# COMPARISON BETWEEN ONE-DIMENSIONAL AND TWO-DIMENSIONAL FLOOD MODELLING AT BATANG LAWAS, SARAWAK

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# COMPARISON BETWEEN ONE-DIMENSIONAL AND TWO-DIMENSIONAL FLOOD MODELLING AT BATANG LAWAS, SARAWAK

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## DEDICATION

This project report is dedicated to my father, who taught me that the best kind of knowledge to have is that which is learned for its own sake. It is also dedicated to my mother, who taught me that even the largest task can be accomplished if it is done one step at a time.

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## ABSTRACT

Flood occurrence in Malaysia can be categorized into two namely flash flood and monsoon flood. Lately, almost every year flood events were recorded within Batang Lawas catchment near Lawas town. Most of the flood events were caused due to heavy downpour within Batang Lawas catchment. Water levels from 0.15m to 1.2m from ground level were recorded and resulting in many of the local resident needs to be evacuated. The aim of this study is to investigate the flood inundation area along Batang Lawas near Lawas town and to compare between 1-D and 2-D hydraulics model. In achieving this aims, hydrologic model using HEC-HMS was developed. 1-D and 2-D HEC-RAS hydraulics model also has been used to study the river hydraulics behaviour at Lawas town. Next, flood peak design simulation was performed within Batang Lawas catchment for 2, 5, 10, 20, 50 and 100-year ARI using three different rainfall temporal patterns namely, normalized, actual storm profile and 25% intensity position. Based on the simulated design hydrograph, the river hydraulics analysis and comparison has been carried out. Last but not least, the flood inundation map for Batang Lawas near Lawas town was produced. The collected information and raw data obtained from various resources was processed to serve as an input for HEC-HMS and HEC-RAS hydrodynamics model. From the overall analysis, it was found that the simulated $T_c$ for Batang Lawas near Lawas town and river mouth is 18 hours and 33 hours respectively. From this, two storm duration have been used which is 12-hour and 24-hour for determination of peak hydrograph under different ARI of 2, 5, 10, 20, 50 and 100-year. Three rainfall temporal patterns were used to determine the highest peak discharge. The normalized rainfall pattern with 12-hours storm duration generates the highest values of 1304.3 $m^3/s$, 1534.3 $m^3/s$, 1747.9 $m^3/s$, 1958.4 $m^3/s$, 2218.8 $m^3/s$ and 2616.2 $m^3/s$ for 2, 5, 10, 20, 50 and 100 year ARI respectively. From 1-D and 2-D HEC-RAS model simulation results, it is founded that the 1-D model gives a smaller WSE values and steeper recession slope compared to 2-D model. In comparison, 1-D HEC-RAS model only require small amount of data as compared to 2-D which require more substantial and complex data collection. Setting up the geometry also differs for both models. 1-D model is more preferable for project reduction cost as it only require cross sectional data rather than 2-D model that require terrain data for whole domain. The main difference identified during this study between pure 1-D and 2-D model is the illustration of generated flood inundation map. 2-D model produce more realistic presentation than 1-D model in terms of water particles flow path over a floodplain area. As conclusion, this study shows the comparison between 1-D and 2-D hydraulics model and generating a flood inundation map for Batang Lawas near Lawas Town area.

# ABSTRAK

Kejadian banjir yang berlaku di Malaysia boleh dikategorikan kepada 2 jenis iaitu banjir kilat dan banjir monsun. Kebelakangan ini, hampir setiap tahun kejadian banjir direkodkan di kawasan tadahan Batang Lawas berdekatan dengan bandar Lawas. Hampir kesemua kejadian banjir ini dikaitkan dan disebabkan oleh hujan lebat yang berlaku dalam kawasan tadahan Batang Lawas. Kedalaman air 0.15m hingga 1.2m daripada aras tanah telah direkodkan dan mengakibatkan ramai penduduk setempat terpaksa dipindahkan. Tujuan kajian ini adalah untuk menyiasat kawasan limpahan banjir disepanjang Batang Lawas berdekatan bandar Lawas dan membandingkan diantara model hidraulik 1-D dan 2-D. Dalam mencapai tujuan ini, model hidrologi menggunakan HEC-HMS telah dibentuk. Model hidraulik 1-D dan 2-D HEC-RAS juga telah dibangunkan untuk mengkaji kelakuan hidraulik sungai berdekatan bandar Lawas. Seterusnya, simulasi rekabentuk banjir juga telah dijalankan pada kawasan tadahan Batang Lawas untuk 2, 5, 10, 20, 50 dan 100-tahun ARI menggunakan tiga corak profil hujan yang berbeza iaitu, normalisasi, profil sebenar rebut dan kedudukan keamatan 25%. Berdasarkan simulasi rekabentuk hidrograf, analisis hidraulik sungai dan perbandingan telah dilakukan. Akhir sekali, penghasilan peta limpahan banjir bagi Batang Lawas berdekatan bandar Lawas. Pengumpulan maklumat dan data daripada pelbagai sumber telah dilakukan dan data-data tersebut telah diproses untuk dijadikan sebagai input kepada model hidrodinamik HEC-HMS dan HEC-RAS. Daripada keseluruhan analisis, didapati bahawa $T_c$ simulasi bagi Batang Lawas berdekatan bandar Lawas dan muara sungai masing-masing ialah 18 jam dan 33 jam. Dua tempoh ribut telah digunakan iaitu 12 jam dan 24 jam dalam menentukan aliran yang tertinggi. Hujan dengan corak normalisasi bagi tempoh ribut selama 12 jam memberikan nilai yang tertinggi iaitu 1304.3 $m^3/s$, 1534.3 $m^3/s$, 1747.9 $m^3/s$, 1958.4 $m^3/s$, 2218.8 $m^3/s$ dan 2616.2 $m^3/s$ masing-masing bagi 2, 5, 10, 20, 50 dan 100-tahun ARI. Daripada hasil simulasi model 1-D dan 2-D HEC-RAS, didapati bahawa model 1-D memberikan nilai rekabentuk WSE yang lebih kecil dan cerun kemelesetan yang lebih curam. Dalam perbandingan, model 1-D HEC-RAS hanya memerlukan jumlah data yang sedikit berbanding dengan model 2-D yang memerlukan pengumpulan data yang lebih banyak dan kompleks. Proses penyelarasan geometric model juga berlainan bagi setiap model. Model 1-D adalah lebih disukai sekiranya ingin mengurangkan kos projek dimana ianya hanya memerlukan data keratan rentas sahaja berbanding model 2-D yang memerlukan data medan muka bumi untuk keseluruhan domain. Perbezaan paling utama yang dapat ditentukan diantara model 1-D dan model 2-D semasa kajian ini adalah ilustrasi peta kawasan limpahan yang telah dihasilkan. Model 2-D menghasilkan peta yang lebih realistik berbanding 1-D dari segi laluan aliran zarah air diatas kawasan limpahan. Sebagai kesimpulan, kajian ini telah menunjukkan perbandingan di antara model hidraulik 1-D dan 2-D dan juga penghasilan peta limpahan banjir untuk Batang Lawas berdekatan dengan bandar Lawas.

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## LIST OF ABBREVIATIONS

| | | |
|---|---|---|
| 1-D | - | One-Dimensional |
| 2-D | - | Two-Dimensional |
| ARI | - | Average Recurrence Interval |
| DDF | - | Depth-Duration Frequency |
| DEM | - | Digital Elevation Model |
| DID | - | Department of Irrigation and Drainage |
| DTM | - | Digital Terrain Model |
| DWA | - | Diffusive Wave Approximation |
| GEV | - | Generalized Extreme Value |
| GIS | - | Geographic Information System |
| GNSS | - | Global Navigation Satellite System |
| HEC-HMS | - | Hydrologic Engineering Centre-Hydrologic Modelling System |
| HEC-RAS | - | Hydrologic Engineering Center-River Analysis System |
| HP | - | Hydrological Procedure |
| IFSAR | - | Interferometric Synthetic Aperture Radar |
| IDF | - | Intensity-Duration Frequency |
| JUPEM | - | Jabatan Ukur dan Pemetaan Malaysia |
| LiDAR | - | Light Detection and Ranging |
| MSMA | - | Manual Saliran Mesra Alam |
| NAHRIM | - | National Hydraulics Institute of Malaysia |
| RTK | - | Real-Time Kinematic |
| SWE | - | Shallow Water Equation |
| $T_c$ | - | Time of Concentration |
| TIFF | - | Tagged Image File Format |
| UH | - | Unit Hydrograph |
| USACE | - | United States Army Corps of Engineers |
| WSE | - | Water Surface Elevation |

## LIST OF SYMBOLS

| | | |
|---|---|---|
| $\delta$ | - | Minimal error |
| $D,d$ | - | Diameter |
| $F$ | - | Force |
| $v$ $v$ | - | Velocity |
| $p$ | - | Pressure |
| $I$ | - | Moment of Inertia |
| $r$ | - | Radius |
| Re | - | Reynold Number |
| $A$ | - | Area |
| $L$ | - | Length |
| $S$ | - | Slope |
| $x$, $y$ | - | Longitudinal and lateral directions |
| $v_t$ | - | Velocity diffusivity |

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# CHAPTER 1

# INTRODUCTION

## 1.1 Background of the Study

According to Akasah and Doraisamy (2015), there are two types of flood that occur every year in Malaysia which is the monsoon flood and flash flood. Monsoon flood usually occurs during the Northeast Monsoon from November to March derived from extreme precipitation at the east of Peninsular Malaysia, Northern of Sabah and Southern of Sarawak as well. More than 4.82 million people and about 29,000 $km^2$ or 9% of the total land area were affected by flood every year. Extreme and long duration of precipitation has affected certain states in Malaysia. Most of the flood occurrences in Malaysia is due to uncontrolled urbanization and drastic land use change over the years especially at flat lands.

The 2014 – 2015 Malaysian floods which occur from 15 December 2014 to 3 January 2015 are described as the worst floods in decades. Kelantan, Terengganu, Johor, Negeri Sembilan and Pahang are the most affected states. Heavy rainfall throughout a series of storms during Northeast Monsoon causing catastrophic flood at Kota Tinggi Johor (Ghazali and Osman, 2015). According to the study conducted by Sani *et al.,* (2014), during this event the highest flood level recorded reach up to 2.75m which is among the highest ever recorded since 1950. The flood strikes from two wave events, 19 – 31 December 2014 and 12 – 17 January 2015 which last for 13 days in total. This results in the evacuation of more than 100,000 people and death of 18 people.

Lawas is a small town and the capital of Lawas district is Limbang Division. Limbang Division is one of the twelve administrative divisions of Sarawak, Malaysia. It is the fourth largest division after Kapit Division, Miri Division and Bintulu Division. Lawas Town located right next to Batang Lawas, the main river at

Lawas District. Lawas Town are highly exposed to tides effect which contributes to flooding especially in the rainy season. The situation becomes worsen when the development in this area is increasing rapidly. According to DID Sarawak, among the area affected by flooding are Jalan Pengiran Matussin, Jalan Hospital, Taman David Kong, RKB Banting, Taman Mujaya, Kampung Temangis, Kampung Batu 3, Perumahan Polis and Kampung Ladang Baru.

Every year, flood event is recorded occur at Lawas. The flood event information that obtained from JPS Sarawak Info Banjir for the past recent years shows that flood event occurs consecutively from 2014 to 2015. Most of the inundation area were located near to the river bank of Batang Lawas.

## 1.2 Problem Statement

Flood inundations are the major issues of the study area. It was severely flooded in year 2015 to 2020 when almost the low laying area in Lawas town was inundated by the rising flood water from the Batang Lawas. The town is still affected by flash floods almost in every year due to heavy downpour within Batang Lawas catchment and mostly due to flood overtopping the river banks and inundated the low laying areas within the study area. Most of the flood issue is not caused by the inadequacy of existing drainage system except very small cases. Water levels in excess of 0.15 - 1.2 meters and has resulted that many residents had to be evacuated. In this study, the flood historical data within the study area is taken from JPS Sarawak Info Banjir.

According to The Star, on 5$^{th}$ December 2019, Lawas district had been severely affected by flood. During the event in 2019, Lawas Airport which is the one of the rural link airport has been shut down after its terminal building and airstrip were inundated by floods. The other nearest village such as Kg. Siang – Siang, Kg. Ulu Merapok, Kg. Luangan and Kg. Seberang also affected with some places inundated by nearly a metre of water caused by continuous heavy rainfall. JPS Sarawak Info Banjir recorded that the runway and parking apron area were inundated

by over 0.61m of floodwater. Six school in Lawas also reported to be flooded after the Lawas river burst its banks.

From the information taken at JPS Sarawak Info Banjir, the flood event derived from heavy rainfall on 14th January 2014, submerge part of the low-lying areas of the town. The water level rose between 0.2m to 0.7m from the ground. The continuous heavy rain caused Lawas Airport and part of Lawas town to be inundated in flood waters. Lawas Airport was closed and passengers who had booked afternoon flights were stranded at airport, shopkeepers scrambled to save their goods, while those living in low-lying areas worry about their safety and losses. JPS Sarawak Info Banjir also recorded that during the flood event of 7th June 2020, high rainfall intensity caused major flooding in Lawas town especially at low – lying areas. Lawas Airport also affected by the flood. In some areas, the water level was recorded to be 1m depth during the flood event.

## 1.3 Aims and Objectives

The objective of this study is to investigate the extend of flood inundation area along Batang Lawas catchment near Lawas town using one-dimensional (1-D) and two-dimensional (2-D) hydraulics model simulation results. In achieving this aim, several scenario analyses have been carried out using available computer models for flood modelling well-known as Hydrologic Engineering Centre – Hydrological Modelling System (HEC – HMS) and Hydrologic Engineering Centre – River Analysis System (HEC-RAS). The proposed specific objectives of the scenario analysis are as follows :-

(a) To develop and calibrate the 1-D and 2-D hydraulic simulation models based on the available historical flood event data at Batang Lawas catchment.

(b) To simulate design flood peak for the average recurrence interval of 2-year, 5-year, 10-year, 50-year and 100-year using rainfall runoff simulation model.

(c) To assess the performance of 1-D and 2-D hydraulic models in the simulation of flood inundation map at Lawas town.

## 1.4 Scopes of Study

The following are designated scopes of study to support objectives of the study:

(a) The relevant data was collected from respective Government Departments (DID, JUPEM) and previous studies conducted by researchers, various consultant and Government Agencies.

(b) Raw data processing to generate an input into HEC – HMS and HEC – RAS format.

(c) Performing the hydrodynamic modelling using HEC – HMS for hydrological analysis under different return period of 2, 5, 10, 20, 50 and 100-year.

(d) Performing 1-D and 2-D HEC – RAS hydraulic model.

(e) Comparing the differences between a 1-D and 2-D flood model and identifying their respective potential and limitations.

(f) Producing flood inundation map at Lawas town under different ARI.

## 1.5 Significance of Study

Lawas is located within Limbang division. Lawas district can be divided into two sub – district which is Sundar and Trusan Sub district. Lawas is a transit busy town between Sarawak, Sabah and Brunei Darussalam. The main economy within Lawas district is timber and agricultural activities. The Government of Malaysia is proposing a plan to develop a small and middle scale industry in Lawas. Based on the statistic from Department of Statistics in 2010, Lawas basic population was

estimated about 42,500 with the rate of population growth of 1.8%. This indicates that Lawas can be categorized as the one of the rural but also developing district of Sarawak.

The study conducted by Ranhill (2011) state that the projected urbanization level for Lawas shall be achieved in 2040 by 10%. However, a few development are currently conducted within Lawas district such as the construction of waterfront along the river reach near to Lawas town indicate the town is experience a steady urbanization and land use change. The projected urbanization level at Lawas might be achieved much earlier than expected. The changes in land use and urbanization especially within the Lawas river corridor might affect the runoff volume, river hydraulics and natural flood plain area. A certain platform level with enough freeboard for nearest development area is needed to prevent flooding. The developed flood inundation map during this study will guide the authorities, local settlers and other stakeholders to prepare before flood strikes.

According to Ranhill (2011), there are 22 major river basin in Sarawak. These rivers originate within the Sarawak mountainous upper catchment areas and flow towards the South China Sea. The minor or small rivers formed at the low land areas of the river basin are influenced by the tidal effect from the nearby coastal zone. There are 32 navigable rivers with the accumulated length of navigable waterways of 3,500 km. Batang Rajang, Batang Baram, Batang Lupar, Batang Kemena, and Batang Limbang are the main navigable waterways in Sarawak. Sarawak River Board is founded in pertaining the river transportation and it is the only state in Malaysia is given this responsibility. Sg. Lawas and its tributaries, Sg. Merapok is located within Miri region which has 32 km and 5km of navigable length respectively. With the preparation of this study, the riverine navigation system along Sg. Lawas also can be improved.

## 1.6 Layout of the Thesis

In general, this report is divided and arranged into five chapters. The arrangements of the chapters are shown as follows:

### 1.6.1 Chapter 1 - Introduction

This chapter presents on the introduction and background of the study. The chapter also includes the problem statement, aims and objectives, scope of study and significant of the study.

### 1.6.2 Chapter 2 – Literature Review

This chapter explains about the related theory to the study being conducted. It presents about the research that has already been done by other scholars. The information on flood event in Malaysia, factor influencing flood magnitude, application of hydrodynamics model on flood modelling and application of flood inundation map are also explained in this chapter.

### 1.6.3 Chapter 3 – Research Methodology

This chapter explains about the details of framework of the study, data collection method, study area, method of conducting the study and analysis methods that being used to achieve the objective of the study. The study was conducted at Batang Lawas catchment area near Lawas town.

### 1.6.4 Chapter 4 – Results and Discussion

This chapter discussed about the result obtained from the hydrodynamics simulation run. HEC-HMS hydrological model and HEC-RAS hydraulics model was used during this stage. The result is present in terms of graph, table and chart to facilitate the understanding of this study. Reviews from previous journals and articles that related to this study also have been carried out to achieve the objective of the study.

### 1.6.5 Chapter 5 – Conclusion and Recommendation

This chapter is the last chapter in report writing of the study where the final output is expressed and summarized. The conclusion is explained based on the objectives of the study. The recommendations for future research are also proposed in this chapter.

# REFERENCES


Akasah. Z. A. and Doraisamy, S. V. (2015) '2014 Malaysia Flood : Impacts & Factors Contributing Towards the Restoration of Damages', *Journal of Scientific Research and Development 2*, 2(14), pp. 53 – 59.

Almeida, I. K., Almeida, A, K., Anache, J. A. A., Steffen, J. L. and Sobrinho, T. A. (2014) 'Estimation of Time of Concentration of Overland Flow in Watershed: A Review', *Sao Paulo, UNESP, Geociencias,* 33 (4), pp. 661-671.

Department of Irrigation and Drainage Malaysia (DID) and National Hydraulic Institute of Malaysia (NAHRIM) (2015), *'Hydrological Procedure No. 1 Revised and Updated 2015– Estimation of Design Rainstorm in Peninsular Malaysia'*, Water Resources Management and Hydrology Division.

Department of Irrigation and Drainage Malaysia (DID) (2018), *'Hydrological Procedure No. 26 Revised and Updated 2018– Estimation of Design Rainstorm in Sabah and Sarawak*, Water Resources Management and Hydrology Division.

Department of Irrigation and Drainage Malaysia (DID) (2000) *'Urban Stormwater Management Manual 1st Edition.*

Department of Irrigation and Drainage Malaysia (DID) (2012) *'Urban Stormwater Management Manual 2nd Edition.*

Dhungel, S., Barber, M. E., and Mahler, R. L. (2019) 'Comparison of One and Two – Dimensional Flood Modelling in Urban Environments', *International Journal of Sustainable Development Planning*, 14 (4), pp. 356 – 366.

Estrada, M. A. R., Koutronas, E., Tahir, M., Mansor, N. (2017) 'Hydrological Hazard Assessment : The 2014 – 2015 Malaysia Flood', *International Journal of Disaster Risk Reduction*, 24, pp. 264 – 270.

Wang, F (2020), 'Temporal Pattern Analysis of Local Rainstorm Events in China During the Flood Season Based on Time Series Clustering', *Multidisciplinary Digital Publishing Institute*, 12, pp. 1 – 18.

Gericke, O. J. and Smithers, J. C. (2016) 'Are Estimates of Catchment Response Time Inconsistent as Used in Current Flood Hydrology Practice in South

Africa?', *Journal of the South African Institutional of Civil Engineering*, 58 (1), 2 – 15.

Ghazali, M. R. (2011), *Modelling Rural Catchment For Muar River Basin By Using HEC – HMS 3.4 Software,* Universiti Teknologi Malaysia : Bachelor Degree Thesis.

Ghazali, M. N. H. and Osman, S. (2015) 'Flood Hazard Mapping in Malaysia : Case Study Sg. Kelantan River Basin', Department of Irrigation and Drainage Malaysia Publication.

Hesham. E. (2018), 'Integrating GIS and HEC – RAS to model Assiut Plateau Runoff', *The Egytian Journal of Remote Sensing and Space Sciences,* 21, pp. 221 – 227.

Kong, Y. Y., Bahrun, N. A., and Kun, Y. (2010) 'A study on the urban flooding', *International Journal of Interdisciplinary Research and Innovations*, 2(4).

Kuok, K. K., Ziet, L. Z., Chan, C. P. (2013) 'Flood Map Development by Coupling Satellite Maps and Three – Dimensional Drafting Software : Case Study of the Sarawak River Basin', *Water Research*, 39(1), pp. 175 – 181.

Lagason, A. L. (2008) *'Floodplain Visualization Using ArcView GIS and HEC – RAS : A Case Study on Kota Marudu Floodplain'*, Universiti Teknologi Malaysia : Bachelor Degree Thesis.

Li, J., Wu, S., Zhao, X., Yin, W., Zhang, S., Li. M.. and Li, J. (2018) 'Analysis on the effect of rain type selection on LID measures', *Water Wastewater Engineering*, 44, pp. 21–27.

Maca, P., and Torfs, P. (2009), 'The Influence of Temporal Rainfall Distribution in the Flood Runoff Modelling', *Soil Water Resources Management*, 14, pp. 369 – 376.

Mahmoud, S. H. and Alazba, A. A. (2015) 'Hydrological Response to Land Cover Changes and Human Activities in Arid Regions Using a Geographic Information System and Remote Sensing', *PLos ONE*, 10 (4), pp. 1 – 19. doi: 10.1371/journal.pone.0125805.

Mark, A. and Marek, P. E. (2011) *Hydraulic Design Manual.* Texas Department of Transportation, Design Division, Texas.

Mudashiru, R., Abustan, I., and Baharudin, F. (2020) 'Methods of Estimating Time of Concentration: A Case Study of Urban Catchment of Sungai Kerayong, Kuala Lumpur', *ResearchGate,* pp. 119 – 160.

Nagy, E. D., Torma, P., Bene, K. (2016) 'Comparing Methods for Computing The Time of Concentration in a Medium – Sized Hungarian Catchment', *Slovak Journal of Civil Engineering*, Vol. 26 (4), pp. 8 – 14.

Noh, M. H. A. M. (2014), *3 – Dimensional Floodplain Mapping By Using Light Detection And Ranging (LIDAR) And HEC – RAS Software*. Bachelor Degree Thesis, Universiti Teknologi Malaysia, Skudai.

Nordlof, A. B. B. (2017), *Potential and Limitations of 1D, 2D, and Coupled 1D-2D Flood Modelling in HEC-RAS : A case study on Hoje River*. Master Thesis, Lund University, Sweden.

Papaioannou, G., Loukas, A. Vasiliades, L. and Aronica, G. T. (2016) 'Flood Inundation Mapping Sensitivity to Riverine Spatial Resolution and Modelling Approach', *National Hazards,* 83(1), pp. 117 – 132.

Pinos, J., Timbe, L. (2019) 'Performance Assessment of Two – Dimensional Hydraulic Models for Generation of Flood Inundation Maps in Mountain River Basins', *Water and Science Engineering*, 12(1) : 11 – 18.

Ranhill Consulting Sdn. Bhd., (2011) 'Review of the National Water Resources (2000 – 2050) and Formulation of National Water Resources Policy – Volume 2, Water Resources Governance, Final Report, August 2011'.

Ranhill Consulting Sdn. Bhd., (2011) 'Review of the National Water Resources (2000 – 2050) and Formulation of National Water Resources Policy – Volume 3, Engineering Study, Final Report, August 2011'.

Ranhill Consulting Sdn. Bhd. (2011) 'Review of the National Water Resources (2000 – 2050) and Formulation of National Water Resources Policy – Volume 20, Sarawak, Final Report, August 2011'.

Salimi, E. T., Nohegar, A., Malekian, A., Hosseini, M. and Holisaz, A. (2016) 'Estimating Time of Concentration in Large Watersheds', *Journal of the International Society of Paddy and Water Environment Engineering*, Vol. 15 (1), pp. 123 – 132.

Samat, S. R., Othman, N. and Zaidi, N. F. M. (2017) 'The Development of Rainfall Temporal Patern For Kuantan River Basin', *International Journal of Engineering Technology and Sciences*, 3 (1), pp. 14 – 21. doi: http://dx.doi.org/10.15282/ijets.5.2.2018.1003.

Sani, G. D., Gasim, M. B., Toriman, M. E. and Abdullahi, M. G. (2014) 'Floods in Malaysia : Historical Reviews, Causes, Effects and Mitigation Approach',

*International Journal of Interdisciplinary Research and Innovations*, 2 (4), pp. 59 – 65.

Suriya. S. and Mudgal, B. V. (2012) 'Impact of Urbanization on Flooding : The Thirusoolam Sub Watershed – A case study', *Journal of Hydrology*, 412 – 413, pp. 210 – 219.

Tahreb, N. N. (2008) *'Floodplain Visualization Using ArcView GIS and HEC – RAS : A Case Study', PhD Thesis'*, Universiti Teknologi Malaysia : Bachelor Degree Thesis.

The Star (2019), 'Flood Forces Closure of Airport' *The Star News Articles.*

Thorndahl, S. and Williems, P. (2008) 'Probabilistic Modelling of Overflow, Surges and Flooding in Urban Drainage Using the 1st Order Reliability Method and Parameterization of local rain series', *Water Research*, 42(1-2), 199 – 213.

Universiti Teknologi Malaysia (UTM) (2020) 'Numerical Model Study on the Physical Model of Ringlet Reservoir, Cameron Highlands', Final Report, National Hydraulic Research Institute of Malaysia (NAHRIM).

US Army Corps of Engineers, USACE (2016) 'Hydrological Engineering Center – Hydrologic Modelling System (HEC – HMS) : User Manual.

US Army Corps of Engineers, USACE (2000) 'Hydrological Engineering Center – Hydrologic Modelling System (HEC – HMS) : Technical Reference Manual.

US Army Corps of Engineers, USACE (2016) 'Hydrological Engineering Center – River Analysis System (HEC – RAS) : User Manual.

US Army Corps of Engineers, USACE (2016) 'Hydrological Engineering Center – River Analysis System (HEC – RAS) : 2D Modelling User Manual Version 5.0

Wang, F. (2020) 'Temporal Pattern of Analysis of Local Rainstrom Events in China During the Flood Season Based on Time Series Clustering', *Water Research*, 12(725), 1 – 18. doi:10.3390/w12030725.