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Propose Design of New Cross Section by Using One Dimensional HEC-RAS at Maran River, Pahang

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Abstract: The usage of hydraulic models for flood simulations is widely used all around the world. The current study employed the Hydrologic Engineering Centers River Analysis System to build the river cross section and solve flood problems in the Maran River in Pahang (HEC RAS-One dimensional).All data was gathered from the Maran Irrigation and Drainage Department, including cross-section data, manning values, contraction and expansion data, and simulations for 10, 20, and 100 year flood events were generated using the Rational approach. The analysis of the cross section included with the impacted area of floodplain was identified as a result of the results. According to the hydraulic model created by HEC-RAS software, 9 of the 10 stations discovered will flood due to their inability to handle the water flow. This is due to the fact that when peak discharge was calculated using the rational technique, the discharge indicated a rising value over time, with a discharge value of 2.42 m^3/s for 10 years, 3.80 m^3/s for 50 years, and 4.40 m^3/s for a 100-year return period. As a result, each chainage's channel has been modified, and a new channel capable of accommodating water for up to 100 years has been created.

Keywords: Hydrologic Engineering Centers River Analysis System (HEC-RAS), Maran, floodplain, river cross section

1. Introduction

Floods were among the most common environmental disasters in Malaysia, especially during the monsoon season which in November until December. Pahang, Terengganu and Kelantan were most affected, as the state is on the east coast. Flooding is defined as an unexpected rise in water level either due to dam failure or long periods of high rainfall intensity [1]. River flooding happen when heavy rainfall in the upstream area caused the riverbed to cannot accommodate and flow huge volumes of water into the sea. As a result, water rises rapidly, overflows along the banks and flooded in the lowland areas or defined as flood plains. Every year, the national media announced that the severity of flood disasters had risen significantly from previous floods [1]. This flood disaster happened because several factors, which are caused by human activity or occur naturally. According to a variety of researchers, flooding is a common natural disaster with a devastating and widespread effect responsible for economic losses and mortality [2-3]. Floods phenomenon also result in homelessness, loss of property, habitat and more serious is loss of life. It may also result in significant financial losses for people of the surrounding area due to the cost of repairing any damage.

However, because of this issue, Maran River, Pahang has overflowed. Several implementations have been made to lessen the flood's effects within Maran River. Here, the most suitable application in order to manage and minimize flood damage is by using 1-Dimensional HEC-RAS software. Hydraulic engineers use HEC-RAS to study water distribution

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across channels and rivers, as well as floodplain control [4]. Based on the data given by Department of Irrigation and Drainage, a solution being proposed by doing some modification of the river channel that could lessen the impact of the flood within Maran River.

2. Literature Review

2.1 Factors Contribute River Flood

Floods are one of the most significant disaster in the world, which is involved more than one million casualties between year 1970 and 2012 [5]. Many factors that can cause flood. In general, the reason that increase the flood hazard and exposure are climate change which resulted in a significant increase in the frequency and intensity of severe rains [6-7]. This factor can pose a threat to a million populations as well as catastrophic destruction. It is possible to divide the cause of flooding into three groups, which are meteorological, hydrological and human factor [8]. Table 1 shows the factor that contribute to river flood in a detail.

Table 1 - Factors that contribute to river flood [9]

Meteorological Factors	Hydrological factors	Human factors
• High intensity of rainfall • Temperature • Snowfall • Cyclonic storms	• Soil onditions (soil moisture level • Rate of natural surface infiltration • Channel cross-sectional shape and roughness • Rate of natural surface Run-off synchronisation from different regions of the urban watershed	• Urbanization activities increase run off volume and rate. • Floodplain encroachment impeding drainage and flow • Changes in climate does have an impact on amount and frequency of rainfall and flooding • Inefficiency or non-maintenance of infrastructure

2.2 HEC-RAS Software

HEC-RAS is a fully featured set of programs for calculating one-dimensional water surface profiles in multi-tasking, multiuser network contexts. United States Army Corps of Engineers Hydrologic Engineering Centers River Analysis System (HEC-RAS) is originally designed in year of 1995 [10]. This software enables to execute one-dimensional stable and the calculations of unstable river flow hydraulic, gain river design, sediment-transport bed modeling, river channel modification, and analysis of water temperature.

HEC-RAS is an integrated system of software, designed for interactive use in a multi-tasking, multi-user network environment. The system is comprised of a graphical user interface (GUI), separate hydraulic analysis components, data storage and management capabilities, graphics and reporting facilities

HEC-RAS is a software that simulates the hydraulics of water moving through different channels and typical streams [11]. It is a computer-based software that models water flow across open channel frameworks and calculates water surface profiles. Using HEC-RAS as a tool of modeling the water surface profile for steady flow and quantifying the influence of any barriers such as weirs, overbank regions, bridges, and culverts is fairly straightforward.

HEC-RAS uses a number of input parameters to perform hydraulic analysis of stream channel geometry and water flow. These values are frequently used to build a series of cross-sections along a stream. The placements of the stream banks are used to divide each cross-section into segments of left floodway (over bank), main channel, and right floodway (over bank), as shown in Fig. 1.

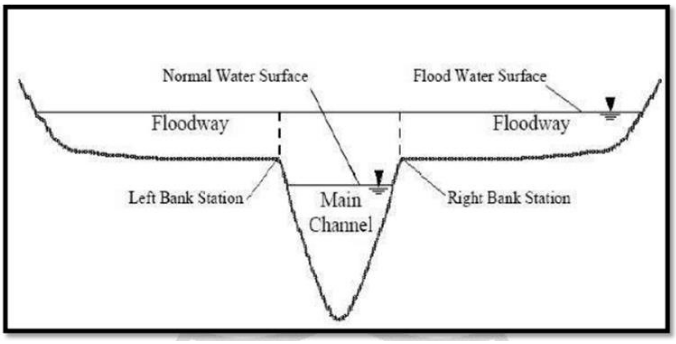

Fig. 1 - Schematic diagram of stream channel

Water surface elevations at all places of interest are calculated using HEC-RAS. For 1-D hydrodynamic modelling with HEC-RAS, the following information is required: Geometric Data (Detailed cross-sections), Manning ‘n’ value, map of the research area and left side and right side bank of the study reach. According to previous researchers [12-14] ,they mentioned that HEC-RAS modeling method gives good results in cases of flood propagation along the main river, as in the area studied by previous researchers .

2.3 Rational Method

In Malaysia, as well as many other parts of the world, the rational method is the most often used strategy for estimating runoff peak. The Rational Method shows a relationship between rainfall intensity and catchment area as independent variables and peak flood discharge as a dependent variable. It's been around for more than 150 years, and it's been known as the Rational Method for over 100 years. The equation 1 shows the formula used to obtained the peak flow value in certain area.

$$Q = \frac{C.i.A}{360} Q = \frac{C.i.A}{360} \quad (1)$$

where,
Q = Peak flow (m^3/s)
C = Runoff coefficient
i = Average rainfall intensity (mm/hr)
A = Drainage area

Rational method is impractical and it is not advised to utilised when stormwater ponds in catchment areas can affect peak discharge as well as when the design and operation of large and more costly drainage facilities are to be undertaken, particularly if they involved storage. The rational method's assumptions are defined in the Malaysian Urban Stormwater Management Manual (MSMA) [15].

3. Methodology

3.1 Data Collection

All fieldwork for this study, such as river depth, area, and width, was obtained from the Maran district's irrigation and drainage department. The collected data was fed into a computer and analysed with HEC-RAS software to generate a channel cross-section that caused flooding as well as a corrected cross-section that accounted for the proper bank depth. Figure 2 is the elevation plan of the river created by DID for Chainage 6350. The plan is used to collect crucial data such as the channel's right and left banks, elevation, and total distance of the case study.

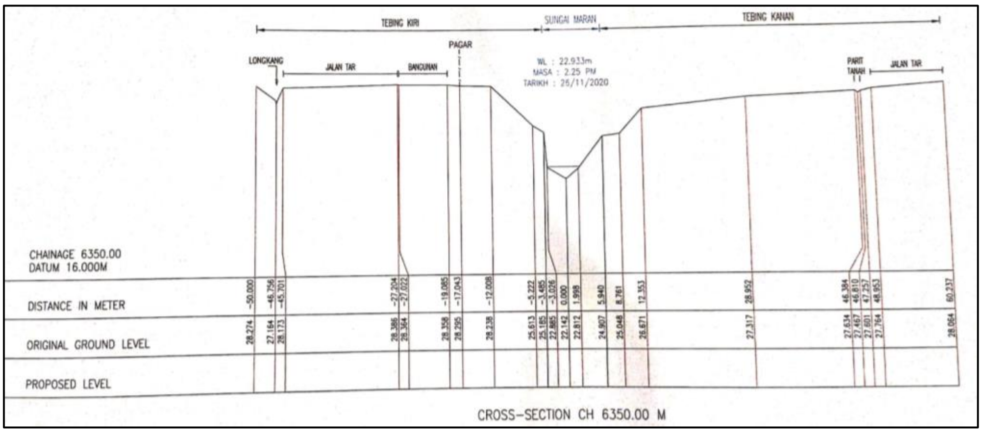

Fig. 2 - Cross section plan for chainage 6350.00 m

3.2 HEC-RAS

Simulation of HEC RAS

A new HEC-RAS project was started with inserted the geometric data and river schematic cross-section data. The geometric data contains reach, river, station identifiers, and reach; cross-section cut lines; main channel bank stations, cross-section surface lines; downstream reach lengths for the left overbank, main channel, and an overbank. Through calculation, the one-dimensional facts were used in the stand for exhibition purposes. Surface profiles were distributed back to the system for the development and display of the overflow inundation map. These are River System Diagram and Cross-section Data (Cross-section surface line, Cross-section main channel bank stations, River, Reach, and River Station identifiers, Downstream reach lengths for the left overbank, main channel, and right over the bank, Cross Section Cut Lines (X and Y coordinates) of the plan-view line that denotes the cross-section).

Calibration and validation of HEC-RAS

Model calibration is the method of defining the optimal standards of model factors that will contribute the smallest variance among the measured and the simulated values. The foremost factor was adjusted with the roughness coefficient of the surface because of the accessibility of the values. Model Validation is the method of analysis of the model capacity to simulate measured data other than those used for the calibration within standard exactness. Calibration was universally done by hand to improve the factor values, starting from the given initial values, until the simulated variable fits with the observed.

4. Results and Discussion

4.1 Catchment Area

The sub catchment area was located at Maran, Pahang, with 40.7 hectares. A catchment region is an area that gathers water after rainfall and is often surrounded by hills in geography. Water accumulates in rivers and streams as it flows down into these locations. These regions are important for assessing a geographical area since they try to comprehend the area's waterfall and flow. In this study, the catchment was divided into several different sub-catchments, which included open spaces, commercial and business centres, parks, roads, and retention ponds (no outlet). This pervious and impervious area will affect the data flow discharge at this catchment. Fig. 3 shows the study area of the sub-catchment and the checkpoint for upstream and downstream

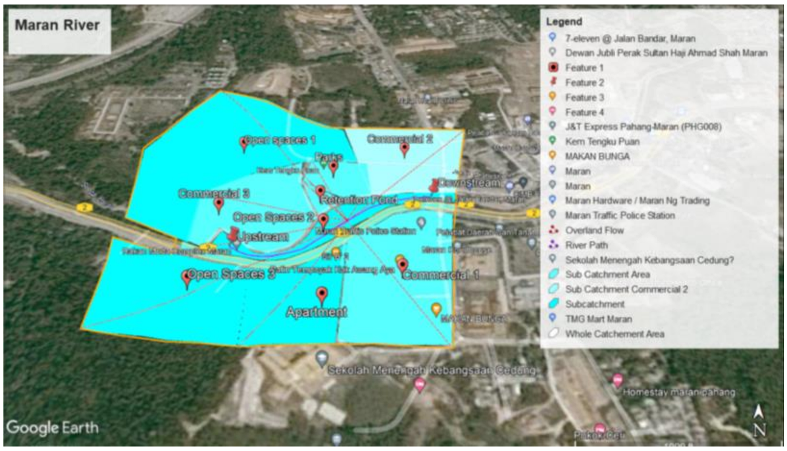

Fig. 3 - Sub-catchment area

Fig. 3 shows the sub-catchment area that will produce the simulation for the study area. The red marks show the types of land use for each of the sub-catchment areas and the upstream and downstream of the river. The sub catchment area had a total of 10 different cross sections of the river starting from Chainage 5900 to Chainage 6350. The sub catchment area, the slope as well as overland sheet path length were determined by using Google Earth where the details are provided in Table 2 and Table 3 respectively.

4.2 Average Runoff Coefficient

Making a good estimate of the runoff coefficient, *C*, is the most important component of employing the Rational Method. In general, *C* values are highly dependent on the catchment's land use and are extremely close to its imperviousness. The value of *C* changes depending on the type of soil, the moisture content of the soil, and the amount of rainfall produced. For C to be utilised as a logical value, the user must analyse the real catchment situation. This is possible with the use of AutoCAD, GIS, or other computer applications for larger areas with considerable spatial variations in land use and other characteristics. However, in this case study, the average runoff coefficient will be determined by combining the different land uses of the sub-catchment and estimated by:

$$Cavg = \frac{\sum_{j=1}^{m} CjAj}{\sum_{j=1}^{m} Aj} \qquad (2)$$

Where,
C_{avg} = Average runoff coefficient
C_j = Runoff coefficient of segment *i*
A_j = Area of segment *i* (ha)
m = Total number of segments

Table 2 - Runoff coefficients for various land uses

Landuse	**Area Catchment (ha)**	**Runoff Coefficient (C) For Minor System (≤10 year ARI)**	**For Major System (>10 year ARI)**
Open Spaces 1: Forest Cover	11.2	0.30	0.40
Open Spaces 2: Grass Cover	1.93	0.40	0.50
Open Spaces 3: Forest Cover	5.42	0.30	0.40
Commercial and Business Centres 1	5.99	0.90	0.95
Commercial and Business Centres 2	4.68	0.90	0.95
Commercial and Business Centres 3	4.10	0.90	0.95
Sport Fields, Park	1.23	0.30	0.40

Roads	1.21	0.95	0.95
Retention Pond (no outlet)	0.34	0.00	0.00
Residential (Flat and Apartment)	3.35	0.80	0.85

Average runoff coefficient for ≤ 10 years ARI

Cavg = (area catchment x minor runoff coefficient)/total area catchment
= 0.59

Average runoff coefficient for > 10 years ARI

Cavg = (area catchment x major runoff coefficient)/total area catchment
= 0.66

4.3 Time of Concentration Estimation

Table 3 showed the formula that will used to evaluate the concentration time, t_c and Table 4 showed the travel time value for each different types of land use where all the value will be added to find the time of concentration, t_c.

Time of concentration, $t_c = t_o$

Table 3 - Equation to estimate time of concentration

Travel	Travel Time	Remark
Overland Flow	$t_o = \frac{107.n^{*}L^{1/3}}{S^{1/5}}$	t_o = Overland sheet flow travel time (minutes) L = Overland sheet flow path length (m) for Steep Slope (>10%), L ≤ 50m for Moderate Slope (<5%), L ≤ 100m for Mild Slope (<1%), L ≤ 200m n^* = Horton's roughness value for the surface S = Slope of overland surface (%)

Table 4 - Parameters used for travel time, t_o

Landuse	Overland sheet flow path length (m)	Slope of overland surface (%)	Land Surface	Horton's Roughness, *n*	Travel Time, t_o
Open Spaces 1: (Forest Cover)	529	9.6	Densely Grased	0.060	33.03
Open Spaces 2: (Grass Cover)	63.0	0.96	Average Grassed	0.045	19.32
Open Spaces 3: (Forest Cover)	508	14.5	Densely Grassed	0.060	30.01
Commercial and Business Centres 1	349	0.3	Paved	0.015	14.38
Commercial and Business Centres 2	376	1.1	Paved	0.015	11.37
Commercial and Business Centres 3	309	0.8	Paved	0.015	11.35
Sport Fields, Park	194	2.8	Paved	0.015	7.56
Roads	322	2.9	Paved	0.015	8.89
Retention Pond	146	3.1	Poorly Grassed	0.035	15.73
Residential (Flat and Apartment)	361	1.0	Paved	0.015	11.43

Where, tc = 33.03 + 19.32 + 30.01 + 14.38 + 11.37 + 11.35 + 7.56 + 8.89 + 15.73 + 11.43
= 163.07 min ~ 3 hr

4.4 Empirical IDF Curves and Peak Flow

When estimating rainfall intensity values using IDF curves, an empirical equation can be employed to reduce inaccuracy. It is written:

$$i = \frac{\lambda T^k}{(d+\theta)^\eta} \; i = \frac{\lambda T^k}{(d+\theta)^\eta} \tag{3}$$

where,
i = Average rainfall intensity (mm/hr);
T = Average recurrence interval – ARI ($0.5 \leq T \leq 12$ month and $2 \leq T \leq 100$ year);
d = Storm duration (hours), $0.0833 \leq d \leq 72$; and
λ, k, θ, η = Fitting constants dependent on the rain gauge location

In this formula the value of fitting constants is been taken from the nearest rain gauge location to the case study area and the description is expressed in Table 5. In addition, the storm durations, *d* is taken as 3 hour which the design of storm duration must be choose as equal or larger than the time of concentration (*tc*). Table 6 provides the summary results for rainfall intensity and discharge for 10 years, 50 years, and 100 years. According to Empirical IDF Curves, when the value of storm duration is low, the rainfall intensity will increase and affecting the dicharge value. As we can see, the trend of discharge is increasing by years which means that the probability of the river to overflow is high. As a result, the discharge value is applied to simulate the river, whether it is flooded or otherwise.

Table 5 - Fitting constants for the IDF empirical for the Pintu Kaw. Pulau Kertam, Pahang

State	No.	Station ID	Station Name	Constants			
				λ	κ	Θ	η
Pahang	10	3628001	Pintu Kaw. Pulau Kertam	50.024	0.211	0.089	0.716

Table 6 - Summary results for rainfall intensity and discharge

Years	Rainfall Intensity (mm/hr) at 3 hr	Discharge, Q (m^3/s) at 3 hr
10	36.26	2.42
50	50.93	3.80
100	58.95	4.40

4.5 Simulation from Existing Drainage

The results from the HEC-RAS simulation are shown for 10 years, 50 years, and 100 years for chainage 6350 (upstream) in Fig. 4, while the remaining for 9 chains are summarised in Table 7. This simulation was produced by entering the elevation data of Chainage 6350 in HEC-RAS software. From this simulation, we can know that most of the chainages are faced with flooding as the water overflows from the left and right banks of the channel, and one solution has been proposed to modify the existing channel by increasing or deepening the right and left banks of the channel. This solution is discussed further in section 4.6.

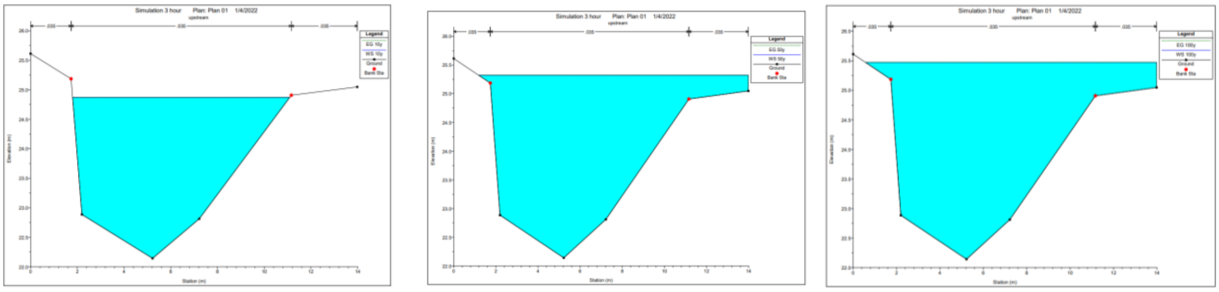

Fig. 4 - Cross section C6350 for 10 years, 50 years and 100 years

Table 7 - Flooded station with different years

Chainage	10 years	50 years	100 years
5900			
5950		Flood	Flood
6000	Flood	Flood	Flood
6050	Flood	Flood	Flood
6100	Flood	Flood	Flood
6150		Flood	Flood
6200		Flood	Flood
6250		Flood	Flood
6300	Flood	Flood	Flood
6350		Flood	Flood

4.6 Simulation from Proposed Channel Modification

Fig. 5 shows the recommendation of new channel cross section for Chainage 6350 for 10 years, 50 years as well as 100 years. Based on these modification, we can see that the water is no longer flooding even until 100 years. There are 7 different template that been used in order to modify 10 chainage of Maran river. The size and shape of each chainage are modify differently based on the existing elevation of the channel.

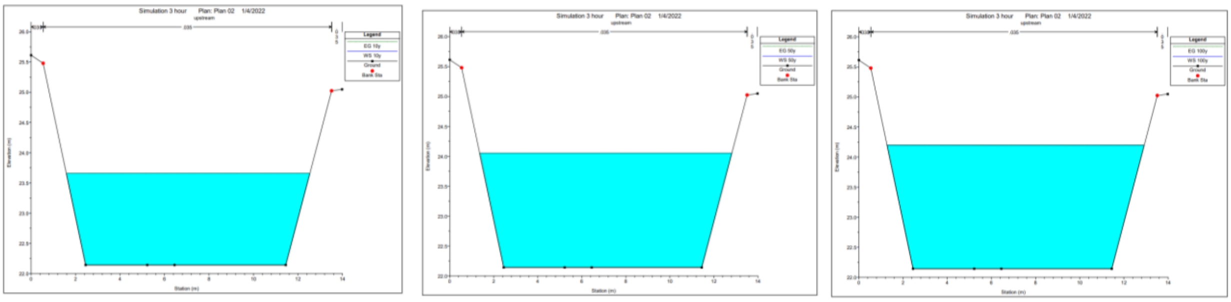

Fig. 5 - New Cross section C6350 for 10 years, 50 years and 100 years

5. Conclusion

Modeling with computer software simplifies the process and saves time when analysing system drainage precisely and effectively. The analytical results are also provided rapidly and provide a clear image that closely mimics the true scenario. The HEC-RAS programme was used to model the drainage hydraulic system in order to learn about the profile conditions, uniform and non-uniform flow rivers, water plots, surface, and hydraulic features. The approach is simple and effective for determining if a river is experiencing flooding or not. Based on the simulations, the objectives were fulfilled by creating a cross section of the river and solving flood problems by modifying river channel sections using the HEC-RAS tabulate method.

According to the hydraulic model created by the HEC-RAS software, 9 out of 10 chainage stations were discovered inundated due to their inability to accept the water flow. This is due to the fact that when the peak discharge was calculated using the logical technique, the discharge value increased by years, with the discharge value for 3 hours storm duration being 2.42 m^3/s for 10 years, 3.80 m^3/s for 50 years, and 4.40 m3/s for 100 years return time. As a result, each chainage's channel has been modified, and the new channel can accommodate water for the next 100 years.

Finally, HEC-RAS software is highly important in easing the process of acquiring an overview of the river cross section, where relevant parties such as District Engineers, Irrigation and Drainage Departments may plan and make preliminary flood preparations. Furthermore, they might propose ideas to change existing river banks or elevations to prevent floods and limit the devastation of victims' property. A few important aspects must be improved in order to get the desired results. This is because accuracy is critical when designing or changing current river courses to avert future floods. Use varying rainfall data and more effective data collection in the field research area.

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References

[1] Prastica, R. M. S., Maitri, C., Hermawan, A., Nugroho, P. C., Sutjiningsih, D., & Anggraheni, E. (2018, March). Estimating design flood and HEC-RAS modelling approach for flood analysis in Bojonegoro city. In IOP Conference Series: Materials Science and Engineering (Vol. 316, No. 1, p. 012042). IOP Publishing

[2] Teng, J.; Jakeman, A.J.; Vaze, J.; Croke, B.F.W.; Dutta, D.; Kim, S. Flood inundation modelling: A review of methods, recent advances and uncertainty analysis. Environ. Model. Softw. 2017, 90, 201–216

[3] Mihu-Pintilie, A.; Cîmpianu, C.I.; Stoleriu, C.C.; Pérez, M.N.; Paveluc, L.E. Using high-density LiDAR data and 2D streamflow hydraulic modeling to improve urban flood hazard maps: A hec-ras multi-scenario approach. Water 2019, 11, 1832

[4] Ahmad, H. F., Alam, A., Bhat, M. S., & Ahmad, S. (2016). One Dimensional Steady Flow Analysis Using HECRAS–A case of River Jhelum, Jammu and Kashmir. European Scientific Journal, ESJ, 12, 32

[5] WMO. (2018). 2018 Annual Report: WMO for the Twenty-first Century (Issue 1229)

[6] Hirabayashi, Y., Mahendran, R., Koirala, S., Konoshima, L., Yamazaki, D., Watanabe, S., Kim, H., & Kanae, S. (2013). Global flood risk under climate change. Nature Climate Change, 3(9), 816–821

[7] Masaru Morita (2014). Flood Risk Impact Factor for Comparatively Evaluating the Main Causes that Contribute to Flood Risk in Urban Drainage Areas

[8] Islam, R., Kamaruddin, R., Ahmad, S. A., Jan, S. J., & Anuar, A. R. (2016). A review on mechanism of flood disaster management in Asia. International Review of Management and Marketing, 6(1), 29–52

[9] WMO (2008). Urban Flood Risk Management–A Tool for Integrated Flood Management. Version 1.0, APFM Technical Document No.11, Flood Management Tools Series

[10] Yadav, V. G., Mehta, D., & Waikhom, S. (2015). Simulation of HEC-RAS model on Prediction of Flood for Lower Tapi River Basin, Surat. Journal of Emerging Technologies and Innovative Research, 2(11), 105-112

[11] Pathan, A. I., & Agnihotri, P. G. (2019). A combined approach for 1-D hydrodynamic flood modeling by using Arc-Gis, Hec-Georas, Hec-Ras Interface-a case study on Purna River of Navsari City, Gujarat. IJRTE, 8(1), 1410-1417

[12] Lea, D.; Yeonsu, K.; Hyunuk, A. (2019) Case study of HEC-RAS 1D – 2D coupling simulation: 2002 Baeksan flood event in Korea. Water, 11, 2048

[13] Dimitriadis, P.; Tegos, A.; Oikonomou, A.; Pagana, V.; Koukouvinos, A.; Mamassis, N.; Koutsoyiannis, D.; Efstratiadis, A (2016). Comparative evaluation of 1D and quasi-2D hydraulic models based on benchmark and real-world applications for uncertainty assessment in flood mapping. J. Hydrol., 534, 478–492

[14] Md Ali, A.; Solomatine, D.P.; Di Baldassarre, G. (2015) Assessing the impact of different sources of topographic data on 1-D hydraulic modeling of floods. Hydrol. Earth Syst. Sci., 19, 631–643

[15] Department of Irrigation and Drainage (2012). Urban Stormwater Management for Malaysia. Government of Malaysia (MSMA)