COMPARATIVE STUDY BETWEEN TWO INDUSTRY-STANDARD FLOOD MODELLING SOFTWARE PACKAGES

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FACULTY OF ENGINEERING
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I, Pricynthia Biusti, declare that this dissertation is based on my original work and research, except for quotations, summaries and references taken from other resources, in which each and every source has been fully acknowledge.

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ABSTRACT

Flooding is amongst the most common natural disasters on the world. 1D modelling tools for hydraulic design make simplifying assumptions that may result in overly cautious, insufficient, or incorrect findings and conclusions. In the other hand, tools for 2D hydraulic modelling are widely accessible and continue to develop as technology develops. The Joint Defra (Department for Environmental, Food, and Rural Affairs) Environment Agency of the United Kingdom (UK) created a series of benchmark tests for 2D modelling as a result. The dataset for the test has been used in this project to compare the performances of HEC-RAS and RiverFlow2D. Total of three tests conducted in this project using HEC-RAS while the result for RiverFlow2D is obtained from previous researchers. Diffusion Wave Equation (DWE) and Shallow Water Equation (SWE) have been used in HEC-RAS to run the test. Based on the three tests, both software showed well performances in running the test include when using complicated terrain profile as the Data Elevation Model (DEM). However, when comparing the result obtained from both software, RiverFlow2D performed well than HEC-RAS. The succession of HEC-RAS and RiverFlow2D to run the test showed that both software can do the prediction and simulation of flooding.

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ABSTRAK

Banjir adalah antara bencana alam yang paling biasa di dunia. Alat pemodelan 1D untuk reka bentuk hidraulik membuat andaian mudah yang mungkin mengakibatkan penemuan dan kesimpulan yang terlalu berhati-hati, tidak mencukupi atau tidak betul. Sebaliknya, alatan untuk pemodelan hidraulik 2D boleh diakses secara meluas dan terus berkembang seiring dengan perkembangan teknologi. Agensi Alam Sekitar Defra Bersama (Jabatan bagi Alam Sekitar, Makanan dan Luar Bandar) United Kingdom (UK) mencipta satu siri ujian penanda aras untuk pemodelan 2D sebagai hasilnya. Dataset untuk ujian telah digunakan dalam projek ini untuk membandingkan prestasi HEC-RAS dan RiverFlow2D. Sebanyak tiga ujian dijalankan dalam projek ini menggunakan HEC-RAS manakala keputusan untuk RiverFlow2D diperoleh daripada penyelidik terdahulu. Diffusion Wave Equation (DWE) dan Shallow Water Equation (SWE) telah digunakan dalam HEC-RAS untuk menjalankan ujian. Berdasarkan tiga ujian tersebut, kedua-dua perisian menunjukkan prestasi yang baik dalam menjalankan ujian termasuk apabila menggunakan profil rupa bumi yang rumit sebagai Model Elevation Data (DEM). Walau bagaimanapun, apabila membandingkan hasil yang diperoleh daripada kedua-dua perisian, RiverFlow2D menunjukkan prestasi yang lebih baik daripada HEC-RAS. Keberhasilan HEC-RAS dan RiverFlow2D untuk menjalankan ujian menunjukkan bahawa kedua-dua perisian boleh melakukan ramalan dan simulasi banjir.

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Flooding is amongst the most common natural disasters on the world. Flooding results in material losses and disrupts social activities, which can impact on the city's low development in all areas (Prastica et al., 2018). Floods can be caused by human action. The national media reported that each year, the result of the flood disaster was significantly increased from previous flooding (Prastica et al., 2018).

Heavy rains that have been falling since 17th until 19th December 2021 have resulted in a series of floods and flash floods across Malaysia (ASEAN Coordinating Centre for Humanitarian Assistance, 2021). In Terengganu and Pahang (Peninsular Malaysia), Jabatan Meteorologi Malaysia (MET Malaysia) has issued the "Danger" warning which indicates continued heavy rain with rainfall above 240 mm/day, and "Severe" warning (continued heavy rain) in Kelantan (ASEAN Coordinating Centre for Humanitarian Assistance, 2021).

In 21st December 2021, the Malaysian Agensi Pengurusan Bencana (NADMA) reported 33 districts in 8 states impacted by floods, with a total of 62,999 people displaced in 430 evacuation centres including Perak, Selangor, Kuala Lumpur, Negeri Sembilan, Melaka, Kelantan, Terengganu, and Pahang (ASEAN Coordinating Centre for Humanitarian Assistance, 2021). Due to this flooding incident, all level of society, the economy and environment in this state have been impacted, as reported by the New Straits Times (2021). Damages to public infrastructure affected a far bigger percentage of the population than on the people's homes or businesses (New Straits Times, 2021).

For years, government agencies that are involved with flood mitigation and management in Malaysia have been looking for the best solutions to flood problems. Eventually, it was discovered that mapping flood susceptibility zones and understanding the primary variables that trigger flood events is amongst the most

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effective and systematic way to anticipate and control floods (Dano et al., 2019). Flood modelling is one of the ways to do flood mapping. Generally, 2D models are more preferred than 1D models, as two-dimensional (2D) grids are used to represent surfaces compared to the one-dimensional (1D) surface network of channels used in the 1D model (Hankin et al. 2008; Leandro, 2009).

1.2 Problem Statement

Floods are one of the most common natural disasters, and they may be destructive to the ecosystem. Its consequences include infrastructure damage, livestock and agricultural destruction, and psychological trauma for the victims (Buslima et al., 2018). Numerous mitigations have been done to prevent or limit the damage due to flooding. As mentioned in the previous section, one of the said approaches is by using flood modelling.

Currently utilised 1D modelling tools for hydraulic design make simplifying assumptions that may result in overly cautious, insufficient, or incorrect findings and conclusions. An important presumption is that important hydraulic characteristics, such velocity and water surface elevation, are averaged at cross-sections and only fluctuate longitudinally (upstream/downstream). This oversimplification hides important details concerning true hydraulic behaviour in many circumstances. (Kramer, 2021).

Two-dimensional (2D) hydraulic flood models are an important tool for estimating flood risk and its effect (Neelz and Pender, 2013). On a grid or mesh, 2D flood modelling interprets the 2D equations of flow to determine the water depth and depth-averaged velocity. The flood flow predicted from these 2D models involves using digital terrain modelling and hydrographic of a water channel (Innovyze, 2020).

According to Collins English dictionary, industry standard is a company standard, practice, or guideline that has been set (Collins, 2022) while software packages mean a collection of code modules that combine to achieve a variety of aims and objectives (Techopedia, 2022). The term "software package" is frequently

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used to represent a collection of software that performs a specific task (Techopedia, 2022).

Custom flood models, developed with industry standard tools like TUFLOW, Flood Modeller Pro, and Infoworks, are widely used by the industrial communities to refine flood risk estimations (Aegaea, 2021). The 2D flood modelling packages benchmarking have been done by comparing several 2D model, for example TUFLOW, MIKE FLOOD, JFLOW, and ISIS Fast. The performances of the 2D models were often assessed by doing several benchmark tests approved for flood modelling applications such as the UK Environment Agency tests (Neelz and Pender, 2013). However, not all 2D models have undergone such comparison, like HEC-RAS and RiverFlow2D.

1.3 Objectives

The objectives of this final year project (FYP) are:

I. To compare the performance of HEC-RAS and RiverFlow2D based on each software results after running the test.

II. To determine benchmark tests for the comparison of these two industry flood models by seeing whether the software can run the tests or not.

III. To provide evidence to ensure that HEC-RAS and RiverFlow2D can accurately forecast the variables on which flood risk management decisions are based by referring on how the software react with the three different tests.

1.4 Scope of Work

This project will focus on the two industry-standard flood modelling software packages. The selected software packages are the Hydrologic Engineering Center's River Analysis System (HEC-RAS) and RiverFlow2D. Three tests will be conduct by using HEC-RAS and existing data of RiverFlow2D that related to the test will be taken

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so that the performances of this two software can be compared. The topic and purpose of the tests have been summarized into Table 1.1. Further information regarding to the tests will be discussed in Chapter 3 and 4.

Table 1.1: Summary of benchmark tests

Test Number	Description	Purpose
1	Flooding a disconnected water body	Evaluate the ability to simulate floods of unconnected water bodies in floodplains or along the coastline.
2	Filling of floodplain depressions	The capacity to anticipate the area of inundation and eventual flood depth for low velocity flow over complicated topographies is put to the test.
3	Momentum conservation over a small obstruction	Tests the ability to simulate flow over an obstruction with an adverse slope at relatively shallow depths.

Source: Neelz and Pender (2013)

1.5 Significance of Study

HEC-RAS and RiverFlow2D are two-dimensional (2D) models that have function to do the flood modelling. Benchmark test have been done by the developer of the software to test the software's performances. The U.S. Army Corps of Engineers Institute for Water Resources Hydrologic Engineering Center have done the benchmark test for HEC-RAS 5.0 in 2018 while Hydronia LLC was do the benchmark test for RiverFlow2d version 4.5 in 2015. However, the performances of these two modelling packages have not yet been compared. It is hoped that from this project, the comparison of both software performances can be done to state which software have better performance in flood modelling.

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1.6 Summary

This project report is divided into five chapters, including this current chapter. The remaining chapters are summarised below:

1. Chapter 2 briefly explains on the past research, facts and information related to the flood modelling using existing industry-standard software packages. Sec 2.1 describes the flood-prone areas in Malaysia, distinguishes the types of floods and discussed the impacts of flood. Sec 2.2 explains about the flood monitoring and forecasting systems. Sec. 2.3 is about the significance of flood modelling in flood management. Sec. 2.4 discussed the software packages investigated for this FYP, namely HEC-RAS and RiverFlow2D. Finally, Sec. 2.5 describes the three benchmark tests that will be used for this project.

2. Chapter 3 will explain on the methodology that will be used for this project. Sec 3.1 is about literature study. Sec 3.2 explains about simulation which includes 2D-Analysis and the two software. Sec 3.3 describes the model validation which is the three test that conducted in this project. Lastly, Sec 3.4 showed the research methodology flowchart.

3. Chapter 4 will discuss the result obtained from the test. This chapter is divided into three subtopic which each subtopic will discuss each test. Sec 4.1 discussed the Benchmark Test 1 which is Flooding a disconnected water body while Sec 4.2 is about the Benchmark Test 2 (Filling of floodplain depressions). Sec 4.3 explained on the Benchmark Test 3, momentum conservation over a small obstruction.

4. Chapter 5 is the conclusion and recommendation. It will conclude the finding of this project and state whether the objectives achieved or not. Future recommendation will be included in this chapter.

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CHAPTER 2

LITERATURE REVIEW

2.1 Flood

A flood is a body of water that rises and overflows from the bank of a stream, drainage system, or any other water system onto adjacent land as a result of a storm, ice melt, tidal action, or channel obstruction (DID, 2017). According to the same source, DID (2017), flooding can be caused by both natural and man-made disasters. It can be short or long, depending on how far the rain spreads and how intense it is. Furthermore, regular solid waste disposal into rivers, sediments from land clearance and construction regions, an increase in impermeable areas, and river obstruction can all contribute to it.

2.1.1 Flood Prone-Areas

The land areas adjacent to rivers and streams that are subjected to recurring inundation are known as flood prone areas, also known as floodplains or flood-susceptible areas. Floodplains and other flood-prone areas must be examined in terms of how development may affect or be affected by them due to their ever-changing nature (OAS, 2014).

According to Insider (2013), flood-prone areas indicate any land area capable to being inundated by water from any source. The National Geographic (2022) agrees, stating that flood prone zones or floodplains are a flat region of land adjacent to a river or stream. It spreads from the river's side to the valley's far reaches. In comparison to other locations, these areas have a higher risk of flooding. It is also a location outside of a main water channel, or, to put it another way, next to the

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stream. Figures 2.1 and 2.2 show the flood-prone areas in West and East Malaysia, respectively, as obtained from the DID website.

Figure 2.1: Green Shahed Areas Indicates the Flood Prone Areas in West Malaysia

(Source: Department of Irrigation and Drainage (DID), 2017)

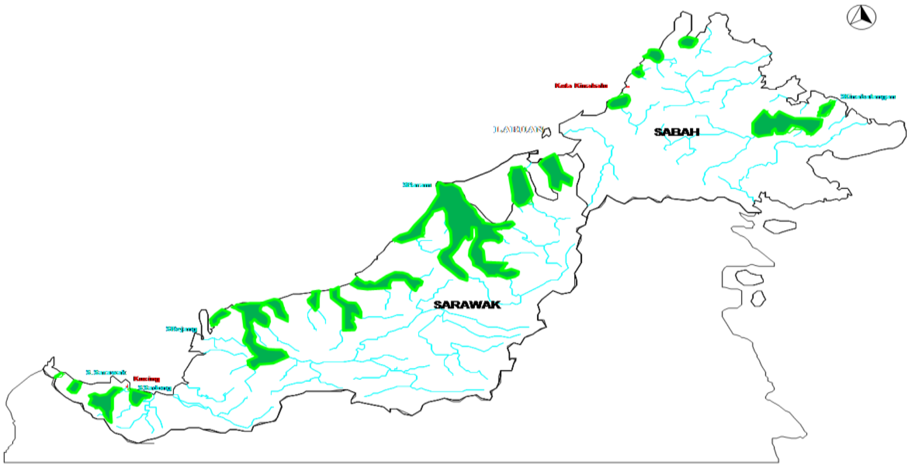

Figure 2.2: Green Shaded Areas Indicates the Flood Prone Areas in East Malaysia

(Source: Department of Irrigation and Drainage (DID), 2017)

Due to the rapid development of urbanisation in the peninsular, there are more regions prone to flooding than in East Malaysia, as shown in Figures 2.1 and

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2.2. As a result, fast development alters geographical characteristics. The geographical features of land, among other aspects, play an important role in influencing flooding susceptibility (Islam., 2016). As new construction proceeds in flood-prone locations, roads and structures are exposed to rising flood risks and erosion (Konrad, 2003).

2.1.2 Types of Floods

In Malaysia, there are no specific flood classifications, however they can be classified as monsoonal, flash, or tidal floods. Floods are classified further by their location, characteristics, cause, onset time, and length. Short, intense rain generates flash flooding, whereas long, heavy, and widespread rain causes land inundation (DID, 2017).

Research from Buslima et al. (2018) stated that flash flooding is characterised by a rapid rise in water level, high velocity, and massive amounts of debris, all of which are caused by the intensity and duration of rainfall while monsoon floods are triggered by a seasonal monsoon known as the Northeast Monsoon. The Northeast Monsoon season in Malaysia begins in early November and finishes in March (Buslima et al., 2018). The Northeast Monsoon brings rainfalls and rough weather to the exposed coasts of southwestern Sarawak and northern and north eastern Sabah, as well as flooding in the peninsula's eastern section (Britannica, n.d). Figure 2.3 shows the rainfall pattern that causes heavy precipitation.

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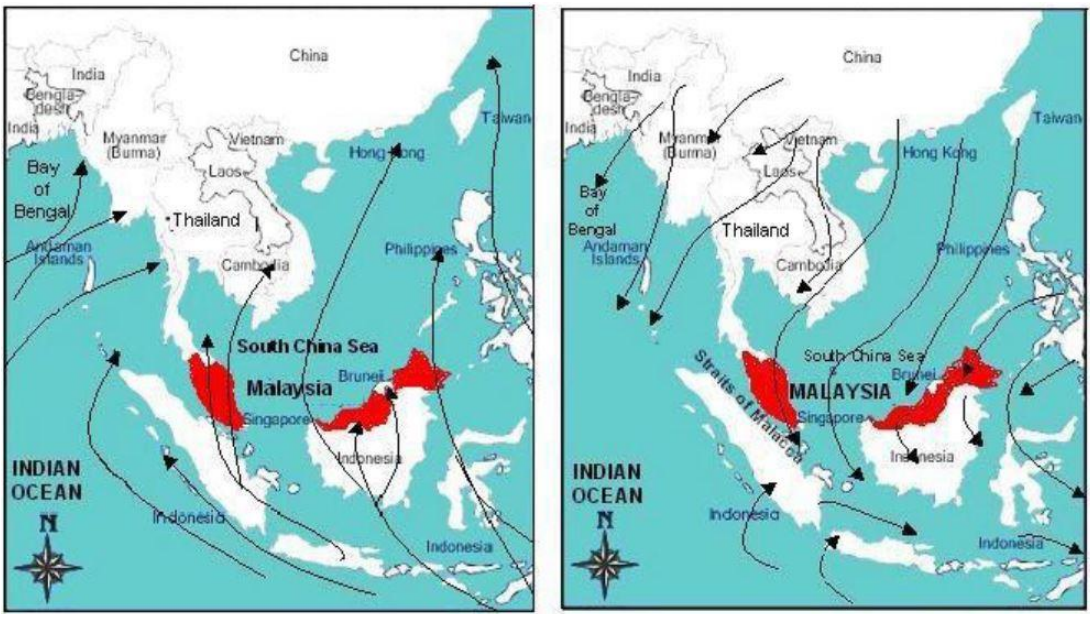

Figure 2.3: Rainfall Pattern Influenced by Southwest and Northeast Monsoons

(Source: Durumin Iya et al., 2014)

Another researcher has distinguished the two types of floods as well. Fauziana et al., (2017) mentioned that flash flood is caused by heavy precipitation associated with a severe thunderstorm in a short period of time (less than six hours), whereas the monsoonal flood is caused by prolonged heavy widespread rain, which causes land inundation over a long period of time. According to Durumin et al., (2014) which referred to Noorazuan (2006), when seen from a hydrological standpoint, the time it takes for the river flow to return to its usual level is monsoon floods can take up to a month to recede, whereas flash floods might take up to an hour to recede.

As conclusion, five references confirms that flash flooding are categorised as short flooding resulting to severe rain but smaller duration of rainfall and lesser time to recede. Moreover, most researchers also says that monsoonal flood are categorised as long flooding due to heavy but less intense rainfall. However, it took more time to recede as the long duration rainfalls. Table 2.1 shows the types of floods summarized from researchers.

Table 2.1: Summary of the Types of Floods According to Researchers

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Types of Floods	Duration of rainfall	Description	References
Flash flood	Short	Takes 1 hour to recede back to normal.	Noorazuan (2006), Durumin Iya et al., (2014)
Monsoonal flood	Long	Up to one month to recede back to normal.	
Flash flooding	Short	Intense rain	DID (2017)
Flood (Land inundation)	Long	Heavy and widespread	
Flash flood	Short	Heavy precipitation with thunderstorm (< 6 hours rainfall)	Fauziana et al. (2017)
Monsoonal flood	Long	Heavy widespread rain, land inundation for a long time (>6 hours rainfall).	
Flash flood	Short	Occurs in rapid development, high intensity rain.	Buslima et al. (2018)
Monsoon flood	Long	Heavy rainfall due to monsoonal season (seasonal wind pattern).	

2.1.3 Impacts of Floods

According to the DID (2017), floods have both beneficial and harmful consequences. The flood can have a positive influence by preserving and enhancing biodiversity in floodplains. Soils rich in nutrients are found in flood-prone places, ensuring natural vegetation and ideal agricultural land. The quality of the soil is ensured by the fact that it recharges groundwater storage and clears debris from flooded regions (Talbot, 2018). On the other hand, flooding poses a threat to the people who live in the area. It poses a danger to people's lives, interrupts social and economic operations, and

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