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Issue and the Effect of Poor Drainage System in Urban Area Toward Flood Problem: A Case Study at Cheng, Malacca

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Abstract: Inadequate drainage capacity is one of many causes that lead to flooding in urban area. Therefore, the drainage network is considered as an important and indispensable infrastructure for the city. Cheng district area has often faced flash floods in recent times. This research work focus on identification of problems and the associated problems causing flash floods occurrence in the study area. Due to inadequate size, lack of proper maintenance and tidal effect, the existing drains in most of the places are not accommodate with the increasing of flow during the rainy season. Therefore, the rainfall distribution was analyzed to identify the relationship between the observe and current situation. The relationship between rainfall intensity and flash flood occurrence were visualized through the rainfall data chart shown in this report. A field survey method was used to identify the existing drainage conditions in the study area. From the analysis, it was found that the existing drainage system in Cheng area are mostly having issues with clogged drain which affecting the drainage flows. From data acquisition such as satellite images, hydrological data and a map of Cheng area, the flood prone area are developed using Quantum Geographical Information System (QGIS) and ArcMap software. This case study work would also propose several solutions to avoid and reduce the issues regarding flash flood occurrence in Cheng, Malacca.

Keywords: Drainage, Flash Flood Problem, Flood Mapping, Rainfall Distribution, Quantum Geographical Information System (QGIS)

1. Introduction

Urban drainage systems are typically designed to drain the surface runoff from urban areas. Storm water that exceeds the drainage capacity on the other hand can cause flash flood which could create traffic disruption, gain economic loss, and produce health concerns. As the importance of connection between the natural water cycle and human activities, a proper drainage system is required in developing urban and residential areas. The rapid development in urbanization and climate change played the most

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part of it as the flash flood event in Cheng district in Malacca has been occurred almost every year. There is a need to figure out the best way to manage water management and flood mitigation by taking all consideration such as social, economic, and environmental factor to find the solution regarding the flash flood issues. Traditionally, upgrading the drainage capacity could reduce the drain clogged and increase the flow rate of runoff by expanding and updating the existing storm drainage system. [1]

Flash flood has become one of major problem that affected many people in this country each year that had been causing thousands of losses by these occurrences. One of the areas that affected by this problem are Cheng, Krubong, and Taman Merdeka. [10] The main cause of flash flood to occur in these places are still questionable for residents that live in that area. There is no proper cleaning service, and the drainage system are quite often facing clogged problems with litter and debris by waste material based on site survey. Furthermore, the lack of drain rubbish traps or gross pollutant traps are one of the main causes of drainage capacity loads exceeding the limits resulting in flash flood occurrences. The capacity and efficiency of the drainage system become very low when not properly maintained or improved from time to time. The aim of this research is to analyze the existing drainage system and its core problem that causing flash flood problems in these areas. This research also aims to evaluate the relationship between rainfall distribution and flood problems in residential and urban area located inside flood prone zones and proposed suitable solution based on data gathered to prevent the issues.

This study involves a survey of several drainage systems around the Cheng, Krubong area in Malacca. There were several housing areas including Bukit Cheng, Cheng Perdana, Pengkalan Rama Pantai, Taman Merdeka, Taman Sri Krubong, Taman Krubong Jaya and Kampung Tampoi which have the same drainage problem. The river junction that connects four main areas is an area of rapid development due to the increase in industrial areas and housing estates. The area also has an existing industrial area which are located to the southeast of Cheng and Krubong that possibly would have the same issues. The investigation requires site survey around the urban area including the open flow channel nearby that causing flash floods problem. The existing drainage condition and its clogged problem need to be investigated as there is no rubbish trap system installed in the drainage system. The drainage condition in the study area is recorded using photograph. The rainfall distribution was analyzed based on Malacca Flood Report and recent data released by several relevant government bodies including Drainage and Irrigation Department (DID).

2. Literature Review

Floods can be defined as bodies of water, which overflow out of the banks of rivers, lakes or drainage systems due to heavy rainfall, melting ice, tides, and obstructions on channels. (Bhuiyan et al., 2018) Flash floods can occur immediately or unexpectedly. Flash floods are among the most frequent natural disasters in our country and can have some adverse effects on all life that can lead to death. Flash floods occur due to several factors. Among them is the result of continuous rain. According to Department of Irrigation and Drainage portal [11], continuous rain without stopping for several hours will cause flooding. In low-lying areas, rainwater will flow into rivers. The water that fills the river will overflow causing the lowlands to be filled with water. The process of urbanization resulted in many areas being modernized. Lowland areas have been redeemed by taking land from hill areas. There are also tributaries that are covered to be used as building sites. Such activities are a factor in the occurrence of flash floods because when it rains, water will flow from the hills to the lowlands and then stagnate, then over time the water will increase, and flash floods will occur. [2]

2.1 Type of Flood in Malaysia

Flood occurrences are usually happened regularly in the development area that have a poor drainage system or places that receive unusual amount of rainfall intensity within a long duration or period. The over received rainfall precipitation area would also having the same issues if there is no possible solution to overcome the problem. There are several types of floods in Malaysia including unpredictable flood occurrence and monsoon flood season which classified as:

a) River Flood

One of main type of flood are river floods which can be classified as one of the major problems especially in Malacca area. The river flood usually happens during a long duration of rainfall precipitation with high intensity of rainfall for hours, days or weeks. Most water produce from rainfall will flow into the river using drainage system. Clogged drainage would absolutely affect the flow rate of water and could also impact some area if the river floods occur. In southeast Asia, stream or river floods can defined as similar as monsoon floods which are usually occur by high intensity rainfall over a large area. [2] It usually happened by monsoon season month of November or December. When the real sum of river stream capacity is bigger than the capacity that the channel can hold, the river floods will overflow its banks which cause the water covered the area and surge the regions nearby the stream. [4]

b) Coastal Flood

According to Samsuri N and Abu Bakar R et al., coastal floods are storm floods that occur in low-lying coastal ranges, deltas, or estuaries where brackish or saline water causes land immersion [8]. These can be found on the ocean's shores and in large lakes. Water levels on the coast will rise because of windstorms with low climatic atmospheric pressure. According to Jonkman, when this scenario occurs with astronomical high tide, it will result in an astronomically large increase in unanticipated water levels and flooding of the coastal range [9]. When river water breaks over dikes or embankments in coastal areas and runs into the ocean as a typical stream, which is hindered by storm surges, or when expansive freshwater fiver streams flow to the estuary, which is caused by brackish water surges. Immersion in salty water surges can occur because of incredibly large wind-generated waves pushed by storm surges or tidal waves caused by structural tectonic activity.

c) Other Type of Flood

Riverine floods, single event floods, multiple event floods, estuary floods, and floods triggered by structural breakdown are some of the other flood types. Flash floods are usually associated with violent convective storms that last only a few minutes.[4] A riverine flood occurs in the valley of a large river that covers a significant region of the watershed and is caused by rain that lasts for hours or even days. Single-event floods are the most common type of flooding, which are caused by widespread torrential rains lasting two to three days across a drainage basin. Heavy rains are often connected with cyclonic disturbances or during the monsoon season, when atmospheric moisture levels are at their highest. [7] While multiple event floods are triggered by a series of strong rains and weather disturbances that are regularly monitored. Estuarine floods are quite rare, and they rarely cause widespread damage on the plain. [3] The failure of a structure, such as a dam, can result in significant flooding in downstream areas due to the pressure of collected water upstream.

2.2 Cause of Flood and Flood Intensifying Factor

Floods can be classified into three categories: meteorological, hydrological, and human. Floods generated by meteorological events such as prolonged and intense precipitation, cyclones, typhoons, storms, and tidal surges account for most flood losses and damages. Meteorologic floods, according to Buslima F, Omar RC et al [5], occur when excessive precipitation over a watershed exceeds the capacity of the basin's internal storage reservoirs and drainage network. Increased runoff from ice and snow melt, impermeable surfaces, saturated ground, low infiltration rates, and land erosion can all contribute to flooding. [4] Human activities in water catchments exhibit anthropogenic influences, which dramatically increase the magnitude and frequency of floods in a variety of ways. As a result, human activities related to land use change, such as deforestation, intensive agriculture, and so on, are the most significant contributors to flooding, followed by population expansion, socioeconomic and development activities, urbanization, climatic change, and global warming. [5] According to Bhuiyan

[4], floods can be caused by a variety of factors, including the rapidly accumulating flash floods, frequently on steep terrain.

2.3 Application of Flood Mapping Software

There are many software and computer program used to mapping the case study area such Earth Pro, ArcGIS, ArcMap, QGIS and many more which are open-source software. Mapping is important in construction site investigation work, especially to identify the plan and topography of a study area. The maps and area drawing plans produced from mapping work can help the subsequent civil engineering work as well as to avoid the problems that are often identified at sites involving the geographical and information system of the case study area. [12]. Application used in this study is QGIS, a cross-platform desktop geographic information system program that used to browse, modify, and analyze geographical data. QGIS is a geographic information system (GIS) program that allows users to analyze and update geographical data as well as create and export graphical maps. Vector data is saved as point, line, or polygon features in QGIS; raster data is stored as point, line, or polygon features. The program can georeferenced pictures and supports many rasters image formats. Shapefiles, coverages, personal geodatabases, dxf, MapInfo, PostGIS, and more formats are all supported by QGIS. Web services, such as the Web Map Service and the Web Feature Service, are also supported, allowing data from external sources to be used. [12]

3. Methodology

The methodology used in this case study consists of two types of data collected which is recorded data and field survey. Data collection of catchment inventory and hydrological data was employed from the reports of Drainage Irrigation Department (DID) in Malacca state. The report consists of Annual Flood Report from year 2010 to 2020 and information about catchment area of this case study. In this report also consist of rainfall intensity, rainfall chart with hyetograph of all flash flood occurrence in Malacca. Photographs were taken directly from the case study area during the field survey and investigation. The collected data from this resource are shown in this report with the comparison and data analysis which are used to develop Geographical Information System (GIS).

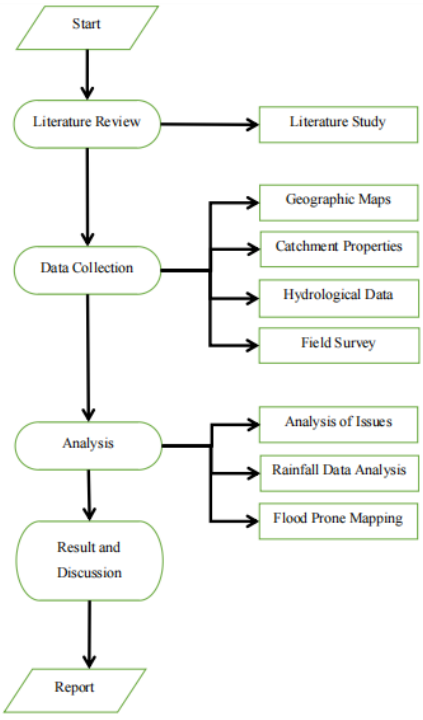

Figure 3.1: Workflow of collecting data.

3.1 Study Area

The study area is at Cheng and Krubong area in Malacca. There were several housing areas including Taman Cheng Perdana, Taman Merdeka, Taman Sri Krubong, Taman Krubong Jaya beside Malacca River. The river junction that connects four main areas which requires investigation on the open flow channel in this area. There are four sub catchments divided as shown in Figure 3.1. The first sub catchment is 23.0 ha, second sub catchment area is 19.9 ha, third sub catchment is 15.9 ha, and the fourth sub catchment is 6.79 ha.

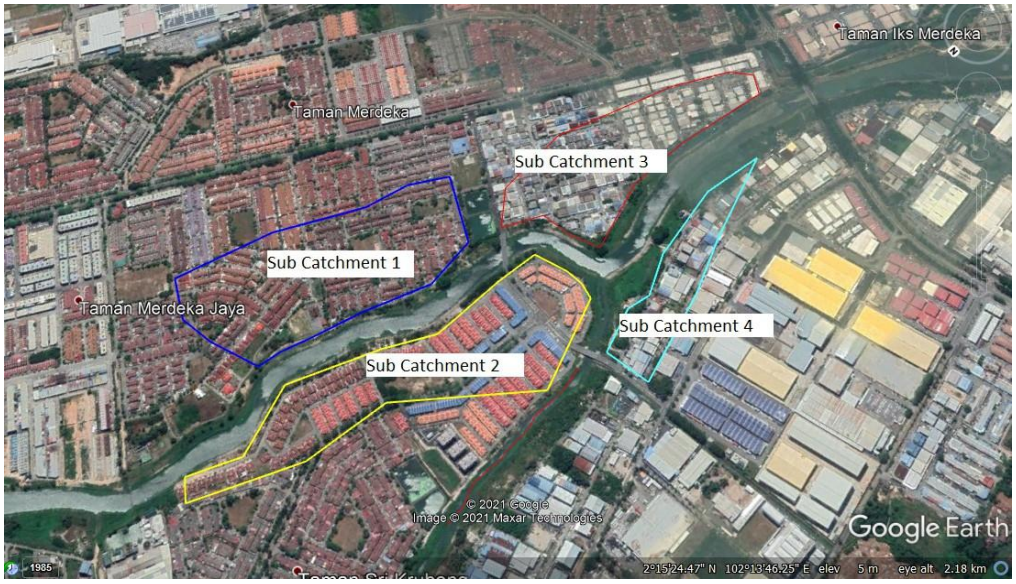

Figure 3.2: The sub catchment of studies area in Cheng and Krubong district. (Google Earth 2021).

3.2 Data Collection

Data collection is the process of gathering and measuring information to established data system that enables to help research findings, test hypotheses, and evaluate the outcomes. The data collection component of this research involves two stages which are data recording that consist of hydrological data and field survey to identify the current issues in Cheng district, Malacca.

3.3 Hydrological Data

Hydrological information or data is used to conceptualize the movement of groundwater through the system. Hydrological information on precipitation, surface water runoff as well as head data and information are used in this analysis. The data can be retrieved from Hydrology Division of the Department of Irrigation and Drainage (DID). The catchment properties data requires for this information are sub catchment areas (ha), drainage catchment characteristics, surface runoff coefficient data, slope of overland surface, channel length for the channels in every sub catchment studied, rainfall Data of Malacca State, Rainfall Distribution Malacca and the most important are the DID Annual Flood Report.

3.4 Field Survey

The field work survey is carried out to identify the problems that happen especially for drainage system inside the study area. The survey includes photographs of the study area and it's surrounding to analyze and point out the issues that happen especially the causes of flash floods occurrence which happen every year. The latest drainage problem is taken by a photograph and compared to the latest flash floods events which occur at the exact same area to point out the issues that have always been a problem in this study area for each year. The field survey is conducted in Taman Cheng, Taman Merdeka, Taman Seri Krubong and Taman Krubong Utama.

3.5 Rainfall Data

Flood features are determined by a mixture of precipitation factors, including volume, severity, duration, and geographical distribution, according to previous research. As a result, high-intensity, short-duration storms or longer-duration, low-intensity rainfall can cause flooding. Floods are also more closely linked to the overall amount of rain that falls during a rainstorm than its severity. Storm rainfall becomes more complicated as the storm grow, making it impossible to generalize the role of rainfall intensity for flood formation. The relationship between rainfall intensity and flash flood occurrence were visualized through the rainfall data chart shown in this report. The rainfall data are gathered from flood report of DID Malacca from 2015 to 2021. The data are analyzed which consist of rainfall data, data from Telemetry Station taken, the date of flash flood events with all the data related to the flood's occurrence.

3.6 QGIS Mapping Method

Cheng District was selected as the study area due to the increasing number of floods in Malacca in recent years. From data acquisition such as satellite images, hydrological data and a map of Cheng area, the flood prone area are developed using QGIS and ArcMap software. Figure 1 shows the flow chart of the data processing steps used in this research study.

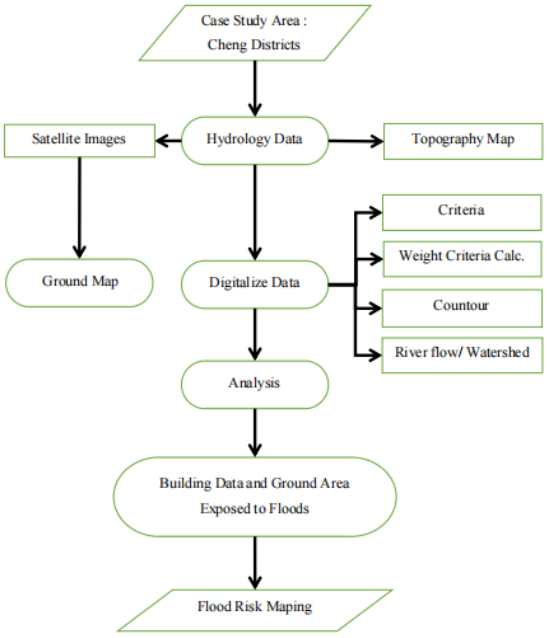

Figure 1: Workflow of QGIS mapping.

4. Results and Discussion

4.1 Analysis of Issues

The Cheng district has a natural drainage topography due to a bit hilly terrain with low gradients to drain off water flow along two main natural drainage channels which connected with Malacca River as shown in Figure 2. There are several issues discovered from the field survey conducted at the case study area. Most of the problems that cause the flash flood occurrence that happen regularly is a drainage system. Some drainage area listed in Table 1 have the same common issues affecting the water flow system. The clogged drain disrupts the peak flow and by time, the water flow in the drain overload and spill outside the drain causing flash flood occurrence.

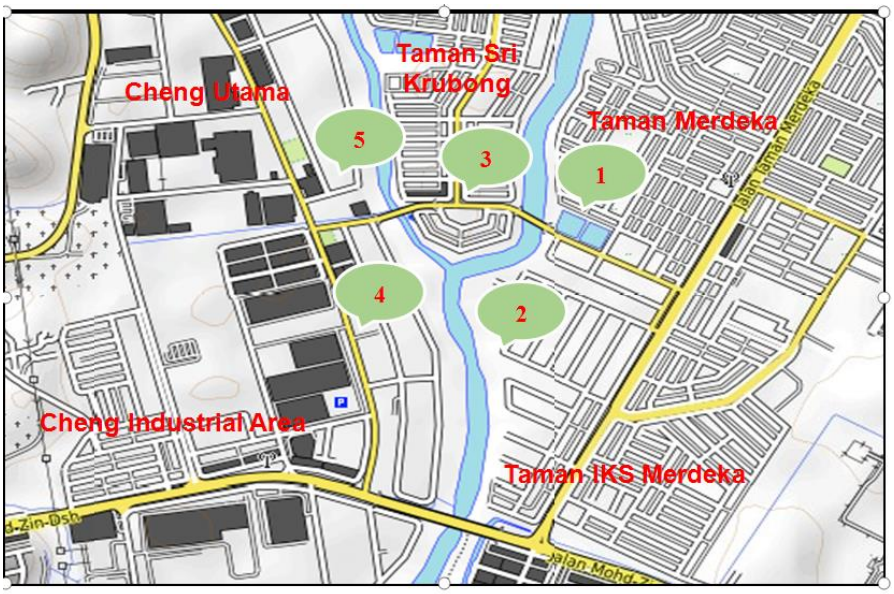

Figure 2: Marked spot of problem in Cheng district area (QGIS)

Table 1: Issues analysis

No.	Locality	Probable Causes	Area
1	Jalan Jasa Merdeka 35	Obstruction to discharge, Improper maintenance cleaning	 Figure 3
2	Jalan Merdeka 14	Inadequate size of drains, Obstruction to discharge	 Figure 4
3	Jalan Seri Krubong	Obstruction to discharge.	 Figure 5
4	Jalan TTC 14	Lack of size and damaged drains.	 Figure 6

From site surveys at Cheng area, there are several drainage systems chosen which indicate as high potential of problem causing flash flood occurrence. Jalan Jasa Merdeka (Figure 3) shows that there is obstruction that prevent the flow of water going smoothly as there are improper maintenance for the drainage system. Jalan Merdeka 14 (Figure 4) and Jalan Seri Krubong (Figure 5) also shows the same problem facing in that area. While at Jalan TTC 14 in Figure 6, the problem figured out are the lack of size and damaged drains which resulting a crack and drainage clogged. Garbage dumped in the drain has clogged some part of the drain system and causing the flow of water to be disrupted along the system

4.2 Flood Prone Area Analysis

The information of flood prone area is important especially for urban and residential area involved as they can take preventive action before the flood occurrence. By using QGIS and ArcMap, the flood prone area was generated based on data and information from Flood Report Drainage and Irrigation Department (DID) Malacca. Figure 7 shows the location of the case study area and the water flows in Malacca developed from QGIS.

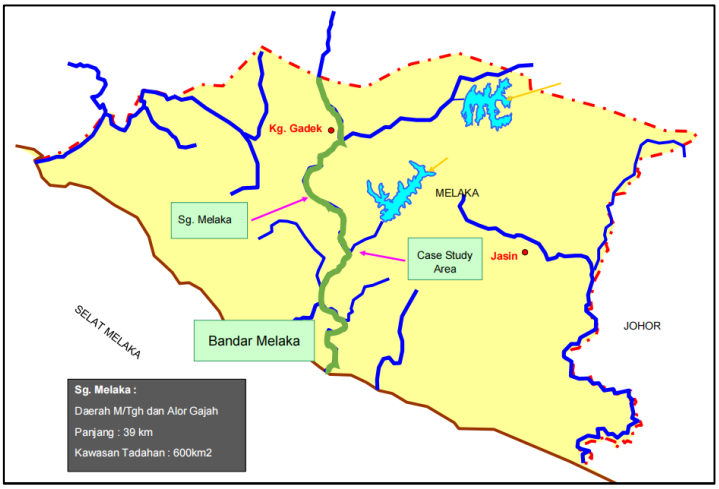

Figure 7: Case study area mapping developed. (Based on DID Report, 2020)

By using ArcMap, the flood prone in case study area were developed based on Flood Report information data from DID Malacca. Figure 8 shows the flood prone that marked by blue polygon involving Taman Cheng, Taman Krubong, Cheng Industrial Area, Taman Merdeka, and Taman IKS Merdeka. This area has experience regular flash flood problem every year since 2010. (RSN Murali, 2021) The number of cases in Malacca keep increasing since then and affecting this case study area.

Figure 8: The flood prone in Cheng, Malacca. (Based on DID Flood Report, 2021)

4.3 Rainfall Analysis

Rainfall data analysis was used based on the Flood Report 2015 to Flood Report 2020 which contain all information about flash flood analysis in Malacca every year. This data was collected to show the relationship between rainfall and the flash flood problem in Cheng area. The data taken from Taman Merdeka Telemetry Station shows the rainfall daily and water level data on 13 December 2015 are shown in Table 2. The water level is based on Flood Report Malacca Daily Rainfall that generated from Rainfall Daily Chart in Figure 9. The flood occurrence at Taman Merdeka and Taman Krubong has been recorded in Flood Report on 13 December 2015 with 0.3m to 0.6 average of flood depth. The report stated that the causes of the flood are from the continuous rain of 8 hours from the upstream causing overflow of Malacca River.

Table 2: Rainfall Daily and Water Level on 13/12/2015. (DID, 2015)

Telemetry Station	District	Water Level 13 December 2015	Daily Rainfall (mm)
Melaka Pindah	Alor Gajah	Danger Level – 12.97m	84
Durian Tunggal	Alor Gajah	Danger Level– 3.97m	21
Taman Merdeka	Melaka Tengah	Normal Level	28
Klebang	Melaka Tengah	Normal Level	43
Chohong	Jasin	Normal Level	84
Telok Rimba	Jasin	Normal Level	33
Duyong	Melaka Tengah	Normal Level	48
Batu Hampar	Melaka Tengah	Normal Level	51

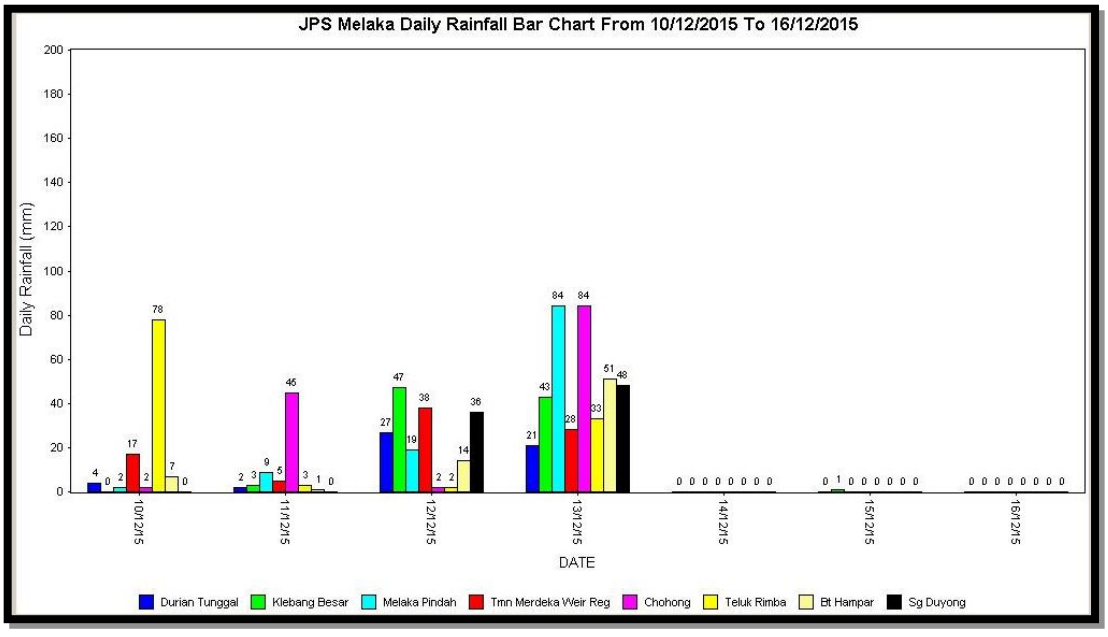

Figure 9: Rainfall Daily Chart 10/12/2015 till 16/12/2015. (DID, 2015)

Daily Rainfall data recorded at Telemetry Station Taman Merdeka on 13 December 2015 are 28mm but as the river overflow from upstream, still causing flash flood occurrence at the downstream including Taman Krubong and Taman Merdeka (Cheng Area).

The data taken from Taman Merdeka Telemetry Station shows the rainfall daily and water level data on 6 February 2016 shown in Table 3. The water level is based on Flood Report Malacca Daily Rainfall that generated from Rainfall Daily Chart in Figure 10. The flood occurrence at Taman Merdeka and Taman Krubong has been recorded in Flood Report on 6 February 2016 with 0.3m to 1.0 average of flood depth.

Table 3: Rainfall Daily and Water Level on 6/02/2016. (DID, 2016)

Telemetry Station	District	Water Level 6 February 2016	Daily Rainfall (mm)
Melaka Pindah	Alor Gajah	Danger Level – 12.95m	43
Durian Tunggal	Alor Gajah	Danger Level– 4.94m	74
Taman Merdeka	Melaka Tengah	Normal Level	8
Klebang	Melaka Tengah	Normal Level	47
Chohong	Jasin	Normal Level	19
Telok Rimba	Jasin	Normal Level	26
Duyong	Melaka Tengah	Normal Level	0
Batu Hampar	Melaka Tengah	Normal Level	36

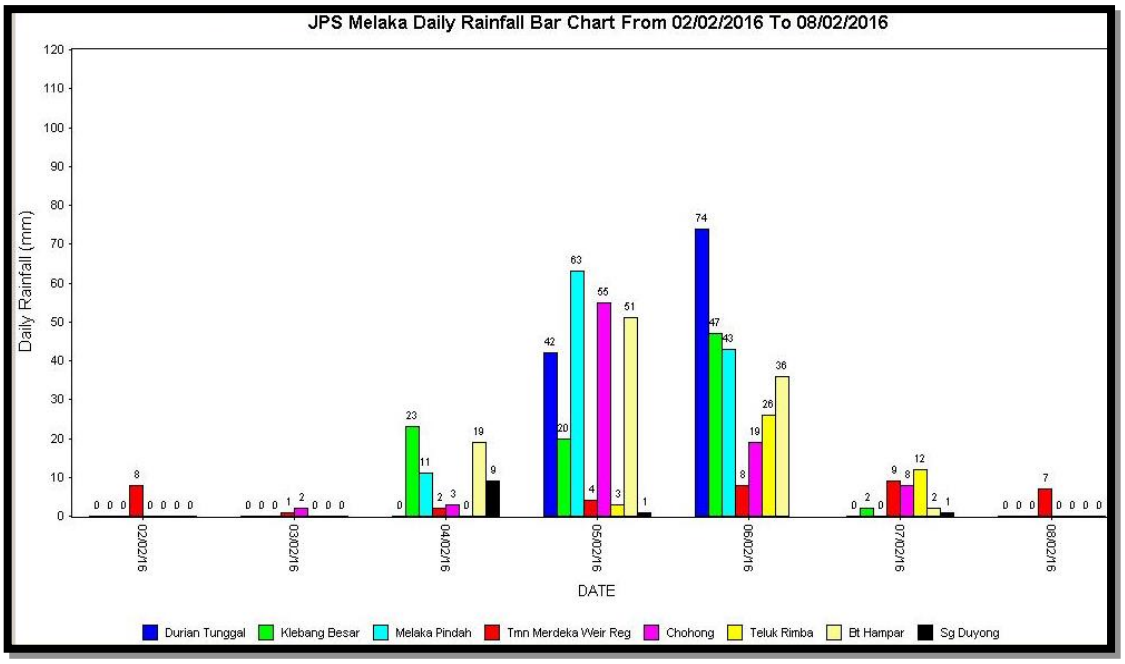

Figure 10: Rainfall Daily Chart 2/2/2016 till 8/2/2016. (DID, 2016)

Daily Rainfall data recorded at Telemetry Station Taman Merdeka on 2 February 2016 until 8 February 2016, are below 10mm but as the river overflow from upstream, which still causing flash flood occurrence at the downstream including Taman Merdeka (Cheng Area).

The data taken from Taman Merdeka Telemetry Station shows the rainfall daily and water level data on 11 August 2017 shown in Table 4. The water level is based on Flood Report Malacca Daily Rainfall that generated from Rainfall Daily Chart in Figure 11. The flood occurrence at Taman Merdeka and Taman Krubong has been recorded in Flood Report on 11 August 2017 with 0.3m to 0.6 average of flood depth.

Table 4: Rainfall Daily and Water Level on 11/8/2017. (DID, 2017)

Telemetry Station	District	Water Level 11 August 2017	Daily Rainfall (mm)
Klebang	Melaka Tengah	Alert Level	98
Taman Merdeka	Melaka Tengah	Alert Level	145
Duyong	Melaka Tengah	Normal Level	0
Batu Hampar	Melaka Tengah	Alert Level	158
Sg Udang	Alor Gajah	Alert Level	103

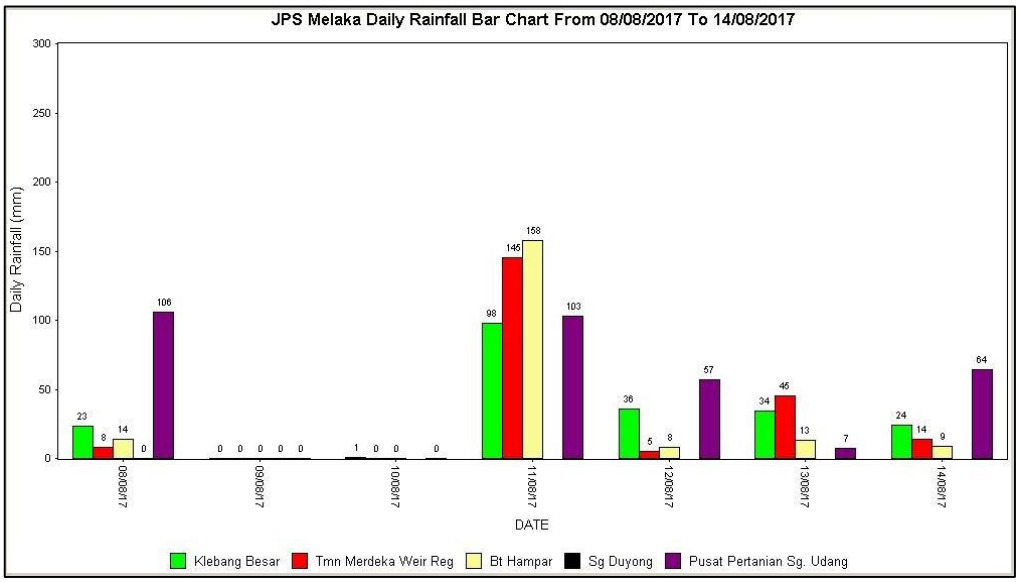

Figure 11: Rainfall Daily Chart 8/8/2017 till 14/8/2017. (DID, 2017)

Daily Rainfall data recorded at Telemetry Station Taman Merdeka on 11 August 2017 are 148 mm, causing flash flood occurrence over several area in Malacca including Taman Merdeka (Cheng Area). The Flood Report also records the high-water level of Sg Salak which also are factor of flash flood occurrence in several places in Malacca.

Based on the rainfall data and the flood occurrence data collected from 2015 until 2020, the data shows that the flash flood occurrence was not only happen because of the rainfall in that area, but it still could happen on certain occasion such as massive rainfall at the upstream which causing overflowing river to the downstream. The data also show that even there are low rainfall distribution in the study area, flash flood still occurred because of the location of study area which located at the downstream.

4.4 Proposed Solution

There are several methods that have been identified for the improvement of the drainage system in residential areas which consist of maintenance methods, river deepening projects, controlling human activities, upgrading the drainage system and construction of embankments.

i. Regular Drainage Maintenance

Local authorities (PBT) need to constantly monitor and maintain drainage infrastructure and drainage systems to reduce the risk of flash floods.

ii. River Deepening Project

This method is done to reduce the amount of river water rising to the mainland which will cause floods. This is because most of the floods are caused by shallow rivers. The result of the process of deepening the river will be done for the process of land reclamation for low-lying areas, especially for residential areas to reduce the impact of floods.

iii. Upgrading the Drainage System

Drainage system upgrade should be planned well and considering of the importance of the drainage system in particular. For housing areas that are narrow and require modification to the drainage system is to deepen the drainage system. In addition, the local authority will work with the DID to upgrade by enlarging the drainage system that brings water flow to the final drainage by not using the same size of drain. It acts to accommodate excess water that cannot be accommodated by other drainage systems.

4.5 Discussion

The results of this study were achieved based on the field survey observation method used. The factors which contribute to the existing drainage problem that causing flash flood occurrence in Cheng, Malacca can be state as poor drainage system which is cause by clogged drainage and the lack of cleaning maintenance. As seen in Table 4.1, the flash flood problem could be reduced if the drainage system is well maintained with proper cleaning regularly. The drains and culverts are rarely maintained and when it comes to heavy rainfall season, the blockage of drains will reduce the capacity and obstruct water flow and then overspill causing flash flood. The flood mapping also was produced in this report by taking the flash flood occurrence which are recorded in DID Flood Report. The flood mapping development by using QGIS for this case study also has achieved the objective of this project for the mapping works. Based on the analysis of study, the flood data collect from DID Flood Report shows the relationship between the rainfall data during floods occurrence. The data records that areas affected by flash floods in Cheng district have high rainfall intensity values when the disaster occurs. It can be concluded that the condition of the drains which cannot accommodate the abundant water capacity especially during the heavy rainy season can result in floods occurring. The data also shows the relationship between the rainy season and flood duration speed where if the rainfall intensity exceeds a few hours and has a high intensity of rainfall, the rate of flooding is faster than areas with better drainage systems and no problems such as drains clogged. Based on the analysis conducted, the best methods for improvement to the drainage system in residential areas are river deepening, deepening drainage systems, building dams and many more. This is in line with literature reviews such as Farahazura (2019), Hafez (2019) and Suhada (2014) stated that the authorities are doing their best to make improvements to the drainage system, especially in housing estates that have the potential to face problems such as flash flood. This aims to appoint the existing problems while proposing the way to reduce the impact of floods on the drainage system.

Conclusion

Based on this study, it can conclude that there are several factors that affecting the flash flood problems in Cheng area. The drainage problem and the rainfall are two main factors contributing to the flash floods occurrence. The drainage problem was proved by conducting field survey and there are several photograph proofs shows the indication of drainage problem in that area. The rainfall data also shows that the rainfall in the case study area also was not only a factor contributing the flood events. The heavy rain from the upstream also can also be the factor as the river flows from upstream to the downstream affecting the most area of the case study. The proper solution also has been stated which can be solution to this problem appointed. The use of QGIS technologies in this flood mapping are

very useful as it can shows the flood prone area information in simplest and easiest way to understands. In this study also focuses on analyzing drainage problem that is important due to the rapid change in flash flood problem in Malaysia. The data such as rainfall intensity, catchment characteristic, the topography of area, past flood report also have some important part in conducting this case study. The Melaka DID has provided cooperation with their feedback, knowledge and understanding on the types of drainage systems, problems, and improvements to the drainage system in the study area. This study has succeeded in achieving the objectives of the study and it should be continued in the future.

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