International Journal of Nanoelectronics and Materials
Volume 14 (Special Issue) August 2021 [21-28]

Implementing Drone as Flood Inundation Laboratory Measurement Tool

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ABSTRACT

Interest in flood inundation study keep increasing due to the increment in the flood hazard around the world. Although the main interest is numerical approach, hydraulic model experiment is still needed. This is because the numerical approach has limitation while the hydraulic model has the capability to replicate the actual condition of flood. To increase the accuracy between hydraulic model and actual site, a large-scale hydraulic model is one of the solutions. However, using a large-scale hydraulic model has drawback, where the measurement of the flood inundation processes is more difficult due its size and duration. Therefore, a fast and accurate measurement approach is required to collect the flood inundation data, especially in terms of flood extent. This study proposed a drone image method to measure the flood extent in a large-scale hydraulic model experiment of flood inundation. A total size of 23 m × 11.5 m hydraulic model were built in a laboratory to replicate the Sungai Bertam with scale 1/25. The ground measurement and drone image were used to measure the flood inundation to determine the capabilities of the drone image. The results demonstrate the efficacy of the proposed approach.

Keywords: Drone image, flood inundation, hydraulic model, laboratory experiment, sungai bertam

1. INTRODUCTION

Large scale hydraulic model of flood inundation studies are not many in the literature. However, several researchers had reported on it [1-16]. Beretta was carried out a simplified urban district model in laboratory to investigate the influence of buildings on flood inundation [4]. Guney built a distorted hydraulic model of Ürkmez dam to investigate the flood propagation due to dam break resulting from trapezoidal shaped breach [7]. Testa carried out urban district model experiment of Alpine Toce River to investigate the flooding of a populated area [17]. Although scarce, there is a need to conduct a large hydraulic model to fully understand the behavior of flood inundation compared with numerical approach which still facing some discrepancy, uncertainty and computational difficulty [16]. Due to the large size of the model, the measurement of the flood inundation is usually made based on point data collection for depth, length and velocity of the flood inundation [4, 17]. This method requires additional time and workers, and may cause problem when deal with the rapid evolution of the flood inundation.

Recently, drone imaging has becoming interesting topic to study by many researchers. This approach capable to take high resolution image remotely in short period of time and more economical compare with other platforms. Drone is also known as unmanned aerial vehicle (UAV) [3], unmanned aerial systems (UAS) [11], and unmanned aircraft system (UAS) [15].

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A drone typically consist of the main aircraft system, which is air frame, propulsion system, navigation system, and also additional tools base on application requirement, which commonly involves cameras for visual from aerial perspective. The other additional tools can be remote sensing system, synthetic aperture radar (SAR), light detection and ranging (LiDAR), and direct measurement sensors such as temperature and gaseous [14]. Several field of studies that employ a drone include monitoring of civil infrastructure [6, 13, 18], monitoring surface temperature [9], tracking air contaminant [19], and transportation [5, 10].

Visual information from drone collected in a field case study has been proven to be able to estimate flow and flood inundation with high acceptable accuracy. Ridolfi estimated the water level in a dam using drone image based on a water and surface boundary and compared it with a traditional method [20]. The outcome was quite promising, with only 0.05m in overall mean error. In terms of a flooded area, the drone images are normally classified into several classes before the estimation being made. The drone images were classified into the grass, buildings, and flooded areas using the local binary pattern algorithm [21]. The outcome was quite encouraging. Similarly, Popescu proposed an analysis using texture feature and sliding box method to divide the drone images into flooded or non flooded classes [22]. The outcome achieved 98.57% accuracy. The capability of the drone can potentially provide the opportunity to overcome the limitation of the previous flood inundation laboratory measurement. This paper sought to examine the use of drone as a laboratory hydraulic model measurement tool for flood extent. In addition, the influence of the upstream discharge to the flood inundation was also discussed.

2. METHODOLOGY

2.1 Hydraulic Model

The laboratory hydraulic model of flood inundation was developed based on the 520 m Sungai Bertam. The scale used was 1:25; given the total area of hydraulic model as 23 m × 11.5 m. Table 1 shows the hydraulic model characteristics for the prototype and model. Figure 1 and Figure 2 shows the whole system of the hydraulic model. Details information of the selected site and hydraulic model was briefly discussed by [8].

Table 1 The hydraulic model characteristic of the prototype and model

Characteristic	Prototype	Model
Channel Length (m)	520	20.8
Channel Width (m)	6	0.24
Maximum Floodplain (m)	97	3.88

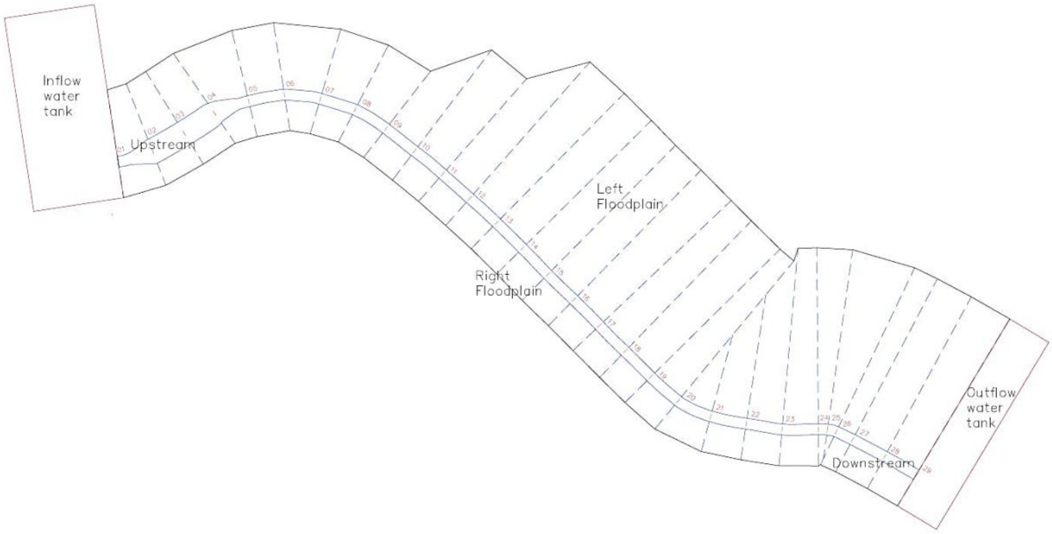

Figure 1. The schematic diagram of the hydraulic model.

Figure 2. The view of the whole system of the hydraulic model.

2.2 Flood Extent Measurement

The commercial grade DJI Phantom 4 (Figure 3) with a gimbal attached to a 4k resolution camera (4,096 × 2,160) was used. To have a reference by which to assess the accuracy of the proposed approach, a standard ruler measurement with an accuracy of 1 mm was used.

2.3 Goodness of Fit Index

Mean absolute error (MAE) and another goodness of fit index were used in analysis, where mean relative absolute error (MRAE) is defined as follows:

$$MAE = \frac{\sum_{i=1}^{n} \left|X_{obs,\,i} - X_{mod,i}\right|}{n} \tag{1}$$

$$MRAE = \frac{\sum_{i=1}^{n} \quad |X_{obs,i} - X_{mod,i}|/X_{obs,i}}{n} \tag{2}$$

where n is the total number of stations; X_{obs} is the observed values at station *i*; and X_{mod} is the modeled value at station *i*.

For this study, the proposed measurement was assessed by comparing the measurement with the standard ruler measurement at all stations (29 station). Besides, Station 1 (upstream) and Station 29 (downstream) will be neglected in the analysis due to the inflow and outflow effect.

3. RESULTS AND DISCUSSION

In this section, the performance of the proposed measurement was described in terms of flood extent followed by discussion on the influence of inflow to the flood inundation of the hydraulic model experiment.

3.1 Calibration of the Drone Measurement

Comparison between both measurements showed that the drone measurement gives a smooth and better data collection than the ground. This is because the ground measurement data was in point measurement while the drone measurement was in line measurement. The trends of flood extent based on the ground measurement and drone measurement when the inflow values were varied over all stations or points are shown in Figure 4. Generally, similar trends were observed in flood extent curves for both measurements. Specifically, two types of different measurements can be seen are if the trend was higher or lower constantly and the trend was higher or lower at specific point or station. For 16 l/s, the differences are more on the first type while for 32 l/s, 48 l/s and 64 l/s, the differences are more on the second type. For Type Two, station 10 (chainage 7.2 m), 14 (chainage 10.4 m), 21 (chainage 16 m), 26 (chainage 18.8 m) and 27 (chainage 19.2 m) gave a significant differences. This station location, the flow started to breach the bank line and enter the surface area. The significant difference is believed due to the small wave which caused error during the measurement of both methods. Besides, selection of the flood extent line in recreating the flood extent line stage also one of the reasons. At this stage, it needs human judgement to identify the flood extent line due to color of the flow boundary line, wetted area, and the surface become almost similar. This error also might contribute to the first type of the different faced by case 16 l/s.

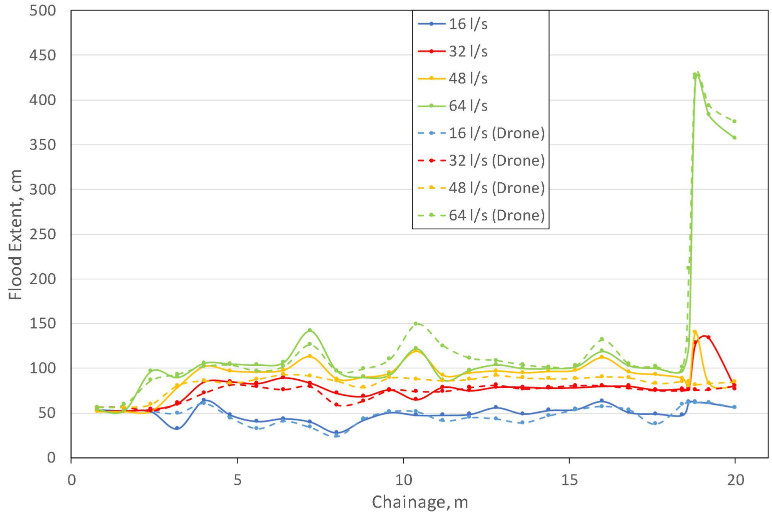

Figure 4. The flood extent comparison between ground measurement and drone image.

The MAE error and percentage MRAE error for drone measurement of flood extent are given in Table 2. In view of the analysis obtained, the MAE error increased with the increase in the inflow parameter. The minimum and maximum value of the MAE are 4.809 cm at the 16 l/s inflow parameter and 11.316 cm at the 64 l/s inflow parameter, respectively. For MRAE, the value is almost constant in between 8.3% to 10.6% which range from good to very good agreement with the ground measurement based on [1] rating index.

Table 2 The result of MAE and MRAE for flood extent

Model code	MAE (cm)	MRAE (%)
Case 1	4.809	10.6
Case 2	7.943	8.3
Case 3	10.661	10.6
Case 4	11.316	9.9

3.2 Influence of the Discharge to the Flood Extent

The distribution of flood extent along channel for inflow cases equal to 16 l/s, 32 l/s, 48 l/s, 64 l/s are depicted in Figure 5, Figure 7, Figure 9 and Figure 11 in drone image, and Figure 6, Figure 8, Figure 10, and Figure 12 in detail results. The dotted box shows the significant location of the flow movement. As can be seen in Figure 8, the location A indicates the highest velocity area of the experiment which reduce the flow width on that location. For Case 48 l/s, the location A shows a location where hydraulic model flow breached the design floodplain at the downstream. However, the edge of the hydraulic model result was neglected due to the influence of hydraulic model setup. For Case 64 l/s in Figure 12, locations A, B, C, D indicate the breaching area for the hydraulic model. This case indicates the weakest location along the channel, which is at the downstream (location D) and the potential breaching location along the channel, which is at the location A, B and C. The capabilities of the drone measurement to reproduce the flood extent in terms of line boundary give advantage in flood inundation analysis to identify the potential breaching or the weakest area that need to be taken into consideration.

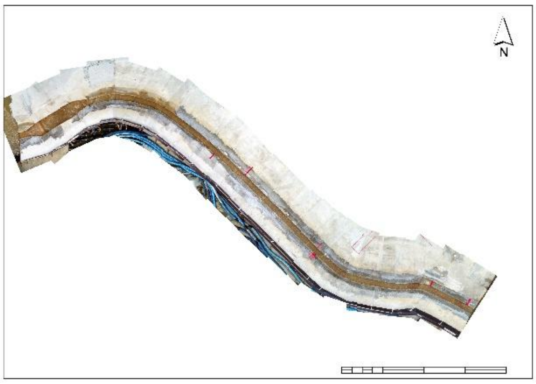

Figure 5. Drone image at 16 l/s.

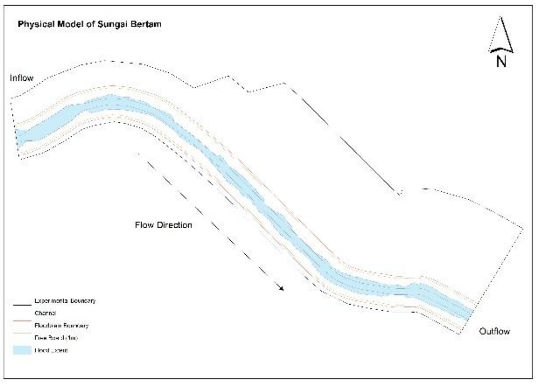

Figure 6. Flood extent at 16 l/s.

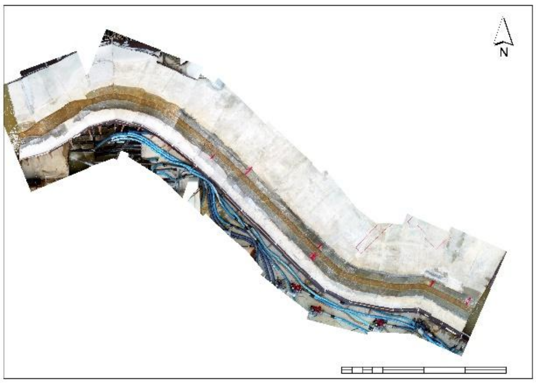

Figure 7. Drone image at 32 l/s.

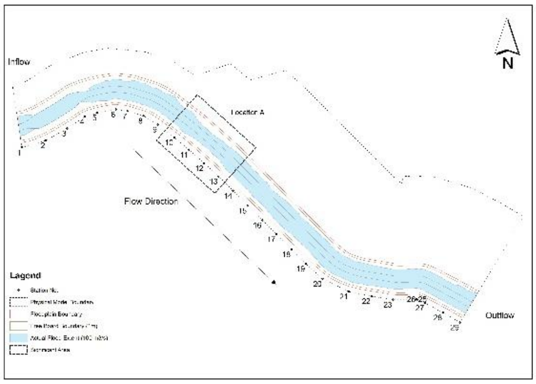

Figure 8. Flood extent at 32 l/s.

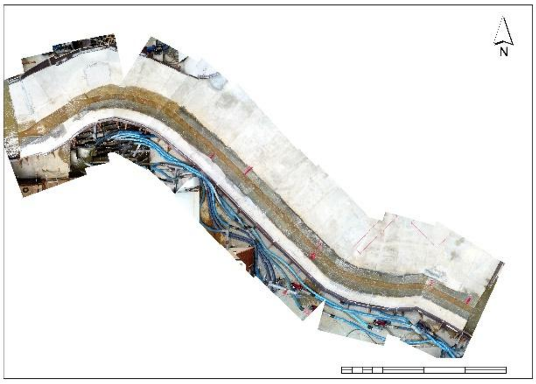

Figure 9. Drone image at 48 l/s.

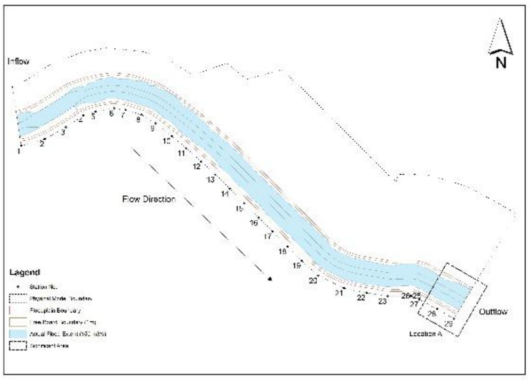

Figure 10. Flood extent at 48 l/s.

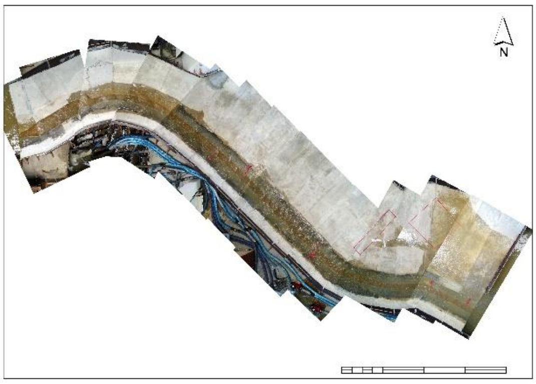

Figure 11. Drone image at 64 l/s.

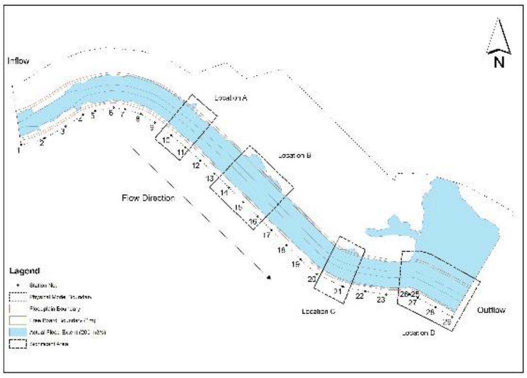

Figure 12. Flood extent at 64 l/s.

4. CONCLUSION

This study investigates the accuracy of drone to be used as measurement tool for large hydraulic model laboratory experiment by testing several inflow boundary conditions. MRAE analysis result showed good to very good result which was between 15% to 5% range of model rating. The percentage of the MRAE can be reduced by improvement in the drone image processing and this will be suggested for future study. The flood extent analysis indicates the weakest and the potential breaching area of the hydraulic model along the channel.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the School of Civil Engineering of Universiti Sains Malaysia for providing the required research facilities for this work. The authors also would like to thank the reviewers of this paper for reviewing the paper and providing valuable suggestions. We would also like to acknowledge the TNB Sdn. Bhd. for providing the financial support to carry out this work and the Registrar Office and Research Management Centre, Universiti Tun Hussein Onn Malaysia for all forms of financial aid.

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