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Research Paper

IDENTIFICATION OF RELEVANT METHOD FOR FLOOD EVENTS DESIGN AN APPROACH TO FLOOD HAZARD ASSESSMENT AT RIVER BASIN SCALE

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ABSTRACT

Flood is one of the most dangerous natural disaster in Vietnam. Assessing flood hazard is a long term ambition of the society, especially in low-land cities where almost its communities expose to flood caused by heavy rainfall over its upstream river basin. In order to do that, designing flood events is one of the very first step. This paper evaluates some methods of flood design and give an advise for choosing relavant method in Vietnam which have been test in Vu Gia Thu Bon river basin. The procedure includes several steps: 1. Design a storm event which cause heavy rainfall over the basin; 2. Estimate the Arial Reduction Factor (ARF); 3. Estimate the flood peak; and 4. Design the flood events. The first step have been done by develop IDF curve over the basin; then several combination methods of Arial Reduction Fator and flood peak estimation have been applied and evaluated to choose the most relevant one with respect to literatural flood peak values. The result show that, USWB method for ARF identification in combination with Rational method for flood peak estimation give a very good result for flood hazard design.

Keywords: *Flood design, Vu Gia Thu Bon, Flood hazard, Flood risk.*

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1. Introduction

Flood is one of the most dangerous natural disaster in Vietnam (Assistance, 2018). Assessing flood hazard is a long term ambition of the society, especially in low-land cities where almost its communities expose to flood caused by heavy rainfall over its upstream basin. The very first step of hazard assessment is designing flood scenarios. In a literature, a design flood is a hypothetical flood (peak discharge or/and hydrograph depending on the purpose of each study) adopted as the basis in engineering design of a water resources system (Jain, 2003). The two most used-approaches for generating the design flood are flood frequency analysis (FFA) and rainfall - runoff analysis (RRA) (Daniel and Wright, 2016). The first one designs a flood via statistical analyses of the observed discharge data. This method is usually used to estimate peak discharge at a certain location during a flood design event. The second one designs a flood by estimating the runoff from design rainfall event which is induced by statistical analyses of observed rainfall data. This method is usually used to design the peak and hydrograph of an expected flood event.

For many developed countries like US or

western regions, they use FFA to estimate the design floods because they have densed discharge stations which cover almost represenative locations in their river basins (Survey, 2006; Hydrology, 1999; Hydrology, 2012; Engineers, 2001). However, in the developing country like Vietnam, where the observed data is usually not long enough for frequencies analysis, the FFA can cause a bias error. Infact, many authors found that the RRA is more reliable than the FFA when applied to the basin with fews observations (MCKerchar and Macky, 2001; Calver et al., 2009; Lee et al., 2011). That is why RRA is recommended to use in many regions in the world.

Vietnam have been issue some technical stardard on flood design for the purpose of engineering design at the site without data such as TCVN 9845:2013 on Calculation of flood flow characteristic which usually used to design transportation structures or TCVN 7957:2008 on Drainage and sewerage - External Networks and Facilities - Design Standard. The first one guides to estimate the flood peak based on the rain height of given frequencies and use a referent-historical-flood for scaling flood peak and defining the hydrogaph. The second guides to design IDF curve over the basin to estimate the rain height of certain frequency needed to be drained in urban area. Both cases give a difficult approach for analyzing the flood hazard at the large basin scale where the rainfall is spacially distrubuted. In Vietnam, the engineer usually choose a reference storm event which happened in the past and be scaled up to the relevant value of design frequency such as 10, 20, 50 or 100 year return periods based on the purpose of the studies. However as we all know, the storm is stochastic event which can not be happen twice in reality. In addition, in flood hazard analysis, the extreme flood is the one contributed by rainfall over the whole basin. This paper introduce a procedure for flood designing using RRA approach for supporting flood hazard assessment. This procedure will be tested on Vu Gia Thu Bon River basin.

2. Method

2.1 Description of study site

Vu Gia Thu Bon River basin is one of the four biggest basins in Vietnam. Base in the Central part of Vietnam and cover the part of Kon Tum, Da Nang and Quang Nam provice, its delta usually face to flood due to its special topography and geographic location (Fig. 1). It has the area of about 10,350 km2. Only approximately 15% its area is low land delta where collects all water from its upper basin when they cover by a storm. That is why the delta annually surffer to inundation and flooding which have been caused human lost and extreme damage in Da Nang and Quang Nam every year. Therefore the study of flood hazard is valuable for this region. However, the mornitoring sites and observed data in this basin are till scarce. There are only two discharge stations in the basin: Nong Son in Thu Bon river and Thanh My in Vu Gia river which are located in the upstream of the system (Fig. 2). Therefore, FFA is difficult application in the basin. This situation is being a case of almost river basins in Vietnam where the data is scarce and short. Hence, to analysis the flood hazard, we should use DRRA method and start from rainfall data instead of discharge data.

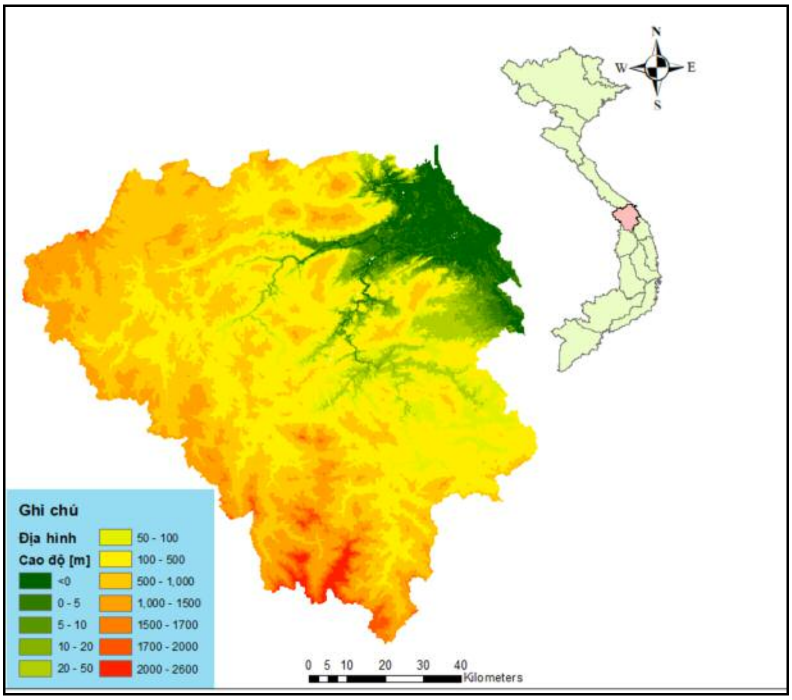

Fig. 1. Geographical location and topographic map of Vu Gia Thu Bon basin

2.2 Methodology

The methodology of flood design for flood hazard assessment at river basin scale is the RRA approach. Starting from rainfall analysis, the hourly data for 20 - 30 years should be collected and make the frequency analysis of the event with different durations from 10 mins upto 72 hours based on the time concentration of the sub-basin. The procedure is presented in Fig. 2.

Step 1: Design point rainfall

Current approach of analyzing the point rainfall at each station within and vincini the basin is using Itensity Duration Frequency curve (IDF) of rainfall data at gauged station. Each curve shows the intensity of rainfall during specific duration at a given frequency. In this study, the DDF curves were developed instead of IDF curve for rainfall design purpose, referring to the rain height instead of the rain intensity for easier use in following phases, as described by Eq. 1.

$$h = axt^n \qquad (1)$$

where h is the rainfall depth (mm) for the duration t; a, n are parameters to estimate from the data series; then i = h/t is the rainfall intensity. DDF curves are computed using this procedure for 10, 20, 50, 100 and 200 years return period for each available station in the basin area using the set of parameters a &n specified for each rain station.

Step 2: Design arial rainfall

After having point DDFs at each station, transformation of point rainfall to areal rainfall can be made by interpolating spatial the parameters of Depth-duration-frequency curves and applying an empirically-derived areal reduction factors (ARFs). Usually, the regionalized rainfall over the sub catchments can be estimated by some popular methods such as Thiessen polygon, gauged rainfall average, etc. In this study, to overcome the lack of measured data and make an homogeneous analysis for the whole basin, maps of regionalized DDF curves parameters (a&n)were developed, similarly to the method proposed in the paper of (Nhat et al., 2008) for ungauged areas.

For each sub-basin, rainfall critical height according to various RP (100, 50, 20, 10) is evaluated based on the DDF curves ($h=axt^n$), considering a duration t equal to concentration time t_c. An area reduction factor is applied to resulting height, considering USWB formula (from U.S. Weather Bureau with coefficients recalibrated by Benaglia (1997):

$$ARF(t,A)=1-\left(1-e^{-0.01298.A}\right).e^{-0.6786.t^{0.332}} \quad (2)$$

This formular will be valid as the best performing concerning flood peak estimation.

Step 3: Design hyetographs

Design hydetographs are developed from design rainfall event which occur in the duration equal to concentration time of the basin. Concentration time can be estimated by some empirical formula, such as SCS formula or Giandotti formula, etc. These methods require some basin's characteristics defined from DEM and land use maps to extract the area, mean elevation, mean slope, hill slope sides of each sub basin, etc.

Step 4: Design hydrographs

By applying a conceptual rainfall-runoff model (rational model). According to this model, the hydrograph shape is triangular, with a central peak and a total time equal to double the concentration time of the sub-basin.

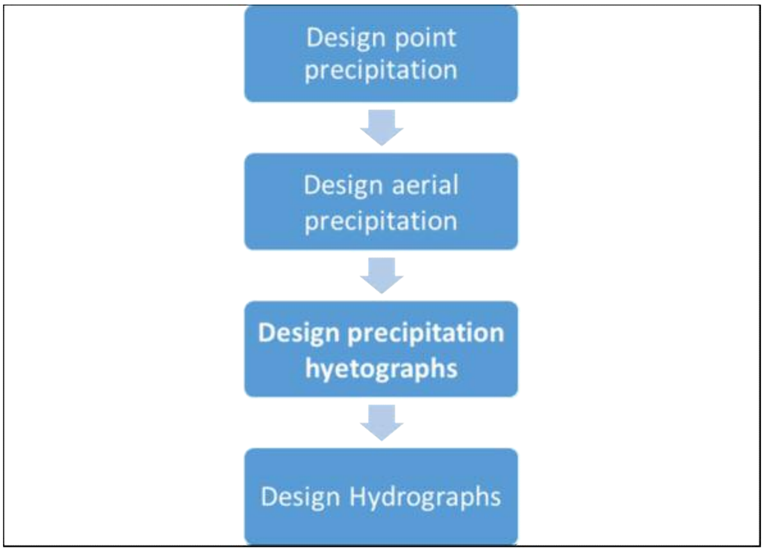

Fig. 2. Flood design procedure

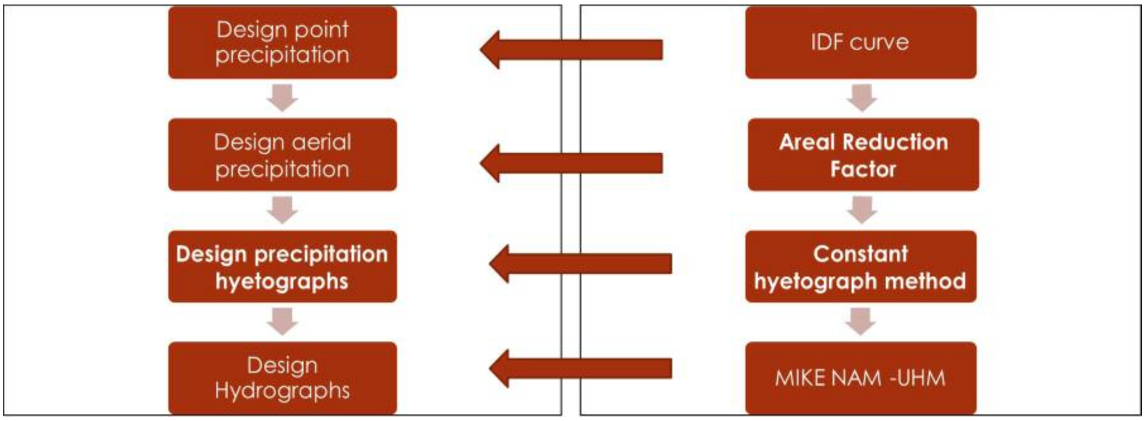

Fig. 3. Solution for each step of the design flood procedure

3. Results and discussion

Vu Gia-Thu Bon River basin is devided into 30 sub-catchments (Fig. 4) which can be analyzing as one unit of hydrograph of a flood event and concatinate each with the other to create the flow of whole system.

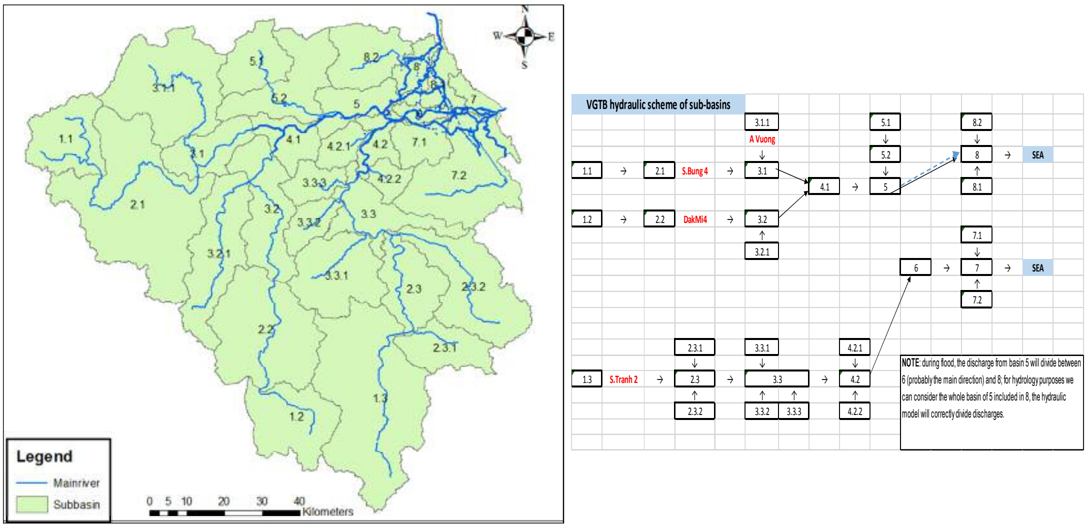

Fig. 4. Sub-basins defined in Vu Gia-Thu Bon River basin for flood analysis

Step 1: Design point rainfall: Designing heavy rainfall events at rain stations

Within the Vu Gia-Thu Bon basin, only observed data of discharge at the stations Nong Son on the Thu Bon river and Thanh My on the Vu Gia are available. Therefore, only two sub-basins are considered for hydrological models' calibration and validation and design flood peaks. Other sub-basins have to be estimated from rainfall. This is the reason why IDF curves of rainfall at all rainfall stations have been built to estimate the discharge peaks of flood events.

For homogeneous analysis, the flood peaks at Nong Son and Thanh My are also estimated based on the rainfall events extracted from IDF curve. A total of 15 rainfall stations within this basin is available, as shown in Fig. 5.

In this study, the DDF curves were developed for rainfall design purpose, referring to the rain height instead of the rain intensity for easier use in following phases, as described by Eq. 1.

DDF curves are computed using this procedure for 10, 20, 50, 100 and 200 years return period for each available station (Fig. 6) in the basin area using the set of parameters &n specified for each rain stations.

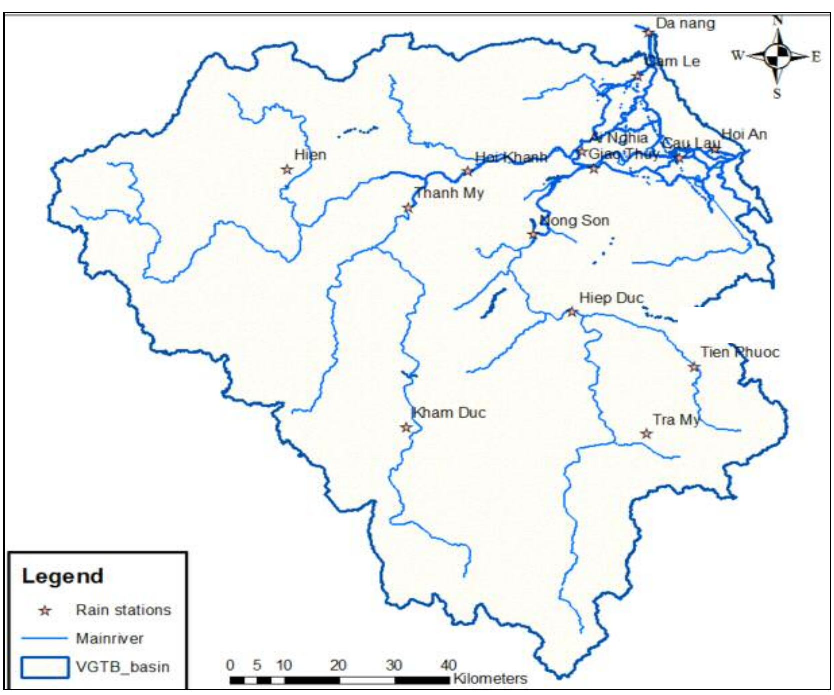

Fig. 5. Rainfall stations in Vu Gia-Thu Bon River basin

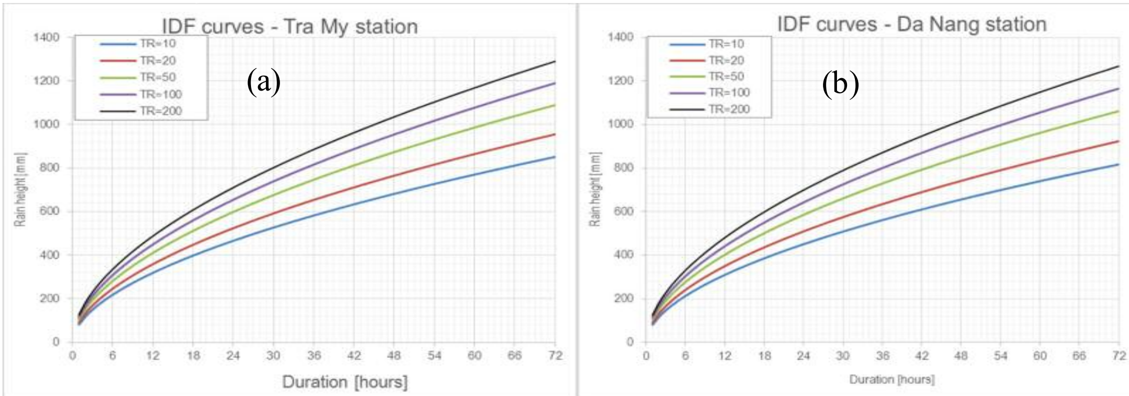

Fig. 6. DDF curves for Tra My (a) and Da Nang (b)

Step 2: Design arial rainfall: Estimating rainfall spatialization over each subbasin

Usually, the regionalized rainfall over the sub catchments can be estimated by some popular methods such as Thiessen polygon, gauged rainfall average, etc. In this study, to overcome the lack of measured data and make an homogeneous analysis for the whole basin, maps of regionalized DDF curves parameters (a&n)were developed, similarly to the method proposed in the paper of Nhat et al. (2006) for ungauged areas.

The validation was made with rain gauges additional to those used for DDF curves estimation. Fig. 7 presents an example of contour maps of a and n parameters under 10-year return period. Then the rainfall heights (Fig. 8) show a more regular and gradually varied distribution on the basin area, as the combination of a and n values tend to attenuate the steeper gradient that can be observed in some area from the contour maps. In any case, the absolute variations in a, n parameters and in obtained rainfall heights are not too relevant between considered gauging stations in the basin area, therefore the use of a regionalization procedure can provide good results.

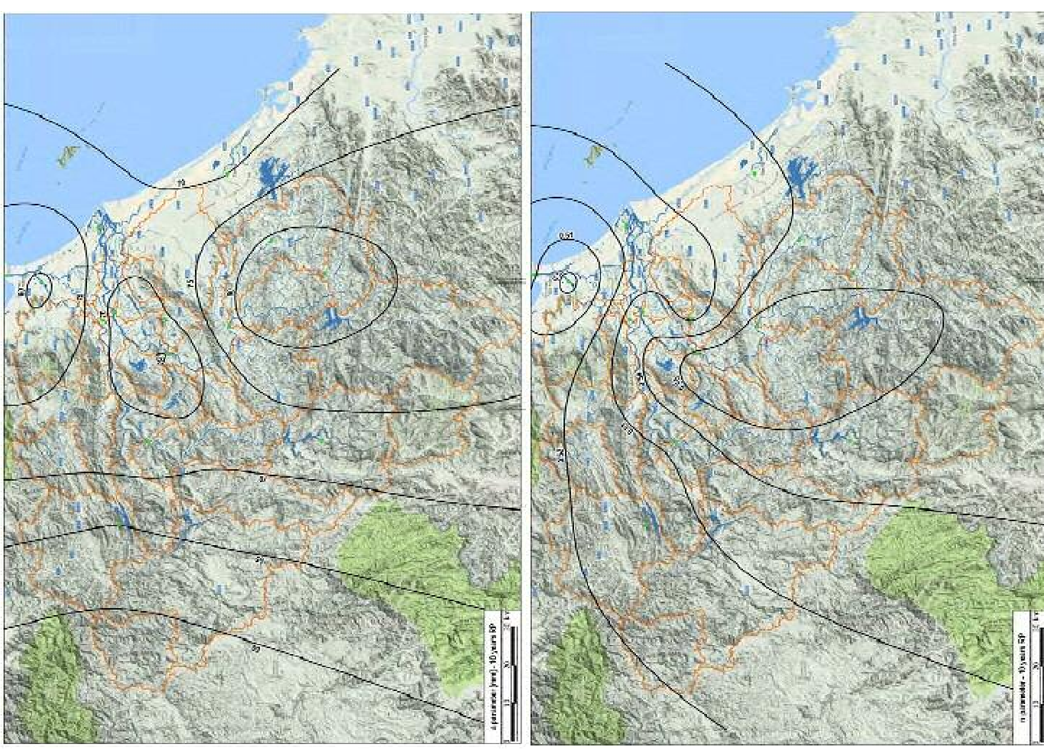

Fig. 7. Spatial values of "a" (left side) and "n" (right side) of 10 year RP

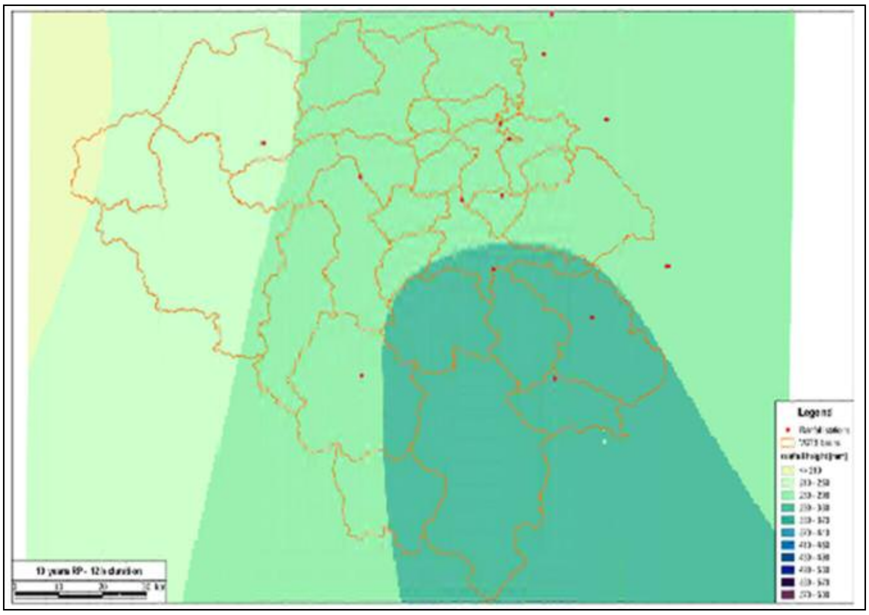

Fig. 8. Distribution of maximum rainfall height for a 12 hour duration and 10 year return period

Step 3: Design hyetographs: ARF values assigned for each sub-basin

For each sub-basin, rainfall critical height according to various RP (100, 50, 20, 10) is evaluated based on the DDF curves ($h=axt_n$), considering a duration t equal to concentration time tc. An area reduction factor is applied to resulting height, considering USWB formula.

Infact, other formulas were tested in pilot basin, as Wallingford formula and a formula cited by Mekong River Commission Secretariat, applied in Cambodia. The latter is the only ARF formula that is found developed in South East Asia, but it is meant for small basins, giving negative values for A > 2500 km^2. USWB formula was identified in pilot basin as the best performing concerning flood peak estimation.

Step 4: Design hydrograph: Flood peaks of relevant frequencies for each sub-basin

Flood peak discharge is computed using a simple rainfall-runoff model, as the rational method (or kinematic method). Thus the flood peak for a given RP will be computed as:

$$Q\left[m^3/s\right] = \frac{\phi.h.a}{3,6.t_c} \qquad (3)$$

where Φ is the runoff coefficient, h the rainfall height for given RP (reduced by ARF coefficient as stated above), the basin area and tc the basin concentration time.

For calibration analysis, maximum flood peaks associated to given frequencies were estimated from available observed discharge series in some gauging station (or official estimates made available from MONRE or previous studies). Hydraulic parameters (CN, runoff coefficients associated to different land use types) were calibrated to have a better representativeness in flood peak estimation from DDF curves.

Table 1. Best presentation of estimated flood peaks at Nong Son and Thanh My

Sub-basin	Estimated flood peak by Rational formula				
Nong Son	Frequencies	10%	5%	2%	1%
	Estimated values	9,201	10,375	11,893	13,032
	Frequencies analysis	9,600	10,860	12,410	13,520
	Different percentage	-4.16%	-4.47%	-4.16%	-3.61%
Thanh My	Estimated values	6,301	7,171	8,298	9,143
	Frequencies analysis	5,990	6,795	7,750	8,420
	Different percentage	5.19%	5.54%	7.08%	8.59%

Table 2. Comparision between statistic design water level and estimated ones at Hoi An (Thu Bon) and Cam Le (Vu Gia)

Station	River		$H_{max}P$ (cm)			
			1%	2%	5%	10%
Hoi An	Thu Bon	Estimate from stage discharge function	386	340	307	267
		Frequency analysis base on observed data	392	358	311	273
Cam Le	Vu Gia	Estimate from stage discharge function	484	422	331	276
		Frequency analysis base on observed data	506	440	355	292

Hydrograph of relevant frequencies for each sub-basin

According to flood peak estimation methodology, the schematic flood hydrograph is developed with an isosceles triangular shape, with a duration equal to the double of the concentration time. This can be smoothed using UHM module of MIKE software, i.e. with SCS model, with parameters calibrated to obtain the same flood peak resulting from previous described methodology. However, this passage is not necessary, as the two shapes are very similar, and considering that the triangular hydrograph will soon smoothen due to hydraulic propagation in the MIKE11 model. The triangular shape is easier to combine in order to define lateral contribution of downstream sub-basins, as described in following point. Hydrographs is defined for every RP (scenario) and every sub-basin with closing section within modeled branches (Fig. 9).

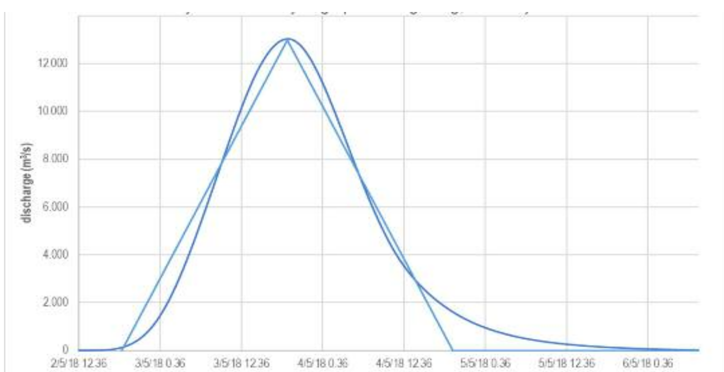

Fig. 9. Comparison between 2 hydrograph shapes: triangular and obtained with UHM - SCS model: an example for Nong Son with 10 year return period

4. Conclusion and Recommendation

The paper have intrduced the procedure on flood design to support flood risk assessment. The procedure have been successfully tested in Vu Gia Thu Bon River basin. The results are compare with references values of discharge at Nong Son and Thanh My and statistical values of water level at Cam Le and Cau Lau in the downstream of the basin. It means that this method can be applied widely for other river basin in Vietnam in the study of flood risk assessment.

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