DESIGN, ANALYSIS & FABRICATION OF A SCALED DOWN MODEL OF AN OPEN CHANNEL FLOW FLUME AND WEIR

MOHD FIRDAUS BIN MOHD ROSLI

Report submitted in partial fulfillment of the requirements
for the award of Bachelor of Mechanical Engineering with Automotive Engineering

Faculty of Mechanical Engineering
UNIVERSITI MALAYSIA PAHANG

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2013

EXAMINERS APPROVAL DOCUMENT

UNIVERSITI MALAYSIA PAHANG
FACULTY OF MECHANICAL ENGINEERING

I certify that report entitled 'Design, Analysis & Fabrication of a Scaled Down Model of an Open Channel Flow Flume & Thin Plate Weir' is written by Mohd Firdaus Bin Mohd Rosli with matric number MH09086. I have examined the final copy of this report and in my opinion, it is fully adequate in terms of the language standard, and report formatting requirement for the award of the degree of Bachelor in Mechanical Engineering with Automotive Engineering. I herewith recommend that it be accepted in fulfillment of the requirements for the degree of Bachelor Engineering.

____

Examiner : Amir Bin Aziz

Position : Lecturer

Date :

SUPERVISOR'S DECLARATION

I hereby declare I have checked this report, which written by Mohd Firdaus Bin Mohd Rosli, and in my opinion, this project report is adequate in terms of scopes and quality for the award of the degree of Bachelor of Mechanical Engineering with Automotive Engineering.

____

Supervisor : Azim Bin Mohd Arshad

Position : Lecturer

Date :

STUDENT'S DECLARATION

I hereby declare that the work in this report is my own, except for quotations and summaries which have been duly acknowledged. The report has not been accepted for any other Degree and is not concurrently submitted for award of another degree.

____

Mohd Firdaus Bin Mohd Rosli

MH09086

Date:

I specially dedicated this to my beloved parents and friends who have motivated me for this project

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First and foremost I would like to express my sincere gratitude to my supervisor of this research, Azim Bin Mohd Arshad. His wide knowledge and logical way of thinking have been of great value for me. His understanding, encouraging, ideas and personal guidance have provided a good basis for the present thesis. I would also like to thank him for the time spent to accomplish this thesis.

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ABSTRACT

Thin plate weirs have been widely used for measuring discharge rate in open channel flow accurately. The flow characteristic over a thin plate weir is completely different between a single V notch weir and double VV notch weir. The continuity of the flow and accuracy of this type of weirs is reported to be poor. As an improvement, a compound weir composed of two triangle parts with a different notch angle and height has been designed. Mathematical method also been proposed to measure the discharge flow rate over the double VV notch compound weir. Height and width of weir plate are the two parameters characterizing discharge rate over the notch weirs. Mathematical calculation and simulation are conducted by measuring the discharge and the height over the weir for variable weir height and width.

ABSTRAK

Empangan plat nipis telah digunakan secara meluas bagi mengukur kadar pelepasan bendalir dalam aliran saluran terbuka dengan tepat. Ciri-ciri aliran melepasi empangan plat nipis adalah sama sekali berbeza diantara satu bentuk V dengan dua bentuk V. Kesinambungan aliran dan ketepatan jenis satu bentuk V ini adalah tidak tepat. Bagi menambahbaikkan nilai keputusan, satu empangan plat nipis berganda terdiri daripada dua bahagian segitiga dengan sudut kedudukan yang berbeza dan ketinggian yang berbeza telah direka. Kaedah matematik juga telah dicadangkan untuk mengukur kadar aliran melalui reka bentuk dua V pada empangan plat nipis. Ketinggian dan lebar plat adalah dua parameter yang merubah sifat kadar pelepasan air melalui empangan plat nipis. Pengiraan matematik dan simulasi dijalankan bagi mengukur kadar pelepasan air dan ketinggian paras melalui empangan plat nipis yang mempunyai nilai ketinggian dan lebar yang berbeza-beza.

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LIST OF SYMBOLS

A_C	Closed Area
A_0	Opening Area
C_d	Discharge Coefficient
g	Gravitational Acceleration
Q	Discharge Flow Rate
–	Degree

LIST OF ABBREVIATIONS

CFD	Computational Fluid Dynamics
ISO	International Organization for Standardization
STEP	Standard for the Exchange of Product Data
V	Single Notch/Single Triangular
VV	Double Notch/Double Triangular
3D	Three Dimensional

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND STUDY

The world depends too much on the fossil fuel in order to generate energy such as electricity to power up gadgets and mechanical machines to use in daily life. An excessive usage of this source makes the fossil fuel deplete as it closer to extinction. In order to decrease the usage of fossil source, an alternative energy should be developed to replace fossil energy.

Tidal power nowadays has received world attention because of its high energy density, high predictability and low environmental impacts. The tidal power industry is expected to have a great potential in the future. Tidal energy current is more predictable, it is because tidal phenomena in the river acting everyday due to the moon rotations around the earth. The motions of the moon create a gravitational force that affects the low tide and high tide phenomena. Tidal wave creates the velocity in water flow and rotates the blades and rotor in the generator when the water flow through it, the rotation of generator will create electricity that can be used in daily life.

1.2 PROBLEM STATEMENT

Tidal wave energy or micro hydroelectric energy is an energy that has been produced from the kinetic energy of water flow into electricity by using the mechanical motion of rotor to generate electricity. Electricity produces from power plant only distributes into urban areas because of the population density and demanding of users is high in urban area compared to the rural area. In this case, rural citizens will have difficulties to obtain electricity for daily use. Micro hydro turbines will be the main option for rural citizens to produce electricity in a small scale. Micro hydro turbine is specially designed to work in a small river with low velocity of water flow. Before installing the micro hydro turbine in real river, we need to have an experiment on a micro hydro turbine to make sure it is fully functional. An open water channel flow flume needs to be design which it has the same flow characteristic as real river. Since UMP does not have a flume for experimental usage, we need to design and fabricate the flume channel that has flow characteristic exactly like real river. In order to create a flume that has a same characteristic as a river, a thin plate weir plays a main part to control the flow characteristic of water flow.

1.3 OBJECTIVES

The main objectives of this project are as follows:

(i) To analyze preliminary data obtained from the calculation and from analysis data source.

(ii) To evaluate the water discharge rate through VV notch thin plate weir.

(iii) To analyze and evaluate fluid behavior, flow characteristic and flow velocity at VV notch thin plate weir.

(iv) To develop an appropriate design of a scaled down model of 0.02m × 0.02m VV notch thin plate weir.

1.4 SCOPE OF STUDY

There are several parameters in order to control this research flow. This means that the parameters in which the boundary of the research is focused on. Therefore, the scopes of this research are as follows:

(i) To design an appropriate VV notch thin plate weir.

(ii) To control a water discharge rate through the thin plate weir.

(iii) Simulate water characteristic such as backflow effect and flow velocity.

By applying this scope of project, the analysis can be done in order to get the best result of this research.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter presents a review of past research efforts related to open channel flow, flow measurement equation of thin plate weirs, discharge measurements and backflow effect. The review shows that the method being used and the results. The review also shows some recommendation so that the present research effort can be properly modified to get more accurate results based on previous study.

2.2 OPEN CHANNEL FLOW FLUME

Flume are the main devices used for flow measurement. They have the advantage that they require minimum head loss or fall which is an important consideration where the fall through the works is critical (Herschy 1995). Accurate flow measurement in open channel flow is very important in engineering applications. The structure used for open channel flow should be accurate, economical and easy to install, operate and maintenance. Open channel flow refers to the flow of liquid in channels open to the atmosphere or a partially filled conduit and is characterized by the presence of a liquid gas interface called the free surface (Cengel 2006). Open channel flow can be laminar or turbulent, and steady or unsteady, it also can be uniform with constant depth along the channel or non-uniform. Flow measuring structures are used for continuous measurement of discharges in open channels (Boiten W. 1993). Long-throated flumes and weirs provide a cost effective, practical and flexible tool for measuring discharge in open irrigation systems. A long throated flume or weir should have two main characteristics which are the flume should provide sufficient constriction to flow so that it is unaffected by the water level downstream of the structure, but not so much that the upstream water level becomes too high at maximum flow (chocking phenomena) and the upstream channel Froude number should be high enough to pass the sediment and low enough to produce a stable and a readable water surface at a gauging station. These criteria's are important to select the shape and size of a control cross section that results in desired flow conditions for the upstream channel (Bos et al. 1984). Open channel flows involve liquids whose densities are nearly constant, and thus the one dimensional steady flow conservation of mass equation is expressed as equation below.

$$\dot{V} = A_c V = \text{constant} \tag{2-1}$$

That is, the product of the flow cross section and the average flow velocity remains constant throughout the channel. Equation 2-1 between two sections along the channel is expressed as continuity equation below.

$$A_{C_1} V_1 = A_{C_2} V_2 \tag{2-2}$$

This continuity equation is identical to the steady flow conservation of mass equation for liquid flow in a pipe. Note that both the flow cross section and the average flow velocity may vary during flow but as stated, their product remains constant (Cengel 2010).

2.3 FLOW MEASUREMENT EQUATION OF THIN PLATE WEIRS

Among different types of weirs, thin plate weirs have been widely used for discharge measurements in open channel. The commonly used cross sections of thin plate weirs are rectangular and triangular. The use of compound thin plate weir having a combination of two triangular weirs with different notch angle has been studied to get an accuracy of flow measurements of discharge (Piratheepan et al. 2006). The discharge coefficient solely depends on the notch angle for fully developed flow and depends on many other parameters for partially developed flow (Piratheepan et al. 2006).

Henderson 1966, present an elementary analysis for discharge over a sharp-crested thin plate weir by assuming that the flow does not contract as it passes over the weir. By assuming that the pressure across the whole water column over the weir is atmospheric and the following equation was derived for discharge as shown below.

$$Q = \frac{8}{15} C_d \tan\frac{\theta}{2} \sqrt{2g}\, h^{\frac{5}{2}} \tag{2-3}$$

Where,

- Q = Discharge Rate, (m^3/s).
- C_d = Discharge Coefficient.
- g = Gravitational Acceleration, (m^2/s).
- θ = Notch angle.
- h = Head over The Weir,(m).

For V-notch weirs, C_d values mainly depended on the notch angle. The C_d values depend on the head, h only for low head values. For higher values of h, the C_d becomes constant since viscous and surface tension effects become negligible (Martinez et all. 2005). Many references from previous study show the similar curves for C_d value without providing the equation for it. So, curve fitting programs are used to obtain the following relationship for C_d which is related to notch angle of the weir. The equation is shown below (Martinez et al. 2005).

$$C_d = 0.6072 - 0.000874\theta + 6.1 \times 10^{-6} \theta^2 \tag{2-4}$$

Where θ = notch angle.

Piratheepan et al. (2006) were studied about discharge measurement in open channel using compound sharp-crested weirs. The authors the equation (1) from Henderson (1966) to predict the flow over the weir when head over the weir (h) is less than the lower weir height (h_0) and in this case, the discharge coefficient corresponding to lower notch is used. When the head over the weir is greater than h_0, four different methods are proposed to estimate the flow over the compound weirs.

Piratheepan Method 1 :

$$Q = \frac{8}{15} C_{d_2} \sqrt{2g} \tan\left(\frac{\overline{\ }_{2}}{2}\right)(h - h_0)^{\frac{5}{2}} + \frac{8}{15} C_{d_1} \sqrt{2g} \tan\left(\frac{\overline{\ }_{1}}{2}\right) h^{\frac{5}{2}} - \frac{8}{15} C_{d_1} \sqrt{2g} \tan\left(\frac{\overline{\ }_{1}}{2}\right)(h - h_0)^{\frac{5}{2}}$$

Piratheepan Method 2 :

$$Q = \frac{8}{15} C_{d_2} \sqrt{2g} \tan\left(\frac{\overline{\ }_{2}}{2}\right)(h - h_0 - x)^{\frac{5}{2}} + \frac{8}{15} C_{d_1} \sqrt{2g} \tan\left(\frac{\overline{\ }_{1}}{2}\right) h_0^{\frac{5}{2}} - \frac{8}{15} C_{d_2} \sqrt{2g} \tan\left(\frac{\overline{\ }_{2}}{2}\right) x^{\frac{5}{2}}$$

Piratheepan Method 3 :

$$Q = \frac{8}{15} C_{d_2} \sqrt{2g} \tan\left(\frac{\overline{\ }_{2}}{2}\right)(h - h_0)^{\frac{5}{2}} + \frac{8}{15} C_{d_1} \sqrt{2g} \tan\left(\frac{\overline{\ }_{1}}{2}\right) h^{\frac{5}{2}} - \frac{8}{15} C_{d_2} \sqrt{2g} \tan\left(\frac{\overline{\ }_{2}}{2}\right) x^{\frac{5}{2}}$$

Piratheepan Method 4 :

$$Q = \frac{8}{15} C_{d_2} \sqrt{2g} \tan\left(\frac{\overline{\ }_{2}}{2}\right)(h - h_0 x)^{\frac{5}{2}} + \frac{8}{15} C_{d_1} \sqrt{2g} \tan\left(\frac{\overline{\ }_{1}}{2}\right) h_0^{\frac{5}{2}} - \frac{8}{15} C_{d_1} \sqrt{2g} \tan\left(\frac{\overline{\ }_{2}}{2}\right) x^{\frac{5}{2}}$$

2.4 THIN PLATE WEIR

Thin plate weirs are commonly used as measuring devices in flumes and channels, enabling an accurate discharge measurement with simple instruments. The V-notch weirs, also called triangular weirs have an overflow edge in the form of an isosceles triangle. Thin plate weirs enable an accurate discharge measurement with simple instruments (Chanson

2012). A very steady discharge measurement technique is the volume per time method. The only rational method of calibrating weirs in accordance with hydrometric principles is the volumetric method, which depends on measuring the volume with a measuring reservoir and the time of flow (Troskolanski 1960).

Martinez et al. (2005) were studied about the design and calibration of a compound sharp crested weir. A weir is an overflow structure built perpendicular to an open channel axis to measure the discharge. There are mainly two types of weirs which is sharp crested weirs and broad crested weirs. In this study, the authors proposed a design and formulae to expressed discharge rate. The cross section of the proposed compound weir results from the composition of three single triangular weir areas. Therefore, the total discharge can be expressed as the sum of the discharges flowing over the overall opening area. Consequently, if the head, h is lower than the height of the lower part of the compound weir, h_0, it behaves as a single triangular weir with a notch angle θ_1. When the head is above the lower part of the weir ($h>h_0$), the flow can be obtained by the following equation.

$$Q=\frac{8}{15}C_{d_g}\sqrt{2g}\left[\tan\left(\frac{\bar{}_{1}}{2}\right)\left[h^{\frac{5}{2}}-(h-h_0)^{\frac{5}{2}}\right]+\tan\left(\frac{\bar{}_{2}}{2}\right)(h-h_0)^{\frac{5}{2}}\right] \qquad (2\text{-}5)$$

The authors also derived a new single global discharge coefficient. The previous equation can be formulated as a function of a single global discharged coefficient. This equation relates the global discharge coefficient to the most significant variables that define the geometry of the weir. If the viscosity and surface tension effects are neglected, the discharge coefficient C_{d_1} and C_{d_2} are independent on the head and have a constant value for each notch angle. Such a simplification is acceptable for the upper section of the weir as h_0 is sufficiently high. The resulting global discharge coefficient is given by the following equation.

$$C_{d_g} = \frac{C_{d_1}\left(\frac{\theta_1}{2}\right) \bullet \left[\frac{1}{\left(1 - \frac{h_0}{h}\right)^{\frac{5}{2}}} - 1 \right] + C_{d_2} \tan\left(\frac{\theta_2}{2}\right)}{\tan\left(\frac{\theta_1}{2}\right) \bullet \left[\frac{1}{\left(1 - \frac{h_0}{h}\right)^{\frac{5}{2}}} - 1 \right] + \tan\left(\frac{\theta_1}{2}\right)}$$

.(2-6)

2.5 BACKFLOW EFFECT.

Triangular weir with a small notch angle is found to be accurate in discharge measurements however, it can be only be used to measure small discharges. When measuring high discharges by using the single thin plate weirs, backwater effects might affect the structures located upstream of the weir (Piratheepan et al. 2006).

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

This chapter presents the overall methodology of this project. Project starts off with planning by using a flow chart as shown in Figure 3.1 acts as a guide to successfully carry out the case study step by step.

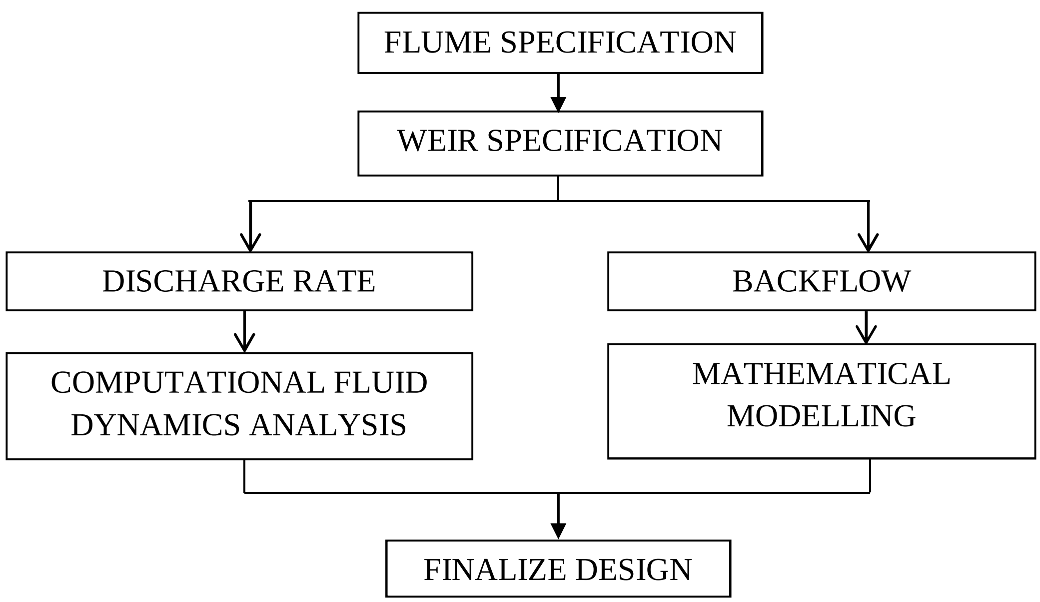


Figure 3.1: Flow Chart.

3.2 FLUME SPECIFICATION

The flume is primary devices for measuring flow of water in open channels. There are few conditions we need to consider before designing on flume and weir which is to maintain the water depth in the flume and to control the flow rate so the inlet flow rate must be equal to outlet flow rate as follow the conservation of mass and energy equations shows in equation 2-1. A flume design of scaled down by 1:10 given the flume specification of 0.2 meter width and 0.2 meter height and 3 meter length showed in Figure 3.2. The aim of this study is to achieve at least a minimum steady flow velocity of 1 m/s in the flume test section. According to equation 2-1, since the cross sectional area of the flume is 0.04 m^2 and the flow velocity need to achieve is 1 m/s, so the volume flow rate need to obtain in the flume test section area is 0.04 m^3/s. Since the continuity equation 2-2 show that the volume flow rate inlet must be equal to volume flow rate outlet, 0.04 m^3/s of discharge rate must be achieved at the weir outlet.

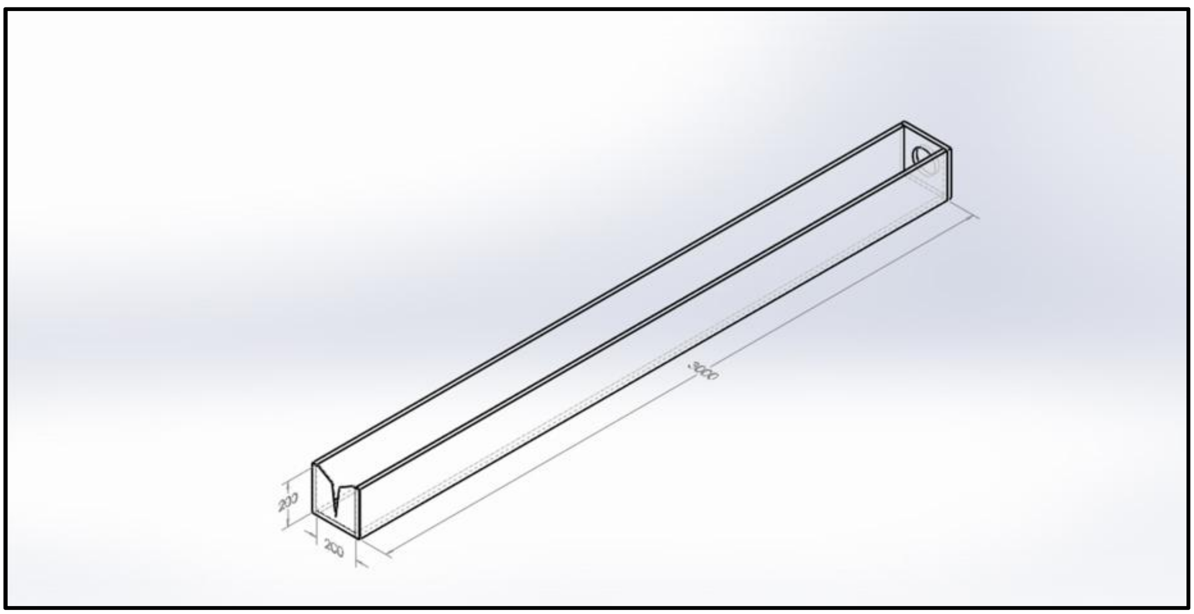


Figure 3.2 : Flume Test Section Dimension

3.3 WEIR SPECIFICATION

The VV notch thin plate weir was designed in 3D design using SolidWorks software. Figure 3.3 shows the 3D design of VV Notch Thin Plate Weir. Based on the objectives, the main part that needs to be focus is the opening area where the water goes through after it. Opening area, A_o of the weir will affect the discharge rate, Q while closed area, A_c will affect the backflow phenomena.

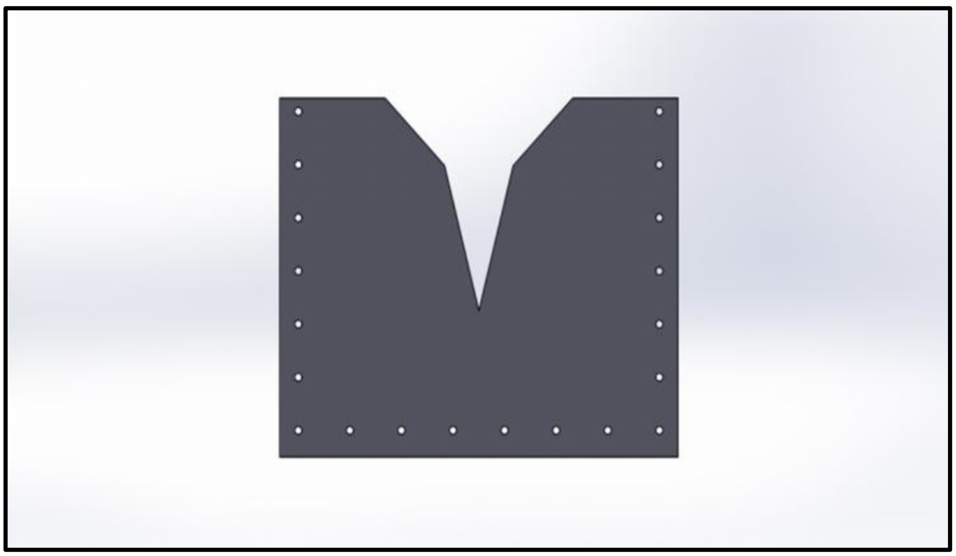


Figure 3.3 : Concept Design of VV Notch Thin Plate Weir Scaled Down Model

Design of VV Notch Thin Plate Weir must follow the tolerances in construction of thin plate weirs are given in the ISO standard but the most important considerations in the design and construction of thin plate weirs are as follows :

i. The structure should be rigid and watertight.
ii. The crest edges should be machined to a 90° angle should not be rounded and should be free of burrs.
iii. The water nappe should be at atmospheric pressure and ventilated.

iv. The water to be gauged should be free of debris which could damage the crest or settle in the approach channel.

v. The crest should not be painted as a means of preventing rust or pitting. A badly rounded or damaged crest should be replaced.

A VV notch thin plate weir are consist of two compound V notch weir, weir 1 which is lower weir and weir 2, upper weir. All the possible design of VV Notch Thin Plate weirs is based on choosing parameters and geometry as shown in Figure 3.4 below.

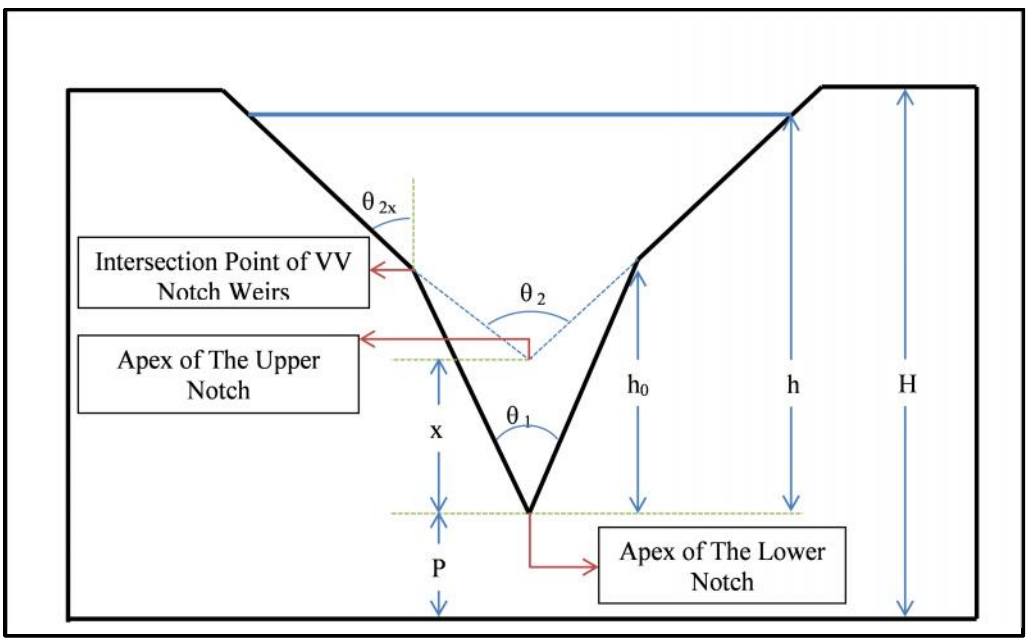


Figure 3.4 : Parameters Considered for VV Notch Thin Plate Weir

In order to design an acceptable weir, there are few limits and qualification to follow.

i. Distance between the apex of lower notch and level of water,h should not be less than 0.02m.

ii. Distance between bottom of the flame of lower notch, p should not be less than 0.02m.

iii. Angle of upper notch, θ_2 should be higher than angle of lower notch, θ_1.

iv. Water level must be higher than intersection point of VV notch weirs.

v. Distance between two notches, x should be higher than 0.02m.

All 662 possible designs of VV Notch Thin Plate weirs were tabulated on a table of Possible Design Data. All the possible design is named based on parameters chosen. The names are based on head, H and the angle of the notch opening, θ for lower notch and upper notch. Upper and lower weir have been chosen as shown in Figure 3.5 & Figure 3.6 below.

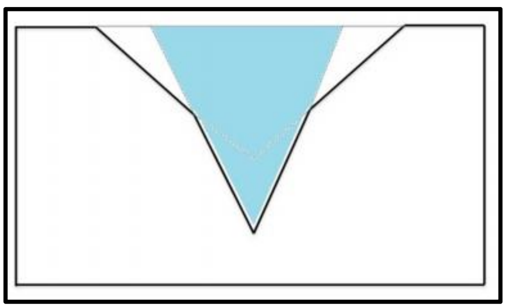


Figure 3.5 : Lower Weir

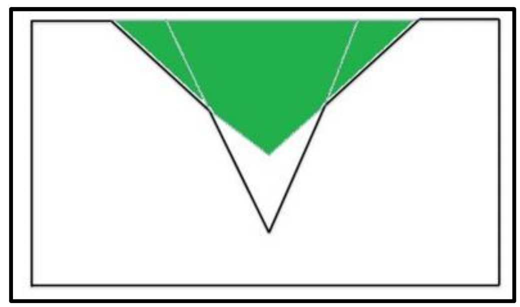
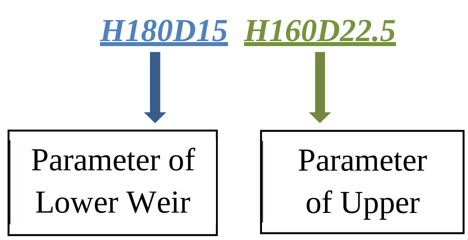


Figure 3.6 : Upper Weir

Each possible design is given their coding name based on parameters variable chosen. The parameters variable chosen is the head, h and angle of opening notch, θ of each lower and upper weir. The example of coding name is shown below.



Let,

H = Head of weir.

D = Angle of notch opening.

3.4 DISCHARGE RATE

All 662 possible design was then arranged in ascending of opening area. The graph of opening area against type of weir were plotted in Figure 3.7. the first group of ten sample design are selected and the mean value of opening area in those group of sample are chosen for the first selected design. This method were repeated until we achieve 62 design of compound VV notch thin plate weir. Graph of 62 possible design in changing of opening area and discharge rate for were plotted to see the pattern of graph. Discharge rate was calculated using five different methods as a benchmark in order to compare with the new derivation method. Graph of 62 designs was plotted below in Figure 3.7

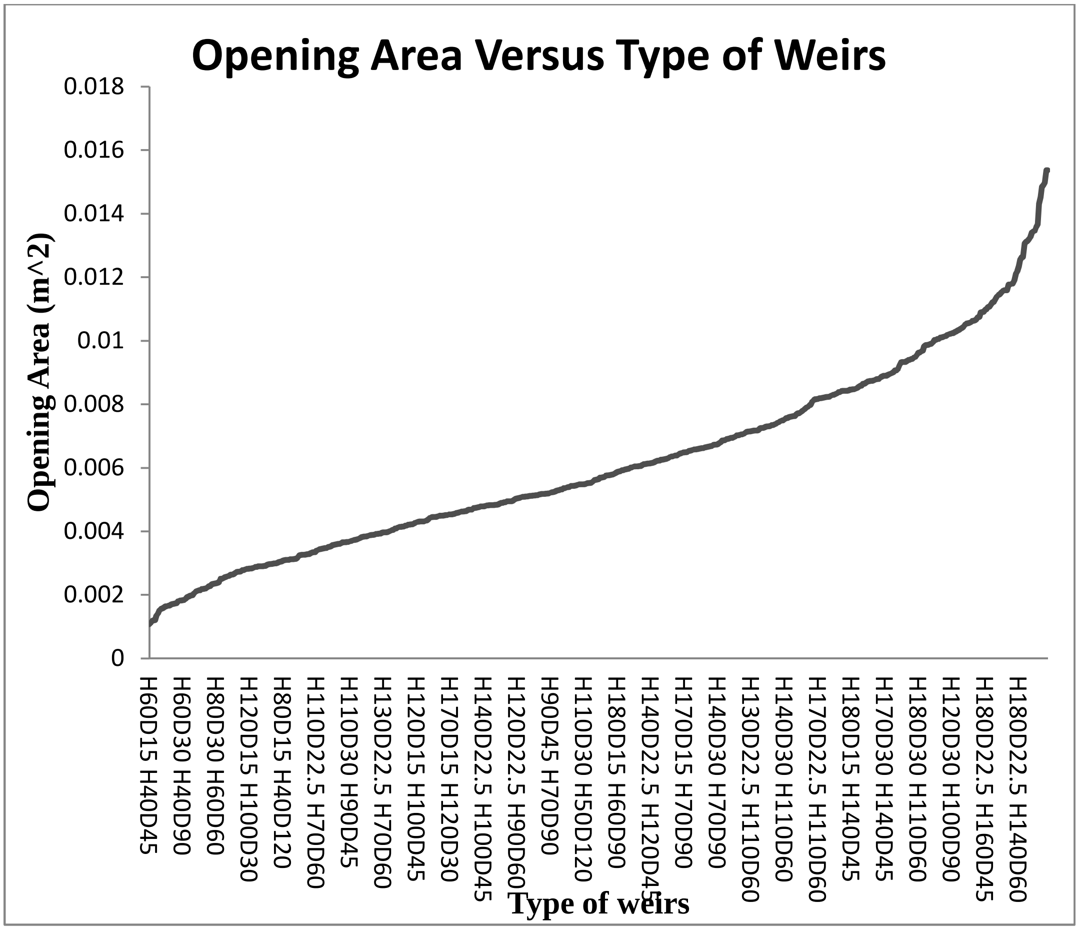


Figure 3.7 : Graph of Opening Area Versus Type Of Weirs

3.4.1 Mathematical Modelling

Mathematical modeling method is the uses of mathematics to describe real world phenomena and test the proposed designs. This method used can make prediction about the real world phenomena. In this study, the usage of mathematical modeling is to describe the value of the Discharge Flow Rate, Q. Discharge Flow Rate, Q equation of double triangular VV notch thin plate weir basically derived from single triangular V notch thin plate weir equation 3-1 and rectangular thin plate weir equation 3-2.

$$\therefore Q = \frac{8}{15} \times C_d \times \sqrt{2g} \times \tan \frac{-}{2} \times H^{\frac{5}{2}} \tag{3-1}$$

$$\therefore Q = \frac{2}{3} \times C_d \times b \times \sqrt{2g} \times (H)^{\frac{3}{2}} \tag{3-2}$$

The discharge equation for typical rectangular weirs and triangular weir were given before. The discharge rate over the compound weir with two triangular weir shape are calculated by adding the flow through the opening area of a strip of triangular and rectangular shape. The C_d values for the lower notch and upper notch are calculated separately. The new equation method is proposed to estimate the flow over the compound weirs which are presented in the following sections. The derivation of new methods for VV Notch thin plate weir is shown in appendix A3. The derivation step of the V notch thin plate weir and rectangular thin plate weir are shown in appendix A1 and appendix A2. Figure 3.8 below show all the parameters that need to consider in the discharge rate calculation of compound triangular weir, VV notch thin plate weir. From 662 possible VV notch thin plate weir design, 62 designs were selected to identify the graph pattern between new derivation method and others 5 others method. Figure 3.9 below shows the graph pattern between 6 difference method, it shows that the new derivation method gives a large discharge rate value than others method.

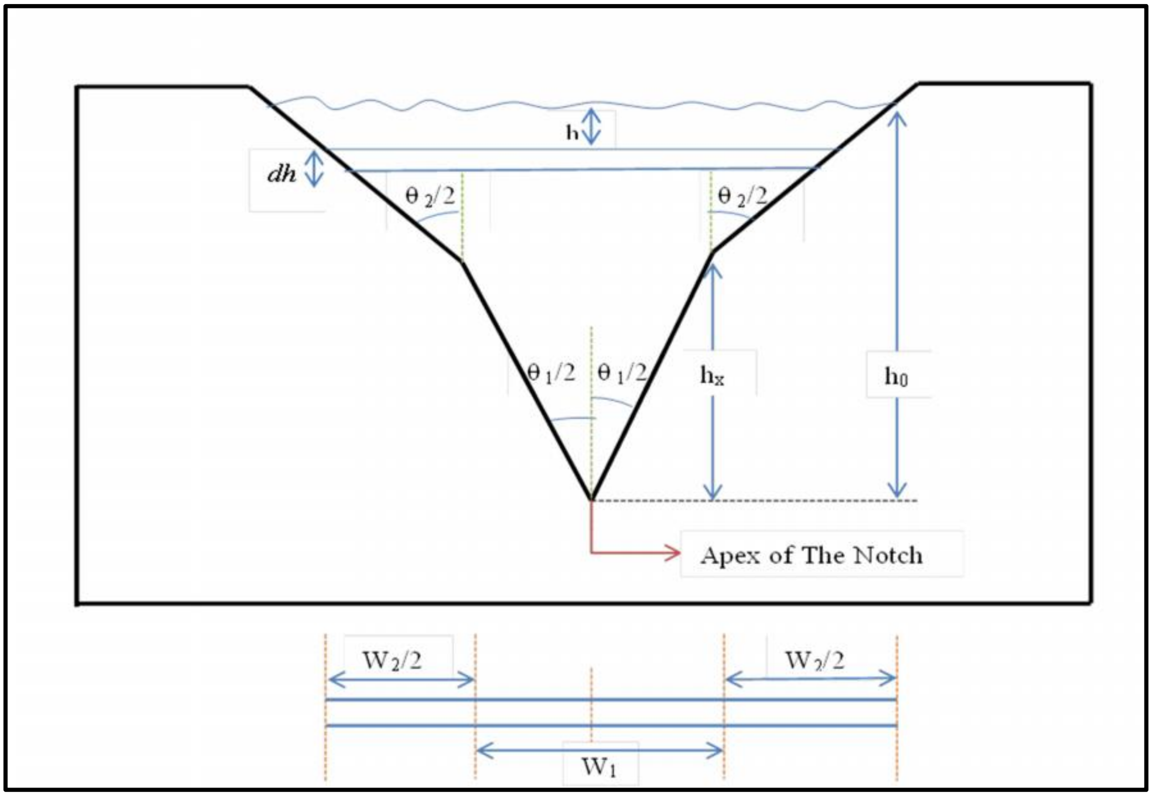


Figure 3.8 : Parameters Considered for Compound Weir VV Notch Thin Plate Weir

Consider a triangular VV Notch Thin Plate Weir located at the outlet of flume where water is flowing over as shown in figure 3.8 below. The new derivation equation is as shown in equation 3-3.

Let,

- h_0 = Water height above the apex of lower notch.
- h_x = Height between intersection of two notches and apex of lower notch.
- θ = Angle of Notch
- C_d = Coefficient of Discharge.

$$Q = \frac{16}{3} C_{d_1} \sqrt{2g} \tan \frac{\overline{}_{1}}{2} h_0^{\frac{5}{2}} + \frac{8}{15} C_{d_2} \sqrt{2g} \tan \frac{\overline{}_{2}}{2} h_0^{\frac{5}{2}} - \frac{4}{3} C_{d_2} \sqrt{2g} \tan \frac{\overline{}_{2}}{2} h_x h_0^{\frac{3}{2}} \quad (3\text{-}3)$$

Discharge rate was calculated using five different methods as a benchmark in order to compare with the new derivation method. The discharge rate versus opening area Graph of 62 designs was plotted below in Figure 3.9.

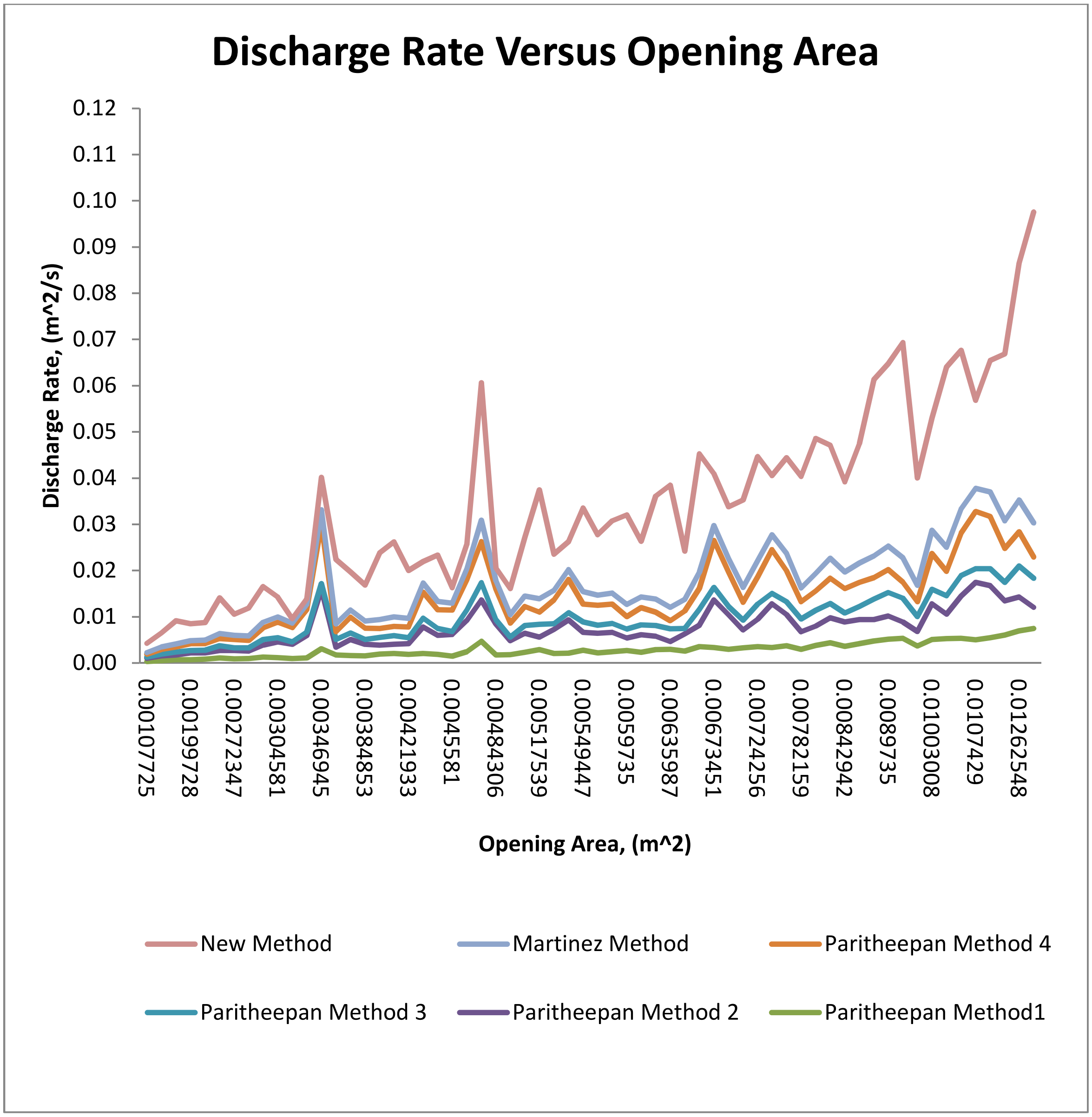


Figure 3.9 : Graph of Discharge Rate Versus Opening Area of 62 Selected Design.

3.4.2 Computational Fluid Dynamics ANSYS CFX Analysis

Data acquisition using Computational Fluid Dynamics (CFD) ANSYS CFX is the backbone of this project to determine the backflow effect. The analysis of the whole project may be tabulated, further discussed, and conclude in the following chapter after all of the data acquired being verified. ANSYS CFX simulation main objective is to predict the behavior of water flow, velocity outlet at VV notch and the distance of the back flow effect happen on the thin plate weir. ANSYSY CFX was selected for this study as simulation tools. The flume test section will be exposed to the atmosphere thus it can be considered as an open channel flow so the setup of this software must be set as an open flow condition.

There are several parameters that need to be set in order to have the same condition as an open channel flow, Table 3.1 shows the boundary condition on each parameter.

Table 3.1: List of Boundary Condition

Geometry Face	**Boundary Condition**
Inlet	Velocity = 11 m/s
Outlet	Static Pressure = 0 Pa
Opening	Free Slip Wall
Wall	Non – Slip Wall

The simulation uses water as the working fluid at 25ºC as the type of fluid, acceleration on y axis with 9.81 m^2/s gravitational acceleration to enable the gravitational force and reference pressure at 1 atm to indicate that, at t = 0 there are atmospheric pressure exert on reservoir wall.

Computational meshing is an important procedure in the CFX simulation process. With the aid of simulation tools, one can analyze the flow problems. To get the reliable and high accuracy result, the mesh refinement method needs to be applied. The refinement operation and number of refinement point closely related in simulation time. Higher levels of refinement will take longer simulation time. However the lower refinement level may cause the result to be inaccurate. In this simulation, the higher level of refinement was used to get the clear and accurate result. Meshing process is shown in Figure 3.10 below.

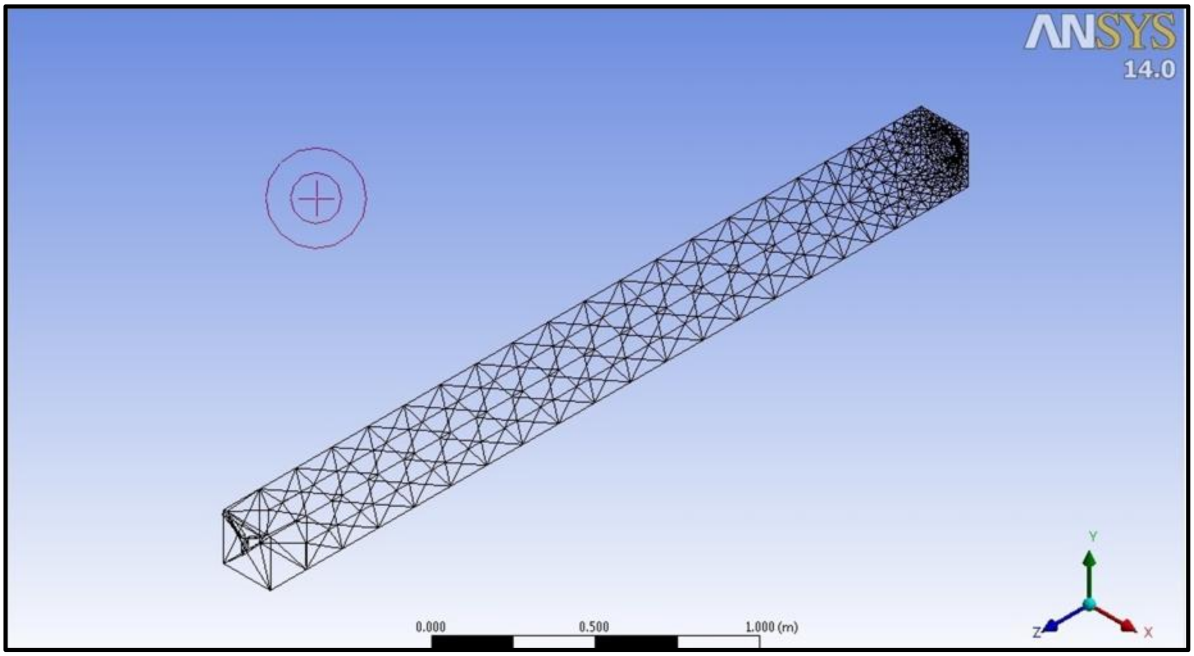


Figure 3.10 : Meshing

The first step in the CFX simulation set up is to setup default domain. In default domain set up, few important general parameters need to be confirmed. Choose the material of analysis testing as water and set up the inlet flow as a continuous flow. Make sure the pressure of geometry testing is 1 atm since flume is an open channel flow. After the general step of default domain, boundary condition should be set up to decide for inlet, outlet and wall are chosen well. On the inlet boundary, the velocity of water from the flume test section is 3 m/s, this value was taken from the simulation result of pipe outlet. On the outlet boundary, static pressure was set up to 0 Pa.

The boundary is important to define the simulation is a free surface model, thus the boundary condition for opening was set up to be a free slip wall in order to get the same velocity profile of an open channel flow. Besides that, the wall selected on the flume were set up as no slip wall boundary condition with no pressure acting on it. After all the boundary were set up, run the simulation to get the result of backflow phenomena and also velocity outlet over the VV notch thin plate weir.

CHAPTER 4

RESULT AND DISCUSSION

4.1 INTRODUCTION

This chapter presents the result of the analysis, mathematical modeling and further discusses the outcome of the analysis. Based on the simulation and calculation data results discharge flow rate, Q and backflow effect are presented in a graphical diagram. These data are used as the guidelines in choosing the best VV notch thin plate weir design.

4.2 FINAL DESIGN

A final 6 designs of VV notch thin plate weir that has been proposed are chosen from Appendix A4. The table below shows the opening area and the discharge rate of six selected proposed designs.

Table 4.1 : Table of Opening Area of Six Selected Designs.

Number	Type of Weir	Tracking	Opening Area (m^2)
1	H90D15 H60D60	542	0.00223195
2	H120D22.5 H50D90	439	0.00371668
3	H110D15 H50D120	483	0.00484306
4	H140D22.5 H70D90	324	0.00611668
5	H170D15 H110D60	108	0.00759988

6	H170D15 H130D60	96	0.01003008

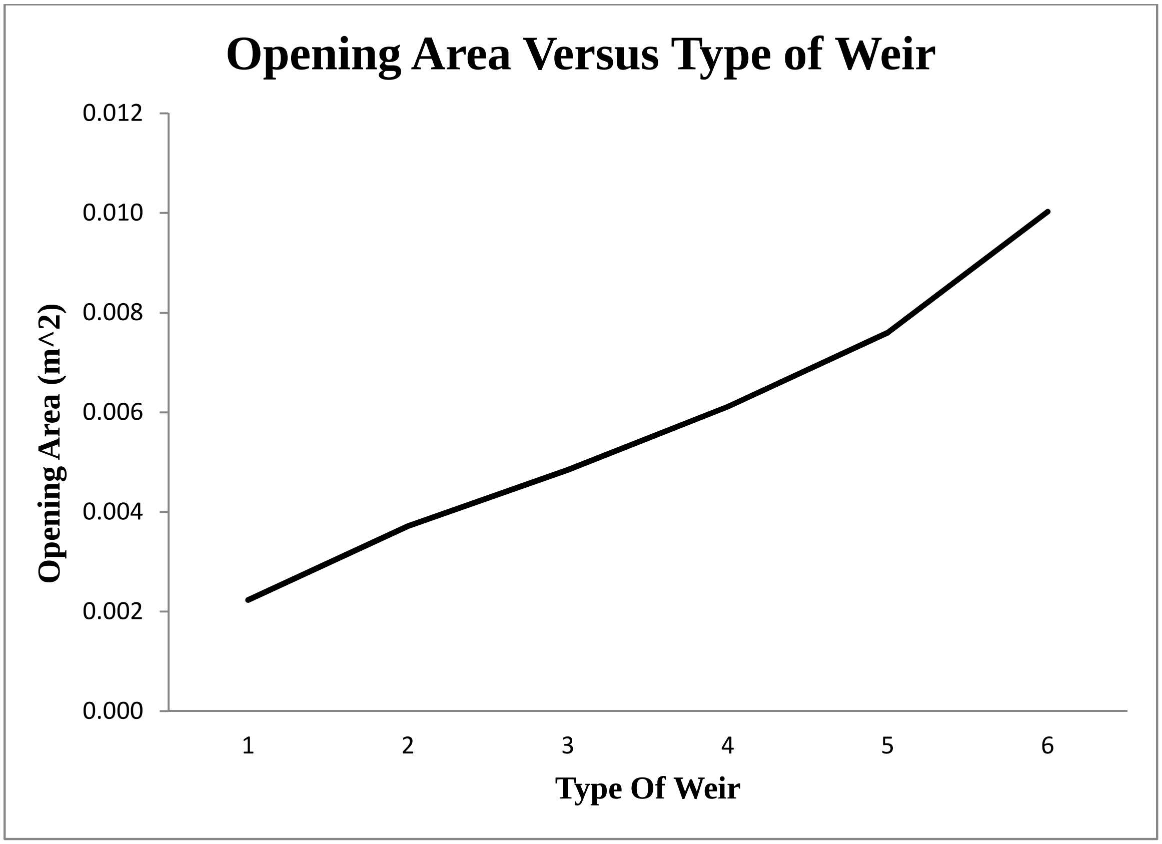


Figure 4.1 : Graph of Opening Area Against Type of Weir of Six Selected Designs.

Figure 4.1 shows the increasing of opening area against the type of weir of six selected designs. Based on the graph show above we can see the pattern of increasing opening area.

4.3 DISCHARGE RATE OF VARIABLE METHOD

In this sub chapter will show the discharge flow rate value by using the new derivation method. As a benchmark to make sure that the new derivation method were acceptable to use for the mathematical method in calculating the discharge flow rate, five other derivation method will be plotted in a graph of discharge rate versus opening area. Five other different derivation method is Paritheepan Method 1, Paritheepan Method 2, Paritheepan Method 3, Paritheepan Method 4, and Martinez Method will be used to observe the of the discharge rate graph. The discharge rate of the new derivation method is stated below.

$$Q = \frac{16}{3} C_{d_1} \sqrt{2g} \tan \frac{\overline{}_{1}}{2} h_0^{\frac{5}{2}} + \frac{8}{15} C_{d_2} \sqrt{2g} \tan \frac{\overline{}_{2}}{2} h_0^{\frac{5}{2}} - \frac{4}{3} C_{d_2} \sqrt{2g} \tan \frac{\overline{}_{2}}{2} h_x h_0^{\frac{3}{2}}$$

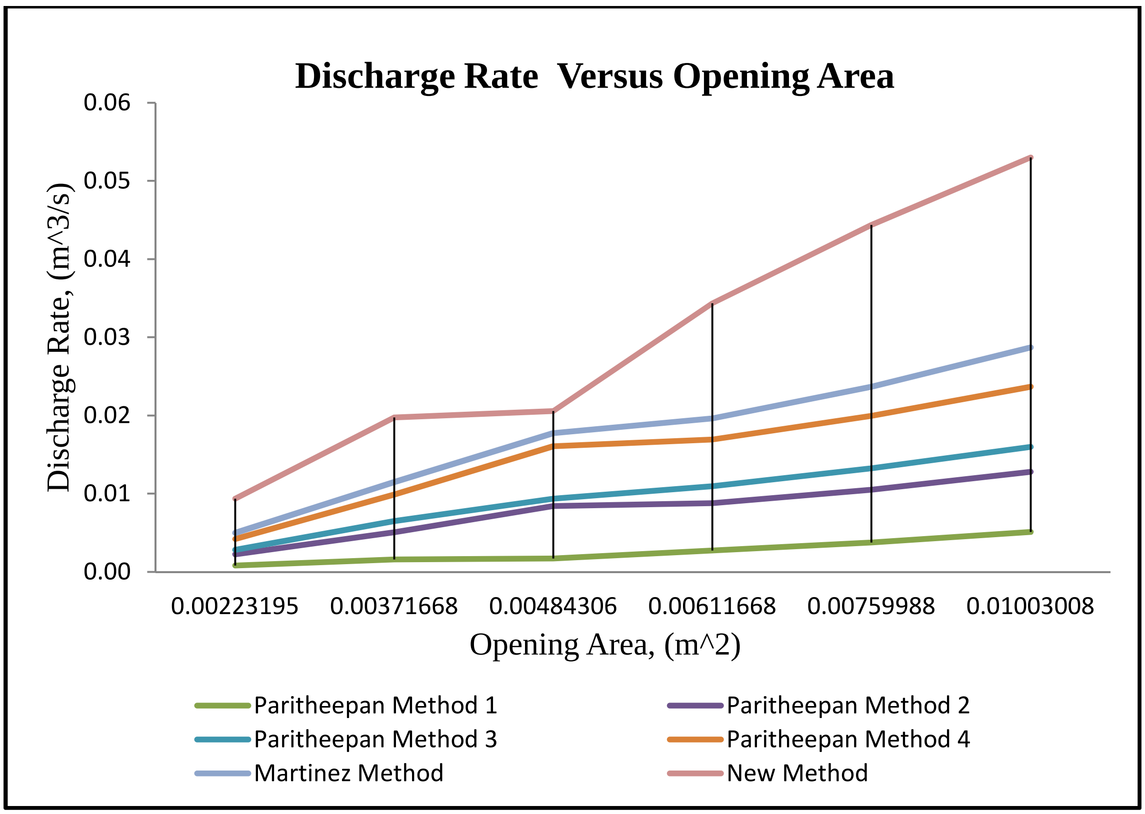


Figure 4.2 : Graph of Discharge Rate Versus Opening Area of Six Final Designs

As shown in the Figure 4.2 above, the graph pattern shows a huge difference between new derivation method and Piratheepan method 3 for discharge rate value. This slight difference exist because the value of height between intersection of two notches and apex of lower notch is not proportional to the value of opening area.

Table 4.2 : Value Difference Between Opening Area, A_0 and Height Between Intersection of Two Notches and Apex of Lower Notch, h_x.

No	Type of Weir	Height Between Intersection of Two Notches and Apex of Lower Notch, h_x (m)	Opening Area, A_o (m^2)
1	H90D15 H60D60	0.03886	0.00223195
2	H120D22.5 H50D90	0.08738	0.00371668
3	H110D15 H50D120	0.06494	0.00484306
4	H140D22.5 H70D90	0.08738	0.00611668
5	H170D15 H110D60	0.07772	0.00759988
6	H170D15 H130D60	0.05182	0.01003008

4.4 BACK FLOW EFFECT

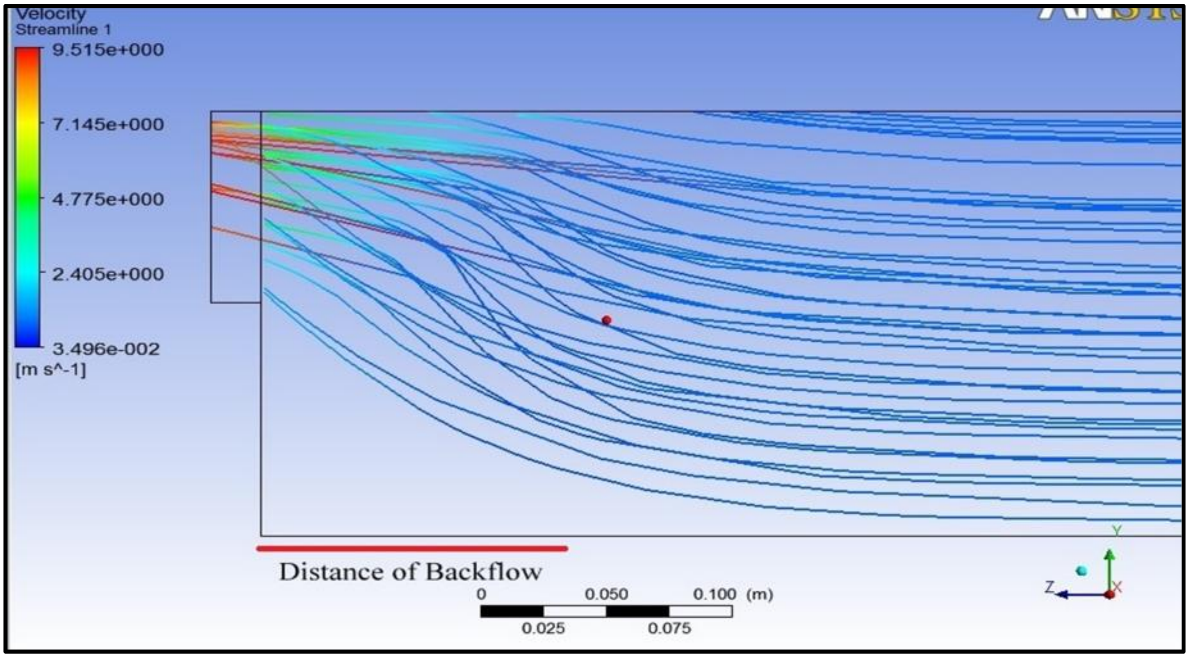


Figure 4.3 : Back Flow Effect Phenomena.

Backflow effect happens when water flow approach the VV notch thin plate weir at the outlet of the flume test section. Each type of VV notch thin plate weirs shows a different value of backflow effect since the back flow effect change proportionally due to opening area of the outlet which means the VV notch plate weirs. In this study, back flow effect is identified using the ANSYS CFX simulation method. The simulation results of the backflow effect for each six types of weirs are shown in the figures below. The grey dotted show the beginning of backflow effect exist at the VV notch thin plate weir.

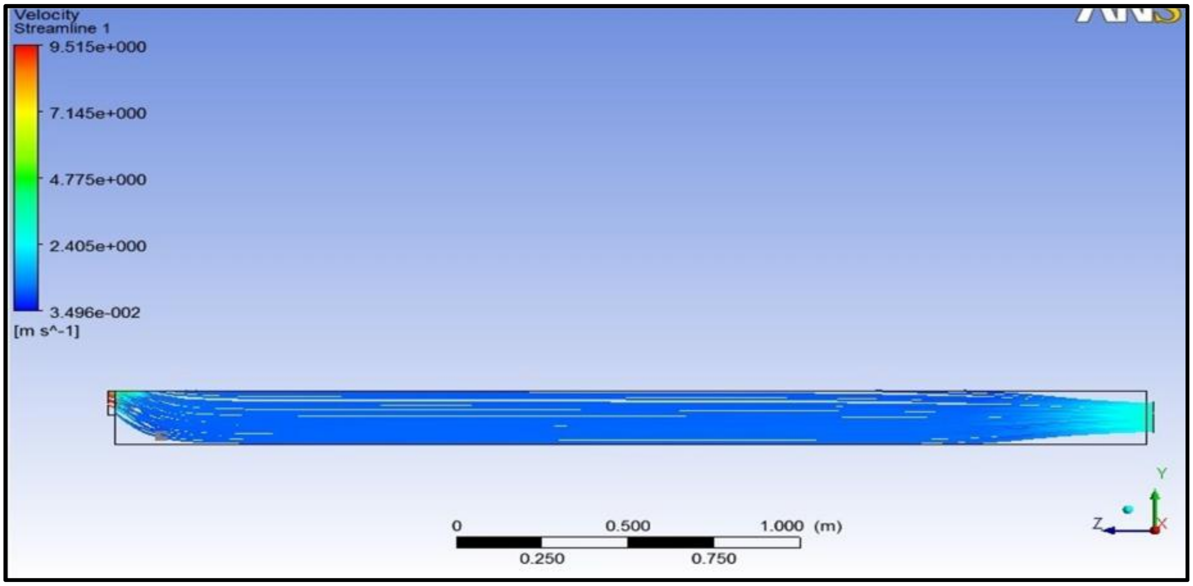


Figure 4.4 : Backflow Effect on Weir H90D15 H60D60

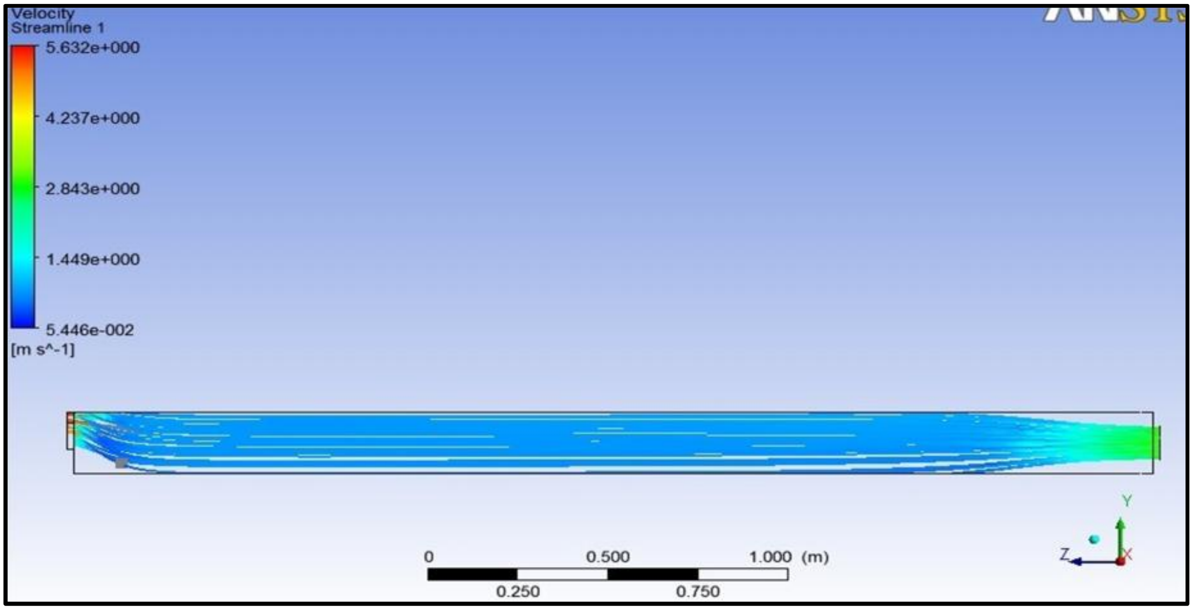


Figure 4.5 : Backflow Effect on Weir H120D22.5 H150D90

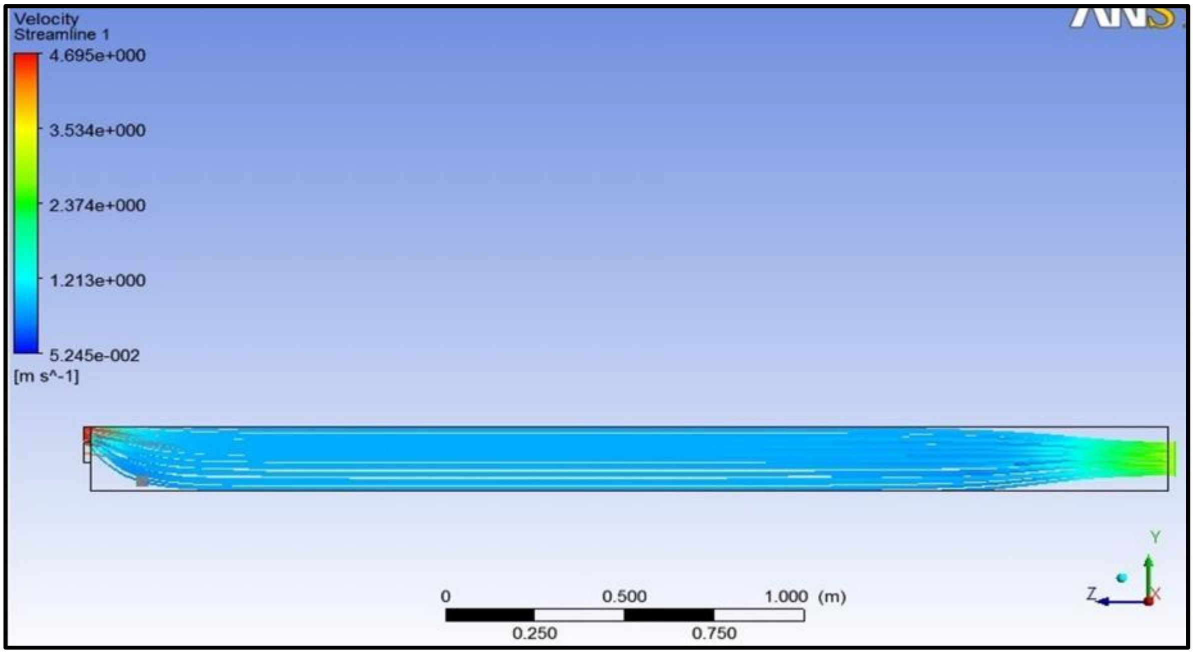


Figure 4.6 : Backflow Effect on Weir H110D15 H50D120

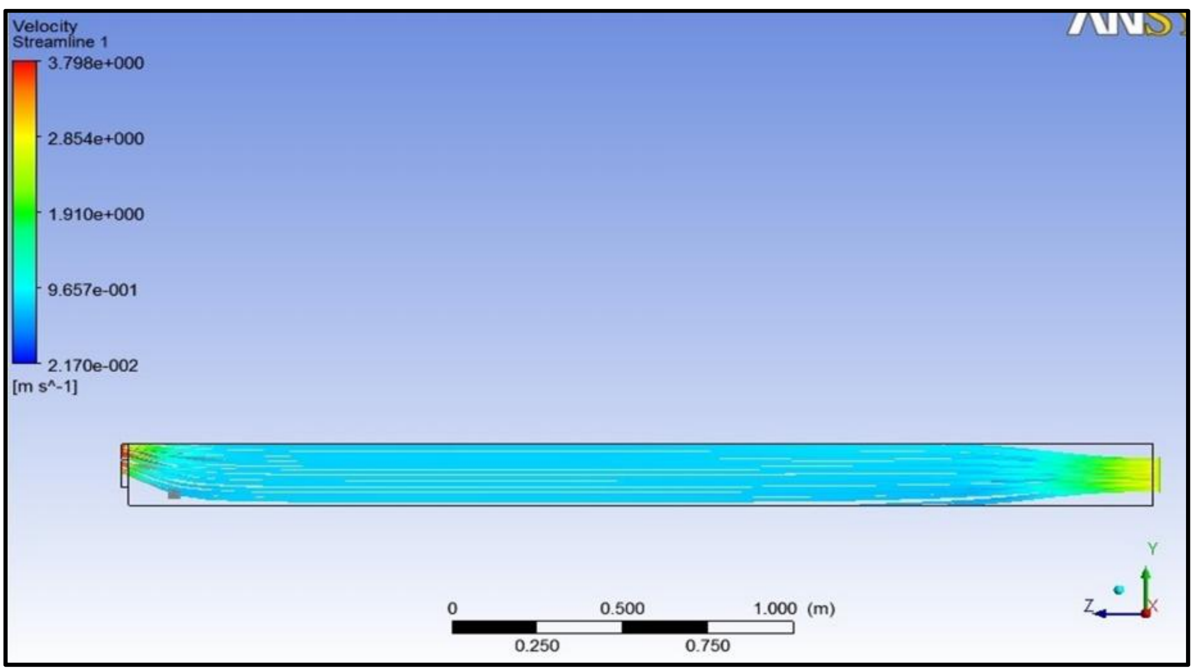


Figure 4.7 : Backflow Effect on Weir H140D22.5 H170D90

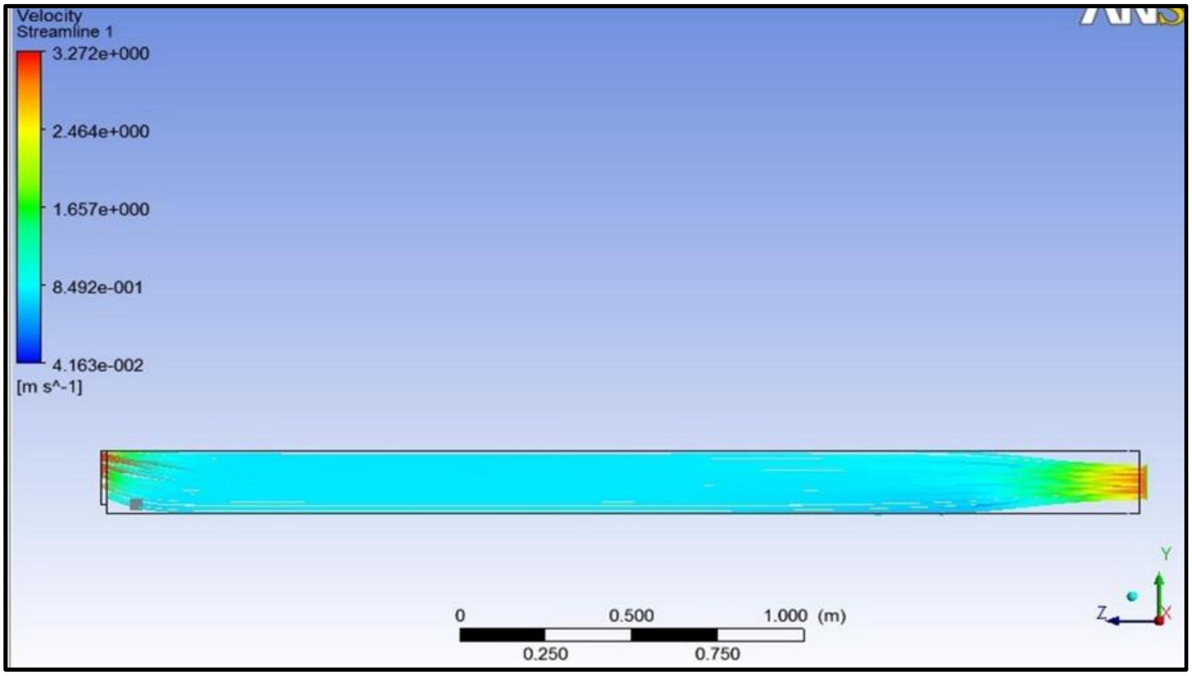


Figure 4.8 : Backflow Effect on Weir H170D15 H110D60

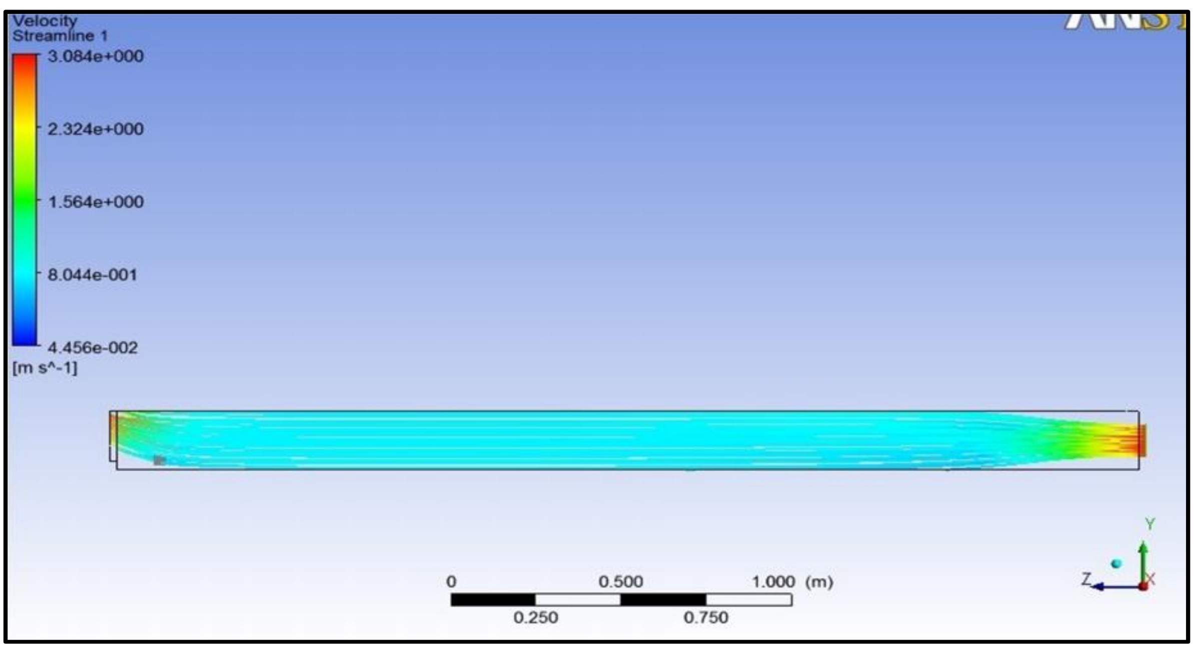


Figure 4.9 : Backflow Effect on Weir H170D15 H130D60

The results of backflow acting on the VV notch weir are then organized in the table 4.3 below. Table show the percentage difference between an opening area and the distance of backflow effect acting on the VV notch thin plate weir.

Table 4.3 : Table of Backflow Effect Acting on Each Type of Weirs.

No	Types of Weir	Opening Area (m^2)	Distance of Backflow Effect (m)	Percentage of Backflow effect in flume (%)
1	H90D15 H60D60	0.00223195	0.14504	4.83
2	H120D22.5 H50D90	0.00371668	0.13706	4.57
3	H110D15 H50D120	0.00484306	0.13475	4.49
4	H140D22.5 H170D90	0.00611668	0.13238	4.41
5	H170D15 H110D60	0.00759988	0.1257	4.19
6	H170D15 H130D60	0.01003008	0.08583	2.86

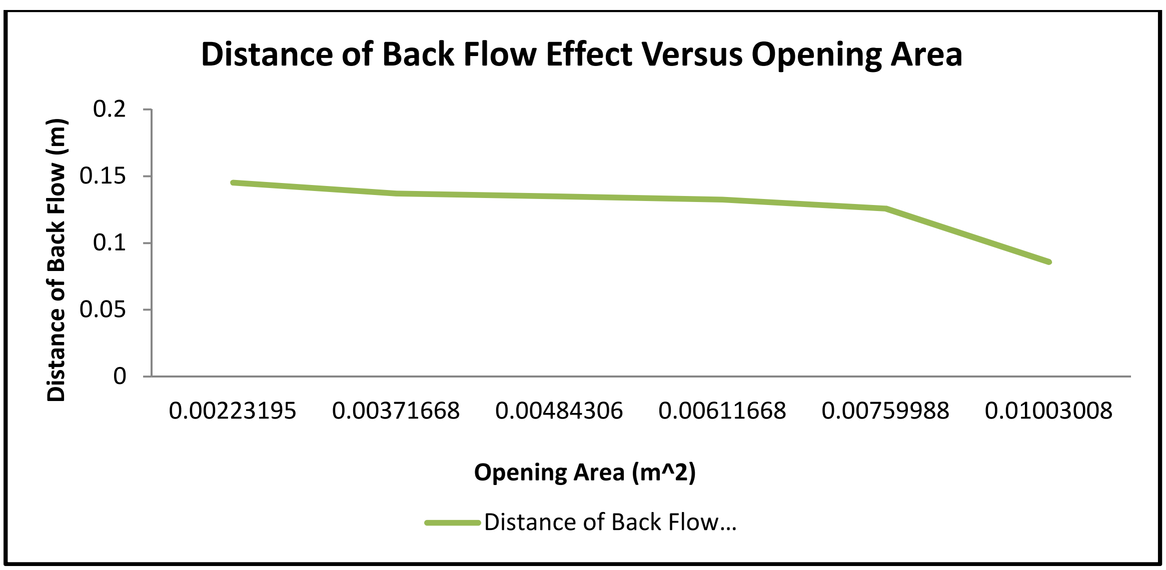


Figure 4.10 : Graph of Backflow Effect Versus Opening Area.

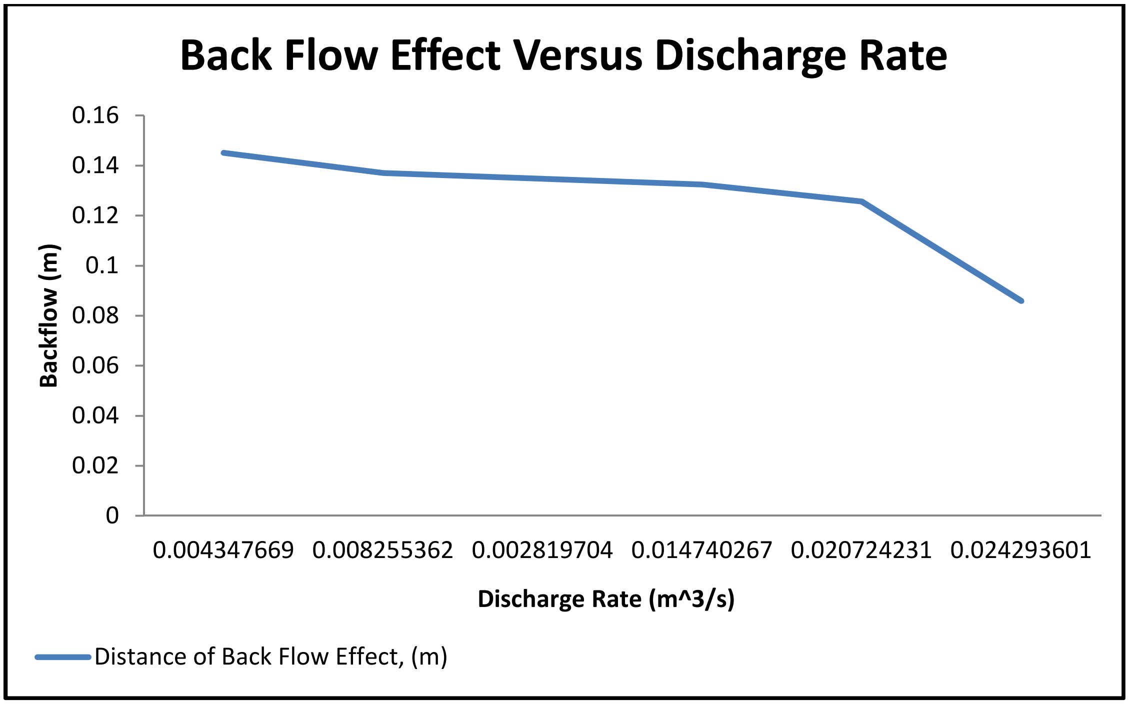


Figure 4.11 : Graph of Backflow Effect Versus Discharge Rate.

Based on the Figure 4.11 above, back flow acting proportial to the opening area of the outlet. If the opening area of VV notch thin plate weir increase, the backflow will decrease.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 INTRODUCTION

This chapter summarized the conclusion and recommendation for the project based on computational fluid dynamic analysis.

5.2 CONCLUSION

A compound thin plate weir composed of two triangular parts with different notch angles has been calculated and analyzed to provide accurate measurement for the discharge flow rate and backflow effect. The new equation derived in this study is acceptable to measure the discharge flow rate through VV notch thin plate weir since it shows the similarity curve pattern. From six of VV notch weir design analyzed, the most suitable design to use is type H170D15 H 130D60. The largest opening areas in this design give the highest discharged flow rate. This design also gives the lowest backflow effect, 2.86% backflow effect along the flume test section show that the usage of the thin plate principle does not affect the flow characteristic along the flume.

5.3 RECOMMENDATION

There are still scopes for further study to improve the optimization analysis. The recommendations are as follows:

(i) The thin plate weir can be designed sharp-crested. It can be done to study more about water nappe behavior through the thin plate weir.

(ii) The new equation can be derive to achieve more appropriate water discharge value. To make sure that the new equation are accurate, curve or new equation have to be compare to the existing equation from Martinez and Paritheepan method.

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APPENDIX A1

DERIVATION OF V NOTCH THIN PLATE WEIR

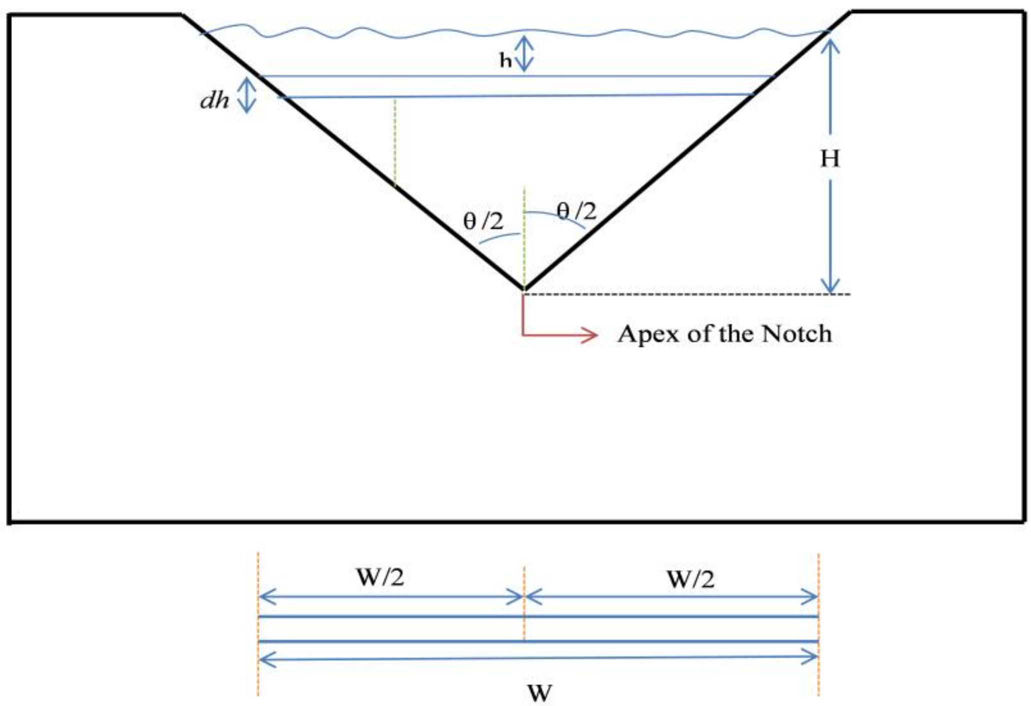

Figure 3.8 : Parameter Considered for Single V Notch Weir

Let,

- H = Water height above the apex of the notch.
- θ = Angle of the notch.
- C_d = Coefficient of Discharge

From the geometry of the figure, we find that the width of the notch at the water surface given by the equation,

$$\tan\frac{-}{2} = \frac{1}{2}w$$

$$w = 2(H-h)\tan\frac{-}{2}$$

Area of the strip is,

$$A = w \times dh$$

$$A = \left[2(H-h)\tan\frac{-}{2}\right] \bullet dh$$

The theoretical velocity of water through strip is [#],

$$v = \sqrt{2gh}$$

Discharge over the notch,

$$dq = \text{Coefficient of Discharge} \times \text{Area of Strip} \times \text{Theoretical Velocity}$$

$$dq = C_d \times \left[2(H-h)\tan\frac{-}{2}\right] \bullet dh \times \sqrt{2gh}$$

Total discharge of water over the notch;

$$Q = \int_0^H dq$$

$$Q = \int_0^H C_d \times \left[2(H-h)\tan\frac{-}{2}\right] \bullet dh \times \sqrt{2gh}$$

Re-arrange;

$$Q = 2C_d \times \sqrt{2g} \times \tan\frac{-}{2} \int_0^H (H - h)\sqrt{h} \times dh$$

$$Q = 2C_d \times \sqrt{2g} \times \tan\frac{-}{2} \int_0^H (H - h) h^{\frac{1}{2}} \times dh$$

$$Q = 2C_d \times \sqrt{2g} \times \tan\frac{-}{2} \int_0^H \left(H h^{\frac{1}{2}} - h^{\frac{3}{2}} \right) \times dh$$

$$Q = 2C_d \times \sqrt{2g} \times \tan\frac{-}{2} \left[\frac{2}{3} H h^{\frac{3}{2}} - \frac{2}{5} h^{\frac{5}{2}} \right]_0^H$$

$$Q = 2C_d \times \sqrt{2g} \times \tan\frac{-}{2} \left(\frac{2}{3} H^{\frac{5}{2}} - \frac{2}{5} H^{\frac{5}{2}} \right)$$

$$Q = 2C_d \times \sqrt{2g} \times \tan\frac{-}{2} \left(\frac{4}{15} H^{\frac{5}{2}} \right)$$

$$\therefore Q = \frac{8}{15} \times C_d \times \sqrt{2g} \times \tan\frac{-}{2} \times H^{\frac{5}{2}}$$

APPENDIX A2

DERIVATION OF RECTANGULAR THIN PLATE WEIR

Consider a rectangular notch is located at the outlet of the flume which water is flowing over the notch as shown in Figure 3.9 below.

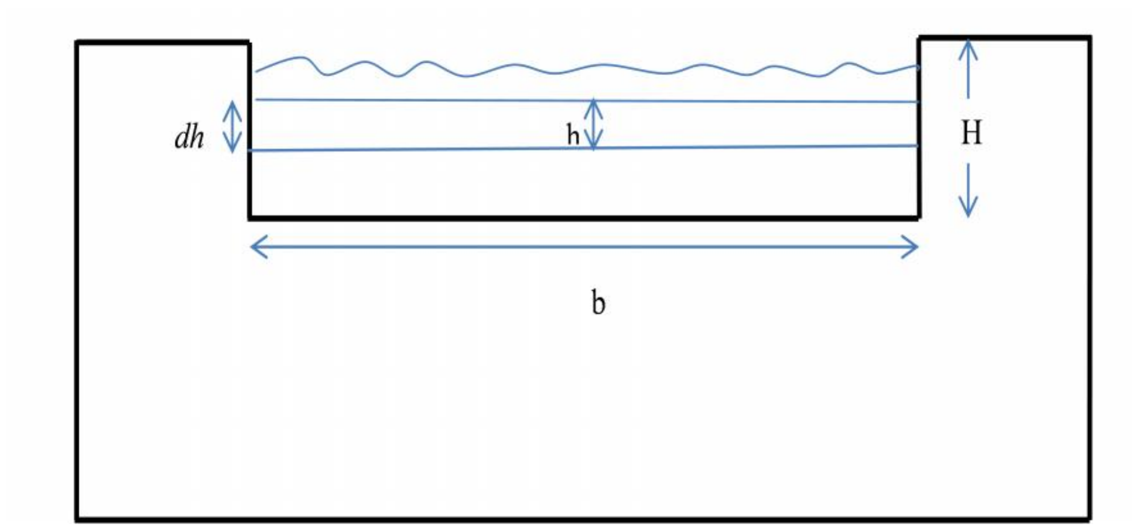

Figure 3.9 : Parameters Considered for Rectangular Thin Plate Weir

Let,

- H = Height of water above sill of notch.
- b = Width or length of the notch.
- C_d = Coefficient of Discharge.

Let consider a horizontal strip of water of thickness *dh* at the depth of *h* from the water level as shown in figure,

Area of the strip is,

$$A = b \times dh$$

The theoretical velocity of water through the strip,

$$v = \sqrt{2gh}$$

Discharge through the strip,

dq = Coefficient of Discharge × Area of The Strip × Theoritical Velocity

$$dq = C_d \times bdh \times \sqrt{2gh}$$

The total discharge over the whole notch may be found out by integrating the above equation within the limits 0 and H.

$$Q = \int_0^H C_d \times b \times dh \times \sqrt{2gh}$$

$$Q = C_d \times b \times \sqrt{2g} \times \int_0^H h^{\frac{1}{2}} \times dh$$

$$\therefore Q = \frac{2}{3} \times C_d \times b \times \sqrt{2g} \times (H)^{\frac{3}{2}}$$

APPENDIX A3

NEW DERIVATION METHOD OF VV NOTCH TRIANGULAR WEIR

The new equation method is proposed to estimate the flow over the compound weirs which are presented in the following sections. The derivation of new methods for VV Notch thin plate weir is shown below.

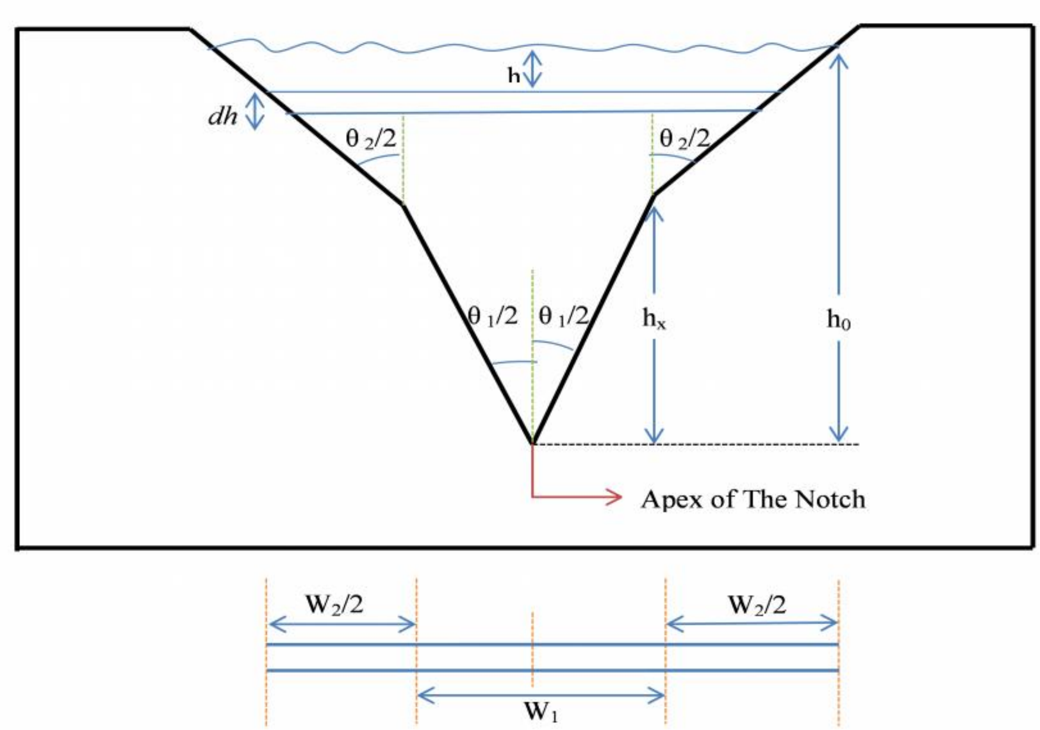

Figure 3.10 : Parameters Considered for Double Triangular VV Notch Thin Plate Weir

Consider a triangular VV Notch Thin Plate Weir located at the outlet of flume where water is flowing over as shown in figure 3.8.

Let,

- h_0 = Water height above the apex of lower notch.
- h_x = Height between intersection of two notches and apex of lower notch.
- θ = Angle of Notch
- C_d = Coefficient of Discharge.

From the geometry of the Figure 3.8, we find that the width of the VV notch at the water surface is given by the equation,

a) $$\tan\frac{\theta_1}{2} = \frac{w_1/2}{h_x}$$

$$\frac{w_1}{2} = h_x \tan\frac{\theta_1}{2}$$

$$w_1 = 2\left(h_x \tan\frac{\theta_1}{2}\right)$$

b) $$\tan\frac{\theta_2}{2} = \frac{w_2/2}{(h_0 - h_x)}$$

$$\frac{w_2}{2} = (h_0 - h_x - h)\tan\frac{\theta_2}{2}$$

$$w_2 = 2\left[(h_0 - h_x - h)\tan\frac{\theta_2}{2}\right]$$

c) $b = w_1$

$$w_1 = 2\left(h_x \tan\frac{\theta_1}{2}\right)$$

Area of the strip is,

$$A = (2w_1 + w_1)\times dh$$

$$A=\left[2\left(2h_x \tan\frac{\bar{\ }_1}{2}\right)+2\left[\left(h_0-h_x-h\right)\tan\frac{\bar{\ }_2}{2}\right]\right]\times dh$$

Discharge over the notch,

dq = Coefficient of Discharge × Area of The Strip × Theoritical Velocity

$$dq=C_d\times\left[2\left(2h_x \tan\frac{\bar{\ }_1}{2}\right)+2\left(\left(h_0-h_x-h\right)\tan\frac{\bar{\ }_2}{2}\right)\right]\times dh\times\sqrt{2gh}$$

Total Discharge of water over the notch,

$$Q=\int_0^{h_0} dq$$

$$Q=C_d\times\left[2\left(2h_0 \tan\frac{\bar{\ }_1}{2}\right)+2\left(\left(h_0-h_x-h\right)\tan\frac{\bar{\ }_2}{2}\right)\right]\times dh\times\sqrt{2gh}$$

Re-arrange;

$$Q=\int_0^{h_0}\left(2C_{d_1}\times\sqrt{2gh}\times 2h_0 \tan\frac{\bar{\ }_1}{2}\times dh\right)+\int_0^{h_0}\left(2C_{d_2}\times\sqrt{2gh}\times\left(h_0-h_x-h\right)\tan\frac{\bar{\ }_2}{2}\times dh\right)$$

$$Q=2C_{d_1}\times\sqrt{2g}\times\tan\frac{\bar{\ }_1}{2}\bullet\int_0^{h_0}2h_0\times h^{\frac{1}{2}}\times dh+2C_{d_2}\times\sqrt{2g}\times\tan\frac{\bar{\ }_2}{2}\bullet\int_0^{h_0}\left(h_0-h_x-h\right)\times h^{\frac{1}{2}}\times dh$$

$$Q=2C_{d_1}\times\sqrt{2g}\times\tan\frac{\bar{\ }_1}{2}\bullet\int_0^{h_0}2h_0\times h^{\frac{1}{2}}\times dh+2C_{d_2}\times\sqrt{2g}\times\tan\frac{\bar{\ }_2}{2}\bullet\int_0^{h_0}h_0h^{\frac{1}{2}}-h_xh^{\frac{1}{2}}-h^{\frac{3}{2}}\times dh$$

$$Q=2C_{d_1}\times\sqrt{2g}\times\tan\frac{\bar{\ }_1}{2}\bullet\left[2\left(\frac{2}{3}h_0h^{\frac{3}{2}}\right)\right]_0^{h_0}+2C_{d_2}\times\sqrt{2g}\times\tan\frac{\bar{\ }_2}{2}\bullet\left[\frac{2}{3}h_0h^{\frac{3}{2}}-\frac{2}{3}h_xh^{\frac{3}{2}}-\frac{2}{5}h^{\frac{5}{2}}\right]_0^{h_0}$$

$$Q = 2C_{d_1} \times \sqrt{2g} \times \tan\frac{-_{1}}{2} \bullet \left(2\left(\frac{2}{3}h_0^{\frac{5}{2}}\right)\right) + 2C_{d_2} \times \sqrt{2g} \times \tan\frac{-_{2}}{2} \bullet \left(\frac{2}{3}h_0^{\frac{5}{2}} - \frac{2}{3}h_x h_0^{\frac{3}{2}} - \frac{2}{5}h_0^{\frac{5}{2}}\right)$$

$$Q = 2C_{d_1} \times \sqrt{2g} \times \tan\frac{-_{1}}{2} \bullet \left(\frac{8}{3}h_0^{\frac{5}{2}}\right) + 2C_{d_2} \times \sqrt{2g} \times \tan\frac{-_{2}}{2} \bullet \left(\frac{4}{15}h_0^{\frac{5}{2}} - \frac{2}{3}h_x h_0^{\frac{3}{2}}\right)$$

$$\therefore Q = \frac{16}{3}C_{d_1}\sqrt{2g}\tan\frac{-_{1}}{2}h_0^{\frac{5}{2}} + \frac{8}{15}C_{d_2}\sqrt{2g}\tan\frac{-_{2}}{2}h_0^{\frac{5}{2}} - \frac{4}{3}C_{d_2}\sqrt{2g}\tan\frac{-_{2}}{2}h_x h_0^{\frac{3}{2}}$$

APEENDIX A4

TABBLE OF POSSIBLE DESIGN DATA

No	Type of Weir	Weir V-Notch 1		Weir V-Notch 2	
		Head 1, H_1 (m)	Degree (θ_1)	Head 2, H_2 (m)	Degree (θ_2)
1	H180D15 H160D22.5	0.18	15	0.16	22.5
2	H180D15 H160D30	0.18	15	0.16	30
3	H180D15 H160D45	0.18	15	0.16	45
4	H180D15 H160D60	0.18	15	0.16	60
5	H180D22.5 H160D30	0.18	22.5	0.16	30
6	H180D22.5 H160D45	0.18	22.5	0.16	45
7	H180D22.5 H160D60	0.18	22.5	0.16	60
8	H180D30 H160D45	0.18	30	0.16	45
9	H180D30 H160D60	0.18	30	0.16	60
10	H180D30 H160D90	0.18	30	0.16	90
11	H180D45 H160D60	0.18	45	0.16	60
12	H180D15 H150D30	0.18	15	0.15	30
13	H180D15 H150D45	0.18	15	0.15	45
14	H180D15 H150D60	0.18	15	0.15	60
15	H180D22.5 H150D30	0.18	22.5	0.15	30
16	H180D22.5 H150D45	0.18	22.5	0.15	45
17	H180D22.5 H150D60	0.18	22.5	0.15	60
18	H180D30 H150D60	0.18	30	0.15	60
19	H180D45 H150D60	0.18	45	0.15	60
20	H180D15 H140D30	0.18	15	0.14	30
21	H180D15 H140D45	0.18	15	0.14	45
22	H180D15 H140D60	0.18	15	0.14	60
23	H180D22.5 H140D30	0.18	22.5	0.14	30
24	H180D22.5 H140D45	0.18	22.5	0.14	45
25	H180D22.5 H140D60	0.18	22.5	0.14	60
26	H180D30 H140D45	0.18	30	0.14	45
27	H180D30 H140D60	0.18	30	0.14	60
28	H180D45 H140D60	0.18	45	0.14	60
29	H180D15 H130D30	0.18	15	0.13	30
30	H180D15 H130D45	0.18	15	0.13	45
31	H180D15 H130D60	0.18	15	0.13	60
32	H180D22.5 H130D45	0.18	22.5	0.13	45

33	H180D22.5 H130D60	0.18	22.5	0.13	60
34	H180D30 H130D45	0.18	30	0.13	45
35	H180D30 H130D60	0.18	30	0.13	60
36	H180D15 H120D30	0.18	15	0.12	30
37	H180D15 H120D45	0.18	15	0.12	45
38	H180D15 H120D60	0.18	15	0.12	60
39	H180D22.5 H120D45	0.18	22.5	0.12	45
40	H180D22.5 H120D60	0.18	22.5	0.12	60
41	H180D30 H120D60	0.18	30	0.12	60
42	H180D15 H110D30	0.18	15	0.11	30
43	H180D15 H110D45	0.18	15	0.11	45
44	H180D15 H110D30	0.18	15	0.11	60
45	H180D22.5 H110D45	0.18	22.5	0.11	45
46	H180D22.5 H110D60	0.18	22.5	0.11	60
47	H180D30 H110D60	0.18	30	0.11	60
48	H180D15 H100D45	0.18	15	0.1	45
49	H180D15 H100D60	0.18	15	0.1	60
50	H180D15 H100D90	0.18	15	0.1	90
51	H180D22.5 H100D45	0.18	22.5	0.1	45
52	H180D22.5 H100D60	0.18	22.5	0.1	60
53	H180D22.5 H100D90	0.18	22.5	0.1	90
54	H180D30 H100D60	0.18	30	0.1	60
55	H180D30 H100D90	0.18	30	0.1	90
56	H180D45 H100D90	0.18	45	0.1	90
57	H180D15 H90D45	0.18	15	0.09	45
58	H180D15 H90D60	0.18	15	0.09	60
59	H180D15 H90D90	0.18	15	0.09	90
60	H180D22.5 H90D60	0.18	22.5	0.09	60
61	H180D22.5 H90D90	0.18	22.5	0.09	90
62	H180D30 H90D90	0.18	30	0.09	90
63	H180D15 H80D45	0.18	15	0.08	45
64	H180D15 H80D60	0.18	15	0.08	60
65	H180D15 H80D90	0.18	15	0.08	90
66	H180D22.5 H80D90	0.18	22.5	0.08	90
67	H180D30 H80D90	0.18	30	0.08	90
68	H180D15 H70D60	0.18	15	0.07	60
69	H180D15 H70D90	0.18	15	0.07	90
70	H180D22.5 H70D90	0.18	22.5	0.07	90
71	H180D15 H60D90	0.18	15	0.06	90
72	H180D22.5 H60D90	0.18	22.5	0.06	90

73	H180D15 H50D90	0.18	15	0.05	90
74	H180D15 H50D120	0.18	15	0.05	120
75	H180D22.5 H50D120	0.18	22.5	0.05	120
76	H170D15 H150D22.5	0.17	15	0.15	22.5
77	H170D15 H150D30	0.17	15	0.15	30
78	H170D15 H150D45	0.17	15	0.15	45
79	H170D15 H150D60	0.17	15	0.15	60
80	H170D22.5 H150D30	0.17	22.5	0.15	30
81	H170D22.5 H150D45	0.17	22.5	0.15	45
82	H170D22.5 H150D60	0.17	22.5	0.15	60
83	H170D30 H150D45	0.17	30	0.15	45
84	H170D30 H150D60	0.17	30	0.15	60
85	H170D45 H150D60	0.17	45	0.15	60
86	H170D15 H140D30	0.17	15	0.14	30
87	H170D15 H140D45	0.17	15	0.14	45
88	H170D15 H140D60	0.17	15	0.14	60
89	H170D22.5 H140D45	0.17	22.5	0.14	45
90	H170D22.5 H140D60	0.17	22.5	0.14	60
91	H170D30 H140D45	0.17	30	0.14	45
92	H170D30 H140D60	0.17	30	0.14	60
93	H170D45 H140D60	0.17	45	0.14	60
94	H170D15 H130D30	0.17	15	0.13	30
95	H170D15 H130D45	0.17	15	0.13	45
96	H170D15 H130D60	0.17	15	0.13	60
97	H170D22.5 H130D45	0.17	22.5	0.13	45
98	H170D22.5 H130D60	0.17	22.5	0.13	60
99	H170D30 H130D45	0.17	30	0.13	45
100	H170D30 H130D60	0.17	30	0.13	60
101	H170D15 H120D30	0.17	15	0.12	30
102	H170D15 H120D45	0.17	15	0.12	45
103	H170D15 H120D60	0.17	15	0.12	60
104	H170D22.5 H120D45	0.17	22.5	0.12	45
105	H170D22.5 H120D60	0.17	22.5	0.12	60
106	H170D30 H120D60	0.17	30	0.12	60
107	H170D15 H110D45	0.17	15	0.11	45
108	H170D15 H110D60	0.17	15	0.11	60
109	H170D22.5 H110D45	0.17	22.5	0.11	45
110	H170D22.5 H110D60	0.17	22.5	0.11	60
111	H170D30 H110D60	0.17	30	0.11	60
112	H170D15 H100D45	0.17	15	0.1	45

113	H170D15 H100D60	0.17	15	0.1	60
114	H170D15 H100D90	0.17	15	0.1	90
115	H170D22.5 H100D45	0.17	22.5	0.1	45
116	H170D22.5 H100D60	0.17	22.5	0.1	60
117	H170D22.5 H100D90	0.17	22.5	0.1	90
118	H170D30 H100D60	0.17	30	0.1	60
119	H170D30 H100D90	0.17	30	0.1	90
120	H170D45 H100D90	0.17	45	0.1	90
121	H170D15 H90D45	0.17	15	0.09	45
122	H170D15 H90D60	0.17	15	0.09	60
123	H170D15 H90D90	0.17	15	0.09	90
124	H170D22.5 H90D60	0.17	22.5	0.09	60
125	H170D22.5 H90D90	0.17	22.5	0.09	90
126	H170D30 H90D90	0.17	30	0.09	90
127	H170D45 H90D90	0.17	45	0.09	90
128	H170D15 H80D60	0.17	15	0.08	60
129	H170D15 H80D90	0.17	15	0.08	90
130	H170D22.5 H80D45	0.17	22.5	0.08	45
131	H170D22.5 H80D60	0.17	22.5	0.08	60
132	H170D22.5 H80D690	0.17	22.5	0.08	90
133	H170D30 H80D90	0.17	30	0.08	90
134	H170D15 H70D60	0.17	15	0.07	60
135	H170D15 H70D90	0.17	15	0.07	90
136	H170D22.5 H70D90	0.17	22.5	0.07	90
137	H170D30 H70D90	0.17	30	0.07	90
138	H170D15 H60D60	0.17	15	0.06	60
139	H170D15 H600D90	0.17	15	0.06	90
140	H170D22.5 H60D90	0.17	22.5	0.06	90
141	H170D15 H50D90	0.17	15	0.05	90
142	H170D15 H50D120	0.17	15	0.05	120
143	H170D22.5 H50D120	0.17	22.5	0.05	120
144	H170D30 H50D120	0.17	30	0.05	120
145	H160D15 H140D30	0.16	15	0.14	30
146	H160D15 H140D45	0.16	15	0.14	45
147	H160D15 H140D60	0.16	15	0.14	60
148	H160D22.5 H140D30	0.16	22.5	0.14	30
149	H160D22.5 H140D45	0.16	22.5	0.14	45
150	H160D22.5 H140D60	0.16	22.5	0.14	60
151	H160D30 H140D45	0.16	30	0.14	45
152	H160D30 H140D60	0.16	30	0.14	60

153	H160D45 H140D60	0.16	45	0.14	60
154	H160D15 H130D30	0.16	15	0.13	30
155	H160D15 H130D45	0.16	15	0.13	45
156	H160D15 H130D60	0.16	15	0.13	60
157	H160D22.5 H130D30	0.16	22.5	0.13	30
158	H160D22.5 H130D45	0.16	22.5	0.13	45
159	H160D22.5 H130D60	0.16	22.5	0.13	60
160	H160D30 H130D45	0.16	30	0.13	45
161	H160D30 H130D60	0.16	30	0.13	60
162	H160D45 H130D60	0.16	45	0.13	60
163	H160D15 H120D30	0.16	15	0.12	30
164	H160D15 H120D45	0.16	15	0.12	45
165	H160D15 H120D60	0.16	15	0.12	60
166	H160D22.5 H120D45	0.16	22.5	0.12	45
167	H160D22.5 H120D60	0.16	22.5	0.12	60
168	H160D30 H120D45	0.16	30	0.12	45
169	H160D30 H120D60	0.16	30	0.12	60
170	H160D15 H110D30	0.16	15	0.11	30
171	H160D15 H110D45	0.16	15	0.11	45
172	H160D15 H110D60	0.16	15	0.11	60
173	H160D22.5 H110D45	0.16	22.5	0.11	45
174	H160D22.5 H110D60	0.16	22.5	0.11	60
175	H160D30 H110D60	0.16	30	0.11	60
176	H160D15 H100D30	0.16	15	0.1	30
177	H160D15 H100D45	0.16	15	0.1	45
178	H160D15 H100D60	0.16	15	0.1	60
179	H160D15 H100D90	0.16	15	0.1	90
180	H160D22.5 H100D45	0.16	22.5	0.1	45
181	H160D22.5 H100D60	0.16	22.5	0.1	60
182	H160D22.5 H100D90	0.16	22.5	0.1	90
183	H160D30 H100D90	0.16	30	0.1	90
184	H160D45 H100D90	0.16	45	0.1	90
185	H160D15 H90D45	0.16	15	0.09	45
186	H160D15 H90D60	0.16	15	0.09	60
187	H160D15 H90D90	0.16	15	0.09	90
188	H160D22.5 H90D60	0.16	22.5	0.09	60
189	H160D22.5 H90D90	0.16	22.5	0.09	90
190	H160D30 H90D90	0.16	30	0.09	90
191	H160D45 H90D90	0.16	45	0.09	90
192	H160D15 H80D45	0.16	15	0.08	45

193	H160D15 H80D60	0.16	15	0.08	60
194	H160D15 H80D90	0.16	15	0.08	90
195	H160D22.5 H80D60	0.16	22.5	0.08	60
196	H160D22.5 H80D90	0.16	22.5	0.08	90
197	H160D30 H80D90	0.16	30	0.08	90
198	H160D15 H70D60	0.16	15	0.07	60
199	H160D15 H70D90	0.16	15	0.07	90
200	H160D22.5 H70D90	0.16	22.5	0.07	90
201	H160D30 H70D90	0.16	30	0.07	90
202	H160D15 H60D60	0.16	15	0.06	60
203	H160D15 H60D90	0.16	15	0.06	90
204	H160D22.5 H60D90	0.16	22.5	0.06	90
205	H160D15 H50D90	0.16	15	0.05	90
206	H160D15 H50D120	0.16	15	0.05	120
207	H160D22.5 H50D120	0.16	22.5	0.05	120
208	H160D30 H50D120	0.16	30	0.05	120
209	H160D15 H40D120	0.16	15	0.04	120
210	H160D22.5 H40D120	0.16	22.5	0.04	120
211	H150D15 H130D22.5	0.15	15	0.13	22.5
212	H150D15 H130D30	0.15	15	0.13	30
213	H150D15 H130D45	0.15	15	0.13	45
214	H150D15 H130D60	0.15	15	0.13	60
215	H150D22.5 H130D45	0.15	22.5	0.13	45
216	H150D22.5 H130D60	0.15	22.5	0.13	60
217	H150D30 H130D45	0.15	30	0.13	45
218	H150D30 H130D60	0.15	30	0.13	60
219	H150D45 H130D60	0.15	45	0.13	60
220	H150D15 H120D30	0.15	15	0.12	30
221	H150D15 H120D45	0.15	15	0.12	45
222	H150D15 H120D60	0.15	15	0.12	60
223	H150D22.5 H120D45	0.15	22.5	0.12	45
224	H150D22.5 H120D60	0.15	22.5	0.12	60
225	H150D30 H120D45	0.15	30	0.12	45
226	H150D30 H120D60	0.15	30	0.12	60
227	H150D30 H120D90	0.15	30	0.12	90
228	H150D15 H110D30	0.15	15	0.11	30
229	H150D15 H110D45	0.15	15	0.11	45
230	H150D15 H110D60	0.15	15	0.11	60
231	H150D22.5 H110D45	0.15	22.5	0.11	45
232	H150D22.5 H110D60	0.15	22.5	0.11	60

233	H150D30 H110D45	0.15	30	0.11	45
234	H150D30 H110D60	0.15	30	0.11	60
235	H150D15 H100D30	0.15	15	0.1	30
236	H150D15 H100D45	0.15	15	0.1	45
237	H150D15 H100D60	0.15	15	0.1	60
238	H150D15 H100D90	0.15	15	0.1	90
239	H150D22.5 H100D45	0.15	22.5	0.1	45
240	H150D22.5 H100D60	0.15	22.5	0.1	60
241	H150D22.5 H100D90	0.15	22.5	0.1	90
242	H150D30 H100D60	0.15	30	0.1	60
243	H150D30 H100D90	0.15	30	0.1	90
244	H150D45 H100D90	0.15	45	0.1	90
245	H150D60 H100D90	0.15	60	0.1	90
246	H150D15 H90D30	0.15	15	0.09	30
247	H150D15 H90D45	0.15	15	0.09	45
248	H150D15 H90D60	0.15	15	0.09	60
249	H150D15 H90D90	0.15	15	0.09	90
250	H150D22.5 H90D45	0.15	22.5	0.09	45
251	H150D22.5 H90D60	0.15	22.5	0.09	60
252	H150D22.5 H90D90	0.15	22.5	0.09	90
253	H150D30 H90D60	0.15	30	0.09	60
254	H150D30 H90D90	0.15	30	0.09	90
255	H150D45 H90D90	0.15	45	0.09	90
256	H150D15 H80D45	0.15	15	0.08	45
257	H150D15 H80D60	0.15	15	0.08	60
258	H150D15 H80D90	0.15	15	0.08	90
259	H150D22.5 H80D60	0.15	22.5	0.08	60
260	H150D22.5 H80D90	0.15	22.5	0.08	90
261	H150D30 H80D90	0.15	30	0.08	90
262	H150D45 H80D90	0.15	45	0.08	90
263	H150D15 H70D45	0.15	15	0.07	45
264	H150D15 H70D60	0.15	15	0.07	60
265	H150D15 H70D90	0.15	15	0.07	90
266	H150D22.5 H70D90	0.15	22.5	0.07	90
267	H150D30 H70D90	0.15	30	0.07	90
268	H150D15 H60D60	0.15	15	0.06	60
269	H150D15 H60D90	0.15	15	0.06	90
270	H150D22.5 H60D90	0.15	22.5	0.06	90
271	H150D15 H50D90	0.15	15	0.05	90
272	H150D15 H50D120	0.15	15	0.05	120

273	H150D22.5 H50D120	0.15	22.5	0.05	120
274	H150D30 H50D120	0.15	30	0.05	120
275	H150D15 H40D120	0.15	15	0.04	120
276	H140D15 H120D30	0.14	15	0.12	30
277	H140D15 H120D45	0.14	15	0.12	45
278	H140D15 H120D60	0.14	15	0.12	60
279	H140D22.5 H120D45	0.14	22.5	0.12	45
280	H140D22.5 H120D60	0.14	22.5	0.12	60
281	H140D30 H120D45	0.14	30	0.12	45
282	H140D30 H120D60	0.14	30	0.12	60
283	H140D45 H120D60	0.14	45	0.12	60
284	H140D15 H110D30	0.14	15	0.11	30
285	H140D15 H110D45	0.14	15	0.11	45
286	H140D15 H110D60	0.14	15	0.11	60
287	H140D22.5 H110D45	0.14	22.5	0.11	45
288	H140D22.5 H110D60	0.14	22.5	0.11	60
289	H140D30 H110D45	0.14	30	0.11	45
290	H140D30 H110D60	0.14	30	0.11	60
291	H140D45 H110D60	0.14	45	0.11	60
292	H140D15 H100D30	0.14	15	0.1	30
293	H140D15 H100D45	0.14	15	0.1	45
294	H140D15 H100D60	0.14	15	0.1	60
295	H140D15 H100D90	0.14	15	0.1	90
296	H140D22.5 H100D45	0.14	22.5	0.1	45
297	H140D22.5 H100D60	0.14	22.5	0.1	60
298	H140D22.5 H100D90	0.14	22.5	0.1	90
299	H140D30 H100D60	0.14	30	0.1	60
300	H140D30 H100D90	0.14	30	0.1	90
301	H140D45 H100D90	0.14	45	0.1	90
302	H140D60 H100D90	0.14	60	0.1	90
303	H140D15 H90D30	0.14	15	0.09	30
304	H140D15 H90D45	0.14	15	0.09	45
305	H140D15 H90D60	0.14	15	0.09	60
306	H140D15 H90D90	0.14	15	0.09	90
307	H140D22.5 H90D45	0.14	22.5	0.09	45
308	H140D22.5 H90D60	0.14	22.5	0.09	60
309	H140D22.5 H90D90	0.14	22.5	0.09	90
310	H140D30 H90D60	0.14	30	0.09	60
311	H140D30 H90D90	0.14	30	0.09	90
312	H140D45 H90D90	0.14	45	0.09	90

313	H140D15 H80D45	0.14	15	0.08	45
314	H140D15 H80D60	0.14	15	0.08	60
315	H140D15 H80D90	0.14	15	0.08	90
316	H140D22.5 H80D60	0.14	22.5	0.08	60
317	H140D22.5 H80D90	0.14	22.5	0.08	90
318	H140D30 H80D90	0.14	30	0.08	90
319	H140D45 H80D90	0.14	45	0.08	90
320	H140D15 H70D45	0.14	15	0.07	45
321	H140D15 H70D60	0.14	15	0.07	60
322	H140D15 H70D90	0.14	15	0.07	90
323	H140D22.5 H70D60	0.14	22.5	0.07	60
324	H140D22.5 H70D90	0.14	22.5	0.07	90
325	H140D30 H70D90	0.14	30	0.07	90
326	H140D15 H60D60	0.14	15	0.06	60
327	H140D15 H60D90	0.14	15	0.06	90
328	H140D22.5 H60D90	0.14	22.5	0.06	90
329	H140D30 H60D90	0.14	30	0.06	90
330	H140D15 H50D90	0.14	15	0.05	90
331	H140D15 H50D120	0.14	15	0.05	120
332	H140D22.5 H50D120	0.14	22.5	0.05	120
333	H140D30 H50D120	0.14	30	0.05	120
334	H130D15 H110D30	0.13	15	0.11	30
335	H130D15 H110D45	0.13	15	0.11	45
336	H130D15 H110D60	0.13	15	0.11	60
337	H130D22.5 H110D45	0.13	22.5	0.11	45
338	H130D22.5 H110D60	0.13	22.5	0.11	60
339	H130D30 H110D45	0.13	30	0.11	45
340	H130D30 H110D60	0.13	30	0.11	60
341	H130D45 H110D60	0.13	45	0.11	60
342	H130D15 H100D30	0.13	15	0.1	30
343	H130D15 H100D45	0.13	15	0.1	45
344	H130D15 H100D60	0.13	15	0.1	60
345	H130D15 H100D90	0.13	15	0.1	90
346	H130D22.5 H100D45	0.13	22.5	0.1	45
347	H130D22.5 H100D60	0.13	22.5	0.1	60
348	H130D22.5 H100D90	0.13	22.5	0.1	90
349	H130D30 H100D45	0.13	30	0.1	45
350	H130D30 H100D60	0.13	30	0.1	60
351	H130D30 H100D90	0.13	30	0.1	90
352	H130D45 H100D90	0.13	45	0.1	90

353	H130D60 H100D90	0.13	60	0.1	90
354	H130D15 H90D30	0.13	15	0.09	30
355	H130D15 H90D45	0.13	15	0.09	45
356	H130D15 H90D60	0.13	15	0.09	60
357	H130D15 H90D90	0.13	15	0.09	90
358	H130D22.5 H90D45	0.13	22.5	0.09	45
359	H130D22.5 H90D60	0.13	22.5	0.09	60
360	H130D22.5 H90D90	0.13	22.5	0.09	90
361	H130D30 H90D60	0.13	30	0.09	60
362	H130D30 H90D90	0.13	30	0.09	90
363	H130D45 H90D90	0.13	45	0.09	90
364	H130D60 H90D90	0.13	60	0.09	90
365	H130D15 H80D30	0.13	15	0.08	30
366	H130D15 H80D45	0.13	15	0.08	45
367	H130D15 H80D60	0.13	15	0.08	60
368	H130D15 H80D90	0.13	15	0.08	90
369	H130D22.5 H80D45	0.13	22.5	0.08	45
370	H130D22.5 H80D60	0.13	22.5	0.08	60
371	H130D22.5 H80D90	0.13	22.5	0.08	90
372	H130D30 H80D60	0.13	30	0.08	60
373	H130D30 H80D90	0.13	30	0.08	90
374	H130D45 H80D90	0.13	45	0.08	90
375	H130D15 H70D45	0.13	15	0.07	45
376	H130D15 H70D60	0.13	15	0.07	60
377	H130D15 H70D90	0.13	15	0.07	90
378	H130D22.5 H70D60	0.13	22.5	0.07	60
379	H130D22.5 H70D90	0.13	22.5	0.07	90
380	H130D30 H70D90	0.13	30	0.07	90
381	H130D15 H60D60	0.13	15	0.06	60
382	H130D15 H60D90	0.13	15	0.06	90
383	H130D22.5 H60D90	0.13	22.5	0.06	90
384	H130D30 H60D90	0.13	30	0.06	90
385	H130D15 H50D90	0.13	15	0.05	90
386	H130D15 H50D120	0.13	15	0.05	120
387	H130D22.5 H50D90	0.13	22.5	0.05	90
388	H130D22.5 H50D120	0.13	22.5	0.05	120
389	H130D30 H50D120	0.13	30	0.05	120
390	H130D15 H40D120	0.13	15	0.04	120
391	H120D15 H100D30	0.12	15	0.1	30
392	H120D15 H100D45	0.12	15	0.1	45

393	H120D15 H100D60	0.12	15	0.1	60
394	H120D15 H100D90	0.12	15	0.1	90
395	H120D22.5 H100D45	0.12	22.5	0.1	45
396	H120D22.5 H100D60	0.12	22.5	0.1	60
397	H120D22.5 H100D90	0.12	22.5	0.1	90
398	H120D30 H100D45	0.12	30	0.1	45
399	H120D30 H100D60	0.12	30	0.1	60
400	H120D30 H100D90	0.12	30	0.1	90
401	H120D45 H100D60	0.12	45	0.1	60
402	H120D45 H100D90	0.12	45	0.1	90
403	H120D60 H100D90	0.12	60	0.1	90
404	H120D15 H90D30	0.12	15	0.09	30
405	H120D15 H90D45	0.12	15	0.09	45
406	H120D15 H90D60	0.12	15	0.09	60
407	H120D15 H90D90	0.12	15	0.09	90
408	H120D22.5 H90D60	0.12	22.5	0.09	60
409	H120D22.5 H90D90	0.12	22.5	0.09	90
410	H120D30 H90D45	0.12	30	0.09	45
411	H120D30 H90D60	0.12	30	0.09	60
412	H120D30 H90D90	0.12	30	0.09	90
413	H120D45 H90D90	0.12	45	0.09	90
414	H120D60 H90D90	0.12	60	0.09	90
415	H120D15 H80D30	0.12	15	0.08	30
416	H120D15 H80D45	0.12	15	0.08	45
417	H120D15 H80D60	0.12	15	0.08	60
418	H120D15 H80D90	0.12	15	0.08	90
419	H120D22.5 H80D45	0.12	22.5	0.08	45
420	H120D22.5 H80D60	0.12	22.5	0.08	60
421	H120D22.5 H80D90	0.12	22.5	0.08	90
422	H120D30 H80D60	0.12	30	0.08	60
423	H120D30 H80D90	0.12	30	0.08	90
424	H120D45 H80D90	0.12	45	0.08	90
425	H120D15 H70D45	0.12	15	0.07	45
426	H120D15 H70D60	0.12	15	0.07	60
427	H120D15 H70D90	0.12	15	0.07	90
428	H120D22.5 H70D60	0.12	22.5	0.07	60
429	H120D22.5 H70D90	0.12	22.5	0.07	90
430	H120D30 H70D90	0.12	30	0.07	90
431	H120D45 H70D90	0.12	45	0.07	90
432	H120D15 H60D45	0.12	15	0.06	45

433	H120D15 H60D60	0.12	15	0.06	60
434	H120D15 H60D90	0.12	15	0.06	90
435	H120D22.5 H60D90	0.12	22.5	0.06	90
436	H120D30 H60D90	0.12	30	0.06	90
437	H120D15 H50D90	0.12	15	0.05	90
438	H120D15 H50D120	0.12	15	0.05	120
439	H120D22.5 H50D90	0.12	22.5	0.05	90
440	H120D22.5 H50D120	0.12	22.5	0.05	120
441	H120D30 H50D120	0.12	30	0.05	120
442	H120D15 H40D120	0.12	15	0.04	120
443	H110D15 H90D30	0.11	15	0.09	30
444	H110D15 H90D45	0.11	15	0.09	45
445	H110D15 H90D60	0.11	15	0.09	60
446	H110D15 H90D90	0.11	15	0.09	90
447	H110D22.5 H90D45	0.11	22.5	0.09	45
448	H110D22.5 H90D60	0.11	22.5	0.09	60
449	H110D22.5 H90D90	0.11	22.5	0.09	90
450	H110D30 H90D45	0.11	30	0.09	45
451	H110D30 H90D60	0.11	30	0.09	60
452	H110D30 H90D90	0.11	30	0.09	90
453	H110D45 H90D90	0.11	45	0.09	90
454	H110D60 H90D90	0.11	60	0.09	90
455	H110D15 H80D30	0.11	15	0.08	30
456	H110D15 H80D45	0.11	15	0.08	45
457	H110D15 H80D60	0.11	15	0.08	60
458	H110D15 H80D90	0.11	15	0.08	90
459	H110D22.5 H80D45	0.11	22.5	0.08	45
460	H110D22.5 H80D60	0.11	22.5	0.08	60
461	H110D22.5 H80D90	0.11	22.5	0.08	90
462	H110D30 H80D60	0.11	30	0.08	60
463	H110D30 H80D90	0.11	30	0.08	90
464	H110D45 H80D90	0.11	45	0.08	90
465	H110D60 H80D90	0.11	60	0.08	90
466	H110D15 H70D45	0.11	15	0.07	45
467	H110D15 H70D60	0.11	15	0.07	60
468	H110D15 H70D90	0.11	15	0.07	90
469	H110D22.5 H70D45	0.11	22.5	0.07	45
470	H110D22.5 H70D60	0.11	22.5	0.07	60
471	H110D22.5 H70D90	0.11	22.5	0.07	90
472	H110D22.5 H70D60	0.11	22.5	0.07	60

473	H110D22.5 H70D90	0.11	22.5	0.07	90
474	H110D22.5 H70D90	0.11	22.5	0.07	90
475	H110D15 H60D45	0.11	15	0.06	45
476	H110D15 H60D60	0.11	15	0.06	60
477	H110D15 H60D90	0.11	15	0.06	90
478	H110D22.5 H60D60	0.11	22.5	0.06	60
479	H110D22.5 H60D90	0.11	22.5	0.06	90
480	H110D30 H60D90	0.11	30	0.06	90
481	H110D15 H50D60	0.11	15	0.05	60
482	H110D15 H50D90	0.11	15	0.05	90
483	H110D15 H50D120	0.11	15	0.05	120
484	H110D22.5 H50D90	0.11	22.5	0.05	90
485	H110D22.5 H50D120	0.11	22.5	0.05	120
486	H110D30 H50D120	0.11	30	0.05	120
487	H110D45 H50D120	0.11	45	0.05	120
488	H110D15 H40D120	0.11	15	0.04	120
489	H110D22.5 H40D120	0.11	22.5	0.04	120
490	H100D15 H80D30	0.1	15	0.08	30
491	H100D15 H80D45	0.1	15	0.08	45
492	H100D15 H80D60	0.1	15	0.08	60
493	H100D15 H80D90	0.1	15	0.08	90
494	H100D22.5 H80D45	0.1	22.5	0.08	45
495	H100D22.5 H80D60	0.1	22.5	0.08	60
496	H100D22.5 H80D90	0.1	22.5	0.08	90
497	H100D30 H80D60	0.1	30	0.08	60
498	H100D30 H80D90	0.1	30	0.08	90
499	H100D45 H80D90	0.1	45	0.08	90
500	H100D60 H80D90	0.1	60	0.08	90
501	H100D15 H70D45	0.1	15	0.07	45
502	H100D15 H70D60	0.1	15	0.07	60
503	H100D15 H70D90	0.1	15	0.07	90
504	H100D22.5 H70D45	0.1	22.5	0.07	45
505	H100D22.5 H70D60	0.1	22.5	0.07	60
506	H100D22.5 H70D90	0.1	22.5	0.07	90
507	H100D30 H70D60	0.1	30	0.07	60
508	H100D30 H70D90	0.1	30	0.07	90
509	H100D45 H70D90	0.1	45	0.07	90
510	H100D15 H60D45	0.1	15	0.06	45
511	H100D15 H60D60	0.1	15	0.06	60
512	H100D15 H60D90	0.1	15	0.06	90

513	H100D22.5 H60D60	0.1	22.5	0.06	60
514	H100D22.5 H60D90	0.1	22.5	0.06	90
515	H100D30 H60D60	0.1	30	0.06	60
516	H100D30 H60D90	0.1	30	0.06	90
517	H100D45 H60D90	0.1	45	0.06	90
518	H100D15 H50D60	0.1	15	0.05	60
519	H100D15 H50D90	0.1	15	0.05	90
520	H100D15 H50D120	0.1	15	0.05	120
521	H100D22.5 H50D90	0.1	22.5	0.05	90
522	H100D22.5 H50D120	0.1	22.5	0.05	120
523	H100D30 H50D90	0.1	30	0.05	90
524	H100D30 H50D120	0.1	30	0.05	120
525	H100D45 H50D120	0.1	45	0.05	120
526	H100D15 H40D90	0.1	15	0.04	90
527	H100D15 H40D120	0.1	15	0.04	120
528	H100D22.5 H40D120	0.1	22.5	0.04	120
529	H90D15 H70D30	0.09	15	0.07	30
530	H90D15 H70D45	0.09	15	0.07	45
531	H90D15 H70D60	0.09	15	0.07	60
532	H90D15 H70D90	0.09	15	0.07	90
533	H90D22.5 H70D45	0.09	22.5	0.07	45
534	H90D22.5 H70D60	0.09	22.5	0.07	60
535	H90D22.5 H70D90	0.09	22.5	0.07	90
536	H90D30 H70D60	0.09	30	0.07	60
537	H90D30 H70D90	0.09	30	0.07	90
538	H90D45 H70D90	0.09	45	0.07	90
539	H90D60 H70D90	0.09	60	0.07	90
540	H90D15 H60D30	0.09	15	0.06	30
541	H90D15 H60D45	0.09	15	0.06	45
542	H90D15 H60D60	0.09	15	0.06	60
543	H90D15 H60D90	0.09	15	0.06	90
544	H90D22.5 H60D45	0.09	22.5	0.06	45
545	H90D22.5 H60D60	0.09	22.5	0.06	60
546	H90D22.5 H60D90	0.09	22.5	0.06	90
547	H90D30 H60D60	0.09	30	0.06	60
548	H90D30 H60D90	0.09	30	0.06	90
549	H90D45 H60D90	0.09	45	0.06	90
550	H90D15 50HD45	0.09	15	0.05	45
551	H90D15 H50D60	0.09	15	0.05	60
552	H90D15 H50D90	0.09	15	0.05	90

553	H90D15 H50D120	0.09	15	0.05	120
554	H90D22.5 H50D90	0.09	22.5	0.05	90
555	H90D22.5 H50D120	0.09	22.5	0.05	120
556	H90D30 H50D90	0.09	30	0.05	90
557	H90D30 H50D120	0.09	30	0.05	120
558	H90D45 H50D120	0.09	45	0.05	120
559	H90D60 H50D120	0.09	60	0.05	120
560	H90D15 H40D90	0.09	15	0.04	90
561	H90D15 H40D120	0.09	15	0.04	120
562	H90D22.5 H40D120	0.09	22.5	0.04	120
563	H90D30 H40D120	0.09	30	0.04	120
564	H80D15 H60D30	0.08	15	0.06	30
565	H80D15 H60D45	0.08	15	0.06	45
566	H80D15 H60D60	0.08	15	0.06	60
567	H80D15 H60D90	0.08	15	0.06	90
568	H80D22.5 H60D45	0.08	22.5	0.06	45
569	H80D22.5 H60D60	0.08	22.5	0.06	60
570	H80D22.5 H60D90	0.08	22.5	0.06	90
571	H80D30 H60D60	0.08	30	0.06	60
572	H80D30 H60D90	0.08	30	0.06	90
573	H80D45 H60D90	0.08	45	0.06	90
574	H80D60 H60D90	0.08	60	0.06	90
575	H80D15 H50D45	0.08	15	0.05	45
576	H80D15 H50D60	0.08	15	0.05	60
577	H80D15 H50D90	0.08	15	0.05	90
578	H80D15 H50D120	0.08	15	0.05	120
579	H80D22.5 H50D60	0.08	22.5	0.05	60
580	H80D22.5 H50D90	0.08	22.5	0.05	90
581	H80D22.5 H50D120	0.08	22.5	0.05	120
582	H80D30 H50D90	0.08	30	0.05	90
583	H80D30 H50D120	0.08	30	0.05	120
584	H80D45 H50D120	0.08	45	0.05	120
585	H80D60 H50D120	0.08	60	0.05	120
586	H80D15 H40D90	0.08	15	0.04	90
587	H80D15 H40D120	0.08	15	0.04	120
588	H80D22.5 H40D90	0.08	22.5	0.04	90
589	H80D22.5 H40D120	0.08	22.5	0.04	120
590	H80D30 H40D120	0.08	30	0.04	120
591	H70D15 H50D30	0.07	15	0.05	30
592	H70D15 H50D45	0.07	15	0.05	45

593	H70D15 H50D60	0.07	15	0.05	60
594	H70D15 H50D90	0.07	15	0.05	90
595	H70D15 H50D120	0.07	15	0.05	120
596	H70D22.5 H50D45	0.07	22.5	0.05	45
597	H70D22.5 H50D60	0.07	22.5	0.05	60
598	H70D22.5 H50D90	0.07	22.5	0.05	90
599	H70D22.5 H50D120	0.07	22.5	0.05	120
600	H70D30 H50D60	0.07	30	0.05	60
601	H70D30 H50D90	0.07	30	0.05	90
602	H70D30 H50D120	0.07	30	0.05	120
603	H70D45 H50D90	0.07	45	0.05	90
604	H70D45 H50D120	0.07	45	0.05	120
605	H70D60 H50D120	0.07	60	0.05	120
606	H70D15 H40D60	0.07	15	0.04	60
607	H70D15 H40D90	0.07	15	0.04	90
608	H70D15 H40D120	0.07	15	0.04	120
609	H70D22.5 H40D90	0.07	22.5	0.04	90
610	H70D22.5 H40D120	0.07	22.5	0.04	120
611	H70D30 H40D90	0.07	30	0.04	90
612	H70D30 H40D120	0.07	30	0.04	120
613	H70D45 H40D120	0.07	45	0.04	120
614	H60D15 H40D45	0.06	15	0.04	45
615	H60D15 H40D60	0.06	15	0.04	60
616	H60D15 H40D90	0.06	15	0.04	90
617	H60D15 H40D120	0.06	15	0.04	120
618	H60D22.5 H40D90	0.06	22.5	0.04	90
619	H60D22.5 H40D120	0.06	22.5	0.04	120
620	H60D30 H40D90	0.06	30	0.04	90
621	H60D30 H40D120	0.06	30	0.04	120
622	H60D45 H40D120	0.06	45	0.04	120