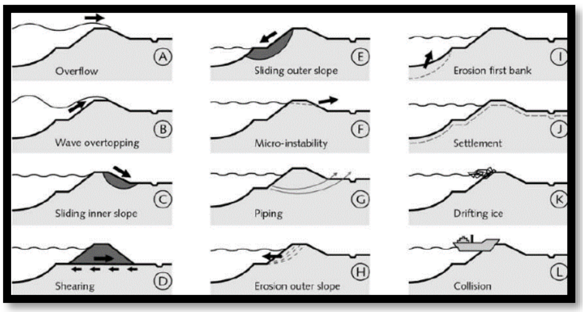

Figure-2: Failure and Collapse Mechanisms of Dike

The Technical Advisory Committee on Flood Defense (1998) identified some of the failure and collapse mechanisms that a dike may encounter. As seen in the Figure 2, some of these are the following: overflow, wave overtopping, sliding of the inner slope, shearing, sliding of the outer slope, micro-instability, piping, erosion of the outer slope, erosion of the first bank, settlement, drifting ice, and collision. The most common type of failure here in the Philippines is due to sliding and erosion of the outer slope (Arriola et. al, 2019).

4. STATEMENT OF THE PROBLEM

1. The pounding of the waves resulted in soil erosion on the dike's sloping side;
2. Poor dike system causing severe flooding that affects the structures along the existing dike;
3. The main source of income for the people in the community, fish farming, is also greatly affected by the sudden rise in the water level in their fishponds.

5. OBJECTIVES OF THE STUDY

5.1 General Objective

The general objective of this study was to propose a design of dike that will protect the community from upland erosion and surge flooding.

5.2 Specific Objectives

1. To identify the causes of failures of the existing dike system.
2. To assess the stability of the existing dike through site analysis
3. To proposed a redesign of the existing dike with slope protection.

6. SIGNIFICANCE OF THE STUDY

This research was beneficial to the following stakeholders:

Residents of Barangay Consuelo in Macabebe: This study was beneficial to the residents near the Consuelo Dike in a way of providing a design of well-improved and safe dike that could lead to giving high degree of protection to them against flooding and big waves produced by the sea. Additionally, it was beneficial in terms of giving safe transportation since it is the only access going to the other areas.

Municipality of Macabebe: The results of this study provided useful data to the Local Government Unit of Macabebe, Pampanga that can be a guide or help in developing the design of the existing Consuelo dike.

Future researchers: This study was beneficial to the future researchers by giving pertinent and helpful information for future studies. Also, the study served as a research guide or possible source and reference of relevant material for their future studies related in proposing a design of dike.

7. SCOPE AND LIMITATIONS

The main focus of this study was to propose a new design of the existing dike along Sitio Delta, Consuelo, Macabebe, Pampanga with a length of 200 meters. Survey was conducted from the residents of Sitio Delta, Barangay Consuelo, Macabebe, Pampanga particularly to determine the present condition of the existing dike. The residents living nearby the existing dike were chosen as prospective respondents of the study with the age of 18 years old and above as they are affected by flooding caused by poor condition of the existing dike system.

The purpose of this research was to identify the causes of failures of the existing Consuelo Dike. The researchers utilized self-formulated survey questionnaires to gather information on the observations of the residents at Sitio Delta, Barangay Consuelo, Macabebe, Pampanga on the failure of dike, as well as to know the insights of the respondents on what causes the dike to fail because they experienced and are still experiencing the effects of failure of the dike system. The survey was done through face-to-face interaction as well on online platforms such as Google Forms, whichever was convenient for the respondents. The subject matter content was only limited on the insights and experiences of the respondents regarding the failures of the dike system.

8. REVIEW OF RELATED LITERATURES

8.1 Techniques in Building Dikes

There are techniques for building dikes and one of them is the use of suction caissons for dike construction. Suction Caisson technique is best suited for building breakwaters in deep water or on soft sea beds. Up until a suitable bearing capacity is reached, suction caissons are sunk into the bottom. In this manner, it is unnecessary to enhance the soft foundation soil. It is possible to manufacture the concrete caissons using a standard modulus. From a barge, they can be installed after being hauled to the installation site. Since no soils treatment is necessary, installation may be completed rapidly (Chu et al, 2012).

8.2 Concrete Block Protection

Concrete block protection measures for a riverbed have been and continue to be acknowledged as a workable option in the field of river engineering. They have been demonstrated for both riverbank and river bed protection activities in supercritical flows. By reevaluating the suction decrease of the soil foundation underneath the works, coastal engineers will also be interested in protection work employing concrete blocks. As a result, concrete block-armored coastal dikes were built to provide enduring resistance to the destructive force of large waves (Yoshida et al, 2018).

8.3 Wave Overtopping

The security of infrastructures, assets, and communities depends on coastal safeguards against extreme marine occurrences. Artificial sea dikes, seawalls, breakwaters, and groins shield 70% of China's coastlines from the elements. Prior marine risks caused damage to, breaches in, or even complete destruction of some of them. The construction details and hydrodynamic situation have a significant impact on how well protective structures work. The process of wave overtopping is regarded as a comprehensive hydrodynamic reaction to the interaction of all these intricate elements. An excessive number and intensity of wave overtopping could result in property losses, deaths, and the breakdown of coastal defenses. A crucial requirement for the safe construction of coastal defenses has been a detailed understanding of the mechanism of sea-dike failure and a reliable evaluation of wave overtopping (Zhang et. al., 2017).

8.4 Soil Erosion

Sometimes we cannot avoid the possibility of damage or failure of the dike and when it happens, it can cause soil erosion and can affect the people around it. Soil Erosion is the detachment and dislocation of soil, either by water or wind action. Soil loss due to erosion has serious repercussions since it reduces soil productivity. Though it happens everywhere in the world, soil erosion is more prevalent and a major issue in dry locations. The agricultural, environmental, and ecological functions of the soil are disturbed by soil erosion. Soil erosion reduces soil fertility, reduces the ability of the soil to retain moisture, and thus lowers crop output (Bashir et al, 2017).

8.5 Construction of Dikes

Dikes are structures that prevent overflow to the inland ground and this must be constructed continuously to protect the flood prone areas. Construction of dikes must follow the design standards to have a long serviceability and non-conformance to the design standards may lead to the structure’s failure. Continuous climate change leads to more destructive disasters. Typhoons come and leave an unforgettable damage, which sometimes leads to the annihilation of shelters and agricultures, extreme flooding, falling of trees and sometimes, the death of some of our fellow countrymen. That is the reason why flood resistant structures (dikes) are installed along some parts of the river. These dikes are used to support the soil from eroding and flooding of water through the adjacent places. Recent typhoons cause the overflow of water in low elevation areas which proves that the existing dikes are no longer effective in preventing future disasters. Due to ineffectiveness, residents’ lives are at risk and possible future soil erosion (upon failure of existing dike) may occur. Before determining the parameters needed in designing, the researchers first assessed the present condition of the existing dike. Data gathering procedure has been conducted like site investigation, river profiling, collecting soil samples, laboratory test, and discharge determination (Arriola et al, 2019).

It is a great significance for dike safety to be ensured when proposing a design. During construction of a dike, slope stability often reaches critical levels, due to the excess pore water pressures in the foundation. The loading condition during construction has similarities with the design conditions during flood loading. Not only in terms of the pore water pressures as the main driving force, but also in terms of criticality of the stability (Van der Krogt M. et al, 2021).

8.6 Slope Instability of Dikes

According to Krogt et al (2019), the protection of low-lying land against flooding often relies on the presence and resistance of earthen dikes. One of the failure mechanisms of dikes is slope instability, where a soil mass slides along a slip plane. The consequences of flooding include both the cost of damage to the flood defense itself and the cost due to damage (and casualties) in the protected area. Therefore, the safety standards, defined as maximum probability of failure, should be interpreted as probability of flooding.

8.7 Flood Control Measures

The Pampanga River's lower basin is prone to floods more than any other part of the region. Pampanga Delta's swampy lowland and Pampanga River's mouth areas were routinely flooded by typhoons, inflicting substantial damage to the farming and fishing sectors, public property, and private property alike in Pampanga. The Pampanga River has a limited water flow capacity because of the delta's low height (0-9 meters). Flood control measures have been used on the Pampanga River since the 1930s. Since the lower basin's development potential has risen, flood control has become more important in west Sulipan. Flood management in Central Luzon's low-lying communities along the Pampanga River was one of the project's objectives, which included river development initiatives. As a result, the region's standard of living improved while the economy grew (Bueno, 2021).

9. METHODOLOGY

This chapter discussed the methods, processes and instruments that were used on collecting data, assessing the stability of the dike and redesigning the dike. It also included different information such as the specifications, considerations, and analysis procedures in designing the existing dike that were essential for this study.

9.1 Research Design

This study used a diagnostic design using a combination of qualitative and quantitative approaches all throughout this study. This design has three phases which include (1) inception, (2) diagnostic, and (3) solution. This design was the most fitting to use because the researchers' aims were (1) identified the root or origin of the dike failure (inception), (2) assessed the stability of the existing dike through the collected or gathered data and secondary data from the Local Government Unit (LGU) of Macabebe and/or DPWH (diagnostic), and (3) redesigned the existing dike as a solution to the dike failure (solution).

9.2 Respondents of the Study

The respondents of this study would be from Sitio Delta, Consuelo, Macabebe, Pampanga. The age of the respondents would be from 18 years old and above. The sampling method used in this study was the availability sampling under non-probability sampling where the respondents were chosen based on their available time and willingness to participate with the study.

9.3 Research Instruments

The researchers used a survey questionnaire under qualitative approach in identifying the causes of dike failure. The survey was done through face-to-face interaction as well as on online platforms such as Google Forms. These two ways of gathering or collecting data were used, whichever was convenient for the respondents. Moreover, the survey questionnaire was available both online and printed copies. The instruments for this study were specifically developed by the researchers, validated and verified by the research consultant used in this study.

Considering the second specific objective of this study which was to assess the stability of the existing dike through site analysis, in addition to the collected or gathered data that were obtained from the respondents, the researchers requested data from the LGU of Macabebe and/or DPWH which were used in assessing the stability of the existing dike in Sitio Delta, Macabebe, Pampanga. The assessment was done through a checklist.

9.4 Data Gathering Procedures

The collected data from the respondents, which was aligned to the first specific objective of the study, identified the causes of failures of the existing dike system, the researchers followed and used the following procedures:

1. The researchers created a self-formulated survey questionnaire.
2. The researchers created a validation letter and assessment that was answered by the research consultants to validate and verify the self-formulated survey questionnaire.
3. The researchers then created a letter that was sent from the Barangay Captain of Sitio Delta, Consuelo, Macabebe, Pampanga in seeking approval to conduct a survey to the residents of the site proposal.
4. The researchers looked for 348 respondents from the citizens at Sitio Delta, Consuelo, Macabebe, Pampanga with the age of 18 years old and above to know who had already experienced problems related to the poor dike system.
5. The survey questionnaire was distributed to participants through actual interaction and/or online platforms.
6. The respondents then answered the survey questionnaire which was sent by the researchers.
7. After the survey questionnaire was answered, it was automatically sent back to the study's proponents.
8. Finally, the answers and results were tabulated and analyzed.

In general, other reliable online materials such as related studies, literature and thesis papers were used as references to analyze and see what methods of data gathering will be used and to identify ways on how the data will be analyzed. The researchers also used past and up to date researchers and studies which were similar to the researchers' study to ensure the reliability and accuracy of the study.

9.4 Data Analysis

After collecting and analyzing data from the respondents, analyzing and interpreting the data followed. For this study, feasibility analysis was used. The definition of the study was based on a survey, which was used to analyze and comprehend the issues (including the causes and effects) that would benefit the community as a whole. The researchers identified potential issues and presented a fresh, improved, and significant project that would help the study's respondents by gathering data.

9.4 Design of Dike

Considering the third specific objective of this study which was to propose a redesign of the existing dike with slope protection, the researchers used the following concepts:

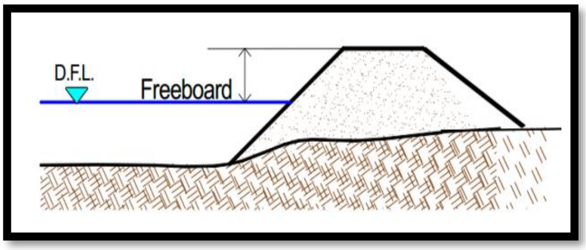

Figure-3: Dike Height

As seen in Figure 3, the height of the dike was based on the past maximum flood level. This can be calculated by

Table-1: Minimum Required Freeboard

Design Flood Discharge (m^3 / s)	**Crest width (m)**
Less than 500	3
500-2,000	4
2,000-5,000	5
5,000-10,000	6
>10,000	7

Freeboard is the space between the elevation of the dike crest and the design flood level. The height's margin prevents overflow because of this. The freeboard of the dike is an allowance in height and shall not be less than the value given in Table 1, according to the design discharge.

Table-2: Crest Width of Dike

Design Flood Discharge (m^3 / s)	**Freeboard (m)**
Less than 200	0.6
200-500	0.8
500-2,000	1.0
2,000-5,000	1.2
5,000-10,000	1.5
>10,000	2.0

A dike's crest width must not be less than the value listed in Table 2 and must be in compliance with the design flood discharge. Regardless of the design flood discharge, the crest width can be made 3 m or greater when the inland ground height is higher than the design flood level (Arriola et al., 2019).

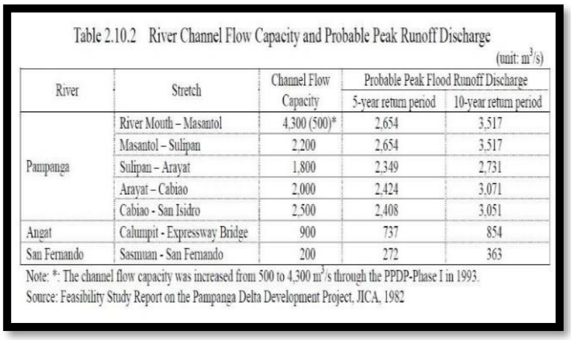

Table 2.10.2 River Channel Flow Capacity and Probable Peak Runoff Discharge

(unit: m^3/s)

River	Stretch	Channel Flow Capacity	Probable Peak Flood Runoff Discharge: 5-year return period	Probable Peak Flood Runoff Discharge: 10-year return period
Pampanga	River Mouth – Masantol	4,300 (500)*	2,654	3,517
	Masantol – Sulipan	2,200	2,654	3,517
	Sulipan – Arayat	1,800	2,349	2,731
	Arayat – Cabiao	2,000	2,424	3,071
	Cabiao - San Isidro	2,500	2,408	3,051
Angat	Calumpit - Expressway Bridge	900	737	854
San Fernando	Sasmuan - San Fernando	200	272	363

Note: *: The channel flow capacity was increased from 500 to 4,300 m^3/s through the PPDP-Phase I in 1993.
Source: Feasibility Study Report on the Pampanga Delta Development Project, JICA, 1982

Figure-4: Volume Flowrate (Q) of ConsuelMacabebe, Pampanga

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Using Figure 4 from Pampanga River Basin Flood Forecasting and Warning Center (PRFFWC) of PAGASA, researchers used $Q = 3{,}517m^3/s$ as the Volume Flowrate of Pampanga River on the nearest station at River Mouth to Masantol. Using this Q, the researchers determined the summary of parameters of the new design of the existing dike. The calculated freeboard was 1.2 meters, dike height was 3.66 meters, crest width was 5 meters, base width was 23.5 meters, length was 200 meters as it was the proposed length of the researchers, and slope was 1V:2.5H. Figure 5 showed the dike's cross section in a 2D view.

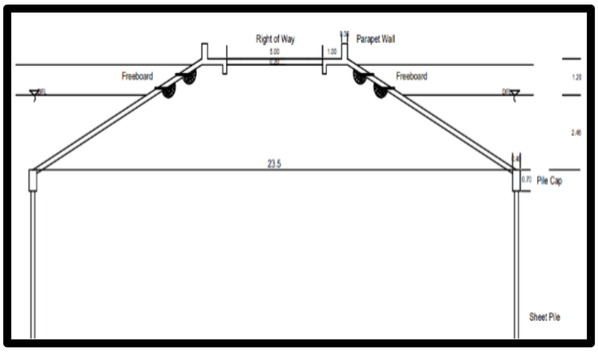


Figure-5: Cross Section of the Proposed Dike

10. RESULTS AND DISCUSSION

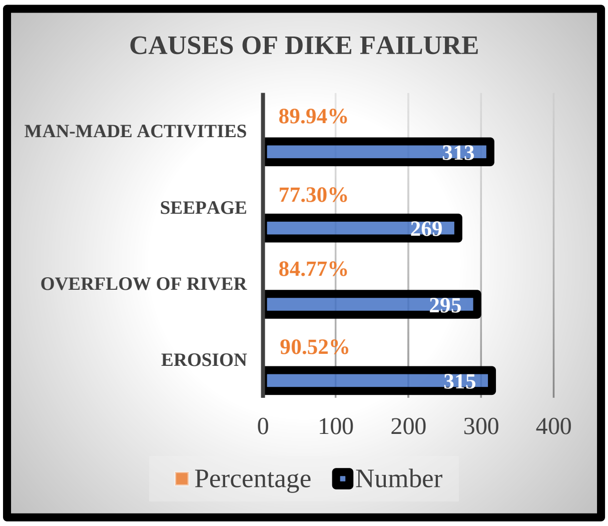


Figure-6: Percentage of Causes of Dike Failure

In Figure 6, there were 315 out of 348 respondents who mentioned that erosion was the main cause of dike failure in Consuelo, Macabebe, Pampanga or 90.52% of the total sample. 295 said that it was the overflow of the Pampanga River. There were 269 who believed that it was seepage which causes the failure of the dike and 313 said that it was the man-made activities which causes the dike to fail. Based from the answers of the respondents, these causes show a great impact on the functionality of the dike and for people to be greatly affected by its negative effects.

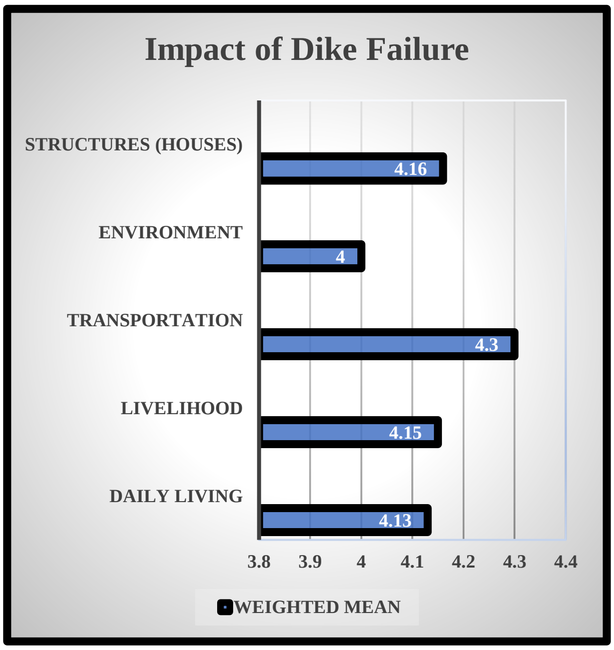


Figure-7: Weighted Mean of Impacts of Dike Failure

The statements shown in Figure 7 were the factors which were greatly affected by the failure of the dike towards the people. Daily living has a computed weighted mean of 4.13. The livelihood of the people has a computed weighted mean of 4.15. As for the transportation, the computed weighted mean is 4.30. The environment has a computed weighted mean of 4.00. Furthermore, the structures of the houses also are very affected by the failure of the dike with a weighted mean of 4.16.

After conducting the study, gathering all the data needed, the proposed design of the existing dike alongside Delta, Consuelo, Macabebe, Pampanga will be of great help to the people and to the community in general.

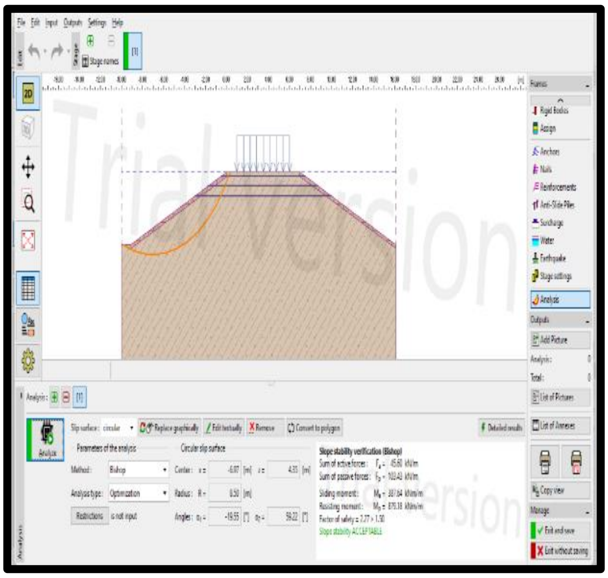
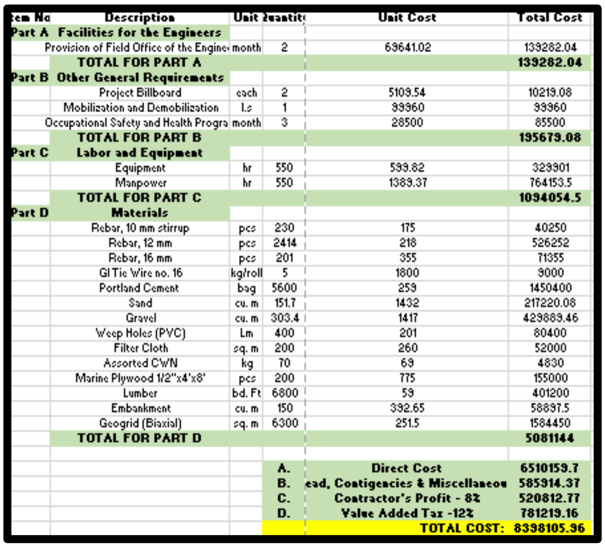


Figure 8. Analysis of the Factor of Safety of the Structure

Table-3: Summary of the Results in Analysis (Reinforced Concrete Slope Protection)

Slope Stability Verification (Bishop)	
Sum of Active forces (F_a)	45.60 kN/m
Sum of Passive forces (F_p)	103.43 kN/m
Sliding Moment (M_a)	387.64 kN/m
Resisting Moment (M_p)	879.18 kN/m
Factor of Safety	2.27 >1.50
Slope Stability **ACCEPTABLE**	

Since, the factor of safety which was equal to 2.27 is greater than 1.50, then the slope stability was acceptable as shown in Figure 8 and Table 3.



tem No	Description	Unit	Quantity	Unit Cost	Total Cost
Part A	Facilities for the Engineers				
	Provision of Field Office of the Engine	month	2	69641.02	139282.04
	TOTAL FOR PART A				139282.04
Part B	Other General Requirements				
	Project Billboard	each	2	5109.54	10219.08
	Mobilization and Demobilization	l.s	1	99960	99960
	Occupational Safety and Health Progra	month	3	28500	85500
	TOTAL FOR PART B				195679.08
Part C	Labor and Equipment				
	Equipment	hr	550	599.82	329901
	Manpower	hr	550	1389.37	764153.5
	TOTAL FOR PART C				1094054.5
Part D	Materials				
	Rebar, 10 mm stirrup	pcs	230	175	40250
	Rebar, 12 mm	pcs	2414	218	526252
	Rebar, 16 mm	pcs	201	355	71355
	GI Tie Wire no. 16	kg/roll	5	1800	9000
	Portland Cement	bag	5600	259	1450400
	Sand	cu. m	151.7	1432	217220.08
	Gravel	cu. m	303.4	1417	429889.46
	Weep Holes (PVC)	Lm	400	201	80400
	Filter Cloth	sq. m	200	260	52000
	Assorted CWN	kg	70	69	4830
	Marine Plywood 1/2"x4'x8'	pcs	200	775	155000
	Lumber	bd. Ft	6800	59	401200
	Embankment	cu. m	150	392.65	58897.5
	Geogrid (Biaxial)	sq. m	6300	251.5	1584450
	TOTAL FOR PART D				5081144
			A.	Direct Cost	6510159.7
			B.	ead, Contigencies & Miscellaneou	585914.37
			C.	Contractor's Profit - 8%	520812.77
			D.	Value Added Tax -12%	781219.16
				TOTAL COST:	8398105.96

Figure-9: Initial Cost Estimate

Figure 9 showed the overall cost estimation of the proposed existing dike including the Biaxial Geogrid which was used by the researchers as a countermeasure against erosion.

11. CONCLUSIONS

1. Based on the obtained data from the respondents' answers to the survey questionnaires, the researchers concluded that overflow of Pampanga River caused the water to rise and pounding of waves resulted to soften the soil and caused an erosion.

2. From the gathered, researchers made a conclusion that flooding is one of the natural disasters happening at Consuelo, Macabebe, Pampanga that caused the foundation of the dike and materials used in dike construction to be weakened resulting to the failure of the dike and brought a great effect on the structures near on the existing dike.

3. Based on the acquired data from the respondents' answers to the survey questionnaires, the researchers concluded that the sudden rise of the water level in

fishponds brought a great effect on the livelihoods of the people in Sitio Delta, Consuelo, Macabebe, Pampanga.

4. Based on the previous plans of the existing dike which obtained from the DPWH and LGU of Macabebe, Pampanga, the dike is still experiencing failures.

5. For the proposed redesigning of the dike, researchers considered a lot of parameters to conclude the possible ways to strengthen the dike. The proposed designed was increased in height since overtopping of water is one of the problems experienced by the Consuelo citizens.

12. RECOMMENDATIONS

Improving dikes is an important area of research, as it can help prevent flooding and protect people and infrastructure in low-lying areas. The following suggestions are provided as strategies for dike improvement.

1. Study the behavior of dikes under different loading conditions. Dikes can be subjected to various loads, such as water pressure, soil weight, and seismic forces. Studying how dikes behave under different loading conditions can help engineers design more effective and durable dikes.
2. Investigate the use of innovative materials. There is a growing interest in using alternative materials, such as geosynthetics, to reinforce and stabilize dikes. Researching the use of innovative materials can help identify new solutions to improve the performance of dikes.
3. Develop new monitoring and maintenance strategies. Effective monitoring and maintenance of dikes are critical to ensure their long-term performance. Developing new monitoring and maintenance strategies, such as remote sensing technologies and predictive maintenance models, can help identify potential issues before they become critical.
4. Assess the impact of climate change on dike performance. Climate change is expected to increase the frequency and intensity of extreme weather events, such as storms and floods, which can pose significant challenges to dikes. Assessing the impact of climate change on dike performance can help engineers design dikes that are more resilient to changing weather patterns.
5. Analyze the social and economic impacts of dike failure. Dike failure can have significant social and economic consequences, such as loss of life, property damage, and disruption of essential services. Analyzing the social and economic impacts of dike failure can help policymakers and stakeholders make informed decisions about the allocation of resources for dike improvement.
6. The researchers recommended to use other ground improvement techniques such as shotcrete, soil nailing, and grouting technique in order to minimize the effects of erosion to the dike.
7. The researchers recommended to use uniaxial geogrid, as counter measure against erosion, for practicality and economical purpose.
8. The researchers recommended to use and explore other types of deep foundation such as load bearing piles, end or point bearing piles, friction piles, pile caps, drilled piers and/or caissons in order to provide more earth retention and excavation support.
9. The researchers recommended to provide a shear resistance for the concrete slope protection to make the other components of dike safer.

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