FLOOD HAZARD MAP OF SUNGAI KULIM USING HIGH PERCENTAGE OF OVERLAPPING IMAGES CAPTURED BY (UAV) DRONE

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By

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ABSTRAK

Sungai Kulim merupakan sungai utama yang mengalir melalui bandar Kulim di selatan Kedah. Ia mengalir secara besar-besaran ke arah barat laut ke Sungai Perai di Seberang Perai. Pada tahun 2017, banjir telah berlaku di kawasan hilir Sungai Kulim. Fenomena ini mungkin disebabkan oleh intensiti hujan yang tinggi menyebabkan jumlah air yang tidak dapat dikawal dari hulu Sungai Kulim. Kesan banjir itu, hampir 100 buah rumah yang terletak di kawasan rendah telah musnah atau di bawah paras air dan penduduk tempatan diminta untuk berpindah ke pusat pemindahan. Oleh itu, kajian terhadap pelbagai purata pelepasan air berdasarkan tempoh pulangan 2, 3, 5, 10, 25, 50, 100, dan 200 tahun sepanjang 5 km panjang dan 200 meter lebar sungai hilir telah dijalankan. Unmanned Aerial Vehicle (UAV) digunakan untuk mengambil gambar ortho sungai dalam peratusan bertindih imej yang tinggi. Objektif utama dalam kajian ini adalah untuk mensimulasi banjir yang menggunakan perisian Sistem Analisis Sungai Hidrolik Pusat Analisis (HEC-RAS) yang dibina oleh US Army Corp. Perisian HEC-RAS digunakan untuk membantu analisis aliran saluran dan penentuan tahap air banjir oleh para penyelidik di seluruh dunia. Tahap air banjir boleh membantu menilai kesan kawasan hiliran disebabkan oleh intensiti purata hujan. Dengan menggunakan Digital Elevation Model (DEM) yang dihasilkan oleh perisian Agisoft Photoscan, HEC-RAS akan mensimulasikan kawasan banjir yang mungkin berlaku. Jumlah pelepasan air yang digunakan dalam simulasi ialah 44.25, 50.58, 57.59, 66.42, 77.58, 85.86, 94.08, dan 102.27 m3 / s. Pelepasan air adalah berdasarkan tempoh pulangan sebanyak 2, 3, 5, 10, 25, 50, 100, dan 200 tahun. Halaju maksimum, kedalaman maksimum, masa ketibaan dan peta sempadan banjir akan dihasilkan. Temuan ini dapat menghasilkan peta bahaya banjir dan meramalkan kawasan bahaya banjir. Kajian ini juga membantu pihak berkuasa untuk membina rancangan kecemasan untuk mengelakkan banjir berlaku di kawasan hilir

Sungai Kulim. Selain itu, kajian ini dapat memberikan kesedaran kepada penduduk tempatan mengenai kawasan berisiko banjir.

ABSTRACT

Sungai Kulim is the main river that flows through the town of Kulim in southern Kedah. It flows largely in a northwesterly direction to empty into the Perai River on the Seberang Perai. In 2017, flood occurred in downstream area of Sungai Kulim. This phenomenon probably due to high intensity of rainfall caused the uncontrollable amount of water discharge from upstream of Sungai Kulim. Impacts of that flood, nearly 100 houses located at the low-lying areas were destroyed or under water and the local residents were urged to move to the relief centre. Thus, study on various average water discharge based on return period of 2, 3, 5, 10, 25, 50, 100, and 200 years along 5 km length and 200 m width downstream river was conducted. The Unmanned Aerial Vehicle (UAV) Drone was used to capture the orthophoto of river in high percentage overlapping images. The main objective in this study is to simulate the flood extent using Hydraulic Engineering Center’s River Analysis System (HEC-RAS) software which is constructed by US Army Corp. HEC-RAS software was used to aid in channel flow analysis and flood water level determination by researchers around the world. The flood water level can helps evaluate effect of the downstream area due to average rainfall intensity. Using Digital Elevation Model (DEM) generated by Agisoft Photoscan software, HEC-RAS will simulate the area of flood probably occurred. The amount of water discharge used in the simulation were 44.25, 50.58, 57.59, 66.42, 77.58, 85.86, 94.08, and 102.27 m^3/s. The water discharge were based on return period of 2, 3, 5, 10, 25, 50, 100, and 200 years. As a result, maximum velocity, maximum depth, arrival time and inundation boundary maps were produced. This finding was able to produce flood hazard map and predict risk area of flooding. This study also helped authorities to construct the emergency plan as to prevent flood occur in downstream area of Sungai Kulim. Besides, this study can give awareness to local residents of risk area on flood.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

HEC-RAS	**H**ydarulic **E**ngineering **C**enter's **R**iver **A**nalysis **S**ystem
DEM	**D**igital **E**levation **M**odel
RTK	**R**eal **T**ime **K**inematic
GPS	**G**lobal **P**ositioning **S**ystem
GNSS	**G**lobal **N**avigation **S**atellite **S**ystem
UAV	**U**nmanned **A**erial **V**ehicle

NOMENCLATURE

Q	Flow discharge
n	Manning’s coefficient

CHAPTER 1

INTRODUCTION

1.1 General

In Malaysia, there are two major water-related problems affecting this country which are excess water (floods) and water shortage (droughts) (Taib, 2016). Both of these problems have disrupted the quality of life and economic growth in this country and can cause severe damages such as loss of properties and also human lives.

A study by Akasah and Doraisamy (2015) found that the worst flood in the history of Malaysia was on December 2014 to January 2015 that hit the Kelantan state according to the Natural Security Council (NSC). The water levels of the flood superseded the flood occurred in 1967 (Azlee, 2015). Two main reasons identified that lead to the flood disaster in the Kelantan state. The change of climatic patterns and weather effects. Also, the uncontrolled land management that leads to the swelling number of trees and exploitation of land resources.

The flood also occurred at the Kulim district when the climatic patterns and weather changed. For example, residents of Kampung Bikan Atas, Kampung Padang Katong in Labu Besar and Merbau experienced a tragic event when their village was inundated on October 2013 (The Star, 2013). A huge volume of water discharges due to heavy rainfall had caused unusual increase of water level in Sungai Kulim. This caused a large area of Sungai Kulim to be inundated with flood water

In order to minimize the impacts of flood disaster, Malaysia Government has developed an innovative project which is Program Ramalan Amaran Banjir in order to improve flood prediction capability and flood emergency plan. Local residents in affected areas will be informed at least 7 days earlier to evacuate to the relief centre (Halid, 2017).

1.2 Study Area

Sungai Kulim is the river that flows through the town of Kulim in southern Kedah. It flows largely in a northwesterly direction into the Prai River at Kampung Labuk Banting on the Seberang Perai. It is the main river not only for Kulim but also Lunas and forms a geographical boundary between Bukit Mertajam in Seberang Perai Tengah and Tasek Gelugor in Seberang Perai Utara. Sungai Kulim have total length of 34 km and width about 8-12 m (Kulim River, 2007). Figure 1.1 shows the location of Sungai Kulim on Google Map.

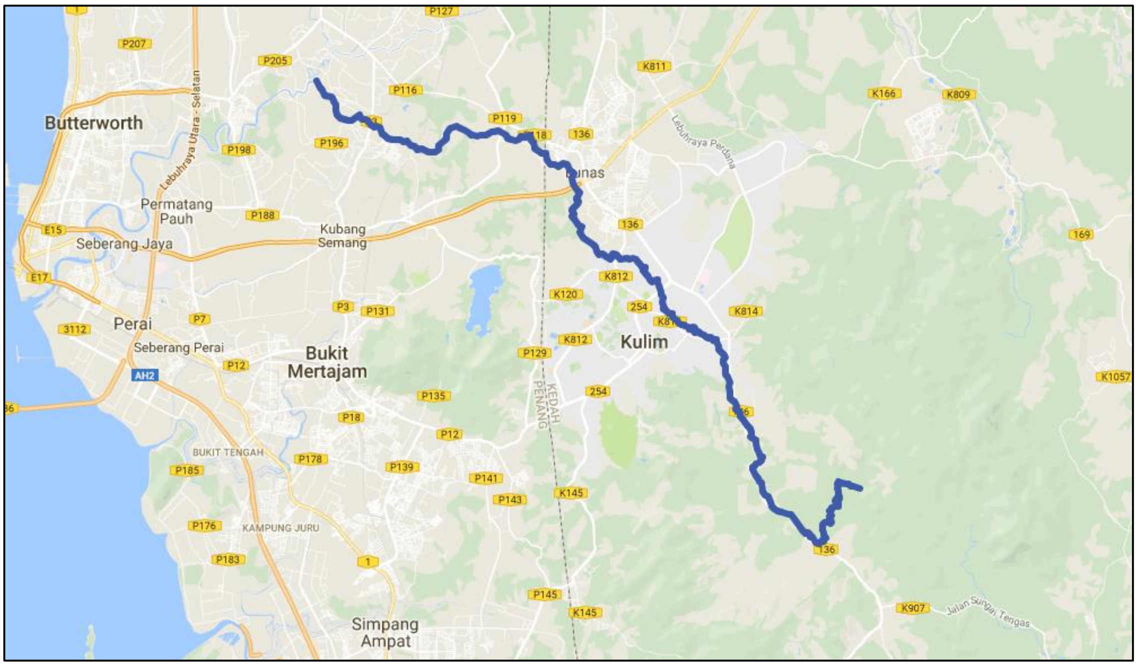

Figure 1.1: Location of Sungai Kulim on Map (Source: Google Map)

Generally, the study is to develop DEM generated by Agisoft Photoscan software and then produce flood hazard of Sungai Kulim using HEC-RAS software. The study area is approximately 5km length, 8 m width and 100 m width downstream river.

1.3 Problem Statement

Flood is the extreme precipitation events caused the rise of water level above land in short duration due to heavy rainfall. It is one of the most expensive natural disaster and often causes significant economic losses, human and social tragedies in many regions of the world due to social and economic development that bring pressure on land use (Mata-Lima et al., 2013). Therefore, governments and local authorities are face the huge challenges to find the effective ways in order to control and prevent the flood from being occur.

In Malaysia, Kulim district is the one of spotted places that flood always occur when rainy season. Hashim (2017) wrote that the latest flooding happened in Kulim is on September 4, 2017, affects a total of 32 houses in Kampung Sungai Tepus. The flood started at 7pm the day before due to prolonged heavy rain. The local resident of affected areas not have enough time to evacuate because of the lack of information about flood warning.

Thus, this study is to investigate the impact on various water discharge along the Sungai Kulim due to rainfall intensity. Using the Unmanned Aerial Vehicle (UAV) drone model Phantom 4 Pro, the images of Sungai Kulim is captured for generation of Digital Elevation Model (DEM). DEM is a specialized database generated by Agisoft Photoscan software. Shingare and Kale (2013) defined that DEM represent 3D visualization of a contour and surface modelling that exported to HEC-RAS software to produce flood hazard. It is important to choose software that required less comprehensive data and gives better precision results. HEC-RAS software is most suitable to be used in simulating the flood hazard map of Sungai Kulim in 2D as it meets all the selection criteria and has been widely used in many hydrological studies.

1.4 Objectives

From the problem statement mentioned above, the main objectives of this study are:

1. To develop Digital Elevation Model (DEM) of Sungai Kulim using UAV to capture the orthophoto.
2. To simulate flood extent using HEC-RAS from developed DEM.

1.5 Scope of Research

The scope of the research is:

i. Topography Map – Digital Elevation Model and 3D Orthomosaics of Sungai Kulim.

ii. Water Discharge – Based on return period of 2, 3, 5, 10, 25, 50, 100 and 200 years.

The input data were processed by using Agisoft Photoscan to get secondary data. The Photoscan helps in preparing the geometric data for importing into HEC-RAS and processing result exported from HEC-RAS to perform calculation in order to obtain flood inundation and hazard maps.

1.6 Advantages of the Research

The outcome of the research will establish flood forecasting model of Sungai Kulim. Other advantages are listed below:

1. Develop DEM data of Sungai Kulim.
2. Flood hazard map of Sungai Kulim using photogrammetry with the hope of giving information to local residents before flood events occur.
3. Help the local authorities to construct the emergency plan for flood evacuation in downstream area of Sungai Kulim.

CHAPTER 2

LITERATURE REVIEW

2.1 General

This chapter describes the history of flood in Malaysia, flood hazard map, photogrammetry, real time kinematic (RTK), ground control point (GCP), Agisoft Photoscan, and HEC-RAS software.

2.2 Flood in Malaysia

2.2.1 Causes of Floods

The research by Weng (2011) revealed that commercial logging and deforestation activities contributed significantly in the increase in water yield. Hence, storm flow volume and initial discharge were increase.

Natural phenomenon that influences the rise of the river level such as changes of geomorphological of river banks, erosion of the river that could lead to high amount of sediment deposited at the river banks and the infiltration rate of the ground soil (Shaari, 2016). Climatic changes such as heavy rainfall intensity also contributes to the water yield which can lead to the flood inundation (Weng, 2011).

2.2.2 Impact of Flood

A study by Taib et al. (2016) revealed that the flood event which occurred in 2014 was the most extreme flood happened in Malaysia. The estimate cost of the damages is likely to exceed 1 billion. This disaster affected the economy and also gave negative impacts to the societies in several states especially in Kelantan. These floods are extensive, severe and unpredictable caused a serious tragedy that claimed many people lost their lives, damaged to crops, livestock, properties, and public infrastructures. Figure 2.1 shows the impact and damages of 2014 flood in Kelantan, Malaysia.

Figure 2.1: Flood in Kelantan (JKR Kelantan, 2015)

2.2.3 Flooding in Kulim, Kedah

In October 2013, flash flood after a heavy rain inundated more than 10 villages and housing estates in Kulim districts, consequently, causing the evacuation of 200 people from their homes to nine flood relief centres. Heavy rains from 3 pm caused overflowing of rivers and drains with several areas submerged up to 2.5 metres (The Malay Mail, 2013).

In September 2017, 4 years after the incident, a total of 32 houses in Kampung Sungai Tepus, Kulim were hit by flash floods. The flood started at 7pm, a day before due to prolonged with heavy rain. The flood water did not recede until 11.53pm and the residents living in low-lying areas were urged to move to the relief centre (Hashim, 2017). Figure 2.2 shows the damages caused by the flood in Kulim.

Figure 2.2: Flood in Kulim (Bernama, 2017)

2.3 Flood Map

Flood mapping is the most important element of flood risk management. A study by Zakaria et al. (2017) found that there are three common types of flood maps which are flood hazard map, flood inundation map and flood risk map. Figure 2.3 shows the different types of flood maps in Malaysia.

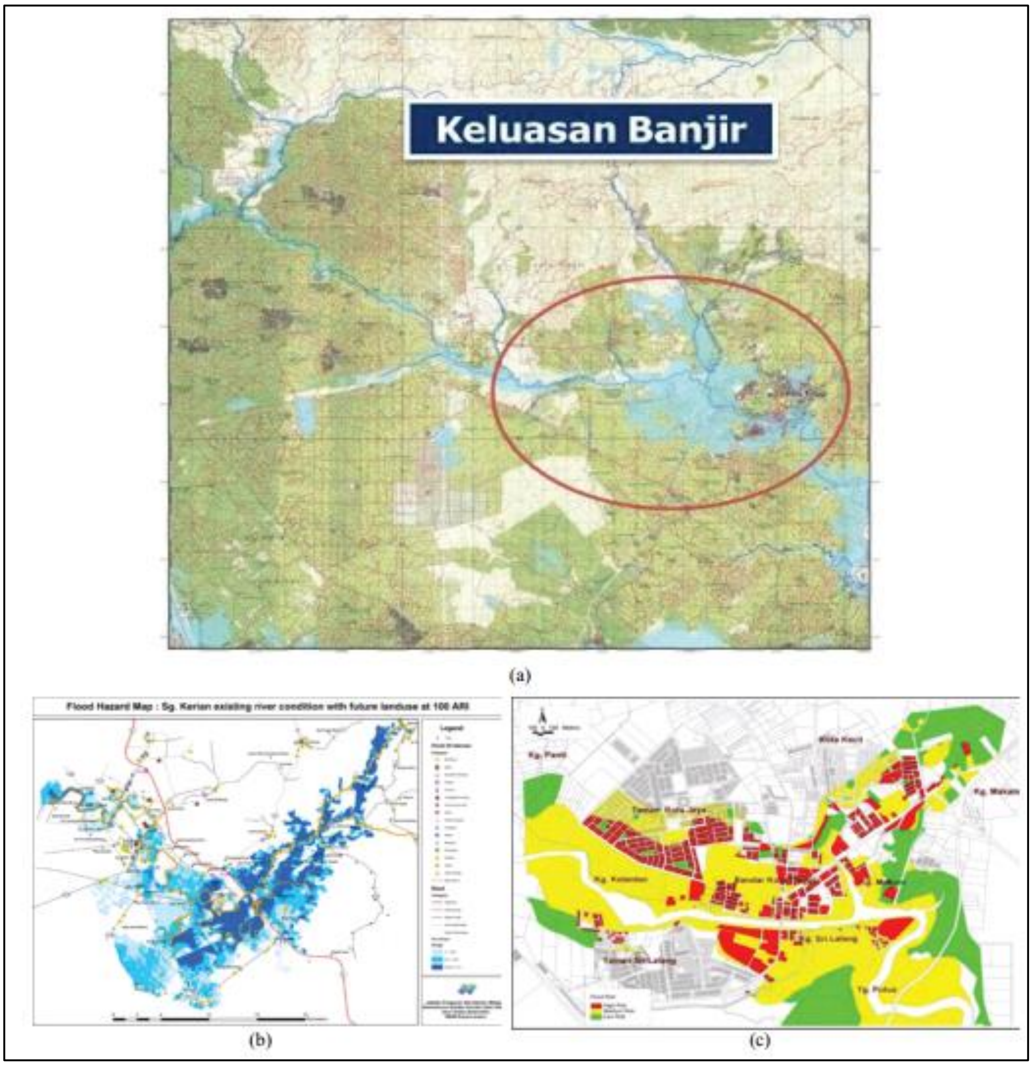

Figure 2.3: Types of Flood Map; (a) Flood inundation map; (b) Flood hazard map; (c) Flood risk map (Zakaria et al., 2017)

2.3.1 Flood Inundation Map

The research by Jung et al. (2014) stated that flood inundation maps were established for the flood discharge values corresponding to the satellite images. Flood inundation map is an important element of flood risk management. It gives precise geospatial information about the flood extent. When combined with a geographical information system, it can help decision makers extract other useful information to assess the risk related to floods such as human loss, financial damages, and environmental degradation.

2.3.2 Flood Hazard Map

Flood hazard maps provide a good basic establishment for efficient flood management. It can be utilized as a decision making tool in preventing flood damages, land use planning, providing information about floods, in rescue operations and in determining a safe platform level from flooding for various types of development. The flood hazard map should be easy to interpret and the simplest flood hazard map should be generated in order to deliver the information accurately. It shows the expected water level of flooded area in three different situation which are low, medium and high probability of flooding. It provides information on types of flooding, depth, velocity, water flow extent and direction of flooding. The map is normally prepared for 10, 20 and 100 years period based on specified flood frequencies (Zakaria et al., 2017). Figure 2.4 shows the list of completed flood hazard map in all regions in Malaysia.

2010	2011	2012	2013
JOHOR 1. Kluang 2. Simpang Renggam 3. Batu Pahat 4. Muar 5. Mersing 6. Sg. Johor SELANGOR 1. Sg. Buloh 2. Sg. Damansara 3. Sg. Kuyoh KELANTAN 1. Pasir Mas 2. Tanah Merah	SABAH 1. Beaufort 2. Tenom 3. Sook KEDAH 1. Lembangan Sg. Muda	MELAKA 1. Lembangan Sg. Melaka 2. Lembangan Sg. Kesang SELANGOR 1. Lembangan Sg. Selangor 2. Lembangan Sg. Labu, Sepang PERAK 1. Lembangan Sg. Kerian 2. Lembangan Sg. Kinta PERLIS 1. Lembangan Sg. Perlis & Sg. Arau NEGERI SEMBILAN 1. Lembangan Sg. Linggi JOHOR 1. WPI-Skudai 2. WPI-Sg. Plentong 3. WPI-Sg. Melayu TERENGGANU 1. Lembangan Sg. Setiu	PAHANG 1. Lembangan Sungai Pahang

Figure 2.4: List of Completed Flood Hazard Map in Malaysia (Zakaria et al., 2017)

2.3.3 Flood Risk Map

Flood risk map is defined as a function of the probability of occurrences and the extent of damages. The extent of damages is constituted by the two factors which are damaging potential and damaging vulnerability. The procedure of hazard assessment is methodologically reliable in determining the hazard potential and the related probability of occurrences by mapping, examining, modelling, and assessing individual processes. Flood risk can be assessed by using the following equation (Spachinger et al., 2008):

$$R = P_{si} \ x \ A_{oj} \ x \ P_{oj.si} \ x \ V_{oj.si} \qquad \text{(Equation 2.1)}$$

Where,

R = Risk

P_{si} = Probability of scenario i

A_{oj} = Value at risk of object j

$P_{oj.si}$ = Probability of exposure of object j to scenario i

V_{ojsi} = Vulnerability of object j, dependent on scenario i

In order to obtain the flood risk map, flood hazard map are necessary to be produced first. Information of risk on environmental and social issues are taken into consideration. For social issues, the data of population and economic activities are necessary to be obtained. For environmental issues, the element of agricultural area, residential area, urban and industrial area are integrated. Figure 2.5 shows the element of a flood risk map.

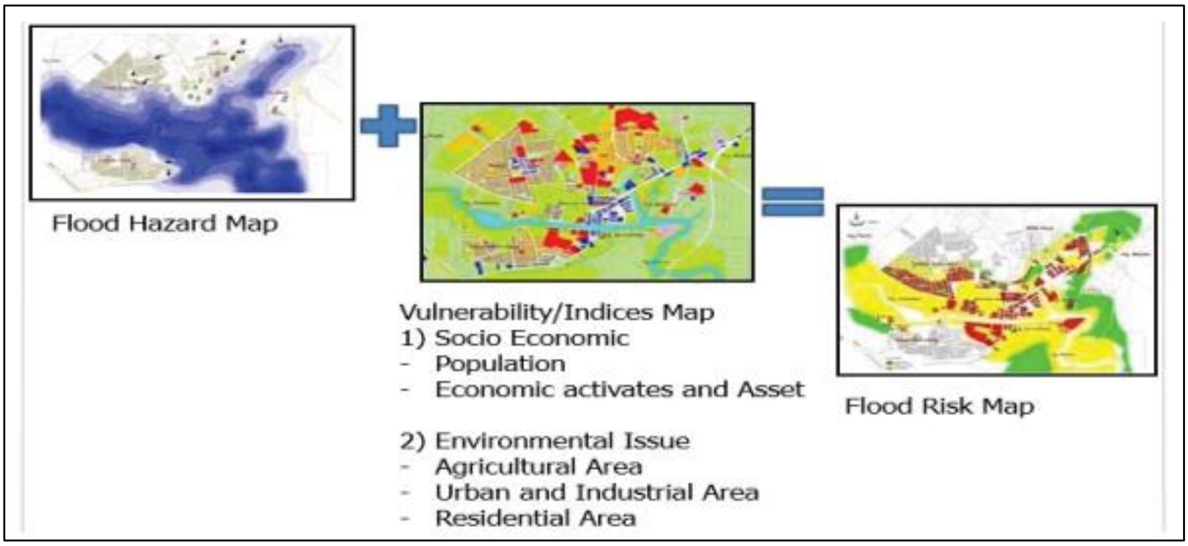

Figure 2.5: Element of Flood Risk Map (Spachinger et al., 2008)

2.4 Photogrammetry

According to Pillay (2015), photogrammetry is a surveying and mapping method that have been utilized in numerous application. It used science and innovation in obtaining the reliable data about the properties of surfaces in interpreting data without physical contact with the objects. Next, the data will be transformed into meaningful results. There are many uses of photogrammetry in the surveying industry. For example, topographic mapping, orthophotography maps and generation of digital elevation models (DEM). Photogrammetry is also useful in various industries such as architecture, manufacturing, police investigation and plastic surgery (Pillay, 2015).

2.4.1 Data Acquisition of Photogrammetry

Data acquisition in photogrammetry is the process to acquiring the reliable data about the physical properties of the objects and it is managed without physical contact with the objects (Schenk, 2005). This data can be grouped into four classes:

1. Geometric information is a single photograph that provide relational information such as the position and the shape of object (Oswald et al., 2013). This information is the most important source of photogrammetry.
2. Physical information is the properties of the objects. For example, the wavelength and radiant energy (Schenk, 2005)
3. Semantic information is the processing of images and interpreting the information obtained from processing images into meaningful result (Khodaskar and Ladhake, 2015)
4. Temporal information is the change of location or shape with time (Johnson et al., 1982). The data obtained by comparing the images recorded with the previous images.

2.4.2 Types of Photogrammetry

2.4.2.1 Aerial Digital Photogrammetry

Aerial digital photogrammetry are often used in constructing topographical mapping. Ion et al. (2008) expressed that an aerial images is a viewpoint perspective of the terrain from above, which is called orthogonal image. The aerial images and video are captured by the camera mounted on the bottom of a plane. In order to produce the topographic maps with overlapping images of the whole area to get complete coverage, Pillay (2015) stated that the images are taken vertically along the flight path as shown in Figure 2.6. Thus, the planimetric details will have different scale towards the objects situated at a height depending on the sea level.

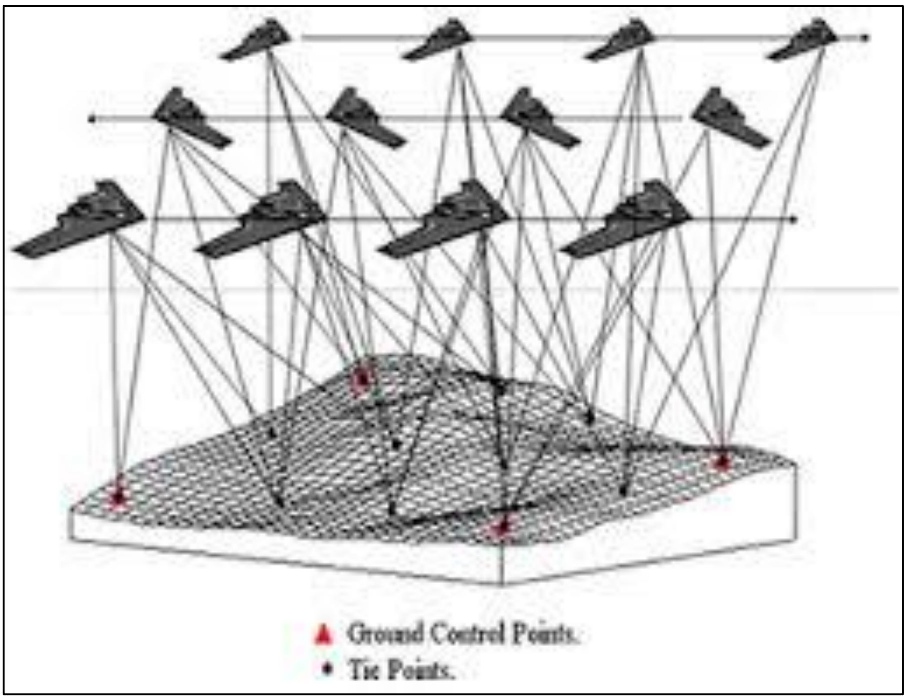

Figure 2.6: Aerial Digital Photogrammetry Terminology

2.4.2.2 Terrestrial (Close Range) Digital Photogrammetry

Derenyi (1996) defined that terrestrial photogrammetry are images obtained by a ground-based stationary sensor. It is a very successful application of photogrammetry. Close-range photogrammetry is a sub-branch of terrestrial photogrammetry, which imply that the object to be imaged has closed vicinity with the sensor situated. In order to deliver a 3D model images are taken from close distance by hand held cameras or mounted to a tripod. This kind of photogrammetry is useful especially for buildings, car crash scenes etc (Pillay, 2015). Figure 2.7 shows the terminology of the close range digital photogrammetry.

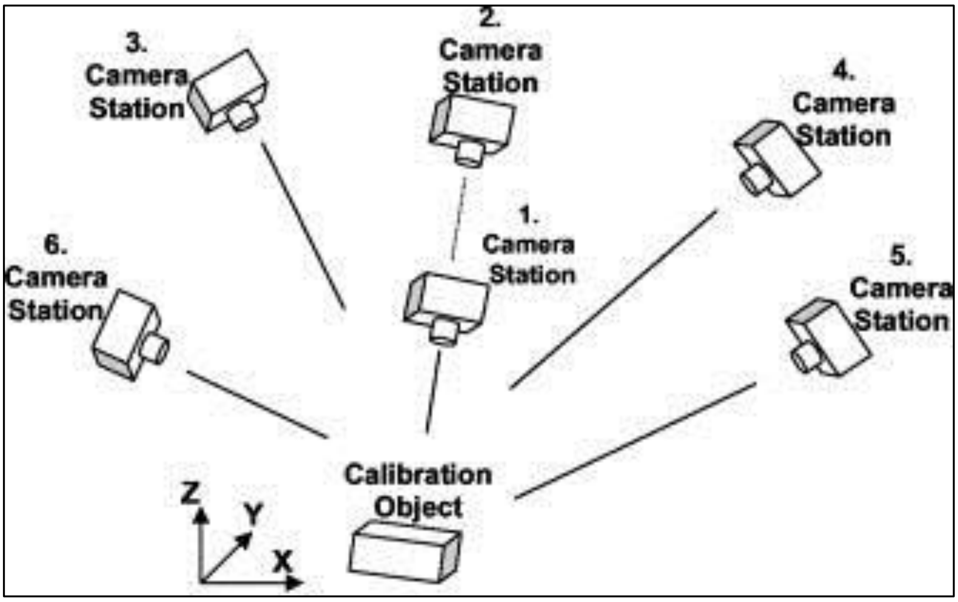

Figure 2.7: Close Range Digital Photogrammetry Terminology

2.4.3 Resolution of Images

The resolution of an image is described as the information or details of an image hold. It is usually measured in m/pix or cm/pix. A study by Mahavir (2000) showed that higher spatial resolution images make the images more exact and precise. Thus, creating sharp images and provide better data. It is useful for ease of interpretation, data volume and data acquisition. Low resolution sieve out unnecessary element, which would be useful only at local level. However, it affects the sharpness of an image. The images that obtained is blurred and the accuracy of the map is affected.

2.4.4 High Overlapping Images

A study by Haala and Rothermel (2012) defined that the overlapping images mean the percentage of similar area of the different images. The higher the percentage of similar area of different images, the higher the overlapping images. In this way, the more accurate 3D model is produced. High overlap between two images is essential in building a 3D model (Ji, 2017).

Ji (2017) stated that front lap is the percentage of overlap between one image and the following images, and both images are taken by the drones when flying in the same direction while side lap refers to the percentage of overlap between flight legs. Figure 2.8 shows a similar size of images is captured on each spot.

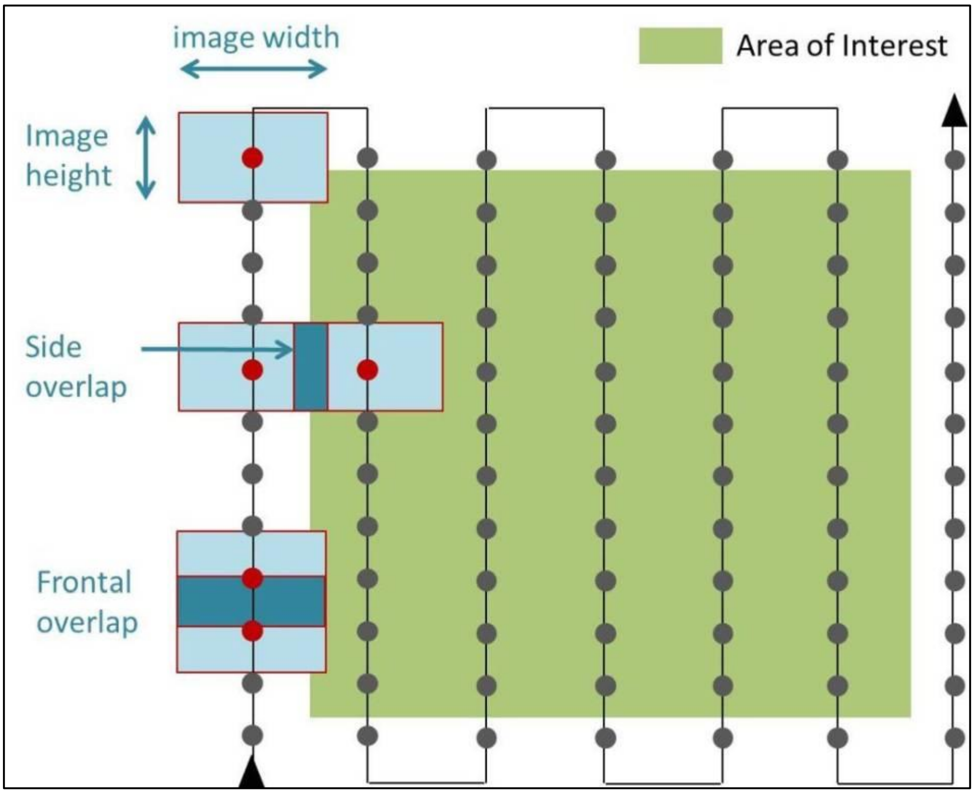

Figure 2.8: Overlapping Images of Drone Flight Mission (King, 2017)

2.5 Real Time Kinematic

Real Time Kinematic (RTK) is a special form of digital Global Navigation Signal System (GNSS) that monitors the signal code and signal carrier. RTK makes GNSS a very efficient tool for several tasks such as construction staking, machine control, topographic survey, and many more where precise real time positioning is valuable (Gakstatter, 2009).

Jensen (2016) stated that at least two GNSS receivers required by RTK to transfer the data between the reference station and rover. It requires a mobile internet or UHF radio for transferring the data. The rover's position is determined in real time using double differences, wide lane, and ambiguity search method. The distance between the reference station and rover must be in the range of 20-30 km and the accuracy of position obtained is in the range of 1-5 cm.

2.5.1 Single Station RTK

Single station RTK is utilized only one reference station which also called base station as shown in Figure 2.9. Data from reference station is transmitted to rover in one way communication. The rover's position accuracy is dependent on the distance between the reference station and rover. The spatially correlated errors are more correlated and better eliminated differences result in better position accuracy for the rover when the distance between the reference station and rover is shorter (Jensen, 2016).

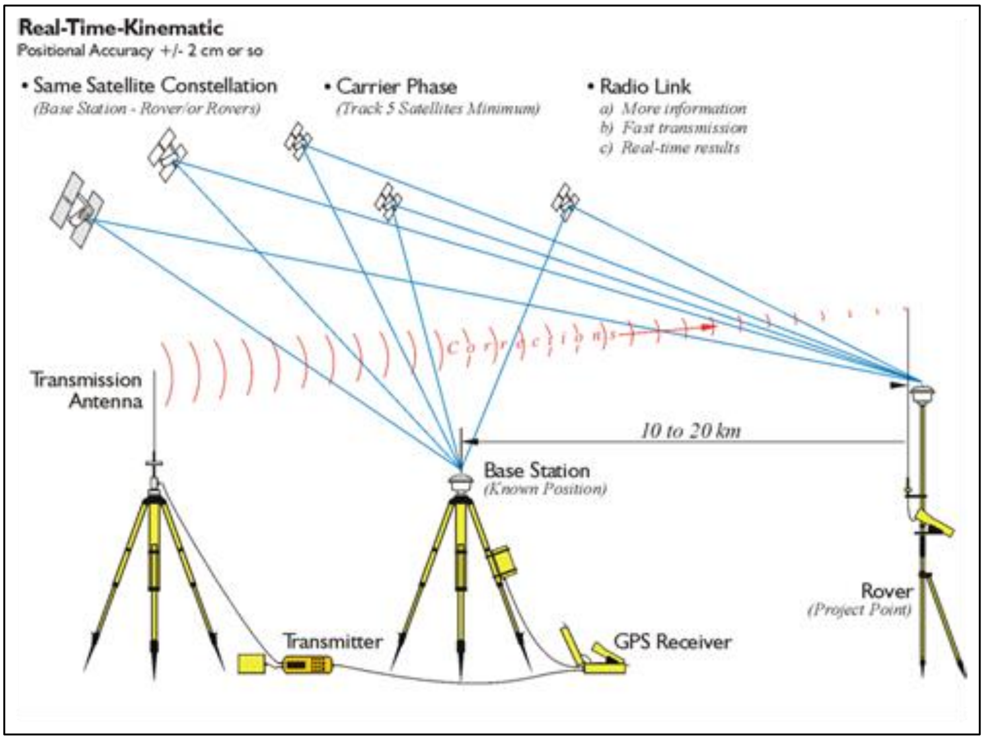

Figure 2.9: Single Station RTK Terminology (GPS and GNSS for Geospatial Professionals, 2018)

2.5.2 Network RTK

Network RTK is RTK with many of reference stations. Gakstatter (2009) stated that the correction of network RTK is based on all of the reference stations in the network. Data from reference stations is combined in a common data processing in a control centre. The control centre processes the corrections for the spatially correlated errors within the network, then transmitted to the rover. The nearest distance of reference station in the network can be up to 50km. Figure 2.10 shows the terminology of network RTK.

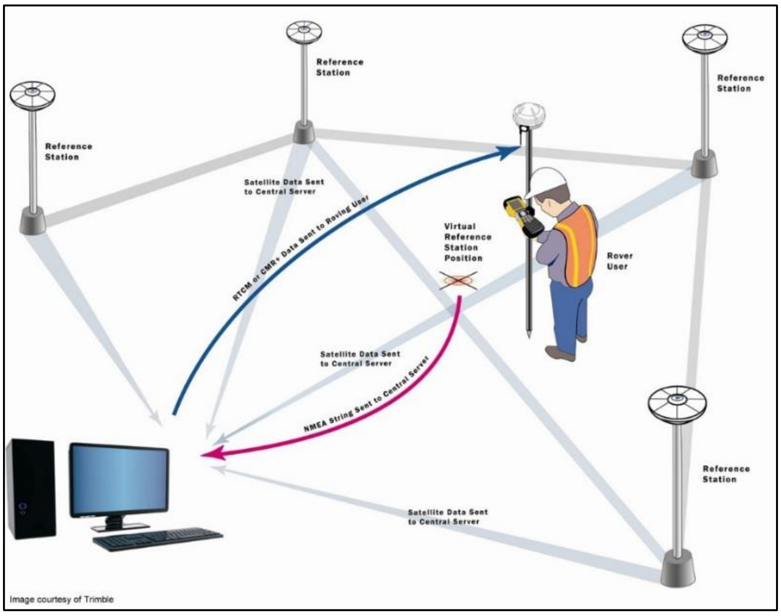

Figure 2.10: Network RTK (RTN Surveying, 2018)

2.6 Ground Control Point (GCP)

Ground Control Points (GCPs) are the GPS coordinates that is obtained from RTK as a tool for accuracy mapping. GCPs increase the global accuracy of drone maps. It ensures coordinates of the latitude and longitude of the points on map are corresponds with GPS coordinates (Sretasathiern, 2017). The GCPs must be visible in aerial imagery at the given altitude where the mission is performed. Figure 2.11 shows the GCP marker located on the ground.

Figure 2.11: The GCP Marker

2.7 Agisoft Photoscan Software

Agisoft Photoscan is a stand-alone photogrammetric software aimed in making proficient quality 3D model from still images. This software is utilized for generating dense point clouds, textured polygonal models, georeferenced true orthomosaics and Digital Surface Model (DSM) and Digital Terrain Model (DTM) from still images.

2.7.1 Capabilities of Agisoft Photoscan Software

Agisoft Photoscan software is capable in processing of thousands of photos. It allows very fast processing, normally within a couple of hours, providing highly accurate result which are up to 3cm for aerial and up to 1mm for close-range photography. This software is also capable for generation of elevation contour lines, true orthomosaics and DSM/DTM, and dense point cloud (Agisoft Photoscan User Manual, 2016).

2.7.2 Advantages of Agisoft Photoscan Software

One of the advantages of Agisoft Photoscan software is this software produces highly accurate and detailed result. The Photoscan are fully automated and has an intuitive workflow. It capable to perform network processing for large project and have GPU acceleration for faster processing (Agisoft Photoscan User Manual, 2016).

2.8 HEC-RAS Software

Hydrologic Engineering Centre – River Analysis System (HEC-RAS) is the software developed by US Army Corps of Engineers (USACE) used one and two-dimensional method for studying stream reaches (Parsa et al., 2016). Agrawal and Regulwar (2016) state that it allows the users to perform a variety of river simulations studies, and for one and two-dimensional steady and unsteady flow, sediment transport computations and water quality modelling.

2.8.1 Capabilities of HEC-RAS Software

The HEC-RAS Software perform one-dimensional (1D) river analysis includes the steady flow water surface profile computations, unsteady flow simulation, movable boundary sediment transport computation, water quality analysis and several hydraulic design features (Lai et al., 2015). The figure 2.12 shows the examples HEC-RAS output for flood mapping.

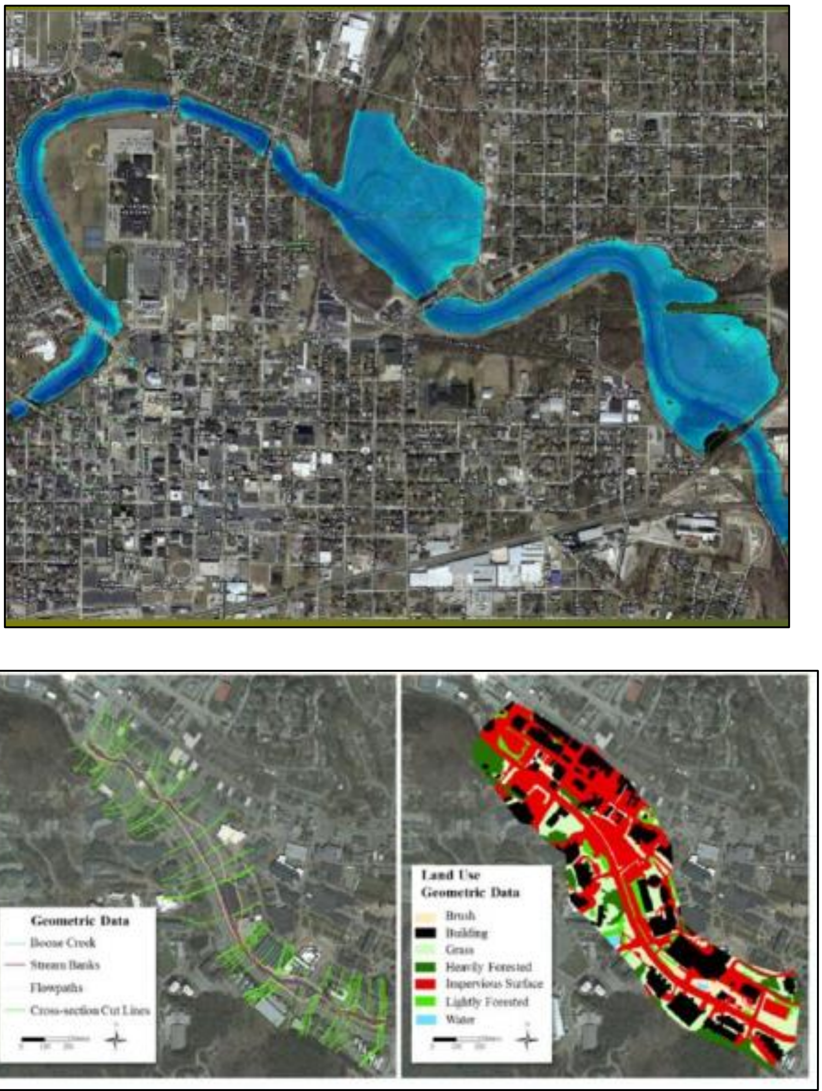

Figure 2.12: HEC-RAS Output for Flood Mapping

2.8.2 Advantages and Disadvantages of HEC-RAS Software

There are several advantages of HEC-RAS Software. First, this software is free for all users and easy to use. This software is accepted by most of government and private agencies and have extensive support by USACE. Besides, the add-on packages also available in this software.

However, there are some weaknesses that have been identified in HEC-RAS Software including problems in modelling highly dynamic rivers and streams. The details of one-dimensional modelling that is shown are limited. Issues of numerical instability have arisen when performing unsteady flow analysis (Lai et al., 2015).