RUNOFF QUANTITY ESTIMATION AT UNIVERSITY MALAYSIA PAHANG (GAMBANG CAMPUS) USING STORM WATER MANAGEMENT MODEL (SWMM)

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ABSTRAK

Dalam kajian ini, Storm Water Management Model (SWMM) digunakan untuk stimulasi kuantiti larian air di UMP Gambang semasa musim tengkujuh. SWMM adalah model yang digunakan untuk menjalankan stimulasi kuantiti larian air di kawasan bandar. SWMM boleh menjalankan koleksi kawasan tadahan air yang mempunyai intensiti hujan tinggi yang mengakibatkan larian air di kawasan yang besar yang boleh berlaku banjir. Kawasan kajian adalah di UMP Gambang sebagai kawasan tadahan dan telah dibahagikan kepada 9 kawasan tadahan. Data yang digunakan adalah data hujan dari tiga bulan iaitu dari Oktober hingga Disember 2018 yang merupakan musim tengkujuh di Pahang. Dua stesen yang berbeza digunakan iaitu dari RF3731018 (JKR Gambang) dan UMP hobo menggunakan baldi tip. Hasil daripada analisis bergantung kepada parameter yang digunakan dalam SWMM tersebut. Data dari kedua-dua stesen ini dikira berdasarkan RMSE dan RMSE terbaik adalah 3.16 m^3/s pada November 2018 berbanding 169.54 m^3/s pada bulan Oktober dan 41.39 m^3/s pada bulan Disember. Jadi, data larian air dari November dari kedua-dua stesen ini boleh digunakan untuk ramalan banjir kilat di UMP.

ABSTRACT

In this study, Storm Water Management Model (SWMM) is used to stimulate the runoff quantity at University Malaysia Pahang (UMP), Gambang Campus during the monsoon season. SWMM is model that used to run the stimulation of runoff quantity at the urban areas. SWMM can run a collection of sub catchments area that having a high intensity of rainfall that lead to the huge amount of surface runoff that can occur flash flood. The study area is in UMP Gambang as a catchment and have been divided into 9 sub catchments. The data are used in this study are three months rainfall data from October 2018 to December 2018 which are during the monsoon season in Pahang from two different station which are from RF3731018 (JKR Gambang) and UMP hobo using tipping bucket. The analysis of the result is depends on the parameter used in SWMM. The data from both station is calculated based on RMSE and best RMSE is 3.16 m^3/s on November 2018 compared to 169.54 m^3/s on October and 41.39 m^3/s in December. So, the runoff data from November from the both station can be used for prediction of flash flood at UMP.

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LIST OF SYMBOLS

JPS	Jabatan Pengairan dan Saliran
SWMM	Storm Water Management Model
RMSE	Root Mean Square Error

LIST OF ABBREVIATIONS

JPS	Jabatan Pengairan dan Saliran
SWMM	Storm Water Management Model
RMSE	Root Mean Square Error

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

Urbanization is the important process in a modern world, where the population in cities and town are increase days by days. The new developments area because of the demand of population in cities and towns increase days by days. This urbanization in our country to continue more than expected. So, this urbanization has a lot of positives and negatives impact on the natural environment condition. For examples, the urbanization has a good impact on the economic situation because can improve the infrastructures and can increase the available resources at the development countries (Bustos et al., 2015). However, the negative effect of this condition has also happened. For example, it harms the environment with air pollution from the traffic (Egondi et al., 2016). Also it can cause heat stress to the people living in the cities (Derkzen et al., 2015). Lastly, urbanization changes the water balance (Paul and Meyer, 2001; Niehoff et al., 2002; Burns et al., 2005, Branger et al., 2013). The most of the problem that are occur during and after the development area had effected to the river condition based on physical, chemical and biological. This situation may be harmful if poor management and control due to the development process.

The most critical path that changes the environment condition is surfaces runoff, this condition might be happened due to imperviousness of the development such as buildings, parking lots and pavement do not allow infiltration process of the water into the ground. Research about this started around 1970, with for example Landsberg (1970), who states that the increasing imperviousness due to urbanization can causes rapid runoff.

Surfaces runoff is a major part of water because water that flow from the rain through land surface occur when more water cannot absorb to the land before it is reach to a channel. Rapid surfaces runoff may happen if there are high demand of developments produce more impervious area and this situation may lead to the increasing amount of water and cause flash flood at the study area because of improper drainage system especially at the urban area. Besides, surface runoff can also pollute the environment of the study area because when water that flow on the impervious surfaces carried out the pollutants such as rubbish, petrol from the vehicles at parking lots , fertilizers from the garden and mini park which is flow down into the streams that can affect the water pollution. The effect of uncontrolled quantity of rainwater runoff in impervious area can also polluted the quality of surfaces runoff.

1.2 PROBLEM STATEMENT

The development in urban area have the side effects at the surrounding. The impervious area at the UMP Gambang can cause rapid surface runoff. The increase volume of surfaces runoff would allow the less water to be infiltrated into the ground and make water flow faster to downstream area that can cause the environment disaster like erosion and flash flood at the area of study.

The climate change can also effect the quantity and quality of surface runoff. During the raining season or northeast monsoon the states at east coast Malaysia such as Pahang, Terengganu and Kelantan will having the heavy rains that often can cause severe floods in this areas. Toriman et al. (2012) revealed that the rainfall intensity and runoff at north-east coastal region of Malaysia is expected to increase extremely in term of inter-annual and intra-seasonal variability in about 6% during year 2041-2050. So, with the higher rainfall intensity during this season will make the volume of surfaces runoff increase and can lead to the flood at the certain area especially at lower area and impervious area because the drainage area cannot effort the high volume of surface runoff.

1.3 STUDY OBJECTIVES

The objectives of this study are:

1. To carry out rainfall-runoff modelling using SWMM Model.
2. To determine the rainfall-runoff relationship in UMP Gambang.
3. To identify the runoff quantity of two different rain data station using Root Mean Square Error (RMSE).

1.4 SCOPE OF STUDY

The study focused on the identifying the quantity surfaces runoff at the UMP Gambang. UMP Gambang is located 30 km from the Kuantan City and the area of this campus approximately 126 acres. UMP Gambang is chosen because there are certain place at this campus will occur flash flood during the raining season. So, to determine the quantity of surface runoff during the raining season the SWMM is adapted to stimulate runoff quantity based on peak flow and runoff depth.

The SWMM model is useful tool for the various type of event based on the hydrological process including the time-varying rainfall and also use for rainfall-runoff stimulation model suitable for single event or continuous of quantity of runoff at urban area. So, based on this model the critical place that possibilities will occur flash flood will obtain.

1.5 SIGNIFICANCE OF STUDY

This study can provide the runoff, water level profile that can detect the possible area that flash flood can occur as a reference for the future. Based on this study, the relationship between rainfall and runoff also can be determined. The runoff capacity is really important to estimate the potential of flood during raining season. The research findings can be as guideline to improve the drainage system for UMP Gambang and human activities can be controlled to prevent flash flood.

The proper management for the surfaces runoff quantity and quality is very important to avoid any problem in the future such as flash flood, soil erosion and sedimentation especially during the raining season in East Coast, Malaysia. The quantity of surfaces runoff are dependent on the characteristics of rainfall event, such as intensity, duration and distribution. For example, the higher the intensity of rainfall, the higher runoff will occur in that catchment's area. During the rainy season in Pahang the higher intensity of rainfall can lead to the flood at a certain area especially at urban and lower area. According to a study made in North Virginia (Anderson, 1970) on the effects of urban development on floods in that area, the general conclusions that could be drawn were that the installation of sewer systems, independent of impervious development, leads to an increase in flood-peak magnitudes. So, this can be concluded that the urbanisation at the area of study increase and the period of time decreases it can cause the volume of runoff peaks and automatically will higher the volumes of water added to receiving water bodies.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Hydrology is the study about the water based on their flow, quantity and quality on the earth. According to Y. L Jhia (2016), hydrology is compromise with the occurrence, distribution and water disposal on earth that involve different phases of the hydrologic cycle. The usage of water need to control wisely to get better quality and quantity in life and the hydrological study is very useful and as a guard line to control any disaster such as flash flood that happen during the rainy season. The water usage is also very important for industrial and agriculture because they are use a large amount of water. There are many process involved hydrology study such as precipitation, runoff, infiltration and evaporation.

2.1.1 Hydrologic Cycle

The natural phenomenon that related with water on Earth called Hydrologic cycle. Hydrological cycle is the situation that including the air, seas, surface water and groundwater that could affect the movement, distribution and quantity of water. The water that move from the land can be transferred through the ground or flow freely to the oceans, rivers, seas. The water also can be transfer through the process such as runoff, infiltration, evaporation, condensation, precipitation and transpiration (NurFatin, 2016).

Hydrologic cycle is endless process which is it is will continue if there is water on Earth. The water from the precipitation will absorb (evaporation) to the atmosphere or to the ground as infiltration process. The overflow water from the land is transfer through the sea or river that called as runoff. This process is continuous naturally on Earth.

2.2 HYDROLOGICAL CHARACTERISTICS

Hydrological characteristics is about the movement of water whether it is on and under the ground surface of earth. These are including the rainfall distribution that the water from the rainfall will infiltrate to the ground or the rainfall water will be flow on the land surface as a runoff. Then the runoff distribution to the surrounding that water cannot infiltrate to the ground can flow freely down to the nearest stream.

2.2.1 Rainfall

Rainfall is one of precipitation from form of water fall from the sky to the ground surface. Rainfall is one of the weather in Malaysia that happened mostly especially during raining season at East Coast, Malaysia including Pahang, Terengganu and Kelantan. According to Malaysia Meteorological Department (MMD), the annual average rainfall in Peninsular Malaysia is 2,420 mm and in Sabah and Sarawak are 2,630 mm and 3,830 mm. In addition, the East Coast and Southern part of Peninsular Malaysia, Sabah and Sarawak are mostly affected by flood during December to January.

Rainfall is the important process in hydrologic cycle because the water from rainfall can accommodates and transfer to another process called evaporation, infiltration, runoff and so on. Accoding to Y. L. Jhia (2016), rain may happen due to thermal convection, conflict between two air masses, orographic lifting and cyclonic. For the thermal convection the rain form of local whirling thunder storms. This is because the air is close to the Earth is being heated and rises to the atmosphere. For conflict between two air masses is two masses with different temperature and density meet with each other. So, the condensation and precipitate will occur at the surface contact. Orographic precipitation is the mechanical lifting of moist air at mountain barriers, and causes the heavy precipitation on the windward side and Cyclonic precipitation happens due to lifting of moist air that converges into a low pressure belt.

2.2.2 Surface Runoff

Surface runoff as known as overland flow that when the excess stormwater or many other earth sources cannot manage properly because too much impervious area. During the raining season in Pahang, Malaysia the intensity of the rainfall is higher and probability the flood will happen at the certain area especially at the development and lower area will be high. According to Jora Ligtenberg (2017), when the further developing into an urban area, the runoff increase due to additional impervious area depending on climate and current urbanization level but the effect will be different or less at certain locations. Lastly, urbanization changes the water balance (Paul and Meyer, 2001; Niehoff et al., 2002; Burns et al., 2005, Branger et al., 2013).

Figure 2.1 Illustration of surface runoff at the development and non-development area (source: The Comet Program).

The condition of surface runoff is depend on the intensity of rainfall at the impervious area especially during the raining season. When the high intensity of rainfall at the large covered of impervious area, the volume of the surface runoff will increase. In addition, the volume of water infiltrate into the ground is limited compared to the water overland flow so the water that cannot infiltrates into the soil will become surface runoff. Infiltration excess normally can be observed in short duration of rainfall. The total discharge is determined during a specified period of time and also based on the depth of drainage area that functionally cover all the runoff for a given period of time.

2.2.3 Quantity of Surface Runoff

The quantity of surface runoff is determine by the intensity of rainfall at certain location or from the sub catchment by using various method such as rain gauges, tipping bucket and rainfall radar from satellite. There are a lot rain gauge come with several of size depend on the country. For the heavy rainfall, the large capacity of gauges needed to cater the size of study area. Over lowland areas, the gauges use is smaller suitable with the area covered. Next, the method using the tipping bucket, the amount of rain measured when the bucket reaches that amount, it will tips the rain out and lastly record the tip. The total rainfall is measure by number of tips. Other method is using satellite radar, this method can measure rainfall at large area approximately 1km from the radar' location.

The amount of quantity of surface runoff will increase if the impervious area is high because when high intensity of rainfall the volume of the water that can be infiltrated to the ground is limited especially at the impervious area, the water from rainfall cannot infiltrated to the ground. So, the surface runoff will happened faster if do not have a proper management such as drainage and on-site detention. At the study area, the problem comes when raining season happened because the intensity of rainfall during raining season is higher than normal season. Based on the literature review of Arnold and Gibbons clearly shown the image of increasing surface imperviousness.

From the figure 2.2 below the different situation happened at forested area and the area with different percentage of imperviousness (10-20%, 35-50%, 75-100%). At the forested area provide only 10% of the water output but when it comes to the developed area with high surface imperviousness, the runoff increase to 55% and the evapotranspiration and infiltration process reduce to 30% and 15%. According to Paul and Meyer (2001), when the percentage of imperviousness at development area is high, the volume of surface runoff will increase because the infiltration and evapotranspiration process cannot function properly.

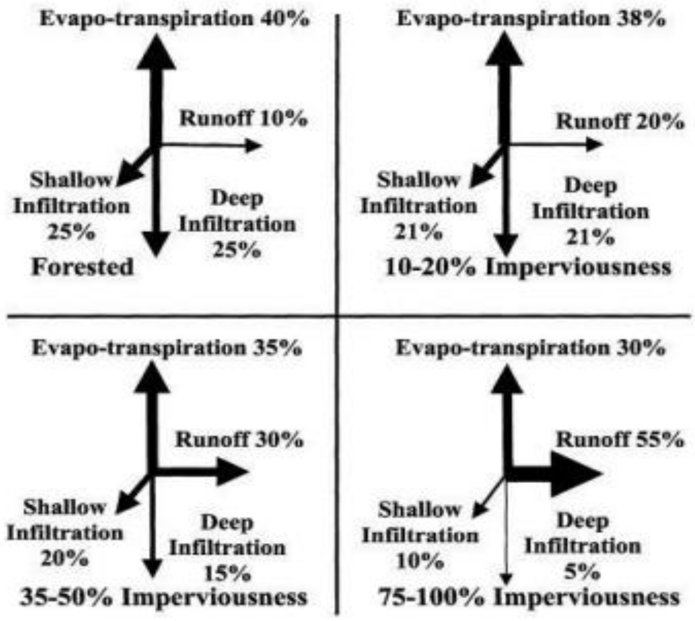


Figure 2.2 Changes in hydrologic flows with increasing impervious surface cover in urbanizing catchments (source: literature review of Arnold and Gibbon).

2.2.4 Specific Peak Discharge

According to NurFatin (2016), the peak discharge is the peak rate of surface runoff from a drainage area based on the rainfall intensity. The intensity of precipitation is will affect the peak discharge compared to the volume of overflow. The high precipitation delivers high peak discharge in small watershed usually does not extend over large area.

2.3 FLOOD

Flood is major problem happen in Malaysia. There are two basic types of flood that occurred in Malaysia which are flash flood and monsoonal flood. The flash flood occur due to heavy rain with severe thunderstorm by the timescale less than six hours while monsoonal flood triggers by the prolonged heavy rain that leads to land inundation (Fauziana, 2017). During the monsoon season the flood would be happened especially at the East Coast which are Pahang, Terengganu and Kelantan. The flood would be happen at urban area due to high intensity of rainfall and inadequate drainage system that cover the whole area especially at the critical place which is lower area.

2.3.1 Factors Affecting Flood

The factors that effecting flood are the increase of the impervious area, inadequate drainage system and high intensity of rainfall during monsoon season. The increase of development will make the impervious area become larger. So the water from rainfall cannot infiltrate to the ground and the rapid surface runoff might happened. The water from rainfall at the impervious area should have a proper drainage area become the runoff can flow through the drain into the downstream. If the drainage system is not good or low maintenance the runoff cannot flow freely and will end up with flash flood at certain area. Lastly, during the monsoon season the intensity of rainfall is higher so the volume of runoff also will high because the soil cannot infiltrate water so fast and flash flood will happened.

2.4 RAINFALL-RUNOFF RELATIONSHIP

Rainfall-runoff is an important relationship in hydrological cycles because when the rain fall to the ground, the water will infiltrate to the soil. When the infiltration capacity is limit the water cannot absorb to the soil. Then the runoff will be flow on the surface of the ground after the storage is filled. Infiltration capacity of the soil is different based on its texture, structure and also soil moisture content. The initial infiltration capacity for the dry soil is high before the rain and change when the rain continues to fall for a period of time the infiltration rates will decreases until it reaches the limit of infiltration rate (Y.L.Jhia, 2016).

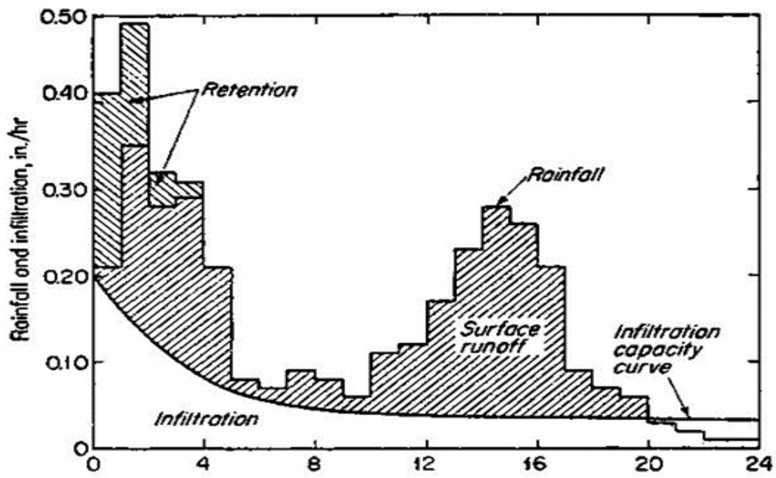


Figure 2.3 Relationship between rainfall and runoff (source: google)

2.5 HYDROGRAPH

Hydrograph is a graphical that represent the runoff or discharge rate against time. A hydrograph shows the total runoff that occur at certain time and its show the time distribution of total runoff at a certain point of measurement (NurFatin, 2016). The relative contribution of each component to the hydrograph is depends on rainfall rate, intensity, infiltration rate, soil moisture and total infiltration of the soil. The hydrograph consist of three region such as rising limb, crest segment and falling limb. Hydrograph is fully depend on rainfall and watershed characters.

Factors that affecting shape of hydrograph climate factors and physiographic factor. The climate factor including the form of precipitation such as rainfall, rainfall will produce runoff rapidly can affect hydrograph with high peak and narrow base. Besides, the high rainfall intensity also affect the volume of runoff that would make the peak flow quick and become conical hydrograph. The longer the duration of rainfall, the peak flow will occur after longer time and the shape of the hydrograph will flat. For the physiographic factor, the shape of catchment will affect the hydrograph and time of concentration. The small size of sub-catchment also will make the flow conquer by overland flow quickly and the peak flow happen faster.

2.5.1 Rational Method

The rational method is largely used for peak runoff computation. According to Ohja et al. (2008), the main function of rational method are the peak runoff rate of the average rainfall rate during the time of concentration and the rainfall intensity is constant during rainfall. This rational method should be applied to watersheds with drainage area between 200 acres or less. It relates peak discharge to contributing drainage area, average rainfall intensity for a duration equal to a watershed response time (typically the time of concentration), and coefficient that represent to hydrologic abstraction and hydrograph weakening (NurFatin, 2016).

$$Q_p = C\ I\ A \tag{2.1}$$

Where:

Q_p = peak discharge (m^3/sec)

C = runoff coefficient

I = rainfall intensity (mm/h)

A = catchment area (km^2)

2.6 STORMWATER MANAGEMENT MODEL (SWMM)

2.6.1 Introduction of SWMM

The Storm Water Management Model (SWMM) is model that used to run the stimulation of quantity and quality of runoff at the urban areas. SWMM can run a collection of subcatchments area that having a high intensity of rainfall that lead to the surface runoff and can affect the water pollution at that area. This modelling is useful tools for the future works because SWMM can transports this surface runoff through a piping system, channel, storage, pumps and regulators. This software also can detect the quantity and quality of surface runoff at the each subcatchment, the flow rate, flow depth and quality of water during a simulation. SWMM is widely used in many countries to plan, analyse and design that relate to storm water runoff, sewer and also drainage systems especially in urban areas.

According to Lewis A. Rossman (2010), SWMM also contains a various set of hydraulic modelling that have ability to check runoff and the flow of water through the drainage system. Besides, the SWMM is created to generate and transport of runoff flows using modelling so SWMM can estimate the production of pollutant loads that carried by the runoff. To model the runoff quality the constituents that are needed are dry-weather pollutant buildup form the different land uses, pollutant washoff from the land uses during storm events, direct contribution of rainfall deposition, reduction of washoff load due to BMPs and routing of water quality through the drainage system.

2.6.2 Rain Gage

Rain gage is the equipment that supply the rain data for the sub-catchment area. The rainfall data can be used as time series or from an external file. The main input of rain gage including the rain data such as intensity or volume of the rainfall, the time interval of the rain data that have been recorded hourly, 15-minutes or 5-minutes, the name of the rainfall data station and lastly the source of rain data such as input time series or external files.

2.6.3 Catchment Physical Description

The physical catchment is accomplished with a sub-catchment model. Runoff process can fully stimulated by conducting the hydrologic element such as storm sewer conduit, conduit junction and system discharges to get all the point, out. The direction flow of water is from the upstream to downstream.

As stated in SWMM5 Manual user the sub-catchment should be divided into the impervious and pervious subareas. Surface runoff will infiltrate into the soil of the pervious area, but it is cannot infiltrate at the impervious area. At the impervious area the subareas should be divided into two which is the area that can contain depression storage and another one is does not contain depression storage. Runoff flow from the subarea in a sub-catchment can be drain to another sub-catchment outlet.

Infiltration process of rainfall from the pervious area of sub-catchment into the soil can be categories into three different model, which are Horton infiltration, Green-Ampt infiltration and Curve number infiltration.

The other main input parameters for sub-catchments include:

- Rain gage
- Sub-catchment
- Land uses
- Surface area
- Imperviousness
- Slope
- Width of overland flow
- Manning's n for overland flow
- Depression storage
- Percentage of impervious area

2.6.3 Junction Nodes

According to SWMM5 Manual, junctions are the drainage system nodes that join together. They are function as the natural surface channels, manholes in a sewer system. The excess water at the junction can become transfer while connecting conduits are surcharged. The water can lost from the system or allow to pond stop the junction and drain back into the junction. The main input parameters for a junction are invert elevation, height to ground surface and external inflow data.

2.6.4 Outfall Nodes

Outfalls are the final terminal nodes of the drainage system and defined as the final downstream boundaries under Dynamic Wave flow routing. But for other type of flow routing the junction is function as only a single link that can connect to outfall node. The main input parameters of outfall are invert elevation, boundary condition type and presence of a flap gate as stated in SWMM5 Manual.

2.6.5 Storage units

Storage units are the nodes that provide storage volume for the drainage system. Basically, storage units is a storage facilities such as catch basin or lake. The properties of storage unit is described by a function or table of surface area vs height. The main input for storage units are invert elevation, maximum depth, surface area data and evaporation potential.

2.6.6 Conduit

Conduits are represent the pipes that able to move water from one node to another node in the system. According to SWMM5 Manual, there are many type or shape of the conduit, for the open channel the rectangular, trapezoidal or irregular cross-section shape are uses. The common shapes for the drainage and sewer pipe are circular, elliptical and arch pipes. The main input parameters for conduit are names of the inlet and outlet nodes, offset height or elevation of nodes, conduit length, manning's roughness and cross-sectional geometry.

2.6.8 Advantages of SWMM

SWMM is capable for the hydrological processes for the place that produce runoff mostly at the urban area. These including the time series of the precipitate (rainfall), evaporation of the surface water, interception of rainfall from the storage of depression, the rainfall that infiltrate into the unsaturated soil layers, the drainage system groundwater interflow and nonlinear reservoir of overland flow.

The capabilities of this SWMM is functioned by categories a study area into sub catchment areas that containing the impervious and pervious area. So between the sub catchments the overland flow can be routed to the end point of the drainage system.

SWMM is an advanced hydraulic modelling that can be used to flow the runoff and internal inflows through the drainage system which are including pipes, channels, storage or treatment units and diversion structures.

In advanced the SWMM has been widely used for the sewer and stormwater studies. The component that include in this stimulation are design and size of drainage system to control the flood, the size of detention pond that useful facilities to control the flood and water quality protection, minimize the sewer overflow by designing the control strategies and identify the impact of inflow and infiltration on sanitary sewer overflows.

2.6.9 Disadvantages of SWMM

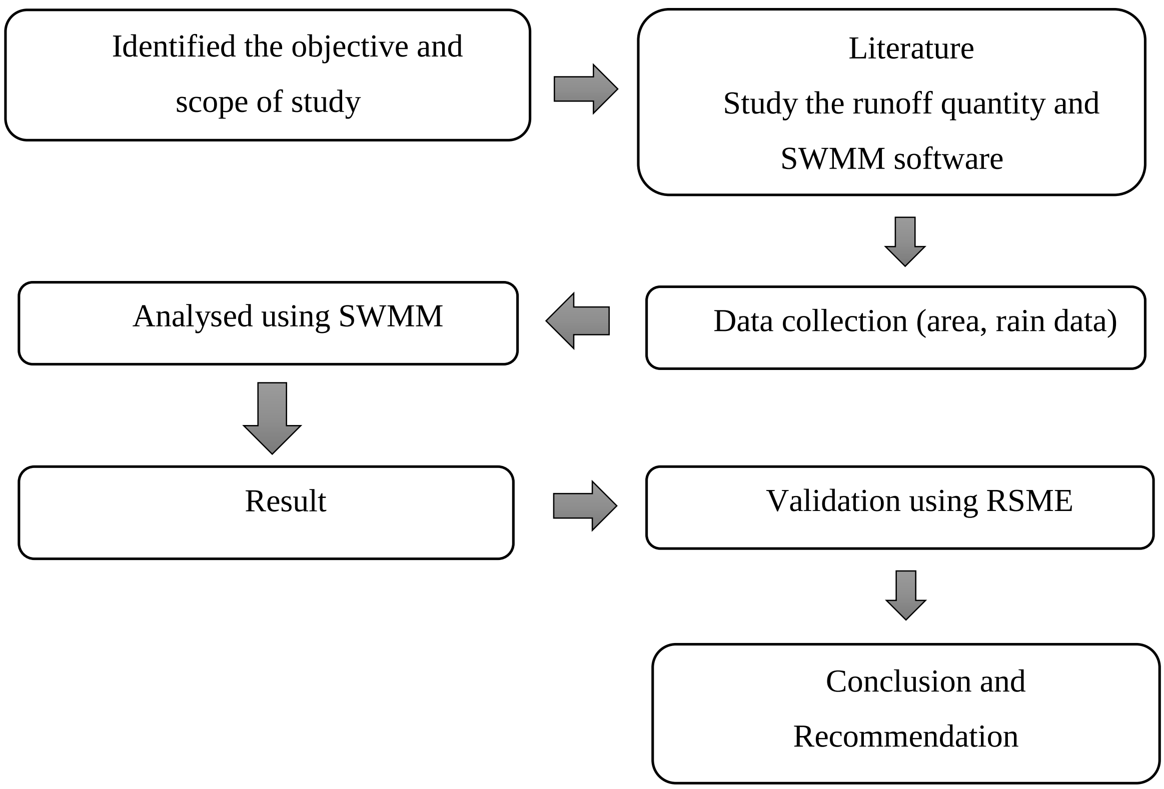
This software also has disadvantage due to the decision making in the design and development of the SWMM. The disadvantages of this model are simplified model formulation and simplified flow representation. The simulation is carried out the program to run simulation in short time with accurate and precise results in simplified model formulation but the software compute the process in efficiency and reducing the duplication in the software in simplified flow representation.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

This research is conducted to study the rainfall runoff relationship at the UMP Gambang. The study area is divided into 9 sub catchment and the area of sub catchment and impervious area have been identified using ArcGIS map. The data collection for the rain data are from the JKR Gambang station (RF3731018) and UMP hobo station using tipping bucket from the October 2018 until December 2018. The rainfall and runoff data collected for every 5 minutes at the rain data station. The data would stimulated using SWMM software. The output from the SWMM which are rainfall, runoff and infiltration are compared between the both stations.



3.2 STUDY AREA

The study area is at Universiti Malaysia Pahang, located at Gambang near the East Coast Expressway and about 30 km from Kuantan City. The total area of this campus is about 126 acres and can accommodate up to 5000 students. The coordinate for this campus is 3.718491, 103.12120784. UMP is chosen as a study area because during the monsoon season there are several location that had the flash flood mostly at the lower area. So study is conducted at this area to identify the rainfall and runoff quantity at UMP during monsoon season and to solve this problem in the future.

Figure 3.1 UMP Gambang map from google earth

3.3 SUB CATCHMENTS

The area of study which is UMP Gambang have divided into 9 sub catchments according to the invert level of the area to make the runoff process can fully stimulated by conducting the hydrologic element such as storm sewer conduit, conduit junction and system discharges to get the sub-catchment should be divided into the impervious and pervious subareas. Surface runoff will infiltrate into the soil of the pervious area, but it is cannot infiltrate at the impervious area. At the impervious area the sub areas should be divided into two which is the area that can contain depression storage and another one is does not contain depression storage. Runoff flow from the sub area in a sub catchment can be drain to another sub-catchment outlet. The area of the sub catchment are obtained from the ArcGIS map which was available online and percentages of impervious area was obtained from the formula below.

$$\frac{total\ area\ of\ impervious\ area}{total\ area\ of\ sub\ catchment} \times 100 \qquad \text{(eq.1)}$$

Table 3.1 Sub catchment at UMP Gambang

Sub catchment	Area(ha)	Impervious area (%)
1	7.7	20
2	5.5	80
3	6.9	80
4	7.9	10
5	3.6	60
6	3.3	75
7	2.2	45
8	5.3	75
9	6.9	75

3.4 DATA COLLECTION

The intensity of rainfall or time series of the rainfall data is very important for this software to stimulate, therefore the rainfall data are obtained from the Jabatan Pengairan dan Saliran (JPS) and UMP hobo using tipping bucket. The rainfall data that have been provided by JPS was the rainfall data from JKR Gambang which is situated around 4.5 km from the UMP Gambang. So the rainfall data at JKR Gambang was the only one rain gauges that available at Gambang area. The data of rainfall are taken using daily basis or every 24 hours. The process of data collection was important because it was very useful for conducting the rainfall and runoff process to produce the hydrograph, the quantity peak flow and volume of discharge. The data was taken from the three months during monsoon season which is October, November and December 2018.

Table 3.2 Rainfall data station

Station Name	Station No
JKR Gambang	RF3721018
UMP HOBO	-

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 INTRODUCTION

In this chapter, the data collection have been analysed. The 9 sub catchments were divided based on invert level, area and their impervious area. The two different station of rainfall were compared to determine the best result based on smallest value of root mean square error. The data including area, invert level, area of impervious and time series for rainfall data were key in into SWMM software so that the rainfall and runoff in UMP Pahang can be determined.

4.2 SWMM

The study map shown in figure 4.1 below was representative of study area at UMP Pahang, there are 9 sub catchments and every sub catchment have different area, invert level and area of impervious area.

The junctions were the drainage system nodes that join together from the sub catchment to the conduit. There was 16 junctions in this area and they was function as the natural surface channels, manholes in a sewer system. The excess water at the junction can become transfer while connecting conduits are surcharged. The water can lost from the system or allow to pond stop the junction and drain back into the junction. The main input parameters for a junction are invert elevation, height to ground surface and external inflow data.

The conduits in the study area map was represent the pipes that able to move water from one node to another node in the system. In this study area map there was 17 conduit all together and the type or shape of the conduit, for the open channel the rectangular, trapezoidal or irregular cross-section shape are uses. The common shapes for the drainage and sewer pipe are circular, elliptical and arch pipes. The main input parameters for conduit were named of the inlet and outlet nodes, offset height or elevation of nodes, conduit length, manning's roughness and cross-sectional geometry.

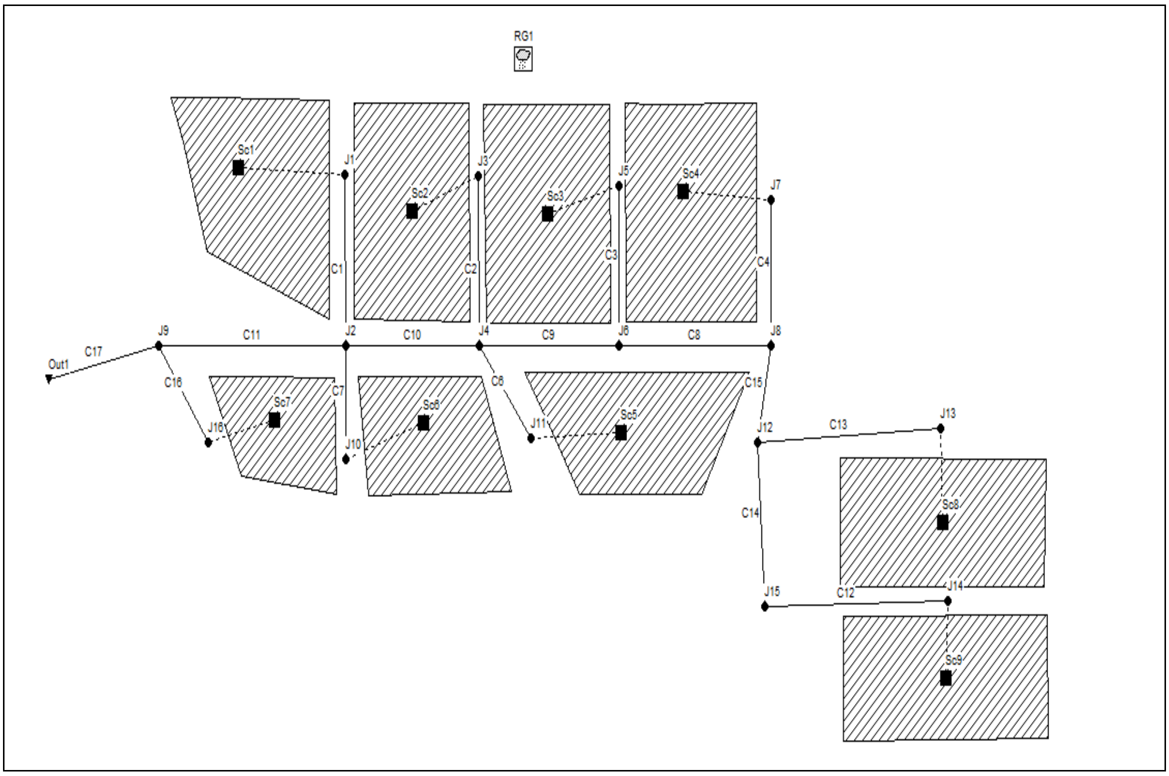


Figure 4.1 The study area map using SWMM

Table 4.1 Sub catchment at UMP Gambang

Sub catchment	Area(ha)	Impervious area (%)
1	7.7	20
2	5.5	80
3	6.9	80
4	7.9	10
5	3.6	60
6	3.3	75
7	2.2	45
8	5.3	75
9	6.9	75

4.3 RUN STATUS

After the run stimulation successful complete, the continuity errors for runoff and flow routing would displayed in the run status. These error represent the present different between initial storage plus total inflow and final storage plus total outflow for the drainage system in the study area. The validity of the result should below 10 percent, if the error is more than that the stimulation had any problem mostly because of the conduit is too long or too short.

The figures 4.2-4.7 below shown the run status for the three months rainfall based on the at two different station rainfall data station.

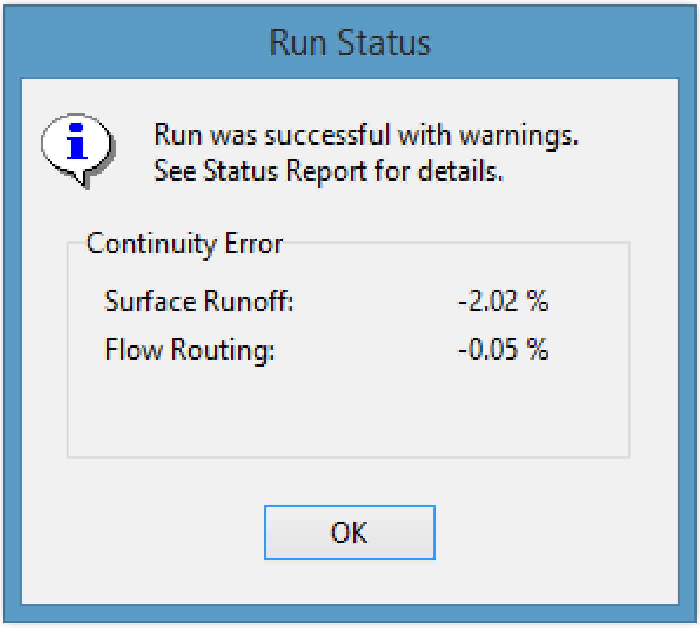


Figure 4.2 Run status of October 2018 at Gambang Station

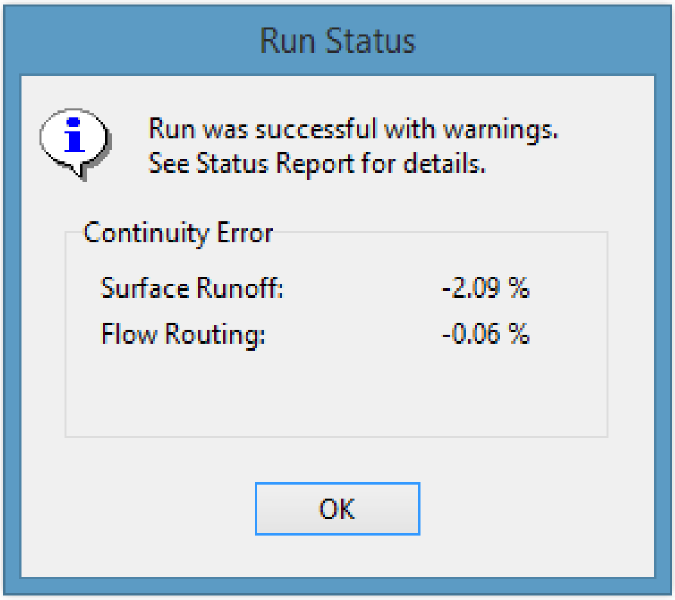


Figure 4.3 Run Status of October 2018 at UMP Station

For the month of October 2018, the run status for both station JKR Gambang and UMP station are below 10 percent of continuity error which mean the run status succeed and completed. The value for both station are not different much for the error of surface runoff and flow routing. The different only 0.07% for surface runoff and 0.01% for the flow routing.

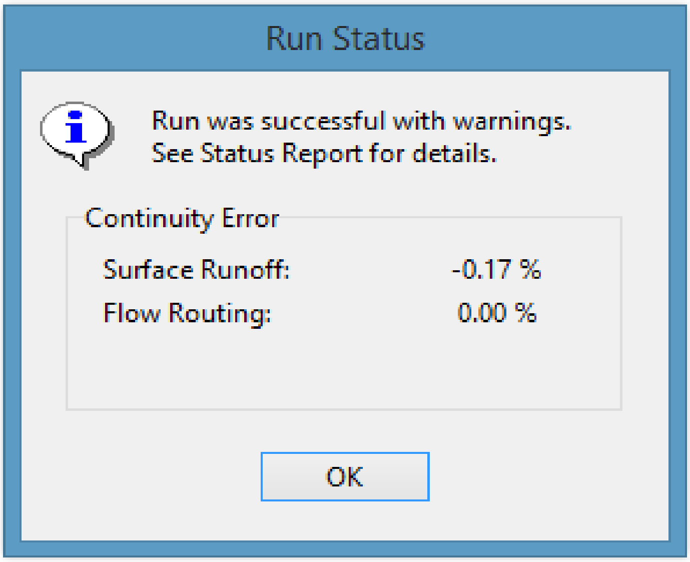


Figure 4.4 Run Status of November 2018 at Gambang Station

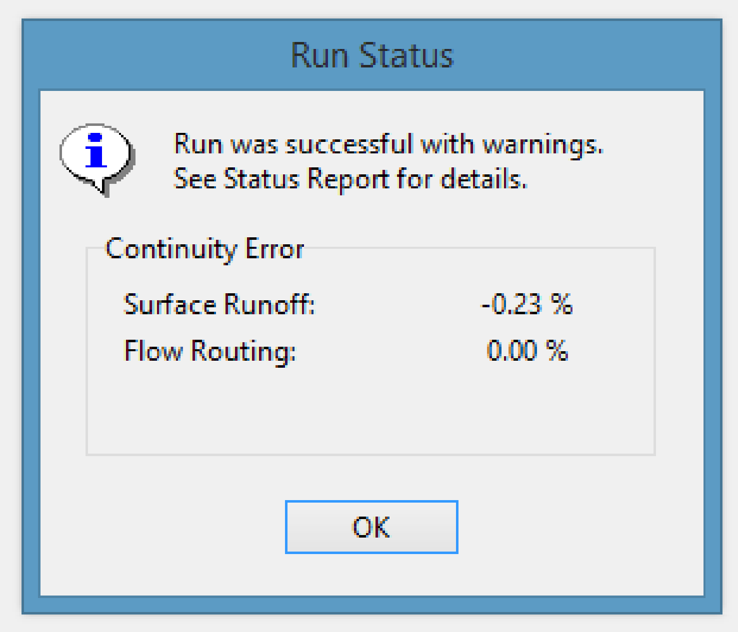


Figure 4.5 Run Status of November 2018 at UMP Station

For the month of November 2018, the value of error for surface runoff was below 10% which are 0.17% for run status at Gambang Station and 0.23% for UMP Station. So that mean the run stimulation of this software succeed and completed. The different of both station is only 0.06%. The value of flow routing is 0% that mean the flow is steady and in good condition.

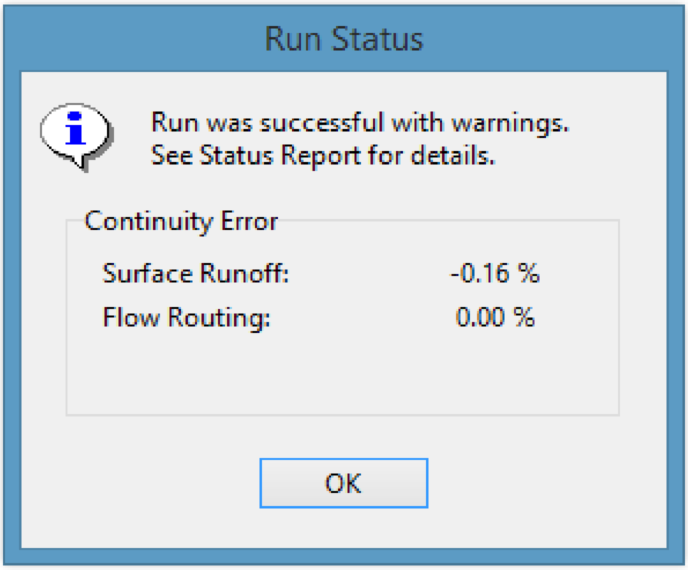


Figure 4.6 Run status of December 2018 at Gambang Station

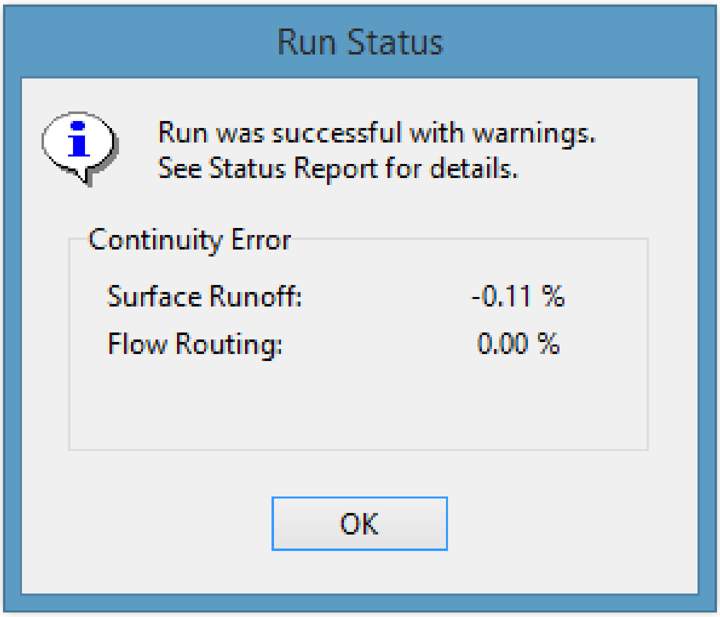


Figure 4.7 Run status of December 2018 at UMP station

For the month of December 2018, the value of error for surface runoff was below 10% which were 0.16% for run status at Gambang Station and 0.11% for UMP Station. So that mean run the stimulation was succeed and completed. The different of both station was only 0.05%. The value of flow routing is 0% that mean the flow was steady and in good condition.

4.4 RAINFALL

Rainfall is one of precipitation from form of water fall from the sky to the ground surface. Rainfall is the one of the weather in Malaysia that happened mostly especially during raining season at East Coast, Malaysia including Pahang, Terengganu and Kelantan. Rainfall is the important process in hydrologic cycle because the water from rainfall can accommodates and transfer to another process called evaporation, infiltration, runoff and so on.

The high intensity of rainfall during the monsoon season would make the different phenomenal or disaster to the area which are lower area and exposed to flash flood. The factors that effecting flood are the increase of the impervious area, inadequate drainage system and high intensity of rainfall during monsoon season. The increase of development will make the impervious area become larger.

The table 4.2, 4.3 and 4.4 below shown the data of the rainfall at two different station which were UMP station and Gambang Station. The figures 4.8, 4.9 and 4.10 below shown the hydrograph pattern of rainfall during one month which are October, November and December 2018. The rainfall data were obtained from two different station which were JKR Gambang Station and UMP Station. Both data were compared to get the better result.

4.4.1 Rainfall Data on October 2018

Table 4.2 The data of rainfall from two different station on October 2018

DAYS	GAMBANG STATION (mm)	UMP STATION (mm)
1	0	0
2	3	0.4
3	0.8	0
4	0	0
5	0.5	0.6
6	0	0.2
7	11	14.2
8	3.5	4.8
9	1.3	1
10	7.5	5.8
11	11.2	10.2
12	53.2	37
13	86.3	31.6
14	8.7	9.6
15	21.5	29
16	0.1	0.2
17	5.4	9.2
18	47.5	53.8
19	12.1	0.4
20	1.2	0
21	4.2	0
22	2.5	0
23	0	0
24	0	0
25	0	0
26	0	0
27	0	0
28	0	0
29	0	0.4
30	37.6	0
31	7.5	0

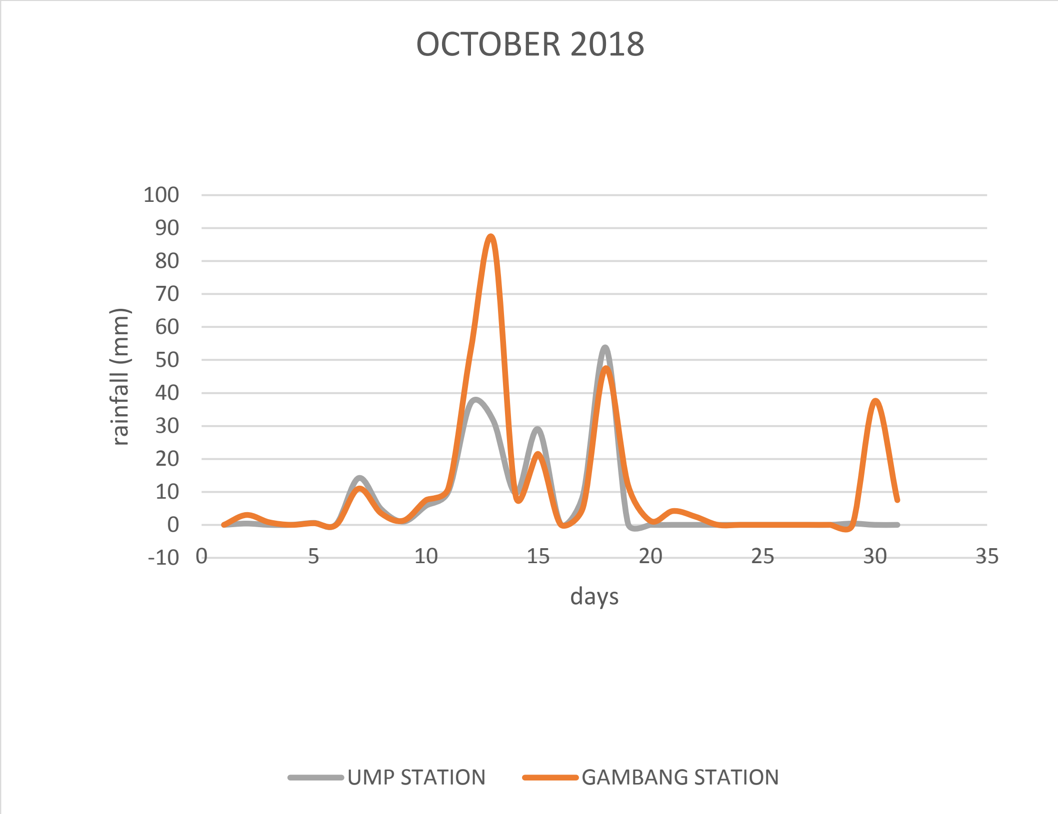


Figure 4.8 Rainfall of October 2018

The total precipitate (rainfall) in October 2018 at JKR Gambang station is 326.6 mm and at the UMP station was 208.4 mm. The large volume of rainfall was 86.3 mm on 18th Oct 2018 and the least volume of rainfall 0.1 mm on 16th Oct 2018. There were 10 days without raining during October 2018 recorded at the JKR Gambang station but 14 days without raining recorded at UMP station.

4.4.2 Rainfall Data on November 2018

Table 4.3 The rainfall data from two different station on November 2018

DAYS	GAMBANG STATION (mm)	UMP STATION (mm)
1	0	0
2	6.4	4
3	0.5	1.4
4	10.2	9.6
5	9.2	11.4
6	1.5	2.6
7	100.3	95.4
8	5.7	23
9	5.3	3
10	15	13.4
11	0	0
12	12.7	13.8
13	0	0
14	4.5	0
15	6.9	9.8
16	0	0
17	21	14.4
18	3.8	14
19	2.5	0
20	1.9	1.6
21	14	12.5
22	0.5	0.2
23	0	0
24	0	0
25	11.9	10.8
26	0	0
27	0	0
28	16.3	14
29	5.1	5
30	4.6	4.2

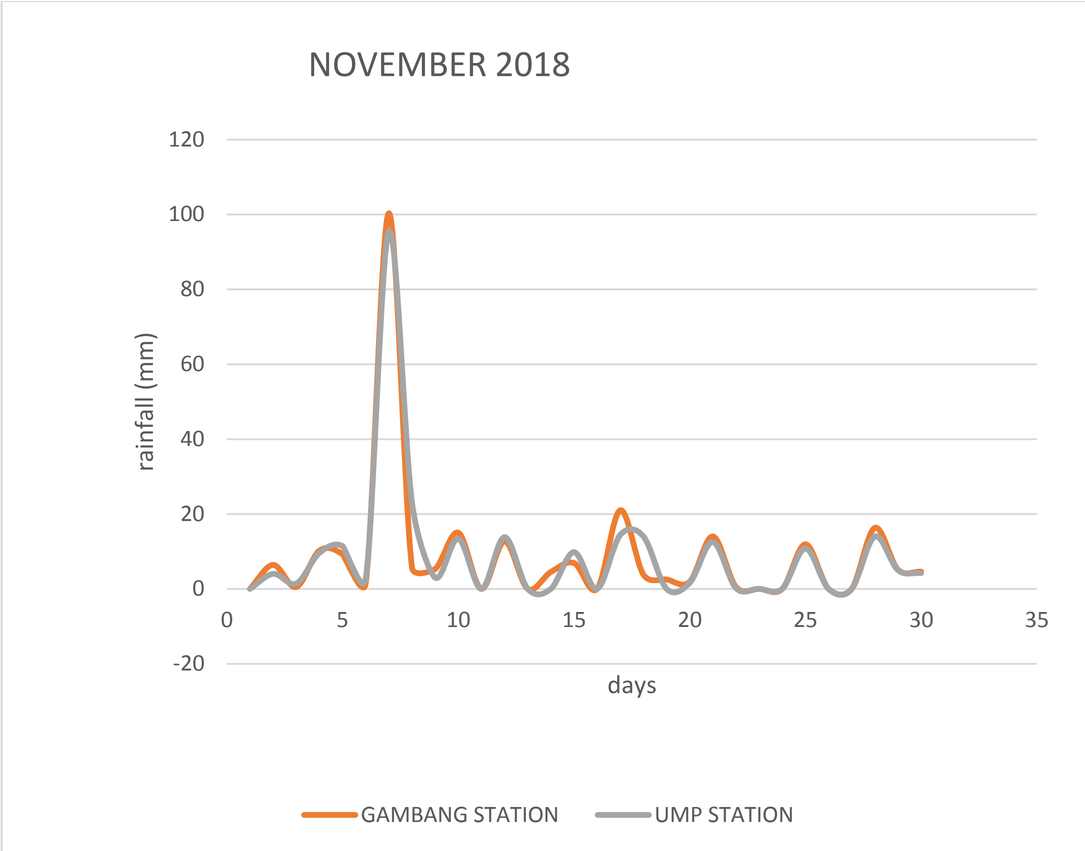


Figure 4.9 Rainfall of November 2018

The graph of rainfall in November show that there were slightly different in total volume of rainfall in mm. The total volume for the JKR Gambang station was 259.8 mm and 264.1 mm for UMP station. The high intensity of rainfall in November is on 7th Nov 2018 (100.3 mm) and the low was on 22nd Nov 2018 (0.5 mm). The days that have no rain were 8 days at JKR Gambang station and 10 days at UMP station.

4.4.3 Rainfall Data on December 2018

Table 4.4 The rainfall data from two different station on December 2018

DAYS	GAMBANG STATION (mm)	UMP STATION (mm)
1	10	9.6
2	4.4	8.8
3	0.5	6.7
4	0	0.6
5	0	1.7
6	0.5	2.6
7	0	0
8	0	3.5
9	0	1.3
10	0	7.1
11	0	0.2
12	12.8	12.4
13	83.3	79.6
14	14.3	12
15	22.9	47.8
16	0	0.7
17	0.5	5.6
18	0	0
19	2	4.2
20	15.5	24
21	0	0.2
22	0	0.8
23	0	0.2
24	0	0
25	1	2
26	9.3	12
27	30.1	26.2
28	0	0.4
29	0	0.4
30	0	0
31	0	1.8

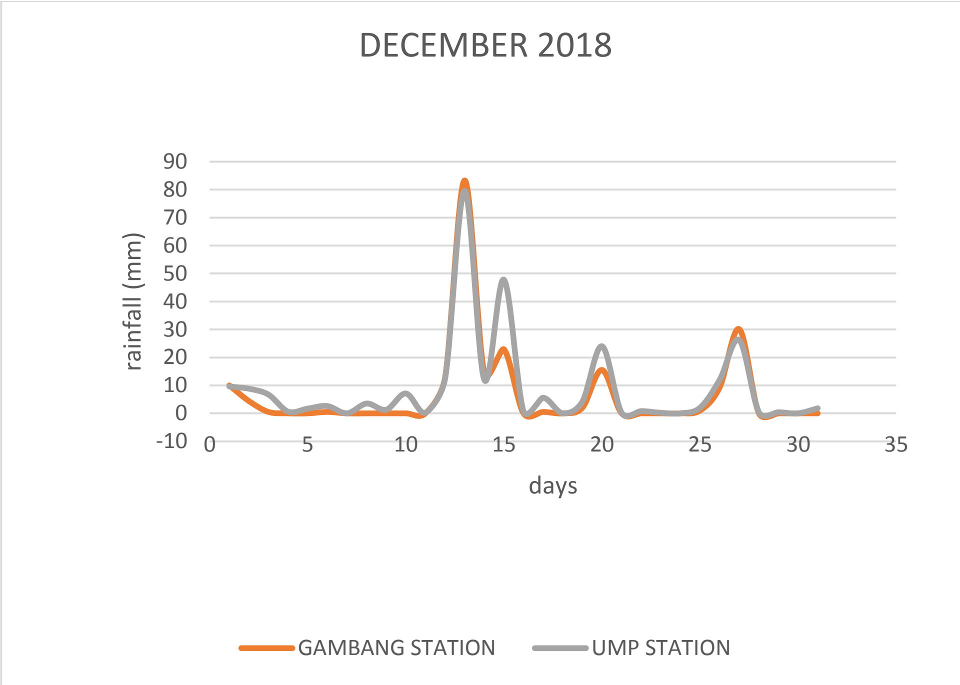


Figure 4.10 Rainfall of December 2018

The total precipitate in December 2018 at the JKR Gambang station was 207.1 mm and 272.4 mm at the UMP station. The high intensity of rainfall was on 13th Dec 2018 which was 83.3 mm and the low intensity is 0.5 mm on 3rd, 6th and 17th Dec 2018. The days without raining record in JKR station are 17 days compared to UMP station that was only 4 days.

Table 4.5 The summary of the rainfall value at two different station.

Month	Higher rainfall value (mm) at Gambang Station	Total rainfall intensity (mm) at Gambang Station	Higher rainfall value (mm) at UMP Station	Total rainfall intensity (mm) at UMP Station
October	86.3	326.6	55.8	208.4
November	100.3	259.8	95.4	264.1
December	83.3	207.1	79.6	272.4

4.5 RUNOFF

Surface runoff as known as overland flow that when the excess stormwater or many other earth sources cannot manage properly because too much impervious area. During the raining season in Pahang, Malaysia the intensity of the rainfall is higher and probability the flood will happen at the certain area especially at the development and lower area. When the high intensity of rainfall at the large covered of impervious area, the volume of the surface runoff will increase. Runoff also occur when the excess rainfall moves quickly from high to lower area surface without proper management from the drainage, sewer, and river.

The amount of quantity of surface runoff will increase if the impervious area is high because when high intensity of rainfall the volume of the water that can be infiltrated to the ground is limited especially at the impervious area, the water from rainfall cannot infiltrated to the ground. So, the surface runoff will happened faster if do not have a proper management such as drainage and on-site detention. At the study area, the problem comes when raining season happened because the intensity of rainfall during raining season is higher than normal season.

The figure 4.11 below shown the runoff quantity at UMP Gambang during three different months which are October, November and December with different rainfall data such as JKR Gambang Station and UMP station. The different of the data were compared based on RMSE. The lowest value RMSE was the best result for the validation.

4.5.1 Runoff Quantity on October 2018

Table 4.6 Runoff quantity data from two different station on October 2018

DAYS	GAMBANG STATION (mm)	UMP STATION (mm)
1	0	0
2	0	0
3	0.02	0
4	0	0
5	0	0
6	0	0
7	0	0.01
8	0	0
9	0	0
10	0	0
11	0	0
12	0.02	0
13	1005.76	449.08
14	0	7.65
15	394.86	201.89
16	0	8.7
17	0	29.4
18	6.91	0.14
19	148.94	0
20	0	0
21	0	0
22	0	0
23	0	0
24	0	0
25	0	0
26	0	0
27	0	0
28	0	0
29	0	0.02
30	68.98	0

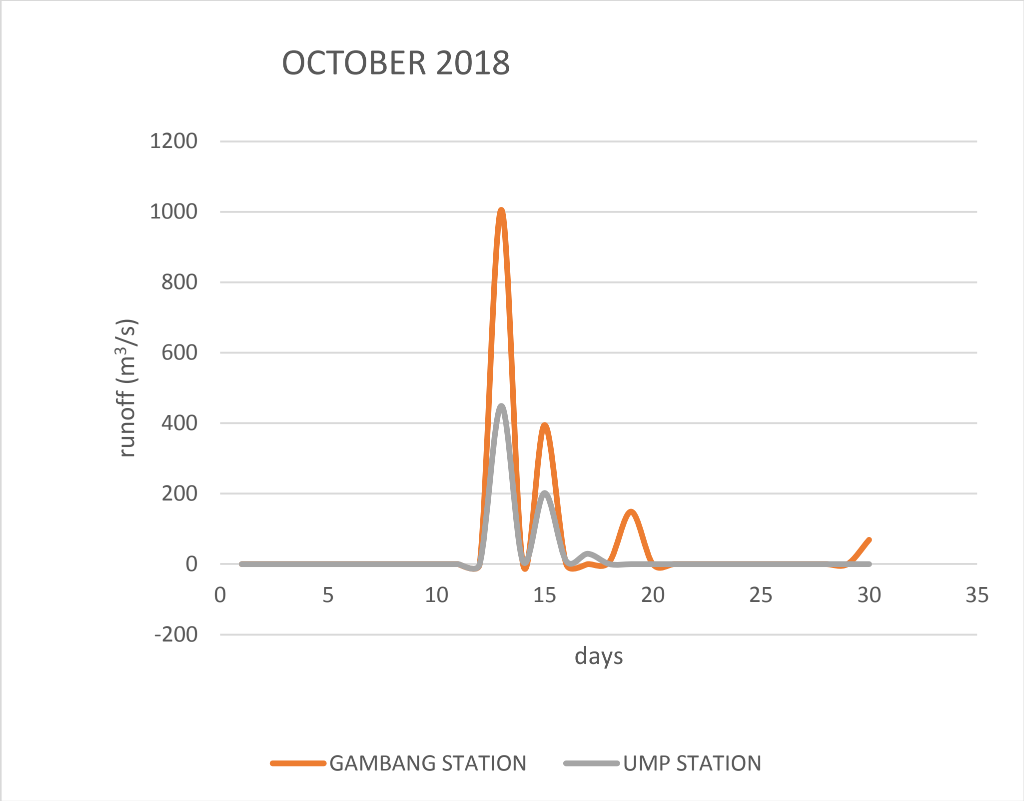


Figure 4.11 Runoff quantity of October 2018

In October 2018, the rainfall data and were taken for 24 hours per day. The graph shows the comparison between JKR Gambang station and UMP station data from the simulation analysis. The maximum runoff at JKR Gambang is 1005.79 m^3/s while the maximum UMP station runoff would be 449.08 m^3/s. The RMSE for October 2018 was 169.54 m^3/s.

4.5.2 Runoff Quantity of November 2018

Table 4.7 Runoff quantity from two different station on November 2018

DAYS	GAMBANG STATION (mm)	UMP STATION (mm)
1	0	0
2	0	0
3	21.38	13.05
4	0.9	4.08
5	34.5	32.52
6	31.13	38.76
7	4.42	8.24
8	347.68	330
9	18.99	79
10	17.61	9.6
11	51.24	45.7
12	0	0
13	43.27	47.08
14	0	0
15	14.83	0
16	23.15	33.19
17	0	0
18	72.06	49.16
19	12.4	47.78
20	7.89	0
21	5.81	4.77
22	47.78	42.58
23	0.96	0
24	0	0
25	0	36.65
26	40.88	0
27	0	0
28	0	0
29	55.74	47.76
30	0	0

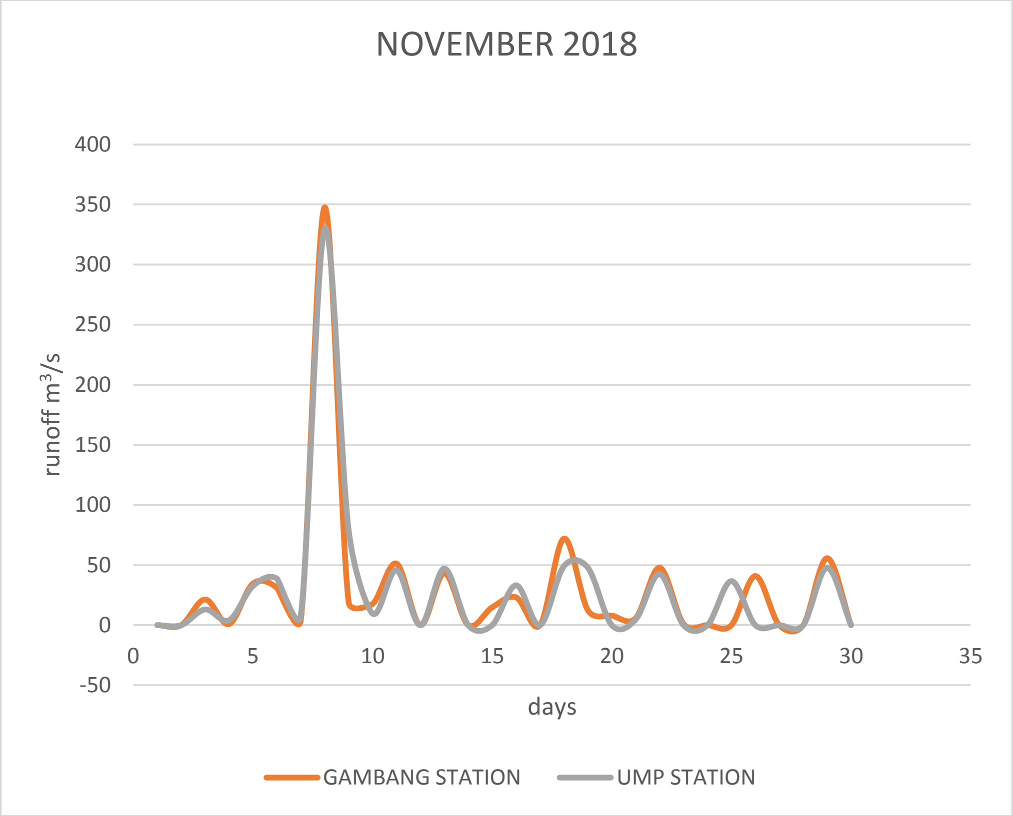


Figure 4.12 Runoff Quantity of November 2018

In November 2018, the rainfall data and were taken for 24 hours per day. The graph shows the comparison between JKR Gambang station and UMP station data from the simulation analysis. The maximum runoff at JKR Gambang is 347.68 m^3/s while the maximum UMP station runoff will be 330.0 m^3/s. The RMSE for October 2018 was 3.16 m^3/s.

4.5.3 Runoff Quantity on December 2018

Table 4.8 Runoff quantity from two different station on December 2018

DAYS	GAMBANG STATION	UMP STATION
1	0	0
2	33.86	32.48
3	14.48	29.75
4	0.96	22.46
5	0	1.3
6	0	5.12
7	0.95	8.24
8	0	0
9	0	11.36
10	0	3.73
11	0	23.85
12	0	0.38
13	43.58	42.28
14	288.12	275.27
15	48.82	40.85
16	64.49	165
17	0	1.65
18	0.96	18.64
19	0	0
20	6.14	13.79
21	52.98	82.46
22	0	0.38
23	0	1.99
24	0	0.38
25	0	0
26	2.79	6.14
27	31.48	40.84
28	103.62	90.09
29	0	0.76
30	0	0.76

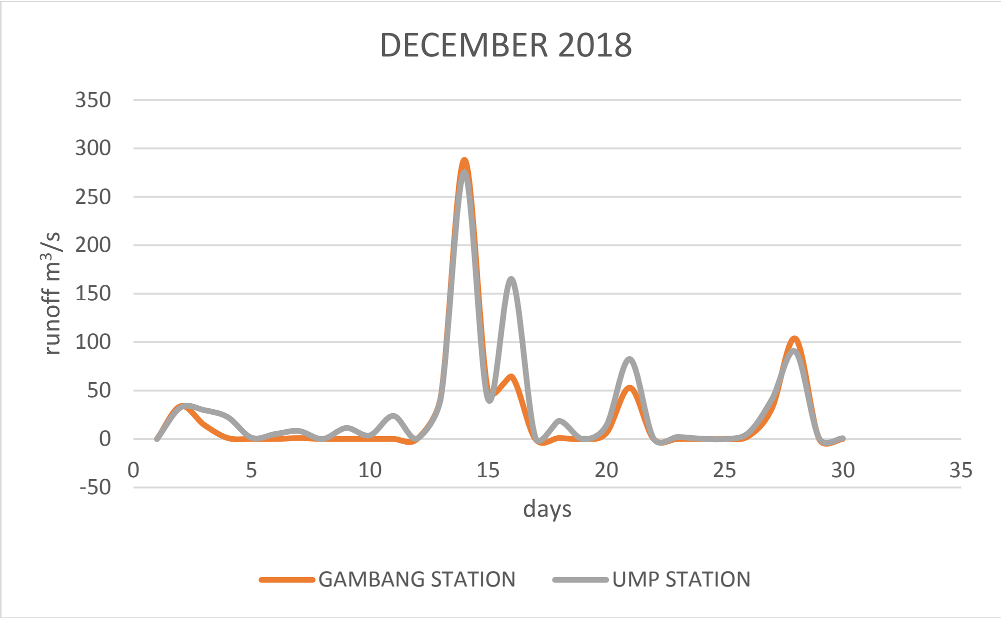


Figure 4.13 Runoff quantity of December 2018

In December 2018, the rainfall data and were taken for 24 hours per day. The graph shows the comparison between JKR Gambang station and UMP station data from the simulation analysis. The maximum runoff at JKR Gambang is 288.12 m^3/s while the maximum UMP station runoff would be 275.27 m^3/s. The RMSE for December 2018 was 41.39 m^3/s.

4.6 Rainfall-Runoff Relationship

4.6.1 Rainfall-Runoff Relationship at Gambang Station

The table 4.9, 4.10, 4.11 below shown the relationship between rainfall and runoff at the UMP Gambang using the rainfall data from the JKR Gambang Station.

Table 4.9 Rainfall-Runoff Relationship on October 2018 at Gambang Station

Rainfall-Runoff Relationship on October 2018 at Gambang Station		
Days	Rainfall value (mm)	Runoff quantity m3/s
1	0	0
2	3	0
3	0.8	0.02
4	0	0
5	0.5	0
6	0	0
7	11	0
8	3.5	0
9	1.3	0
10	7.5	0
11	11.2	0
12	53.2	0.02
13	86.3	1005.76
14	8.7	0
15	21.5	394.86
16	0.1	0
17	5.4	0
18	47.5	6.91
19	12.1	148.94
20	1.2	0
21	4.2	0
22	2.5	0
23	0	0
24	0	0
25	0	0
26	0	0
27	0	0
28	0	0
29	0	0
30	37.6	68.98
31	7.5	0

Table 4.10 Rainfall-Runoff Relationship on November 2018 at Gambang Station

Rainfall-Runoff Relationship on November 2018 at Gambang Station		
Days	Rainfall value (mm)	Runoff quantity m3/s
1	0	0
2	6.4	21.38
3	0.5	0.9
4	10.2	34.5
5	9.2	31.13
6	1.5	4.42
7	100.3	347.68
8	5.7	18.99
9	5.3	17.61
10	15	51.24
11	0	0
12	12.7	43.27
13	0	0
14	4.5	14.83
15	6.9	23.15
16	0	0
17	21	72.06
18	3.8	12.4
19	2.5	7.89
20	1.9	5.81
21	14	47.78
22	0.5	0.96
23	0	0
24	0	0
25	11.9	40.88
26	0	0
27	0	0
28	16.3	55.74
29	5.1	0
30	4.6	0

Table 4.11 Rainfall-Runoff Relationship on December 2018 at Gambang Station

Rainfall Runoff Relationship on December 2018 at Gambang Station		
Days	Rainfall value (mm)	Runoff quantity m3/s
1	10	33.86
2	4.4	14.48
3	0.5	0.96
4	0	0
5	0	0
6	0.5	0.95
7	0	0
8	0	0
9	0	0
10	0	0
11	0	0
12	12.8	43.58
13	83.3	288.12
14	14.3	48.82
15	22.9	64.49
16	0	0
17	0.5	0.96
18	0	0
19	2	6.14
20	15.5	52.98
21	0	0
22	0	0
23	0	0
24	0	0
25	1	2.79
26	9.3	31.48
27	30.1	103.62
28	0	0
29	0	0
30	0	0
31	0	0

From the table 4.10-4.12, the rainfall-runoff relationship were stimulate wisely for the November 2018 and December 2018 so it can be concluded that the runoff was increasing when the intensity of the rainfall higher. But for the October 2018 the rainfall-runoff relationship stimulate was not very consistent as the runoff quantity was not depend on the rainfall intensity. This is due to some rainfall data on this month were missing.

4.6.2 Rainfall-Runoff Relationship at UMP Station

The table 4.10, 4.11, 4.12 below shown the relationship between rainfall and runoff at the UMP Gambang using the rainfall data from the UMP Gambang Station.

Table 4.12 Rainfall-Runoff Relationship on October 2018 at Gambang Station

Rainfall Runoff Relationship on October 2018 at UMP Station		
Days	Rainfall value (mm)	Runoff quantity m3/s
1	0	0
2	0.4	0
3	0	0
4	0	0
5	0.6	0
6	0.2	0
7	14.2	0.01
8	4.8	0
9	1	0
10	5.8	0
11	10.2	0
12	37	0
13	31.6	449.08
14	9.6	7.65
15	29	201.89
16	0.2	8.7
17	9.2	29.4
18	53.8	0.14
19	0.4	0
20	0	0
21	0	0
22	0	0
23	0	0
24	0	0
25	0	0
26	0	0
27	0	0
28	0	0
29	0.4	0.02
30	0	0
31	0	0

Table 4.13 Rainfall-Runoff Relationship on November 2018 at UMP Station

Rainfall Runoff Relationship on November 2018 at UMP Station		
Days	Rainfall value (mm)	Runoff quantity m3/s
1	0	0
2	4	13.05
3	1.4	4.08
4	9.6	32.52
5	11.4	38.76
6	2.6	8.24
7	95.4	330
8	23	79
9	3	9.6
10	13.4	45.7
11	0	0
12	13.8	47.08
13	0	0
14	0	0
15	9.8	33.19
16	0	0
17	14.4	49.16
18	14	47.78
19	0	0
20	1.6	4.77
21	12.5	42.58
22	0.2	0
23	0	0
24	0	36.65
25	10.8	0
26	0	0
27	0	0
28	14	47.76
29	5	0
30	4.2	0

Table 4.14 Rainfall-Runoff Relationship on December 2018 at UMP Station

Rainfall Runoff Relationship on December 2018 at UMP Station		
Days	Rainfall value (mm)	Runoff quantity m3/s
1	9.6	32.48
2	8.8	29.75
3	6.7	22.46
4	0.6	1.3
5	1.7	5.12
6	2.6	8.24
7	0	0
8	3.5	11.36
9	1.3	3.73
10	7.1	23.85
11	0.2	0.38
12	12.4	42.28
13	79.6	275.27
14	12	40.85
15	47.8	165
16	0.7	1.65
17	5.6	18.64
18	0	0
19	4.2	13.79
20	24	82.46
21	0.2	0.38
22	0.8	1.99
23	0.2	0.38
24	0	0
25	2	6.14
26	12	40.84
27	26.2	90.09
28	0.4	0.76
29	0.4	0.76
30	0	0
31	0	0

From the table 4.13-4.15, the rainfall-runoff relationship were stimulate wisely for the November 2018 and December 2018 so it can be concluded that the runoff was increasing when the intensity of the rainfall higher. But for the October 2018 the rainfall-runoff relationship stimulate was not very consistent as the runoff quantity was not depend on the rainfall intensity. This is due to some rainfall data was not available or error on this month.

4.7 ROOT MEAN SQUARE ERROR

The figure below the result of the rainfall and runoff after the stimulation using the SWMM. The data from the two different station compared to identify the validity of the result. The Root Mean Square is the commonly used method for measuring the differences between the values predicted by a model is known as root mean square error. RMSE is an estimator and the values observed. RMSE has high measure of accuracy; therefore, it is ideal if it is small. Moreover, RMSE value should be used also to distinguish model performance in a calibration and validation process.

$$\text{RMSE}=\sqrt{\frac{\sum_{i=1}^{n}(X_{obs,i}-X_{model,i})^2}{n}} \qquad \text{(Eq.2)}$$

Table 4.15 Summary of runoff quantity from two different station.

Month	Higher Runoff Quantity (m3/s) at Gambang Station	Total Runoff Quantity (m3/s) at Gambang Station	Higher Runoff Quantity (m3/s) at UMP Station	Total Runoff Quantity (m3/s) at UMP Station	Root Mean Square Error (RMSE) (m3/s)
October	1005.79	1625.49	449.08	696.89	169.54
November	347.68	852.62	330	869.92	3.16
December	288.12	693.23	275.27	919.95	41.39

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

From the three months of rainfall hydrograph, the high intensity of rainfall at UMP is 100.3 mm on 7th November and the runoff during this day is 347.68 m3/s. But the maximum quantity of runoff is 1005.79 m^3/s on 13th October and the intensity of rainfall on this day is only 83.6 m^3/s.

By referring to the RMSE after the stimulation, the value of RMSE for the three months October, November and December are 169.54 m^3/s, 3.16 m^3/s and 41.39 m^3/s. the value of RMSE in November is so low and it is very suitable to be used as prediction of the quantity of runoff at the UMP but the value of RMSE for October is too high because there are rainfall data missing during this month so the data were affected so much. After the verified with RMSE it can be concluded the data from the both station in October are not suitable to use to predict the runoff at the UMP Gambang.

Based on the lowest RMSE on November 2018, the runoff quantity can be used as estimation of runoff quantity at UMP Gambang. Then, the qunoff quantity at November 2018 was 852.62 m^3/s at Gambang Station and 869.92 m^3/s at UMP station. So, can be concluded that the higher runoff quantity at UMP Gambang was 869.92 m^3/s.

Based on the result above, SWMM is a useful tool to estimate the runoff quantity as a prediction of the flash flood that would be happened in UMP and for the future project including drainage and development.

5.2 RECOMMENDATION

The rainfall data obtained from UMP Gambang are not as accurate as it is manual rain gauges and so many rainfall data missing this will affect the estimation of runoff quantity at certain place. To make sure that the missing rainfall data could not affect the estimation of runoff quantity, the rainfall data should interpolate to get the value of rainfall that have been missing. Thus, in future, automatic rainfall stations with hourly increment data should be used for more accurate results and to avoid the rainfall data missing.

From the rainfall data, there are some missing data, which means that analysis cannot be done for that particular month. It is recommend that the data collection should be upgraded to effective real time data which is more effective in terms of minimizing the error. Besides, the rain gauges should be inspected at least once in month to make sure the rain gauges are a good condition and function well. This is because if the rain gauges are low maintenance the possibility this tools will not function well.

Therefore, to obtain more accurate result, a few rainfall station should be proposed evenly throughout the catchment area and should be near to each other so that the data can be taken easily and better result and also can avoid the error of rainfall data. There should be more rainfall station for sub catchments area. For better accuracy, two or more method are used in the analysis and consider some other parameters in SWMM modelling.

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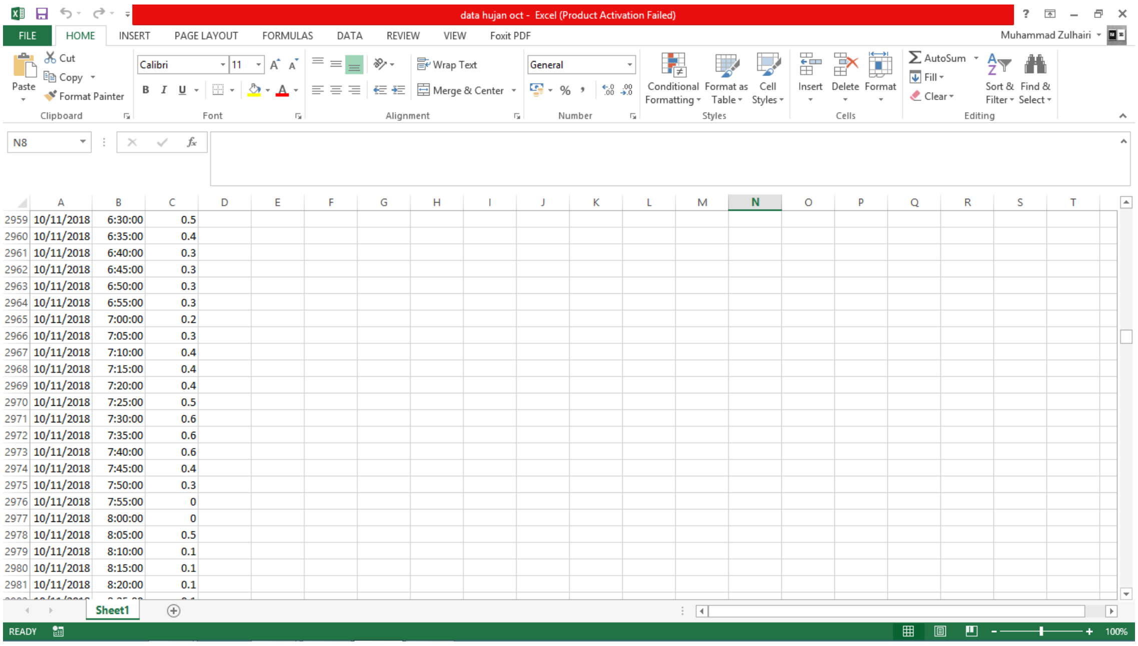
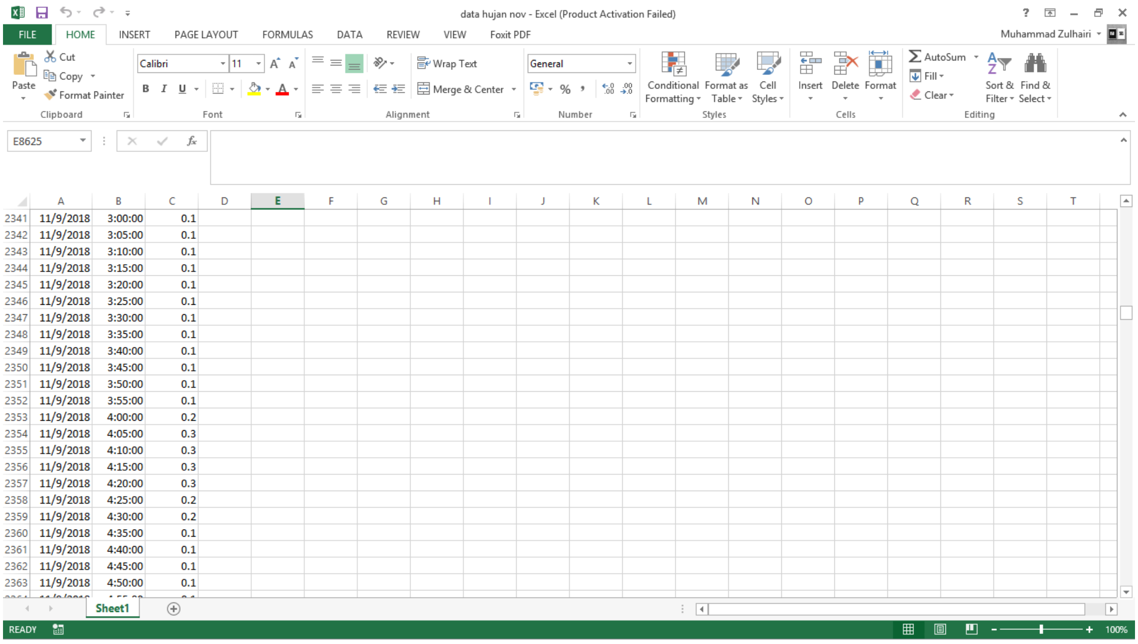
APPENDIX

RAINFALL DATA AT GAMBANG STATION AND UMP STATION



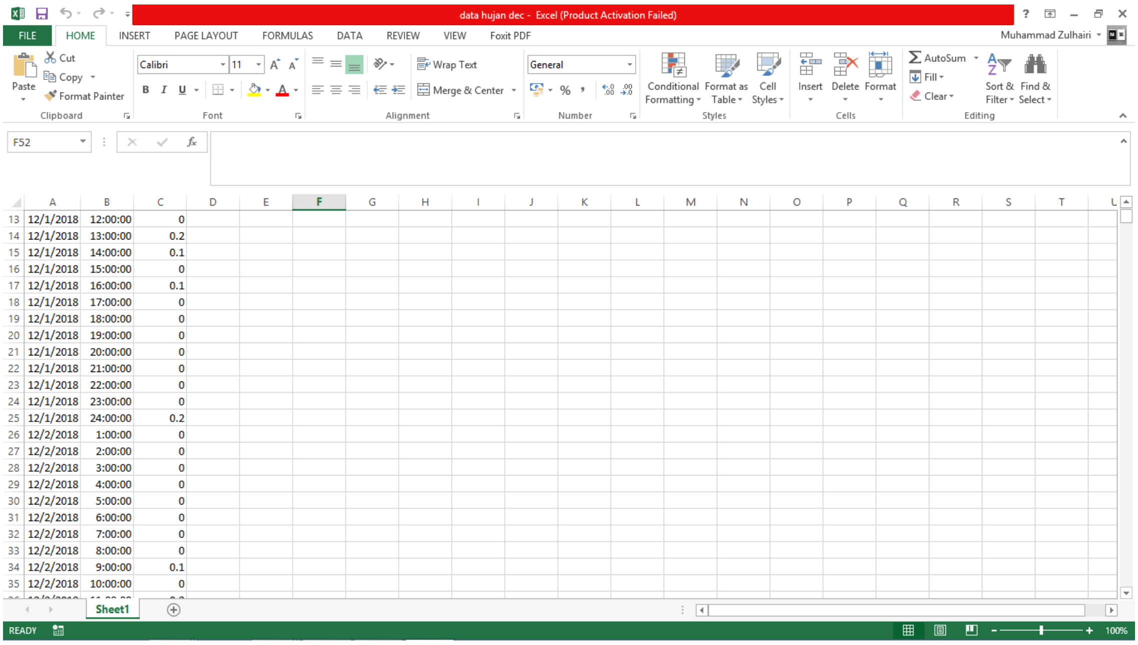
	A	B	C
2959	10/11/2018	6:30:00	0.5
2960	10/11/2018	6:35:00	0.4
2961	10/11/2018	6:40:00	0.3
2962	10/11/2018	6:45:00	0.3
2963	10/11/2018	6:50:00	0.3
2964	10/11/2018	6:55:00	0.3
2965	10/11/2018	7:00:00	0.2
2966	10/11/2018	7:05:00	0.3
2967	10/11/2018	7:10:00	0.4
2968	10/11/2018	7:15:00	0.4
2969	10/11/2018	7:20:00	0.4
2970	10/11/2018	7:25:00	0.5
2971	10/11/2018	7:30:00	0.6
2972	10/11/2018	7:35:00	0.6
2973	10/11/2018	7:40:00	0.6
2974	10/11/2018	7:45:00	0.4
2975	10/11/2018	7:50:00	0.3
2976	10/11/2018	7:55:00	0
2977	10/11/2018	8:00:00	0
2978	10/11/2018	8:05:00	0.5
2979	10/11/2018	8:10:00	0.1
2980	10/11/2018	8:15:00	0.1
2981	10/11/2018	8:20:00	0.1

Figure 6.1 Raw data of rainfall at Gambang station on October 2018.



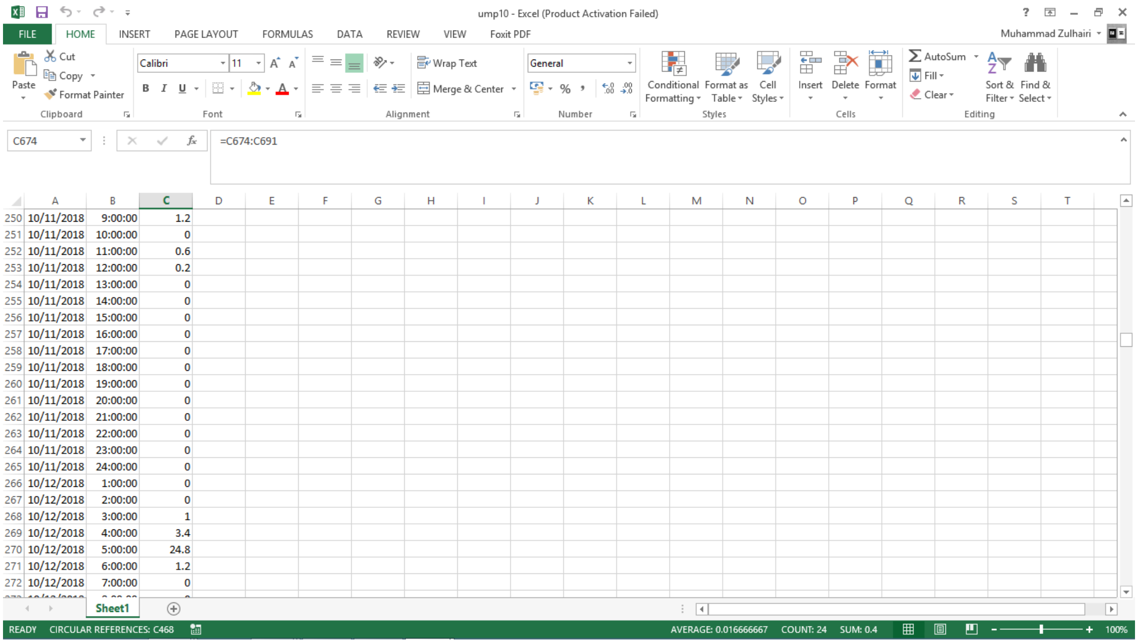
	A	B	C
2341	11/9/2018	3:00:00	0.1
2342	11/9/2018	3:05:00	0.1
2343	11/9/2018	3:10:00	0.1
2344	11/9/2018	3:15:00	0.1
2345	11/9/2018	3:20:00	0.1
2346	11/9/2018	3:25:00	0.1
2347	11/9/2018	3:30:00	0.1
2348	11/9/2018	3:35:00	0.1
2349	11/9/2018	3:40:00	0.1
2350	11/9/2018	3:45:00	0.1
2351	11/9/2018	3:50:00	0.1
2352	11/9/2018	3:55:00	0.1
2353	11/9/2018	4:00:00	0.2
2354	11/9/2018	4:05:00	0.3
2355	11/9/2018	4:10:00	0.3
2356	11/9/2018	4:15:00	0.3
2357	11/9/2018	4:20:00	0.3
2358	11/9/2018	4:25:00	0.2
2359	11/9/2018	4:30:00	0.2
2360	11/9/2018	4:35:00	0.1
2361	11/9/2018	4:40:00	0.1
2362	11/9/2018	4:45:00	0.1
2363	11/9/2018	4:50:00	0.1

Figure 6.2 Raw rainfall data at Gambang station on November 2018



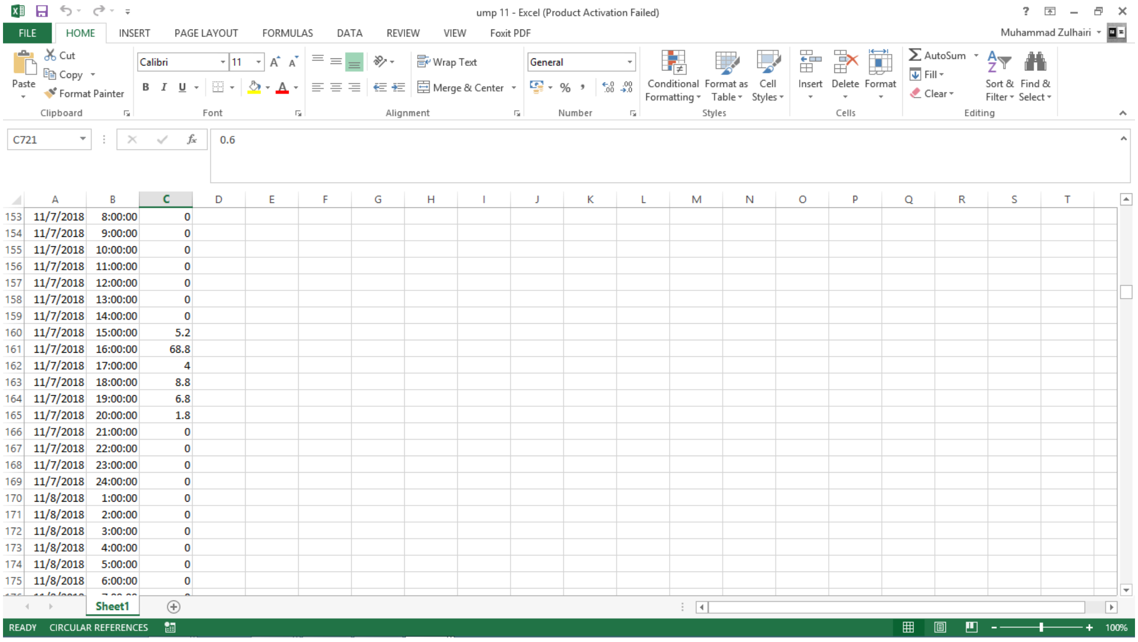
	A	B	C
13	12/1/2018	12:00:00	0
14	12/1/2018	13:00:00	0.2
15	12/1/2018	14:00:00	0.1
16	12/1/2018	15:00:00	0
17	12/1/2018	16:00:00	0.1
18	12/1/2018	17:00:00	0
19	12/1/2018	18:00:00	0
20	12/1/2018	19:00:00	0
21	12/1/2018	20:00:00	0
22	12/1/2018	21:00:00	0
23	12/1/2018	22:00:00	0
24	12/1/2018	23:00:00	0
25	12/1/2018	24:00:00	0.2
26	12/2/2018	1:00:00	0
27	12/2/2018	2:00:00	0
28	12/2/2018	3:00:00	0
29	12/2/2018	4:00:00	0
30	12/2/2018	5:00:00	0
31	12/2/2018	6:00:00	0
32	12/2/2018	7:00:00	0
33	12/2/2018	8:00:00	0
34	12/2/2018	9:00:00	0.1
35	12/2/2018	10:00:00	0

Figure 6.3 Raw rainfall data at Gambang station on December 2018



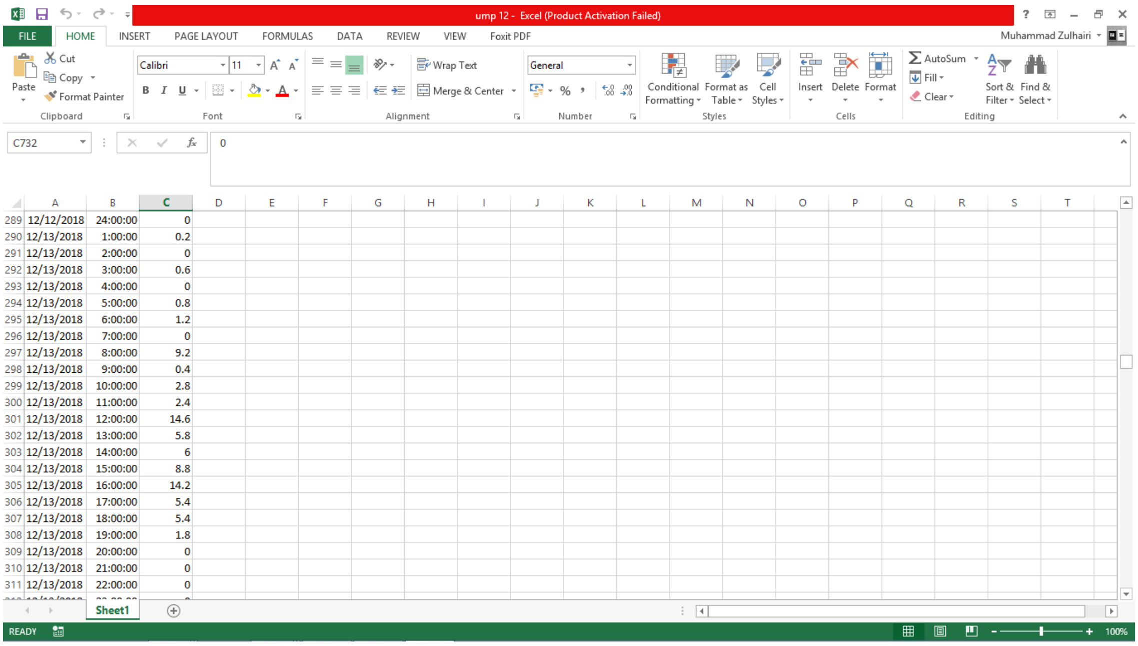
	A	B	C
250	10/11/2018	9:00:00	1.2
251	10/11/2018	10:00:00	0
252	10/11/2018	11:00:00	0.6
253	10/11/2018	12:00:00	0.2
254	10/11/2018	13:00:00	0
255	10/11/2018	14:00:00	0
256	10/11/2018	15:00:00	0
257	10/11/2018	16:00:00	0
258	10/11/2018	17:00:00	0
259	10/11/2018	18:00:00	0
260	10/11/2018	19:00:00	0
261	10/11/2018	20:00:00	0
262	10/11/2018	21:00:00	0
263	10/11/2018	22:00:00	0
264	10/11/2018	23:00:00	0
265	10/11/2018	24:00:00	0
266	10/12/2018	1:00:00	0
267	10/12/2018	2:00:00	0
268	10/12/2018	3:00:00	1
269	10/12/2018	4:00:00	3.4
270	10/12/2018	5:00:00	24.8
271	10/12/2018	6:00:00	1.2
272	10/12/2018	7:00:00	0

Figure 6.4 Raw data of rainfall at UMP station on October 2018.



	A	B	C
153	11/7/2018	8:00:00	0
154	11/7/2018	9:00:00	0
155	11/7/2018	10:00:00	0
156	11/7/2018	11:00:00	0
157	11/7/2018	12:00:00	0
158	11/7/2018	13:00:00	0
159	11/7/2018	14:00:00	0
160	11/7/2018	15:00:00	5.2
161	11/7/2018	16:00:00	68.8
162	11/7/2018	17:00:00	4
163	11/7/2018	18:00:00	8.8
164	11/7/2018	19:00:00	6.8
165	11/7/2018	20:00:00	1.8
166	11/7/2018	21:00:00	0
167	11/7/2018	22:00:00	0
168	11/7/2018	23:00:00	0
169	11/7/2018	24:00:00	0
170	11/8/2018	1:00:00	0
171	11/8/2018	2:00:00	0
172	11/8/2018	3:00:00	0
173	11/8/2018	4:00:00	0
174	11/8/2018	5:00:00	0
175	11/8/2018	6:00:00	0

Figure 6.4 Raw data of rainfall at UMP station on November 2018.



	A	B	C
289	12/12/2018	24:00:00	0
290	12/13/2018	1:00:00	0.2
291	12/13/2018	2:00:00	0
292	12/13/2018	3:00:00	0.6
293	12/13/2018	4:00:00	0
294	12/13/2018	5:00:00	0.8
295	12/13/2018	6:00:00	1.2
296	12/13/2018	7:00:00	0
297	12/13/2018	8:00:00	9.2
298	12/13/2018	9:00:00	0.4
299	12/13/2018	10:00:00	2.8
300	12/13/2018	11:00:00	2.4
301	12/13/2018	12:00:00	14.6
302	12/13/2018	13:00:00	5.8
303	12/13/2018	14:00:00	6
304	12/13/2018	15:00:00	8.8
305	12/13/2018	16:00:00	14.2
306	12/13/2018	17:00:00	5.4
307	12/13/2018	18:00:00	5.4
308	12/13/2018	19:00:00	1.8
309	12/13/2018	20:00:00	0
310	12/13/2018	21:00:00	0
311	12/13/2018	22:00:00	0

Figure 6.3 Raw rainfall data at UMP station on December 2018