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Flood Inundation Assessment under Climate Change Scenarios in Kuantan River Basin, Malaysia

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Abstract. The changing of climate pattern will increase the magnitude and frequency of excessive precipitation events which may trigger the possibility of river flooding with more severe and with higher risks. The objective of this current study is to assess and determine the flood inundation at the midstream to downstream part of Kuantan River Basin without and with consideration on Climate Change Factor (CCF). This coefficient is obtained from a technical guide on future design rainstorm with Climate Change Factor (CCF) by National Hydraulic Research Institute of Malaysia (NAHRIM). Next, design storm used in this study is a 24-hour storm duration and 100 years Annual Recurrence Interval (ARI). The finding of this study shows that climate change brings a significant impact on flood inundation depth and also in area. This result will be useful for city and or state government in term of formulating of appropriate strategies in order to minimize the negative impacts of flooding in Kuantan River Basin.
Keywords: Flood inundation, climate change, Kuantan River

1. Introduction

Climate change will modify type of flooding as a result of river discharge changing in term of frequency and also magnitude. Besides that, it also gives effect on water scarcity and availability in river systems and currently that might become the most important concern [1, 2]. The impact of climate change on river flows has been studied by many researchers [3, 4, 5, 6, 7, 8]. The transformation in flood characteristic will have inference on the flood mitigation and reduction strategies. Therefore, concerning on flooding future changes is very decisive [9, 10, 11].

The Kuantan River Basin has a drainage area of approximately 1638km^2 with the basin total length of 86km. The upstream part of Kuantan River is Chereh Dam which has 54km^2 of water surface area and 250x10^{6}m^3 of maximum reservoir volume. This dam will spill out the water by way of 50m width un-gated chute spillway. Therefore, the Kuantan River flows will be depending on the scenario of water releasing from the Chereh Dam. The present study applies the HEC-HMS and HEC-RAS model to generate and simulate flood inundation under some design scenarios: 100 years ARI with and without consideration on climate change coefficient. The objective of this present study is constructing flood inundation map due to 100 years ARI with particular scenarios as mentioned before. Then, the finding of this study will help city or state government make suitable formulation related to policy, rule and strategy in term of city planning.

2. Methods

2.1 HEC-HMS and HEC-RAS Model

HEC-HMS (Hydrologic Engineering Center - Hydrologic Modeling System) model was developed by the US Army Corps of Engineers [12] that could be used for many hydrological simulations. This model can be applied for various hydrological analyze purposes, such as: urban flooding assessment, computation of flood frequency, design and formulation of flood warning system, determination of reservoir spillway capacity, etc. The main components of HEC-HMS model are: 1) an analytical model to compute the amount of overland flow runoff, 2) an advanced graphical user interface (GUI) which illustrate hydrologic system components

Similar to HEC-HMS, HEC-RAS (Hydrologic Engineering Center - River Analysis System) is also made by US Army Corps Engineer and both models are freeware application. HEC-RAS has ability to assess one and two-dimensional hydraulic calculations for a natural river and also design channels [13]. There are four main modules of HEC-RAS: (a) water surface profiles under steady state condition; (b) unsteady flow computation, which can simulate in one dimensional (1-D), two-dimensional (2-D) and combined one/two dimensional unsteady flow through a full network of open channels, natural river and or floodplains; (c) sediment transport calculation, which is intended to simulate 1-D sediment transport from scouring and deposition process with reasonable prediction to long time periods of calculation; and then, (d) water quality model; which is intended to allow performing water quality analyses.

3. Result and Discussion

3.1. Hydrological Model

One of the primary input data used as an input of HEC-RAS model was flow hydrograph. This present study used 24-hours of 100 years ARI with and without considering climate change coefficient in order to generate flood inundation along Kuantan River. Flow hydrograph data in here was obtained from calibrated and confirmed HEC-HMS model. The process and the result of calibration and confirmation of HEC-HMS model applied in Kuantan River basin can be found in the prior publication [14].

3.2. Design Storm

In the current study, the Intensity Duration Frequency (IDF) constant of Sg. Lembing PCC Mill (SF 3930012) was used to simulate 24-hours design under 100 years ARI (Q_{100}). The empirical of IDF curve is written in Eq. 1 and then, the rainfall intensity for 100 years ARI with storm duration of 24 hours are tabulated in Tabel. 1.

$$i = \frac{\lambda T^{\kappa}}{(d+\theta)^{\eta}} \tag{1}$$

where,

i = average rainfall intensity (mm/hr),
T = average recurrence interval (ARI) = 100 years
d = storm duration = 24 hours
λ = 45.999; κ = 0.210; θ = 0.074; η = 0.590

Table 1. Calculated rainfall intensity and rainfall depth at SF 3930012

ARI (years)	24-hours	
	Rainfall intensity (mm/hr)	Rainfall depth (mm)
100	18.520	444.474

The technical guideline proposed and published by National Hydraulic Research Institute of Malaysia (NAHRIM) in term of Climate Change Factor (CCF) divided Peninsular Malaysia into 5 regions and Pahang State is grouped in to region 1 for Northern Pahang, while another Pahang area is in the region 2 [15]. Climate Change Factor constant of Rumah Pam Pahang Tua (3533102) was selected to calculate storm flood hydrograph of Kuantan Rivers and tributaries and the value of CCF is 1.46 as shown in Table 2 below. The generated flood hydrograph for 100 years (Q_{100}) ARI in the confluence of Lembing River and Kuantan River where stream flow station of SF 3930012 located are displayed in **Figures 3** in the next page. This figure informs the 100 years ARI maximum flood without and with CCF.

Table 2. Climate Change Factor (CCF) for Pahang State proposed and published by NAHRIM [15]

State	Station ID	Station Name	Climate Change Factor (CCF) ARI	
			50 years	100 years
Pahang	4219001	Bukit Betong	1.49	1.52
	4127001	Hulu Tekai Kwsn B	1.26	1.27
	3424081	JPS Temerloh	1.44	1.48
	4223115	Kg. Merting	1.51	1.55
	4023001	Kg. Sungai Yap	1.52	1.57
	3628001	Pintu Kaw. Pulau Ketam	1.62	1.64
	3924072	Rumah Pam Paya Kangsar	1.52	1.56
	3533102	Rumah Pam Pahang Tua	1.41	1.46
	3818054	Setor JPS Raub	1.37	1.40
	3121143	Simpang Pelangi	1.43	1.48

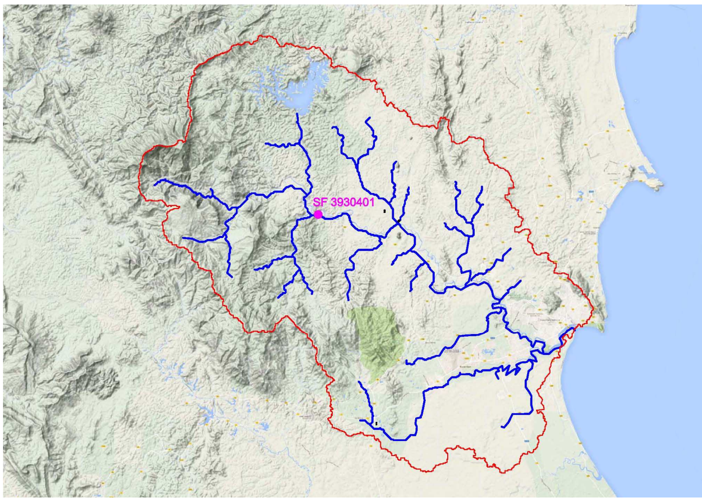

Figure 1. Location of streamflow station SF 3930012 in the confluence of Lembing River

and Kuantan River

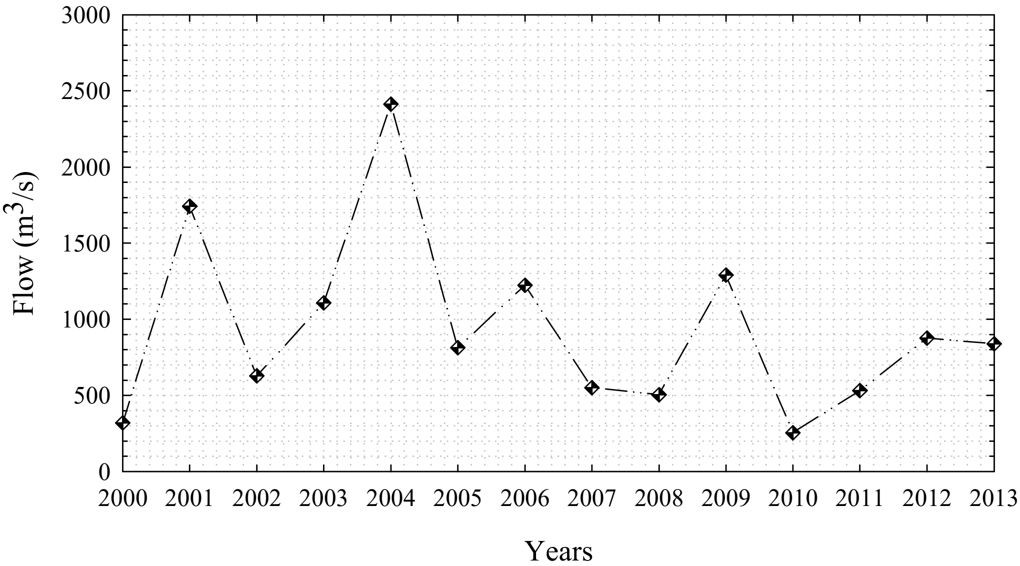

Figure 2. Maximum flood recorded at streamflow station (SF 3930401) in a last decade from 2000 to 2013

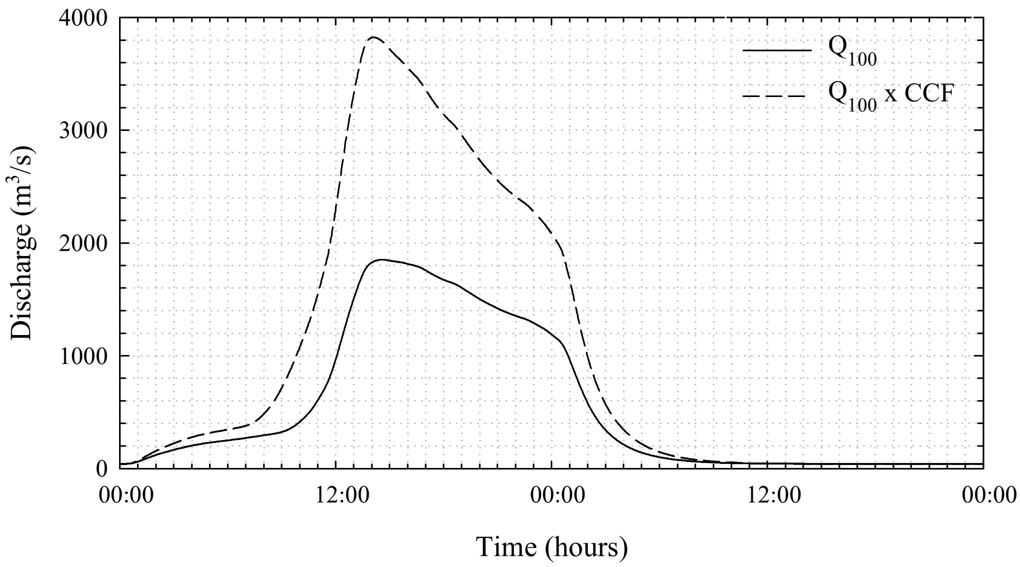

Figure 3. Simulated flood hydrograph in the junction of Lembing River and Kuantan River for 100 years ARI without and with concern on CCF = 1.46 [14]

Figure 2 reports the historical maximum floods which once occurred at stream flow station SF 3930401, while Figure 3 shows the generated flood hydrograph 100 years ARI in the same location. Based on those figures, great flood was recorded on December 11, 2004 with the magnitude 2413m^3/s, this size is above the simulated maximum flood 100 years ARI. It can be said that 100 years ARI flood design has happened in a recent decade. Furthermore, in the last 10 years, severe flood above of 50 years ARI occurred on December 22, 2001 with the magnitude 1742.40 m^3/s and 2413m^3/s on December 11, 2004. This phenomenon also clarified that climate change exists.

3.3. *Hydraulics Model*

Hydraulics model scheme of Kuantan River is displayed in Figure 4. This scheme illustrate that there are some tributaries that will contribute on flood accumulation of Kuantan River, such as: Chereh River, Lembing River, Reman River, Riau River, Pandan River, Belat River etc. Figures 5, 6, 7 and 8 depict the magnitude of simulated flood hydrograph of Kuantan River tributaries for 100 years ARI without and with consideration on Climate Change Factor. Belat River gives quite big flood discharge to the downstream part of Kuantan River about 700m^3/s and 1500m^3/s for 100 years ARI flood design without and with consider on CCF. Next, Reman River and Riau River contribute flood flow in the midstream of Kuantan River with almost similar size around 400m^3/s and 800m^3/s. Then, Lembing River gives additional amount of flood discharge in the upstream part of Kuantan River with the magnitude of 400m^3/s and 800m^3/s.

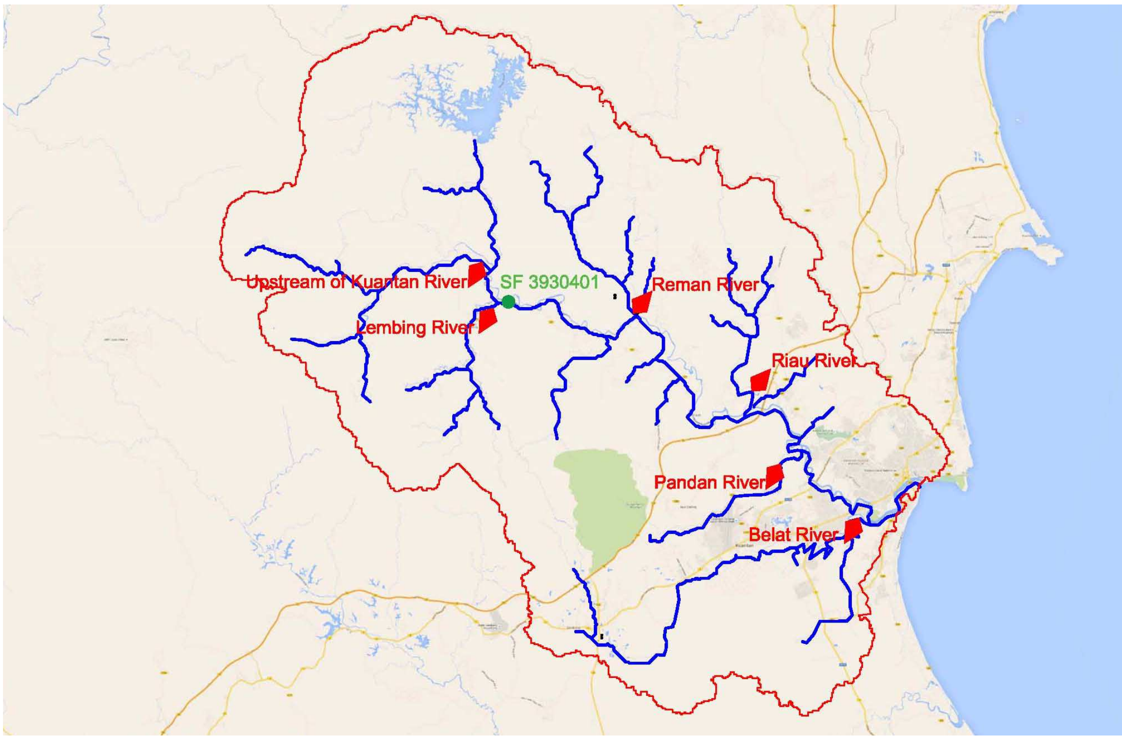

Figure 4. Hydraulics model scheme of Kuantan River basin

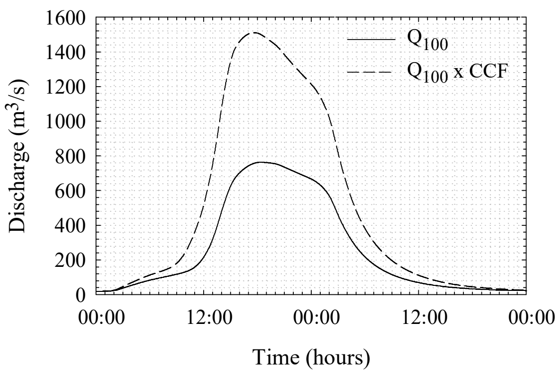

Figure 5. Simulated flow hydrograph of Belat River

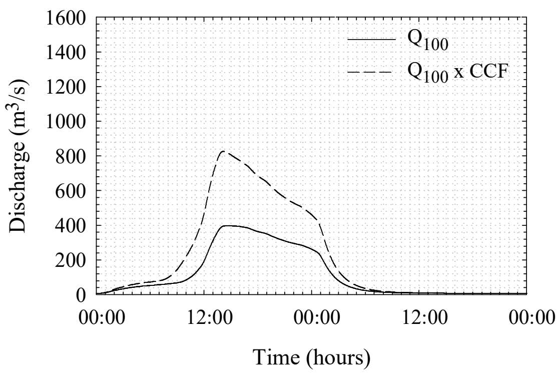

Figure 6. Simulated flow hydrograph of Lembing River

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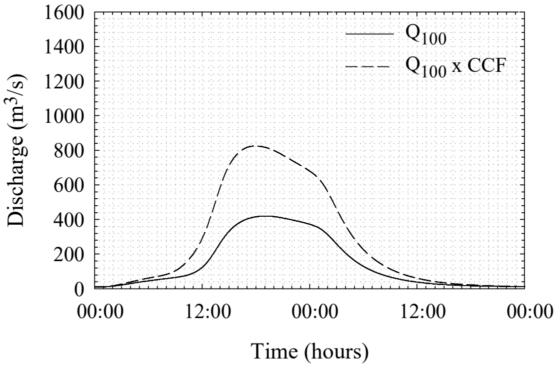

Figure 7. Simulated flow hydrograph of Reman River

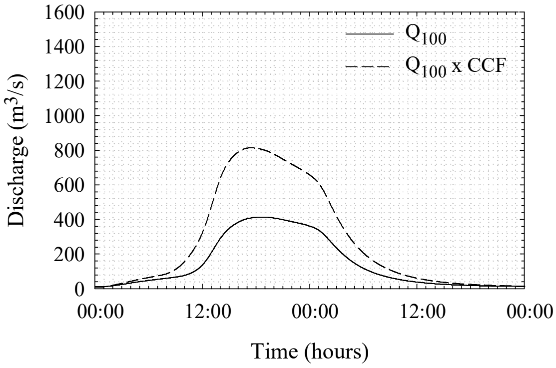

Figure 8. Simulated flow hydrograph of Riau River

The result of generated flood inundation is due to design scenarios as mentioned before shown in the following figures. Figure 9 tells about inundation due to design flood of 100 years ARI without any consideration on Climate Change Factor. Then, Figure 10 informs about flood inundation due to 100 years ARI by involving CCF in simulation and calculation. From Figures 9 and 10, it could be concluded briefly that Climate Change Factor (CCF) creates a significant impact in term of the area and also the depth of flood inundation.

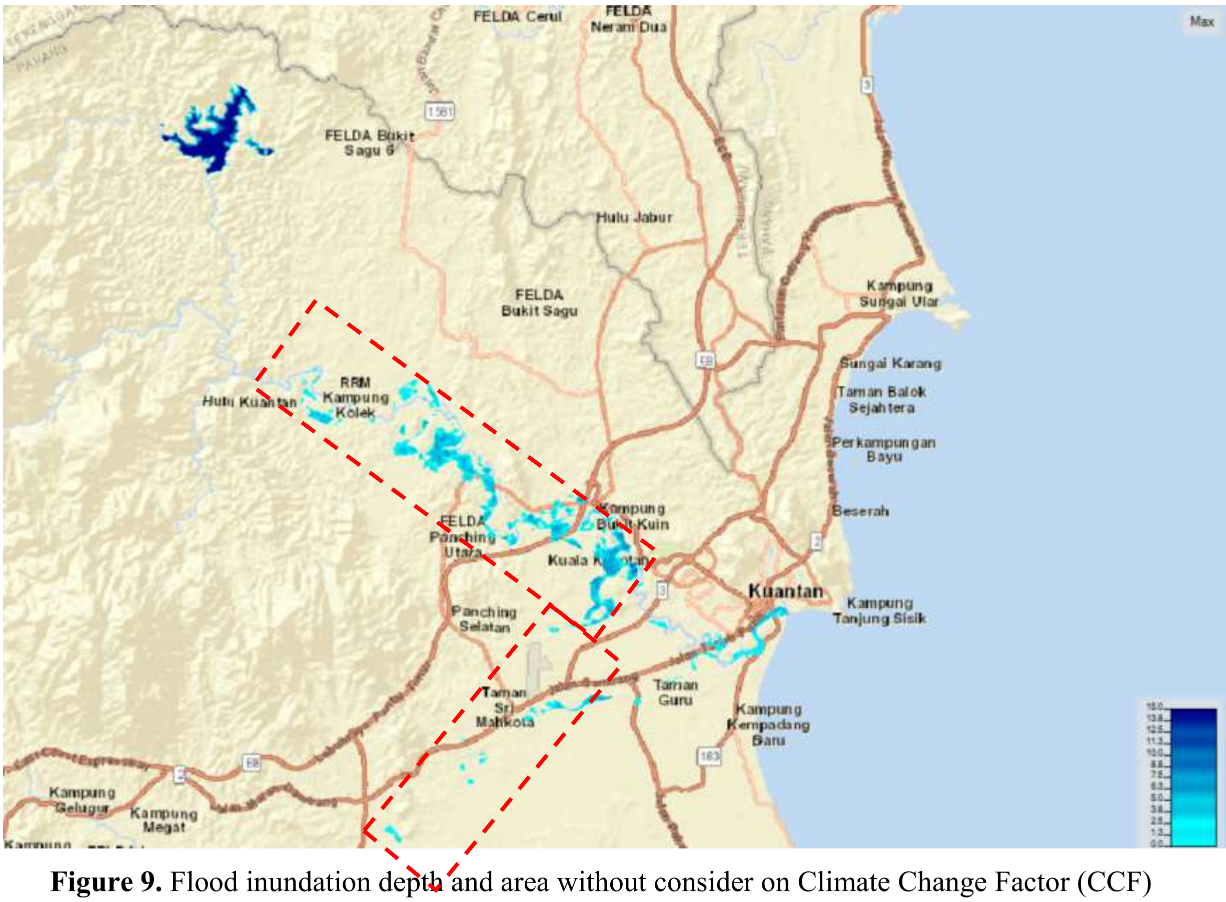

Figure 9. Flood inundation depth and area without consider on Climate Change Factor (CCF)

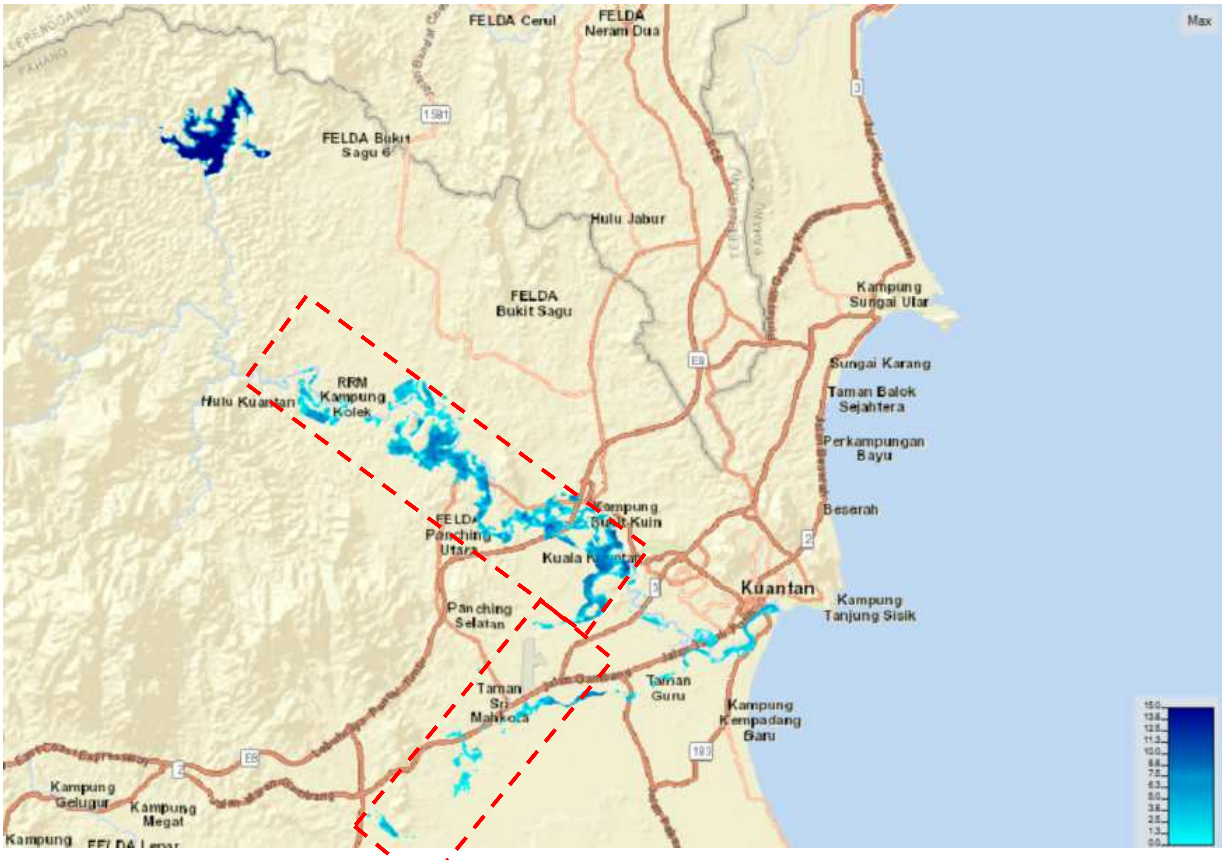

Figure 10. Flood inundation depth and area with consider on Climate Change Factor (CCF) constant of Rumah Pam Pahang Tua (3533102) which is equal to 1.46

Figures 9 and **Figure 10** demonstrate the flood inundation due to 100 years ARI without and with concern on climate change coefficient. As mentioned before, the most significantly differences that we can observe clearly from the simulation result are the area and the depth of inundation. Flood inundation map produced under situation of 100 years ARI without concern on CCF shows that some areas are flooded such as: Lorong Sungai Isap and SMK Bukit Rangin are flooded up to 3.5m, while the meeting point of Sungai Lembing road and Panching road is about 6.5m, then Tanah Putih Baru is flooded up to 5m and Kampung Padang Perdana is around 3.0m. When CCF was involved in calculation and simulation, the area and the depth of flood inundation are getting wider and higher. Lorong Sungai Isap and SMK Bukit Rangin are flooded up to 5.3m, then Sungai the meeting point of Sungai Lembing road and Panching road is around 9.2m. Tanah Putih Baru and Kampung Padang Perdana are inundated by the depth of 6.3m and 6.5m respectively. When flood inundation map is generated with consider on climate change factor, it can be seen clearly that some vital areas are flooded severely.

4. Conclusions

Climate change factor have been involved in generating of flood flows along Kuantan River and all tributaries. The result clearly shows that there are significantly differences in term of the depth and the area of inundation in the midstream to the downstream part of Kuantan River basin under condition with and without consider on climate change coefficient as illustrated in **Figures 9** and **10** (red box mark). By involving CCF in calculation and simulation the area of inundation are getting wider and also the depth of inundation are getting higher. As mentioned before that the finding of this current study is to produce flood inundation map, this map will be very useful for city or state government to formulate of appropriate strategies in order to minimize the negative impacts of flooding in Kuantan River Basin.

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