# IMPACTS OF VEGETATION ON THE CHARACTERISTICS OF THE FLOW: MANNING ROUGHNESS COEFFICIENTS FOR OPEN CHANNEL

By

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14906

FINAL YEAR PROJECT REPORT

Submitted to the Civil Engineering Programme in partial fulfilment of the requirement for the Bachelor of Engineering (Hons)

(Civil Engineering)

Universiti Teknologi PETRONAS

Bandar Seri Iskandar

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Perak Darul Ridzuan.

# CERTIFICATION OF APPROVAL

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Approved:

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ASSOC PROF HJ KHAMARUZAMAN B WAN YUSOF

Project Supervisor

**UNIVERSITI TEKNOLOGI PETRONAS**
**TRONOH, PERAK**

**January 2015**

# CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

_______________________________

Nur Liyana Afiqah binti Abd Wahid

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# Abbreviations and Nomenclature

| | |
|---|---|
| UTP | Universiti Teknologi PETRONAS |
| FYP | Final Year Project |
| JLG | Japanese Lawn Grass |

# ABSTRACT

The presence of vegetation in waterways plays an important role from ecological point of view as it can be used to improve water quality and reduce soil erosion by altering the flow magnitude. Vegetation roughness is an important parameter in describing flow through river systems. Vegetation impedes the flow, which affects the stage-discharge curve and may increase flood risks. To understand the impact of vegetation flow, an experimental approach using a field channel is adopted. The present study will consider natural vegetation in a rectangular flume located in Universiti Teknologi PETRONAS. Geometrical dimensions of the drainage system, vegetation properties and flow parameters such as flow depth, velocity and discharges will be measured for different inflow scenarios into the drainage system. Subsequently, several flow scenarios will be allowed to pass through the vegetation array emerging from the water surface and when fully submerged.

Vegetation can influence the transport of sediment and contaminants by changing the mean velocity and turbulent flow structure in channels. It is important to understand the hydraulics of the flow over vegetation in order to manage the process. Experiments in an open-channel flume with natural vegetation were carried out to study the influence of vegetation on the flows. In a half channel with different densities, slope, flow velocity, the height of the natural vegetation and the flow transition between the vegetated zone and non-vegetated zones in different flow regimes. In this paper a number of roughness descriptions are compared. All descriptions give a reasonable fit to experimental flume data. At large submergence ratios vegetation roughness can be approximated by a constant Manning coefficient.

## ACKNOWLEDGEMENTS

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The author would also like to dedicate this appreciation to Dr Izma and Dr Raza for their assistance and guidance and to a number of people for their cooperation in easing the learning process. Last but not least, the author dedicate thousands appreciation to the beloved family, colleagues and also to those who were involved directly or indirectly in guiding the author throughout the whole duration of Final Year Project and completing this final report.

# CHAPTER 1
# INTRODUCTION

## 1.1 Background of Study

Vegetation can be found growing naturally on the beds of channels or on the riverbanks or where it has been purposely planted. It is often classified by its shape and the locations where it grows. Vegetation growing on the river floodplains typically comprises various combinations of trees, herbs, shrubs, hedges, bushes and grasses. The vegetation in channel usually consists of aquatic plants and these may be divided into four categories: emergent, submerged, floating-leaf, and free-floating leaf. The presence of vegetation in river channels provides both benefits and problems. From an environmental point of view, aquatic plants are essential parts of natural aquatic systems and form the basis of a water body's health and productivity. And from an engineering point of view, vegetation can improve the strength of bank materials through buttressing and root reinforcement.

**Figure 1 – Example of Vegetated Plants, *Limnocharis flava* *(Adopted from http://www.affnanaquaponics.com/2013/02/paku-rawan-aquatic-outcast.html)***

Figure 1 shows an example of aquatic vegetation in Malaysia, limnocharis flava and it grows in open-channel like lake and rivers. Other examples of aquatic vegetation appropriate for stormwater drainage systems include reed canary grass, grass-legume mixtures and red fescue. Aquatic vegetation have to be controlled to an acceptable level to improve the open-channel performance, as growing of aquatic plants in channels generally produce large obstructions to the water flow and blocks the water to reach the downstream.

The aquatic vegetation along the bed and banks of rivers, mainly the open-channel plays an important role on the hydrodynamic behaviour, the ecological equilibrium and the characteristics of the river. The aquatic vegetation in open-channel faces the problem of resistance that formed by concentrated colonies of vegetation. The presence of vegetation plays an important role from ecological point of view as it can be used to improve water quality and reduce soil erosion.

This vegetation inside and at the edge of rivers may significantly affect hydrodynamic behaviour of the flow, and will also affect the sediment transport by obstructing the flow and changing the flow characteristic such as the mean velocity and turbulence flow structure in channels. Most of the previously studies focus on the flow resistance, using traditional numerical simulations based only on the algebraic stress model with the vegetation as an internal resistance as stated by Wang (2008).

Stormwater management has been promoted for number of years in response to a need to manage urban runoff. Storwater usually discharge to open-channel like rivers and lake and increasing of runoff may cause flooding. Urban areas tend to have more runoff and less infiltration and evaporation than forested or grassland areas. Stormwater is rainwater that runs off streets, lawns, drains and other sites. When stormwater is absorbed into the ground, it is filtered and ultimately replenished aquifers or flows. Open-channel systems involve a free surface subject to atmospheric pressure and treat this stormwater runoff through combination of filtration through vegetative cover and infiltration. However, the presence of vegetation in open-channel flow sometimes regarded as a problem because it can reduce flow capacity, with implications for flooding. Floods occur when large volumes of runoff flow quickly into streams and rivers. Konrad(1993) stated that removing vegetation and soil, grading the land surface, and constructing drainage networks increase runoff to streams from rainfall and snowmelt. As a result, the peak discharge, volume, and frequency of floods increase in nearby streams.

The study of the impact of vegetation on water flow in an open-channel has its particular importance. The presence of vegetation in open-channels like rivers influences significantly the velocity and the depth flow. The vegetation properties like height, size and density will be measured and studied. There will be three types of flow that going to pass through the vegetation like laminar, transitional and turbulent flow. The velocity and discharge profiles will be drawn based on the vegetation roughness. A good management of stormwater drainage systems at the source will give a better water quality at the downstream area.

**Figure 2 – Japanese Lawn Grass, *Zoysia japonica Steud.***

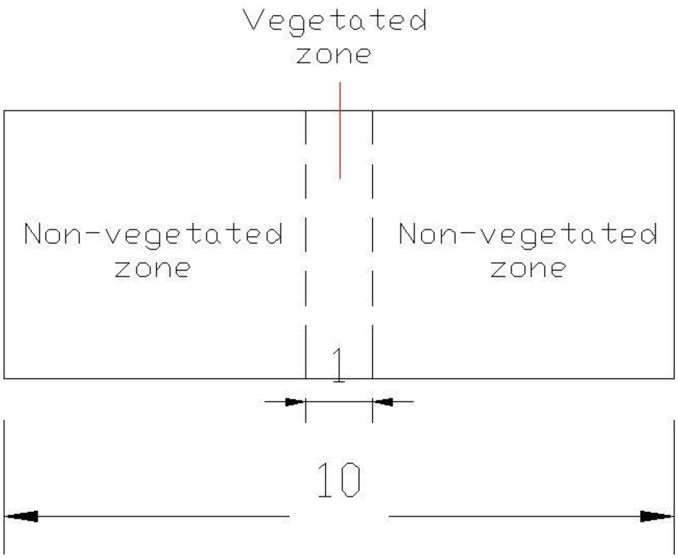


**Figure 3 – Cross Section of the Flume**

Flume experiments have been conducted and the vegetation alters flows structures and enhances sedimentation as stated by Leonard and Croft (2006). Those changes substantially affect the nutrient and contaminant transport, also contribute to sediment resuspension and bank erosion. Thus, Tsujimoto (1999) mentioned that vegetation is a key factor in transportation of sediment and flow connection.

## 1.2 Problem Statements

Unrestricted growth of such vegetation in an open channel can lead to its complete loss of the hydraulic capacity which has potential to generate flood. A laboratory study has been conducted to analyse the effects of different types of vegetation to the velocity and on the Manning roughness coefficient, n in an open channel on the hydraulic roughness. Vegetation was being eliminated in waterways to improve conveyance capacity without pay attention on potential ecological benefits. The presence of vegetation in open-channel is sometimes regarded as a problem because it can reduce flow capacity, with implications for flooding. The constant Manning's value is normally used in practice for all flow and vegetation conditions. Effect of flow depth and velocity on vegetation roughness is considered.

## 1.3 Objectives of Study

The objectives of this study are listed as follows:

i. To determine the effect of vegetation on flow characteristics.
ii. To establish relationship between Manning’s vegetative roughness and flow depth and density of vegetation.

## 1.4 Scopes of Study

This study is limited towards examining the flow of water by using the vegetated field channel of Universiti Teknologi PETRONAS. There will be planting of natural vegetation in part of the channel cross-section of a flume and allow the flow of water to pass through the vegetation.

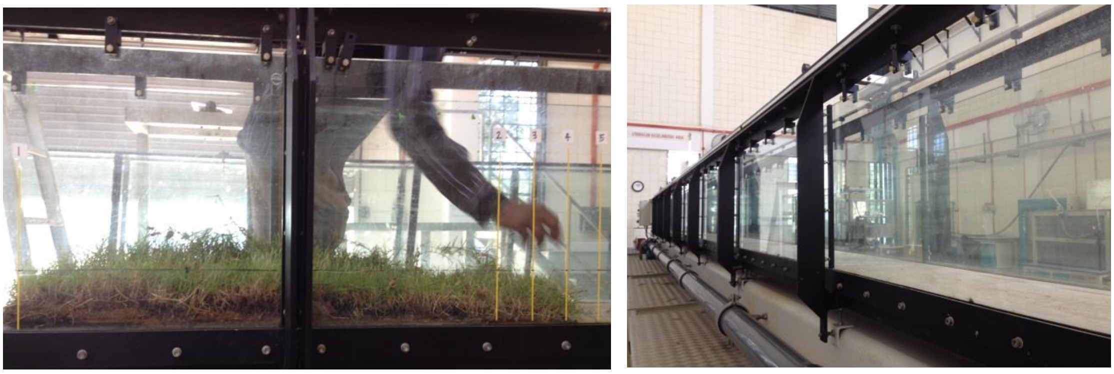

**Figure 4 – Channel of Flume**

Instruments like depth gauge, digital water velocity meter and current meter will be used in measuring the depth flow, velocity and magnitude of discharge as shown in Figure. Manning’s equation will be used in modelling the hydraulic characteristics of flow through the vegetated open-channel flow.

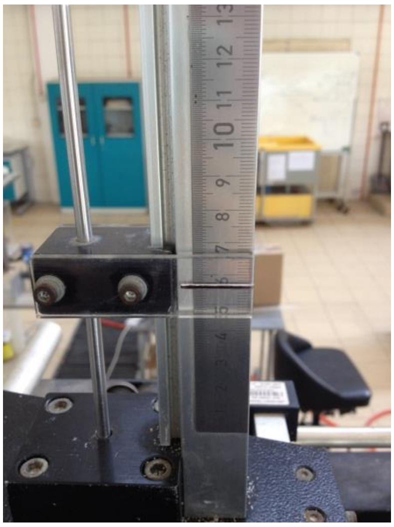

**Figure 5 – Depth Gauge**

## 1.5 Relevancy of Study

It is very important to determine the predicted velocity, depth of flow and magnitude of discharge of water in order to address the related issues like flood impact. Therefore, the conventional method is applied to gather and monitor the forecasted data which is the flume experiments. In this study, the impact of vegetation on the characteristics of the flow in an open-channel is being investigated experimentally. The presence of aquatic vegetation in an open-channel and rivers influences significantly the velocity, the depth flow and magnitude of discharge. Therefore, the study is very vital for understanding and managing rivers, wetlands, flood plains and any similar aquatic environment through the application of open-channel flow principles.

# CHAPTER 2
# LITERATURE REVIEW

## 2.1 Application of Aquatic Vegetation

Vegetation is an important part of any aquatic system, but sometimes it can get out of control and create problems. Aquatic vegetation is generally divided into three major classes which are the submerged, emergent, floating plants as proposed by Yang et. Al. (2001). Submerged plants are rooted plants with most of their vegetative mass below the water surface, although some portions may stick above the water. One discerning characteristic of submerged plants is their flaccid or soft stems. Emergent plants are rooted plants often stand above the surface of the waters. The stems of emergent plants are stiff and firm. Floating plants, however, growing mainly in areas of slow flow waters and being rarely seen around open-channels, hence, will not be covered in this study.

**Figure 6 – Installation of Japanese Lawn Grass**

The vegetation in channel usually consists of aquatic plants and these may be divided into four categories: emergent, submerged, floating-leaf, and free-floating leaf. The presence of vegetation in river channels provides both benefits and problems. From an environmental point of view, aquatic plants are essential parts of natural aquatic systems and form the basis of a water body’s health and productivity. And from an engineering point of view, vegetation can improve the strength of bank materials through buttressing and root reinforcement.

Vegetation can be used in constructing water ways for it aesthetic value in maintaining aquatic environments. Also, in urbanization areas, vegetation can be planted along the drainage system in order to improve the water quality by at least the settling of sediments as a result of decrease in flow velocity in vegetated open-channel flow.

## 2.2 Effects of Vegetation in Open-channel Flow

There are numbers of studies (as in the case of Helmio (2005); Chen et al. (2009); Afzalimehr et al. (2011); Huthoff (2013); Wu et al. (1999); Freeman et al. (2000); Kuwen and Fathi Moghadem (2000) which proposed for several application of forecasting technique to predict the water flow in the open-channel. In fact, an accurate and reliable forecasting technique is vital to maintain the operational open-channel management as well as to prevent and minimize the flooding impact.

However, invariably aquatic plants become over abundant or unsightly and require control. The obvious problems related to excessive growth are retardation, a reduction in hydraulic capacity and flooding. The effects of vegetation on the open channel vary depending on the species, distribution, density and size of vegetation as stated by Jain (2001). Although the flow capacity can be increased by complete or partial removal of vegetation, this solution will lead to erosion of the banks and increase the sediment load carried by flowing water. On the other way, unrestricted growth of such vegetation in an open channel can led to its complete loss of the hydraulic capacity. Many studies have been conducted in previous years to investigate the resistance to flow provide by the vegetation, using either artificial or real vegetation at the open channel. Fathi Maghadam and N. Kouwen (1997) used pine and cedar tree samplings to model the resistance to flow in a water flume.

The effects of vegetation on the flow structures are investigated in this paper. In previous studies of modelling a few vegetated flows, the model was applied to an experiment flume to study the flow field of vegetation. To study the impact of vegetation on flow, the artificial vegetation was used to simulate vegetation roughness in the past. The estimation of these friction factors depends on the roughness where it is a very critical point in open hydraulic flume.

## 2.3 Numerous Model Equations

The proposed equations for modelling the flow vegetative cover will be the basic equations developed for open channel according to Manning's equation as Equation 1.1. Manning's Roughness formula is used to estimate flow in open channel situations where it is not practical to construct a weir or flume to measure flow with greater accuracy. The friction coefficients across weirs and orifices are less subjective than along a natural channel reach like earthen, stone or vegetated channel. Cross sectional area will likely vary along a natural channel. Accordingly, more error is expected in predicting flow by assuming a Manning's n, than by measuring flow across a constructed weirs, flumes or orifices.

$$Q = VA = \frac{1}{n} A R^{\frac{2}{3}} S^{\frac{1}{2}} \qquad (1.1)$$

Where:

Q = Flow Rate, ( $m^3/s$ )

V = Velocity, ( m/s )

A = Flow Area ( $m^2$ )

n = Manning's Roughness Coefficient

R = Hydraulic Radius, ( m )

A channel roughness can be described through Manning roughness coefficient n as stated at equation 1.1.

## 2.4 Experimental Conditions of Previous Studies

Table 1 shows the experimental conditions of previous study by a few authors with their different perspective on vegetated open-channel flow.

**Table 1 – Studies on Vegetated Open-channel Flow**

| Author | Findings | Remarks |
|---|---|---|
| Wu *et al.* (1999) | Conducted experiments on simulated vegetation and proposed a simplified model to estimate the vegetal drag coefficient for submerged and non- | The regression analysis indicated that the important factors were the Reynolds number, slope, and height of vegetation. |

| | | |
|---|---|---|
| | submerged vegetation. | |
| Freeman *et al.*(2000) | Conducted flume experiments for 20 natural plant species with both homogeneous and mixed plant spacing. | There is need for the vegetation to be tested in different height and sizes in order to improve it. |
| Kouwen and Fathi-Moghadam (2000) | Used coniferous trees in air experiments and concluded that the friction factor has good correlation with the flow velocity. | The friction factor varied greatly with the mean flow velocity due to bending of the vegetation and with flow depth caused by an increase in the submerged momentum absorbing area. |
| Helmio, (2005) | Developed 1D flow model which was applied to a river with partially vegetated floodplains and found that the estimated discharges and water depths has a good correlation when compared to the observed. | There is need for the model to be tested in different sizes and shapes of rivers, in order to improve it. |
| Huthoff, (2003) | Uses a simple hydraulic resistance model that give slight discrepancies in estimating flow in vegetated waterways. | Vegetation roughness changes under submerged condition have not been addressed. |
| Fathi-Moghadam (2006) | He studied effects of land slope and flow depth on friction factors for non-canalized flow. | It was found that friction factors decrease significantly with increase of land slope as result of increase of flow velocity. The friction factor increased with increase of flow depth due to increasing of more submerged elements. |
| Baptist and et al. (2007) | Compared some methods and solved one-dimensional k-3 equation using an artificial network for calculation of | Suggested that a two-dimensional model for calculation depth- average |

| | | |
|---|---|---|
| | vegetation friction factor | velocity and shear stress for flow in straight compound channel with flood plain vegetation. |
| Chen *et. al* (2009) | Demonstrated that the resistance coefficient due to the vegetation is highly related to the Manning number exponentially. | Used a constant plant height of 10cm throughout the experiment under submerged condition only. |
| Afzalimehr, *et. al.* (2011) | Investigated the turbulence characteristics in channel with dense vegetation, and pointed out that there is a turning point along the velocity profile that coincides with the maximum turbulence intensity just above the vegetation cover. | Considers only two aspect ratios under submerged, this will not give adequate room to vary the flow. |

# CHAPTER 3
# METHODOLOGY

## 3.1 Study Methodology

Experimental approach will be adopted using a field open-channel to investigate the hydrodynamics relating to natural vegetation instead of artificial vegetation. The final outcomes will be finalized in a final report. The component of study methodology has been summarized in Figure 2.

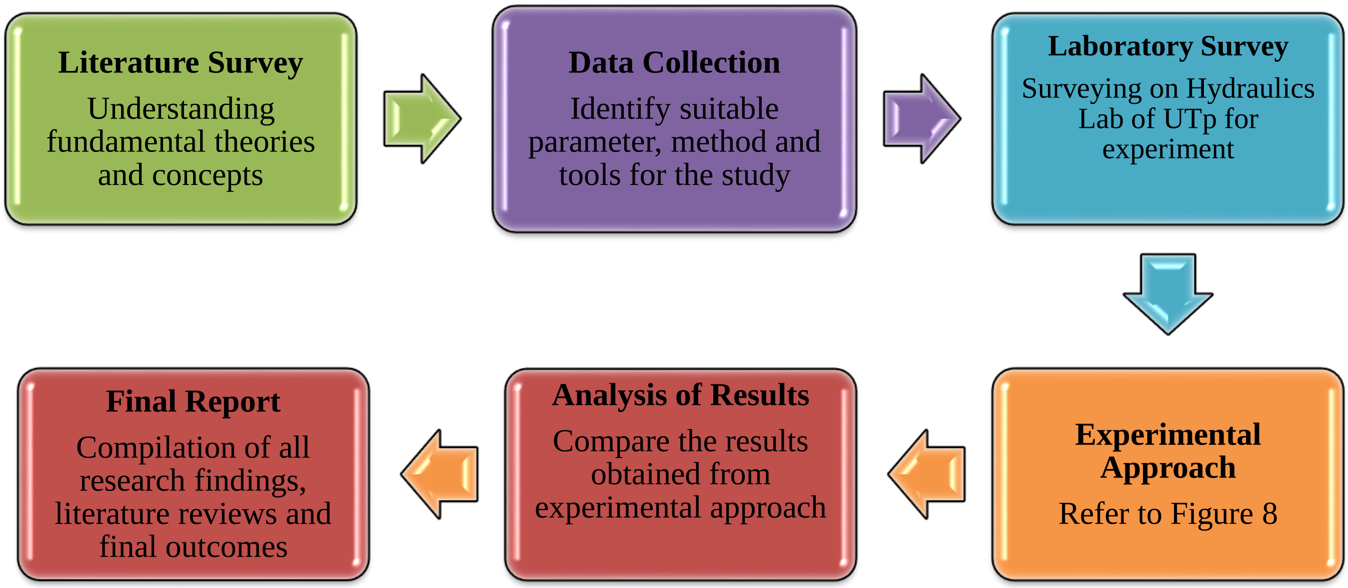


**Figure 7– Overview of Study Methodology**

## 3.2 Experimental Methodology

The present study will adopt an experimental approach using a field channel to investigate the hydrodynamics relating to natural vegetation, by employing the principles of open-channel flow. The proposed experimental methodology is shown as per below in order to achieve the stated objective. The proposed experimental methodology will be executed during Final Year Project II. Subsequently, the materials and methods to be adopted will be presented in this study. Below is the proposed of experimental approach where the experimental tests and measurements of the flow in an open-channel were performed using vegetation in a flume.

Characterization of flow resistance (friction factors) due to vegetation flexible roughness for different plant parameters was attained.

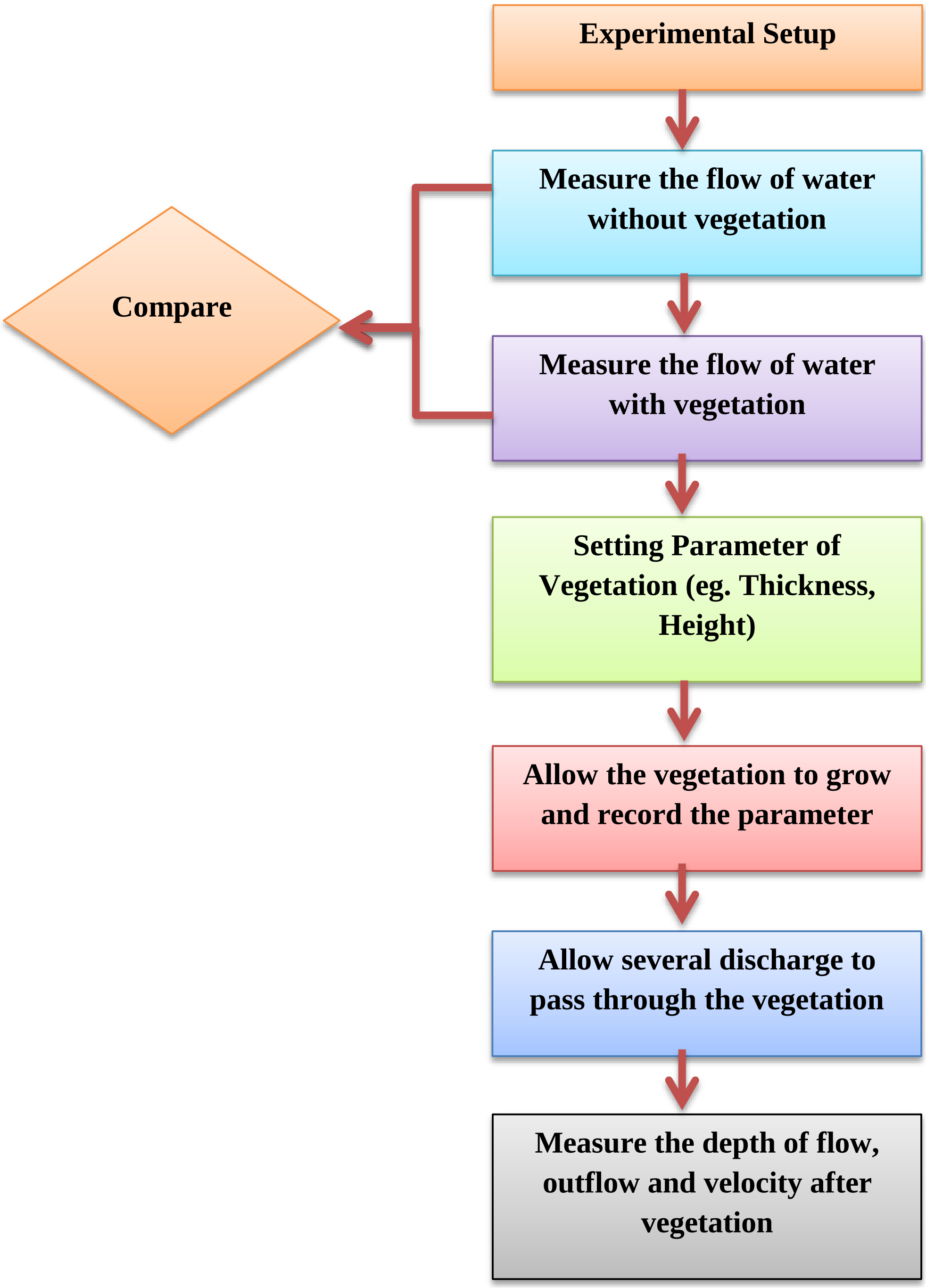


**Figure 8 – Proposed Experimental Approach**

## 3.3 Materials

### *3.3.1 Flume Channel*

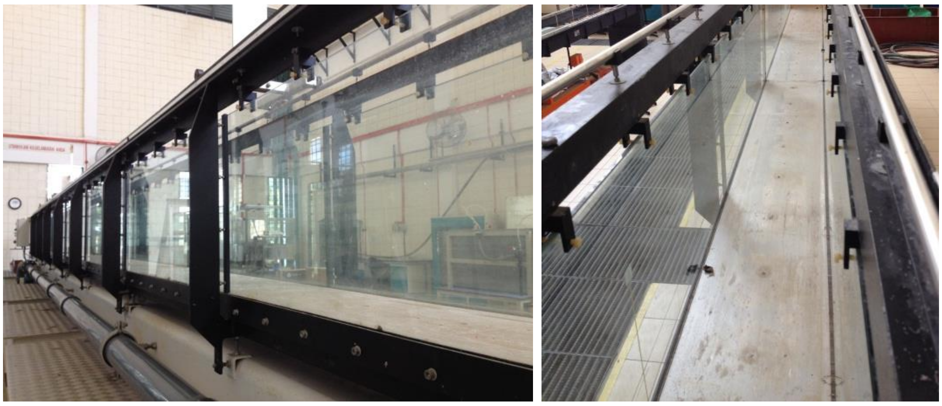

**Figure 9 – Rectangular Flume**

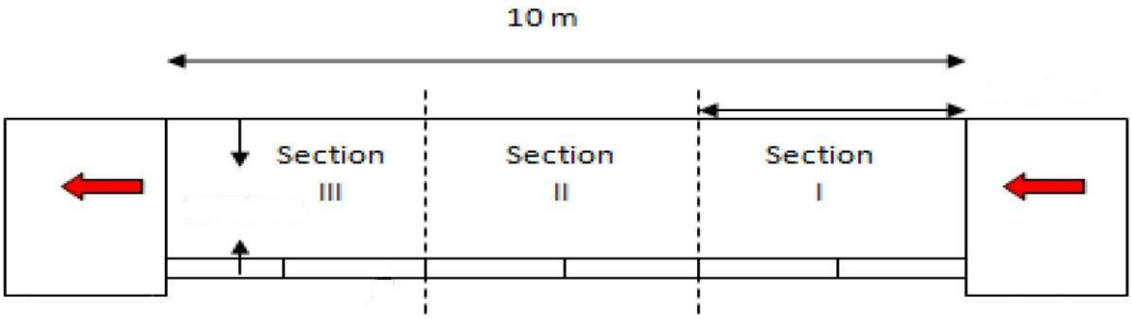


**Figure 10 – Illustration of Dimension of the Flume**

### *3.3.2 Depth Gauge*

The depth gauge is a precision measuring instrument, designed specifically and used by engineers to measure depths of flow. Figure 11 below shows one of the depth gauge that has been used in the laboratory:

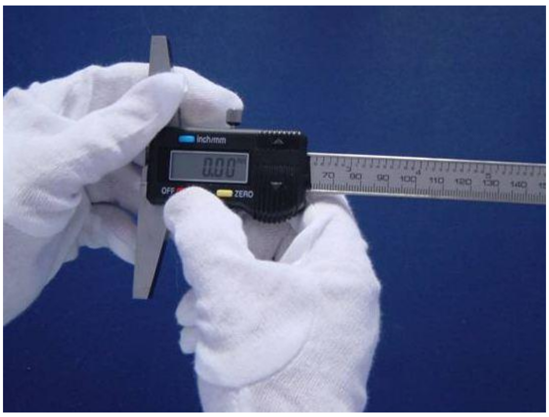

**Figure 11 – Digital Depth Gauge** (*Adopted from http://www.tresnainstrument.com/how_to_use_and_read_a_digital_depth_gauge.html)*

### *3.3.3 Weighing Scale*

This weighing scale will be put at the end of the open-channel to measure and calibrate the mass of water that passes through the aquatic vegetation. The mass will be recorded at the end of the experiment.

### *3.3.4 Current Meter*

A current meter is an instrument used to measure the velocity of flowing water. The principle of operation is based on the proportionality between the velocity of the water and the resulting angular velocity of the meter rotor.

**Figure 12 – Current Meter**

## 3.4 Methods

### *3.4.1 Field Experimental Procedure*

Flume experiment will be conducted in the laboratory of Universiti Teknologi PETRONAS. The experiment will be conducted in the hydraulics laboratory in a rectangular flume. The flume has length, width and height of a x b x c respectively.

**Figure 13 – Depth Gauge**

Subsequently, several discharges will be allowed to pass through the submerged vegetation where the upstream depth of water will be measure by depth gauge, similarly the depth of the downstream.

**Figure 14 – Vegetation Plank**

The experiment work will start by planting natural vegetation at the midpoint of the rectangular flume occupying 1m length, which it will be allowed to grow. Then, the average height of the vegetation will be determined. Subsequently, several discharges will be allowed to pass through the submerged vegetation where the upstream depth of water will be measure by depth gauge, similarly the depth of the downstream.

**Figure 15 – Measurement of Japanese Lawn Grass**

**Table 2 – Other Names of Japanese Lawn Grass**

| Vegetation (Common Name) | Scientific Name | Family Name |
|---|---|---|
| Japanese Lawn Grass | Zoysia japonica Steud. | Poaceae (Gramineae) |

Life Stage and Characteristic:

**Plant Division :**
Angiosperms (Flowering Seed Plants) (Monocotyledon)

**Plant Growth Form :**
Shrub (Creeper; Trailing), Grass & Grass-like Plant

**Mode of Nutrition :**
Autotrophic

**Plant Shape :**
Compact

Foliar:

**Foliage Retention :**
Evergreen

**Mature Foliage Colour(s) :**
Green

**Mature Foliage Texture(s) :**
Papery, Thin

**Foliar Venation :**
Parallel

**Typical Foliar Area :**
Microphyll ( 2.25$cm^2$ - 20.25 $cm^2$ )

Also, in each run the inlet discharge as well as the outlet discharges will be determined using current meter with the rectangular flume been kept horizontal. Velocity profiles will be measured along three cross section at x = 3.5m, 5m and 7.5m using velocity meter.

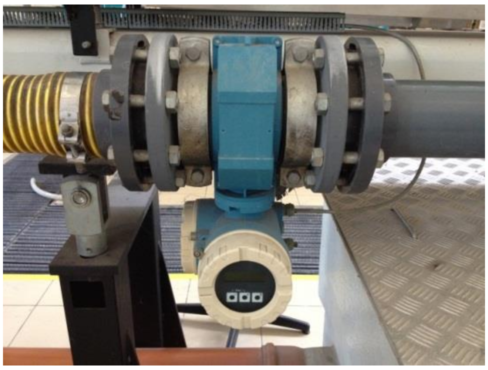

**Figure 16 – Flow Meter Reading**

### *3.4.2 Manning's Equation (Open-channel)*

Manning coefficient was highly correlated to vegetation density and inflow rate with empirical equations that has been proposed. The Manning's equation is an empirical equation that applies to uniform flow in open-channels and is a function of the channel velocity, flow area and channel slope. The Manning's vegetation roughness was computed for different flow rates and vegetation densities and is shown as per below:

$$Q = VA = \frac{1}{n} A R^{\frac{2}{3}} S^{\frac{1}{2}} \quad (2)$$

Where:

Q = Flow Rate, ( $m^3/s$ )

V = Velocity, ( m/s )

A = Flow Area ( $m^2$ )

n = Manning's Roughness Coefficient

R = Hydraulic Radius, ( m )

S = Channel Slope, ( m )

Based on the Equation 2, the author can conclude that the higher the density of vegetation, the value of Manning's roughness coefficient, n is higher, hence the value of flow rate, Q will be lower as it is inversely proportional.

The Manning's Roughness Coefficient, n represents the roughness of friction applied to the flow by the channel. Manning's Roughness Coefficient is often selected from tables. In many flow conditions the selection of a Manning's roughness coefficient can greatly affect computational results.

### *3.4.3 Mean Velocity Profiles*

The vegetation in channels results in the loss of energy form and the retardance of flowing water. However, it helps to stabilize the slopes and bottoms of open-channel. Recently, according to Chen and Kao (2010), vegetated channels have been utilized to improve the quality of surface water and reduce the delivery of sediment and nutrient to rivers and open-channels. Accordingly, understanding the velocity distribution of vegetated channels is important.

A vegetated channel, because of its flexible bed, is very different from channel beds with rigid boundaries. Accurate discharge estimates, flow patterns and hydraulic characteristics in vegetated channels can be obtained by studying their velocity distribution.

## 3.5 Gantt Chart FYP I

| No | Task to Perform | September | | | | October | | | | Novmber | | | | December | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 |
| 1 | Selection of Project Topic | | | Plan / Complete | Plan / Complete | | | | | | | | | | | | |
| 2 | Preliminary Research Work | | | | Plan / Complete | Plan / Complete | Plan / Complete | Plan / Complete | | | | | | | | | |
| 3 | Submission of Extended Proposal Defence | | | | | | | | Plan | | | | | | | | |
| 4 | Proposal Defence | | | | | | | | | | Plan | Plan | | | | | |
| 5 | Project Work Continues | | | | | | | | | | | | Plan | Plan | Plan | | |
| 6 | Submission of Interim Draft Report | | | | | | | | | | | | | | | Plan | |
| 7 | Submission of Interim Report | | | | | | | | | | | | | | | | Plan |

Legend:

Plan

Complete

## 3.6 Gantt Chart FYP II

| No | Task to Perform | January | | | | February | | | | March | | | | April | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 |
| 1 | Project Work Continues | Plan | Plan | Plan | Plan | Plan | Plan | | | | | | | | | | |
| 2 | Submission of Progress Report | | | | | | Plan | | | | | | | | | | |
| 3 | Project Work Continues | | | | | | | Plan | Plan | Plan | Plan | Plan | | | | | |
| 4 | Pre-SEDEX | | | | | | | | | Plan | | | | | | | |
| 5 | Submission of Draft Report | | | | | | | | | | Plan | | | | | | |
| 6 | Submission of Project Dissertation (Soft Bound) | | | | | | | | | | | Plan | | | | | |
| 7 | Submission of Technical Paper | | | | | | | | | | | Plan | | | | | |
| 8 | VIVA | | | | | | | | | | | | Plan | | | | |
| 9 | Submission of Project Dissertation (Hard Bound) | | | | | | | | | | | | | | Plan | | |

Legend:

Plan

Complete

## 3.7 FYP 1 Suggested Milestone

| No | Detail/Week | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Selection of Project Topic: | ■ | ■ | | | | | | | | | | | | | |
| | **Effects of Vegetated Open-Channel to Stormwater Drainage System** | ■ | ■ | | | | | | | | | | | | | |
| 2 | Preliminary research on literature related to the topic: | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | | |
| | Determination of flow resistance of vegetated channel | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | | |
| | Flow characteristics in different densities of submerged flexible vegetation from an open-channel flume study of artificial plants | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | | |
| | Experimental study on the hydrodynamic characteristics of a vegetated channel | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | | |
| | The impact of vegetation on the characteristics of the flow in an inclined open channel | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | | |
| 3 | Submission of Extended Proposal | | | | | ■ | ■ | | | | | | | | | |
| 4 | Project Work: Study on the research scope and method | | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| 5 | Proposal Defense | | | | | | | | | | | ■ | ■ | | | |
| 6 | Project work continues: Further investigation on the project and do modification if necessary | | | | | | | | | | | ■ | ■ | ■ | ■ | ■ |
| 7 | Submision of Interim Report | | | | | | | | | | | | | | ■ | ■ |

## 3.8 FYP 2 Suggested Milestone

| No | Detail/Week | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1** | **Project Work Continues** | ■ | ■ | ■ | ■ | ■ | ■ | | | | | | | | | |
| | Natural Vegetation Surveys | ■ | ■ | ■ | ■ | ■ | ■ | | | | | | | | | |
| | Planting Vegetation | ■ | ■ | ■ | ■ | ■ | ■ | | | | | | | | | |
| | Flume Preparation | ■ | ■ | ■ | ■ | ■ | ■ | | | | | | | | | |
| | Install Natural vegetation into Flume | ■ | ■ | ■ | ■ | ■ | ■ | | | | | | | | | |
| | Laboratory Session | ■ | ■ | ■ | ■ | ■ | ■ | | | | | | | | | |
| **2** | **Submission of Progress Report** | | | | | | ■ | | | | | | | | | |
| **3** | **Project Work Continues** | | | | | | | ■ | ■ | ■ | ■ | ■ | | | | |
| | Laboratory Session | | | | | | | ■ | ■ | ■ | ■ | ■ | | | | |
| **4** | **Pre-SEDEX** | | | | | | | | | ■ | | | | | | |
| **5** | **Submission of Draft Report** | | | | | | | | | | ■ | | | | | |
| **6** | **Submission of Project Dissertation (Soft Bound)** | | | | | | | | | | | ■ | | | | |
| **7** | **Submission of Technical Paper** | | | | | | | | | | | ■ | | | | |
| **8** | **VIVA** | | | | | | | | | | | | ■ | | | |
| **9** | **Submission of Project Dissertation (Hard Bound)** | | | | | | | | | | | | | | ■ | ■ |

# CHAPTER 4
# RESULTS AND DISCUSSION

The results obtained from the laboratory experiment were then analysed in order to get the Manning's roughness value, n. Manning's equation method has been used for the analysis. The method used is shown below:

$$Q = \frac{1}{n} R^{\frac{2}{3}} S^{\frac{1}{2}} \quad \text{(SI units)}$$

Where:

R : Hydraulic radius, in m

Q : Discharge, in $m^3/s$

Analyses have been done after getting all the parameters needed from the experiments. The parameter measurement has been repeated a few times to reduce error towards the outcome and results by the end of analysis. The average of Manning's roughness coefficient, n was calculated using Manning's equation.

### Field Study and Data Collection

The experiment was conducted in a 10 m x 0.31 m x 0.25 m glass-wall flume as shown schematically in Figure 17 in the Hydraulics Laboratory of Universiti Teknologi PETRONAS. The purpose of the experimental program was to obtain spatial patterns of flow characteristic in a flume with natural vegetation. The natural vegetation was arranged uniformly in the flume of 1m long. The length of the flume was 10 m and the author decided to put 1 m length of vegetation inside the flume.

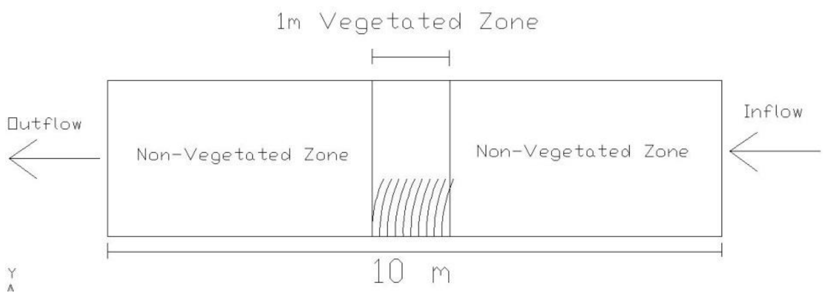


**Figure 17 – Schematic Diagram Inside of the Flume**

Depth gauge has been used to measure the depth of flow. The flow of water has a consistent value for certain point along the flume and few readings were taken to be compared. The results show the flow of water varies according to its slope.  In open channel flow prediction, it is usually assumed that the flow is parallel and has a uniform velocity distribution (steady-uniform flow). As the velocity is varied, the author can conclude that with the slope available in the flume, the velocity is getting faster while the depth of water is decreasing at both upstream and downstream of the flume. By comparing the experiment conditions for different works as in experiment without vegetation and with involving vegetation, the author confirmed that the differences may be attributed to the slope although the difference of this value is slightly not same.

Based on the above assumptions, a series of empirical methods of discharge estimation in open channels has been developed. The simplest of these are uniform flow equations attributed to Manning. In analysing the flow through open channels of regular sectional shape and hydraulic roughness, it is sufficient, in general, to use the overall hydraulic radius as the parameter, which characterized the properties of cross section.

Figure 18 shows the flow transition in vegetated zone where there is a different between the vegetated and non-vegetated zone in flow regimes. The results show that the flow depth of water in vegetated zone is much higher compare to non-vegetated zone. With the slope, the flow velocity is getting faster while the depth is decreasing.

**Figure 18  – Flow Transition for Vegetated Zone**

When discharge remains the same and depth does not change then we have uniform steady flow. In this condition, the surface of water is parallel to the bed of the flume or S = $S_w$.

Where S is the slope of the channel. The slope of the channel can be expressed as an angle, as per cent or as a fraction.

The slope of the flume also has been set up into three different levels which are + 1:500 and + 1:300. Flow discharges have been selected from 0.001519 $m^3/s$ – 0.002889$m^3/s$, based on available flow discharges at the Hydraulics Laboratory. To obtain an aspect ratio of 0.001519 $m^3/s$ for the first run until 0.002889 $m^3/s$ for the last run, the author need to monitor the meter that connect to the pump. The average height of the natural vegetation is 0.630 m and all reading is shown as per Table.

**Table 3 –Height Vegetation Readings**

| Reading | Height (m) |
|---|---|
| 1st | 0.130 |
| 2nd | 0.128 |
| 3rd | 0.700 |
| 4th | 0.970 |
| 5th | 0.950 |
| 6th | 0.900 |
| **Average Height** | **0.630** |

The Manning's vegetation roughness shows the higher the density of vegetation, the value of Manning's roughness coefficient, n is higher; hence the value of flow rate, Q will be lower as it is inversely proportional. According to the Manning's vegetation roughness below, the value of flow rate depends on the value of n which is the roughness coefficient. To get the higher value of Q, the value of n should be lower.

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

Where:

Q = Flow Rate, ( $m^3/s$ )

V = Velocity, ( m/s )

A = Flow Area ( $m^2$ )

n = Manning's Roughness Coefficient

R = Hydraulic Radius, ( m )

S = Channel Slope, ( m )

Table 4 shows a flume experiment for the slope of 1:500 without and with vegetation where the reading of flow depth is taken during the experiment. There are five selected sections in the flume where every section shows a different reading.

**Table 4 – Data Analysis for Slope 1:500**

| Discharge, ($m^3/s$) | Sections in the Flume | | | | | | |
|---|---|---|---|---|---|---|---|
| | 3 (Non-Vegetated) | 4 (Non-Vegetated) | | 5a (Vegetated Zone) | 5b (Vegetated Zone) | 5c (Vegetated Zone) | |
| | Flow Depth, y (m) | | Average y (m) | Flow Depth, y (m) | | | Average y (m) |
| 0.001519 | 0.120 | 0.127 | **0.1235** | 0.186 | 0.197 | 0.194 | **0.1790** |
| 0.001794 | 0.122 | 0.123 | **0.1225** | 0.181 | 0.192 | 0.191 | **0.1880** |
| 0.002022 | 0.127 | 0.129 | **0.1280** | 0.183 | 0.193 | 0.195 | **0.1903** |
| 0.002350 | 0.132 | 0.134 | **0.1330** | 0.183 | 0.195 | 0.192 | **0.1900** |
| 0.002633 | 0.136 | 0.139 | **0.1375** | 0.186 | 0.199 | 0.194 | **0.1930** |
| 0.002889 | 0.138 | 0.140 | **0.1390** | 0.189 | 0.203 | 0.196 | **0.1960** |

Table 5 shows a computation of Manning's roughness coefficient at that particular slope which is 1:500. Results shows that the value of Manning's roughness is higher at the vegetated zone compare to non-vegetated zone. Table 5 also shows that the higher the value of discharge, the smaller the value of Manning's roughness.

**Table 5 – Manning's Roughness Computation for the slope at 1:500**

| Discharge, ($m^3/s$) | Average Flow Depth at **Non Vegetated** (m) | Manning's Roughness | Average Flow Depth at **Vegetated Zone**(m) | Manning's Roughness |
|---|---|---|---|---|
| 0.001519 | **0.1235** | 0.189 | **0.1790** | 0.311 |
| 0.001794 | **0.1225** | 0.158 | **0.1880** | 0.280 |
| 0.002022 | **0.1280** | 0.149 | **0.1903** | 0.253 |
| 0.002350 | **0.1330** | 0.135 | **0.1900** | 0.217 |

| | | | | |
|---|---|---|---|---|
| 0.002633 | **0.1375** | 0.126 | **0.1930** | 0.197 |
| 0.002889 | **0.1390** | 0.116 | **0.1960** | 0.184 |

Figure 16 below shows a graph of flow depth against the sections in the flume for the particular slope. At the slope of 1:500, the value of flow depth is increasing when the water flow pass through the vegetated zone.

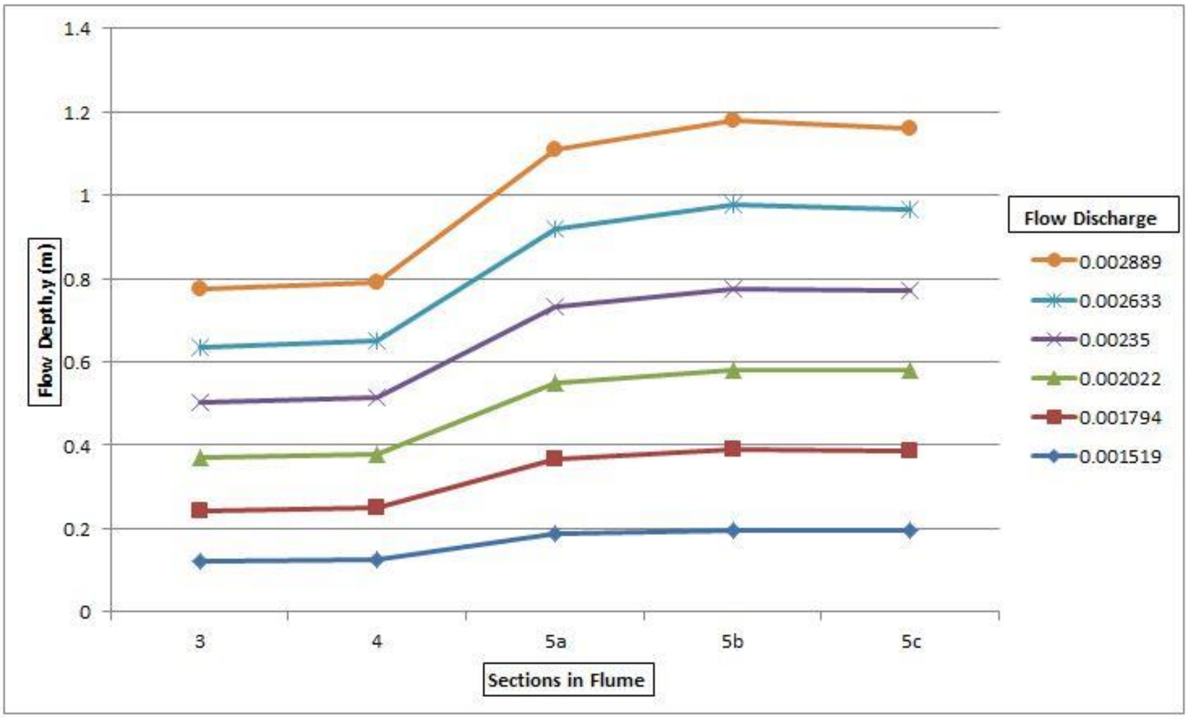


**Figure 19 – Graph of Flow Depth vs Sections in Flume for 1:500 Slope**

Table 6 shows a flume experiment for the slope of 1:300 without and with vegetation where the reading of flow depth is taken during the experiment. There are five selected sections in the flume where every section shows a different reading.

**Table 6 – Data Analysis for Slope 1:300**

| Discharge, ($m^3/s$) | Sections in the Flume | | | | | | |
|---|---|---|---|---|---|---|---|
| | 3 (Non-Vegetated) | 4 (Non-Vegetated) | | 5a (Vegetated Zone) | 5b (Vegetated Zone) | 5c (Vegetated Zone) | |
| | Flow Depth, y (m) | | Average y (m) | Flow Depth, y (m) | | | Average y (m) |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 0.001519 | 0.060 | 0.067 | **0.0635** | 0.126 | 0.137 | 0.134 | **0.1323** |
| 0.001794 | 0.067 | 0.067 | **0.0645** | 0.121 | 0.132 | 0.128 | **0.1270** |
| 0.002022 | 0.069 | 0.069 | **0.0680** | 0.123 | 0.133 | 0.131 | **0.1288** |
| 0.002350 | 0.074 | 0.074 | **0.073** | 0.124 | 0.135 | 0.130 | **0.1300** |
| 0.002633 | 0.079 | 0.079 | **0.0775** | 0.126 | 0.139 | 0.133 | **0.1327** |
| 0.002889 | 0.080 | 0.080 | **0.0790** | 0.129 | 0.143 | 0.136 | **0.1360** |

Table7 shows a computation of Manning's roughness coefficient at that particular slope which is 1:300. Results shows that the value of Manning's roughness is higher at the vegetated zone compare to non-vegetated zone. Table 7 also shows that the higher the value of discharge, the smaller the value of Manning's roughness. In open channel, Manning formula has been widely used to determine the roughness coefficient, n. The variation of roughness coefficient, n occurs due to the many contributing factors, for instance surface roughness, vegetation, channel irregularity, channel alignment and obstruction. For this study, the author was focused more on the surface roughness and vegetation itself.

**Table 7 – Manning's Roughness Computation for the slope at 1:300**

| Discharge, ($m^3/s$) | Average Flow Depth at **Non Vegetated** (m) | Manning's Roughness | Average Flow Depth at **Vegetated Zone**(m) | Manning's Roughness |
|---|---|---|---|---|
| 0.001519 | **0.0635** | 0.090 | **0.1323** | 0.254 |
| 0.001794 | **0.0645** | 0.077 | **0.1270** | 0.203 |
| 0.002022 | **0.0680** | 0.074 | **0.1288** | 0.184 |
| 0.002350 | **0.073** | 0.071 | **0.1300** | 0.160 |
| 0.002633 | **0.0775** | 0.069 | **0.1327** | 0.147 |
| 0.002889 | **0.0790** | 0.065 | **0.1360** | 0.139 |

From the graph below, it is shown that the value of roughness increases when the flow depth increasing. It is also found that the value of n increasing with the increasing of the flow depth. This results show an agreement with the statement of Jarvela (2002) which the roughness coefficient value is depending on the flow depth where the Manning;s roughness coefficient is increasing while velocity is decreasing due to the friction. Vegetation exerts a strong influence on stream-channel. It is expected at the end of this study, a few outcome will be accomplished according to two objectives that have been setting up earlier. The expected outcome will be able to determine the effect of vegetation on flow characteristics and be able to establish relationship Manning's vegetative roughness and the flow depth.

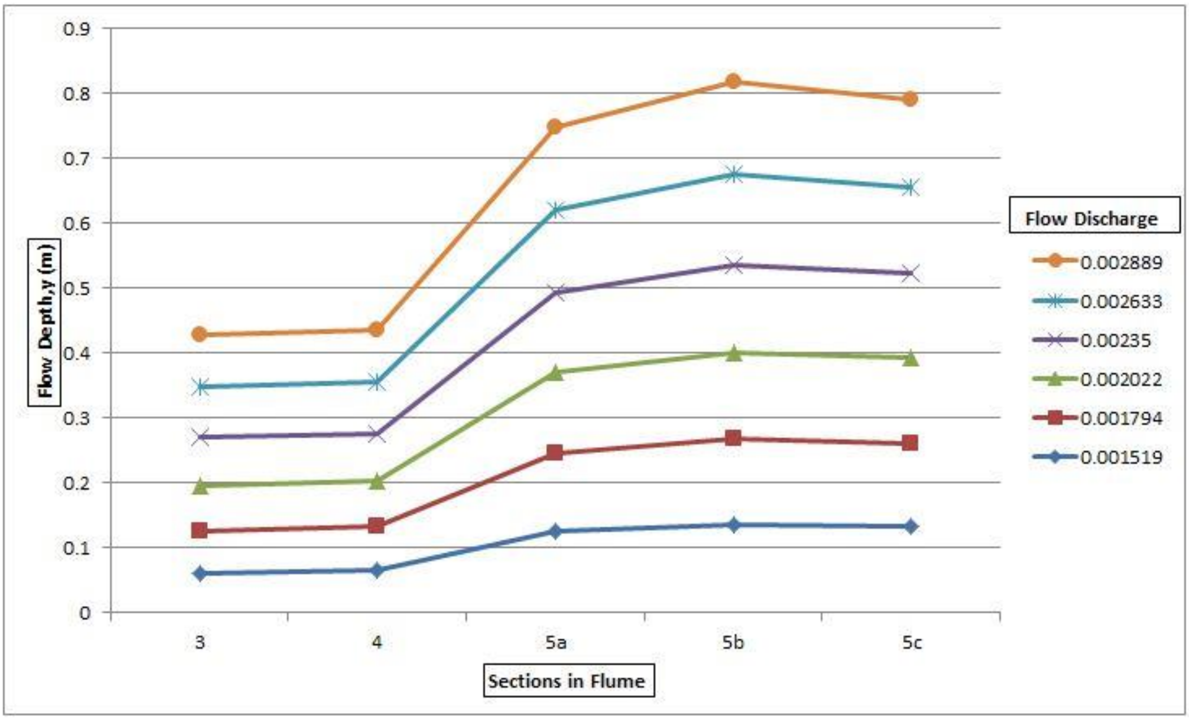


**Figure 20 – Graph of Flow Depth vs Sections in Flume for 1:300 Slope**

According to the calculated data, the author can conclude that the value of Manning's roughness is higher when there is varying roughness and alignment. The highest the value of Manning's roughness is for extremely bad alignment, deep pools, and vegetation or floodways with heavy stand of timber and underbrush. With the least value of this Manning's roughness shows the very smooth and true surfaces without projections.

It is expected at the end of this research, the determination of the velocity distribution will serve as an indicator for sediments deposition based on the degree of the vegetation roughness. The roughness resistance due vegetation will be established by Manning's vegetation roughness. The flume was divided into vegetated zone and non-vegetated zone. For the vegetated zone, the author decided to save 1 m length out of 10 m length of the flume. The natural vegetation was planted in order to investigate the pattern of the water flow. Since early of February 2015, data collection of water flow has been carried out in the laboratory.

The selected grass for this experiment is the grass which has the scattered pattern and the random one. During the experiment that has been conducted in the laboratory, the author realized that the grass is not fully submerged and no longer enough for the water to flow completely along the rectangular flume. However, the results still shows a positive value where it is completely follow the concept of previous studies where the value of Manning's roughnes should be higher where there is a varying roughness and alignment. The Manning's roughness value increases along with the increment of the flow depth of vegetation in an open channel. In this case, it were found that on 0.18 m depth, the value of n increases about 475%, 200% at 0.20 m depth and 90%.

# CHAPTER 5
# CONCLUSION AND RECOMMENDATION

Unrestricted growth of such vegetation in an open channel can lead to its complete loss of the hydraulic capacity which has potential to generate flood. A laboratory study has been conducted to analyse the effects of different types of vegetation to the velocity and on the Manning roughness coefficient (n) in an open channel on the hydraulic roughness. This study investigated the impact of vegetation on flow and mostly natural vegetation will be used in a flume experiments. The effect of vegetation density on flow characteristics is studied and the relationship between flow resistance and Manning number is established experimentally. By comparing the experiment conditions for different works as in experiment without vegetation and with involving vegetation, the author confirmed that the differences may be attributed to the vegetation densities. With increasing vegetation density, the velocity and corresponding flow rate increased.

The vegetation selected for this experiment is Japanese Lawn Grass (Zoysia japonica Steud.). From the experiment conducted that the roughness of Japanese Lawn Grass is in range of 0.139 – 0.254 for slope of 1:300 and 0.184 – 0.311 for slope of 1:500. It is also found that the increasing of Manning's n value is depending on the increasing of flow depth. The increasing of Manning's n value also identified when density of vegetation increased. The values of velocity and flow rate were proportionally inversed with Manning's n. The Manning's vegetation roughness was computed for different flow rates and vegetation densities. From the expected result, the author can conclude that the higher the density of vegetation, the value of Manning's roughness coefficient, n is higher; hence the value of flow rate, Q will be lower as it is inversely proportional. This relationship will be used as an alternative solution for channel designs for the benefit of practitioners in determining a more accurate roughness and discharge values. As there are a few problems that has been faced by the author as in the selected grass is not fully submerged and the grass in no longer enough for the water to fully developed at that area, the results still gave the value that the author was looking for. The flow of depth is decreasing when the slope is increasing.

The occurrence of vegetation in water courses has numerous impacts by at least altering the magnitude and direction of flow which will affect the shape of velocity profile, turbulence structures and sediment transport in an open-channel flow. Aquatic vegetation in a channel reduces flow speed and increase the water level. When channel velocity increases, the aquatic vegetation slows the flow at the bottom of the channel. Therefore, aquatic vegetation protects the bottom of the channel and reduces erosion.

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