A New Approach for Unit Flood Response Method for Spatial Prioritization of Flood Control Activities

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1-Introduction

Floods have always been a great cause of loss of life and resources throughout the world. Due to the high rate of population growth and deterioration of natural resources, risk of flooding is increasing day by day. Therefore, watershed management and protective operations are critical issues to control floods in high flood hazard areas. It is not possible to control the floods for the entire basin considering the large extent of the basins. Therefore, in flood control studies, flood contributing areas should be identified and prioritized in order to control the floods with minimum price and maximum performance. In other words, nowadays, instead of focusing on downstream areas under flooding threat, controlling flood generation in upstream flood contributing areas (source areas) using effective flood control activities, is an accepted practice.

One of the proper methods to identify and rank flood contributing areas in the sub-basin scale is Unit Flood Response method (UFRM). In this method, firstly the basin is divided into smaller study units (sub-basins), and by using flood routing module of a rainfall-runoff model (such as HEC-HMS model used in this study), contribution of each unit to the peak flood discharge at the basin outlet is determined using an organized one at a time sub-basin elimination procedure. Then, the areas which have the most contribution to the peak outflow of the basin are identified as the flood contributing areas or flood sources. Although UFRM can be used for identifying and ranking flood contributing areas, it faces challenges when it is used in practice for prioritizing the sub-basins in terms of conducting flood control activities. In this study, a new method called Flood Reduction method (FRM) is introduced for spatial prioritization of flood control activities.

In order to compare the performance of UFRM with that of the proposed FRM for spatial prioritization of flood control activities, Kardeh basin (located upstream of the Kardeh dam) in the Khorasan Razavi province, Iran was selected as the study area, and the results of prioritizing the sub-basins by the two methods were analyzed and compared. The effect of the design rainfall duration on the prioritization of the sub-basins was also investigated in this study.

2- Flood Reduction Method

In the UFRM, the overall peak discharge at the basin is determined first. Then, in order to determine the contribution of a sub-basin to the overall flood peak discharge at the basin outlet, the hydrograph of that particular sub-basin is totally eliminated in the flood routing procedure. The difference between the resulting peak discharge at the basin outlet under non-sub-basin conditions with the basin overall peak discharge is used to determine a flood contributing index for that particular sub-basin. Such indices, determined for all sub-basins, are used to rank flood contributing areas. If the UFRM is used for spatial prioritization of flood control activities, the elimination of flood hydrograph for a sub-basin would indicate that the activities are 100% efficient in the removal of all flow from that sub-basin. However, in real flood control projects, although the peak flood discharge and flood volume decrease as a result of flood control activities, the total elimination of sub-basin flood hydrograph is far from reality. The FRM proposed in this study basically follows the same procedure used in UFRM, but instead of totally eliminating the flow hydrograph of a sub-basin, the CN (curve number) of that sub-basin is reduced by some reasonable percentage in agreement with the flood control activities.

In this study, HEC-HMS model was used to simulate the rainfall-runoff process and thereby determine the flood hydrographs and discharges under different conditions.

3- Simulation of rainfall-runoff using HEC-HMS

The HEC-HMS model is composed of three components: Basin model, Meteorologic model and Control specifications. In order to prepare the basin model, the digital elevation model (DEM) layer of the study area was produced in ArcGIS. By using the prepared DEM, the entire basin was divided into 24 sub-basins and the physical characteristics of the basin and sub-basins were extracted using HEC-GeoHMS extension in ArcGIS. The value of CN for each sub-basin was also determined considering the hydrologic soil group and land use. The developed basin model was transferred to HEC-HMS model. In the modelling process, SCS loss method, SCS Unit Hydrograph method and Muskingum method were used to estimate precipitation losses, to transform excess precipitation to surface runoff and to conduct flood routing, respectively. The Inverse Distance Weighting method (IDW) was used for spatial distribution of precipitation data. A calibrated HEC-HMS model for the study area was developed by calibrating initial abstraction, curve number and lag time parameters using a rainfall-runoff event data. Fig. 1 shows the observed versus simulated hydrographs for the single event.

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For the purpose of this study, a 50-year return period rainfall with 10 hours duration, corresponding to the basin time of concentration, was considered. The storm temporal pattern was assumed to follow the pattern of a local rainfall gauging station. For the selected design storm, runoff was simulated using HEC-HMS model, and all of the required hydrographs for URFM and FRM were generated.

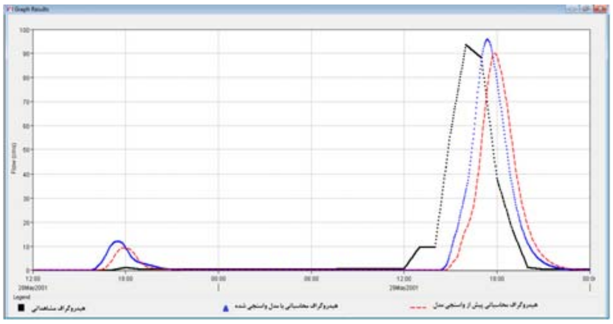

Fig1. Observed outflow hydrograph (black) vs. simulated ones (red before calibration, blue after calibration) in Kardeh basin

4- Results of prioritization of sub-basins

Under the design storm (10-hour rainfall with a 50-year return period), prioritization of sub-basins was performed for both UFRM and FRM. In order to prioritize the sub-basins by the proposed FRM as described in previous section, the 10% and 20% reduction in the CN of the sub-basins were considered. Table 1 refers to the results. The sub-basins' names in Table 1 are arbitrary names selected for different sub-basins in this study. Table 2 shows the prioritization results for FRM (for -10%CN condition) under 50-year return period rainfalls with different durations. The effect of rainfall duration on the prioritization results is quite evident in Table 2.

5- Conclusions

The following conclusions can be drawn from the study conducted on upstream Kardeh basin.

1- Generally, there is a significant difference between the sub-basins prioritization based on FRM and UFRM (Table 1.).

2- Prioritization of sub-basins using FRM depends on the percentage reduction considered in CN (Table 1.).

3- Design rainfall duration can affect the sub-basins prioritization results of FRM (Table 2.) and UFRM. Therefore, determining the proper duration of design storm is necessary to conduct spatial prioritization of flood control activities.

4- The findings in this study are in agreement with the non-linearity which is present in rainfall-runoff process.

Table1. Comparison of sub-basin prioritization results based on Unit Flood Response method and Flood Reduction method (for two different percentages of CN reductions)

Ranking in Prioritization	Flood Reduction Method	Flood Reduction Method	Unit Flood Response Method
	-10%CN	-20%CN	
1	W340	W340	W410
2	W370	W370	W370
3	W280	W410	W340
4	W390	W390	W390
5	W310	W280	W420
6	W410	W420	W280
7	W420	W310	W310
8	W260	W360	W480
9	W360	W260	W260
10	W290	W480	W360
11	W480	W290	W290
12	W240	W270	W450
13	W270	W240	W250
14	W490	W250	W440
15	W250	W490	W270
16	W320	W320	W490
17	W300	W450	W240
18	W440	W440	W320
19	W450	W300	W300

Table 2. Comparison of sub-basin prioritization results using Flood Reduction method (-10%CN case) under 50-year return period rainfalls with different durations

Ranking in Prioritization	Rainfall Duration		
	6hr	10hr	18hr
1	W260	W340	W260
2	W280	W370	W280
3	W290	W280	W310
4	W310	W390	W290
5	W340	W310	W370
6	W370	W410	W340
7	W390	W420	W250
8	W360	W260	W240
9	W250	W360	W270
10	W420	W290	W390
11	W270	W480	W360
12	W480	W240	W420
13	W490	W270	W410
14	W410	W490	W490
15	W240	W250	W480
16	W320	W320	W450
17	W440	W300	W320
18	W300	W440	W440
19	W450	W450	W300