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Use of GIS for Flood Zoning In Urban Watershed Area Case Study: Iran, North of Tehran

Hamidreza Joodaki[1], Masoud Mohammadi[2]

[1]Department of Geography and Urban Planning, Islamic Azad University, Islamshahr Branch, Tehran, Iran
[2]MA Student of Urban Planning, Arak Branch, Islamic Azad University, Arak, Iran

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ABSTRACT

Urban Irregular development has created a lot of problem in urban areas of the world. This problems include natural hazards such as flood, earthquake and in some cases drought, percentage of occurrence of flood is more than other natural hazards. Rivers are the most essential resources for providing water for human and other creatures and sometimes this resource of life has caused destruction and uncompensated damages. Forecasting hydraulic behavior of river against probable flood for decreasing damages entered into urban areas, installations under construction, fields and other usages around the river has special importance. City of Tehran as the most important urban center of country every year exposed to natural potential hazards including flood. This urban area is located on flood plain of rivers such as north of Tehran, Kan, Golabdareh and Darband, each of them can generate terrible floods. Determining flood plain in urban area could be enumerated as one of the most basic information in non-structural control of flood water. In this research, we paid to determining flood plain areas in a part of urban watershed area of Tehran (Tehran north river). Used mathematical model in research is HEC-RAS which has very high capability in simulation of river hydraulic behavior, analyzing lasting and non-lasting flows, calculation of profile of water level and relation with geographic information system. Geographic information system also is considered as an applicable science in systematic attitude and inspection interaction of various factors as supporter of making decision which in this research, its relation with mathematic model of HEC-RAS was evaluated. With regard to results of research, this relation was accepted well and map of flood plains was provided against return periods of 25, 50, 100 and 200 years.

KEYWORDS: Flood Zoning, Geographic information system, Mathematics model, Flood plain and urban watershed area.

1. INTRODUCTION

In recent years, growth of cities which are located in border of rivers or are considered pass bed of rivers caused hazards of flood for residents and assets exist in these areas. From hydrological sight, a flood is a hydrological cycle and in mathematic language arises from an operating system by an input function, in a continuous period (Singh, 1992). Flood in Urban Watersheds in level surfaces and impenetrable which is made in artificial drainage system by human hand and is occurred in high speed. With regard to his factor, urbanization of natural areas caused extending value and intensity of runoff hydrograph and occurrence of flood in lower areas (Bromandnasab, 2002). Existence of various resources in them has been many important. Therefore exercising management in these areas is complex and execution of a comprehensive program in such a critical area is not possible easily, because flood plains programmer mainly are not aware of all existence functions in it or for achieving considered objects for improvement of procedure governed on flood plain, various departments and organizations show partial views which coordination between these departments always is not easy. Increasing of population and technology development in one side and increasing hazards of flood in urban area in another side caused that river engineering researchers and hydrologists severely inspect hydraulic behaviors of overflowing rivers in this areas. Flood zoning as one of the management methods encounter with flood at the present have very applicable. Therefore, achieving to suitable methods and tools for accuracy and increasing of flood zoning speed is very important.

First activities about application of geographic information System (GIS) in study of flood phenomenon returns to first of 1980s on which the first operation in this field began by analyzing figure height model for hydrological applications began, but relation of hydrological and GIS turns to last of 80s B.C. and the first of 90s.

Kao, et.al (1973) inspected impact of urbanity upon rate of flowing water in small urban watershed in Arizona. James, et.al (1980) while enumerating special management needs in dry districts, acted to flood zoning in Utai State of America. Djokic and Maidment (1990), used from Triangular Irregular Network, TIN for modeling flood drainage in an urban area in Tegzas State. Tate, et al (1999), represented a method of increasing of output analyzing accuracy HEC-RAS in GIS by compatibility of ground mapping data, river geometry and

*** Corresponding Author:** Masoud Mohammadi, MA Student of Urban Planning, Arak Branch, Islamic Azad University, Arak, Iran. Masoud_493@yahoo.com

control structures to ground model exist in GIS. Lin, et.al (2000), inspected flood zoning of Norh of Karolina water shed area on the basis of the best management practices (BMPs) and introduced it as a very useful operation in management of watershed areas. Safari (2001), by using HEC-RAS model acted took action about zoning of flood hazard in Neka river located in Mazandaran province and Motei, et.al (2002) by using HEC-GeoRAS and Geographic Information System took action about flood zoning in Sefid Rood river.

2. MATERAL AND METHODS

In present research single dimension model of HEC-RAS for determining profile of water surface against various return periods applicable in urban watershed area is used in Darabad of Tehran. Since output of this model for providing flood zoning maps is not accurate (Tate, 1999), GIS was used for maps of zoning in high accuracy. Used materials and methodologies are as follows:

2.1. UNDER INSPECTION AREA

Under inspection area is a part of flood plain of Darabad River in East North of Tehran city. Mountainous part of Darabad watershed area (before Ghalak Hydrometric station) has about 17km area. General situation of under study area is showed in figure bellow:

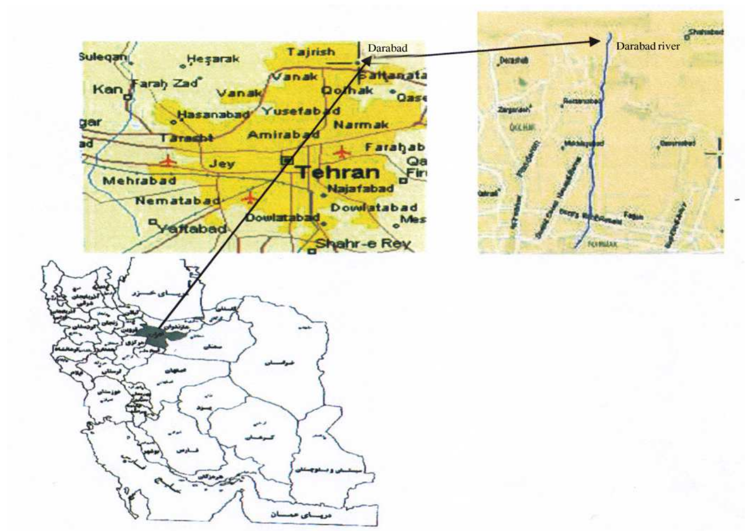

Figure 1: Under study Area Situation

In this research, discharge data registered in Ghalak hydrology station located in outlet of Darabad mountainous watershed area (upper under study area) was used. Table 1 shows morphometric specifications of mentioned area.

Table 1: Morphometric Specifications of Mentioned Area

Quantity	Parameter
17	Area (Km^2)
1.2	Gravelious Coefficient
6.5	Waterway length (km)
1730	Minimum height of area (meter)
3525	Maximum height of area (meter)
13.5	Average slope of main waterway (%)
10.5	Average slope of area (%)

District of under study area is semi-dry and cold and mainly influenced by height. Plant cover of this area more include grassland plants with Artmizia prevailing type and water resources more include seasonal spring.(Saberi,1997)

2.2.METHODOLOGY

In this research fist topography map, statistics about discharges and related rainfalls (Niavaran rainfall recorder) was gathered. Flood maximum time discharge data of Pasghaleh stations, Maghsoud Beig, Najarkala and Roodak in case of relation, adequacy and accuracy were analyzed. Compatibility of data of Ghalak station by using sequence test method and in confidence level of 0.05 was certified.

With regard to statistic non-continuity, short of period and defectiveness of it, we pay to renovation and lengthening of statistic. For renovation, to complete and expanding statistic in suitable confidence level, suitable regression relation was used. Then the best statistic distribution in method of moment (Pierson type III distribution) was determining and discharge of Ghalak station time peak with various return period was extracted.

With regard to necessity of existence of registered peak time hour discharges for providing hydrograph of unit of area and lack of existence of limnograph in hour discharges statistic area several important flood was gathered and adjusted with statistics of Niavaran simultaneously was occurred with mentioned floods. Among them hydrograph of 5 flood on 80.03.22, 77.01.10, 80.06.29, 80.02.14, 79.07.26 were chosen. Time base of effective rainfall was considered about 0.25 of lag time. Table 2 shows occurred rainfalls on above dates.

Table2: Occurred rainfalls in Niavaran hydrograph station (in mm.)

Ref.	77.11.10	79.07.26	80.06.29	80.02.14	80.03.22
1	0.8	1.1	1	0.95	0.9
2	2.5	1.9	1.5	1.4	2.1
3	0.4	0.3	6.4	1.8	1.3
4	0.6	0.8	3.8	3.2	2.4
5	3.4	0.7	1.5	0.9	6.6
6	6.2	1.4	1.2	1.1.	2.4
7	0.8	2.6	0.4		0.4
8	4.40.5	9.5			
9	4.2	0.7	5.8		
10	1.2		0.7		
11	0.5		5.6		
12	0.6		0.3		
13	3.8				
14	2.6				
15	0.7				

In next phase, hydrograph of floods related to each rainstorm was analyzed and after separation of flow of base water and under layer flows, direct runoff hydrograph related to each flood was determined and height of direct runoff hydrograph related to each flood was specified. The with regard to height of runoff hydrograph if each flood and related rainstorm hyetograph, exceed rainfall amounts in various hours and also average amount of rainfall wastes (ϕ-Index) in each rainfall event was calculated. Average ϕ-Index arise from 5 considered events, is considered as wastes index average of Darabad watershed area which is used in next calculations. Since in selected rainstorms intensity of rainfall for each rainstorm is not uniform, therefore, for making unit hydrograph of evidential hydrograph matrix method was used (Subramanya, 1999). The selected one hour natural unit hydrograph was provided. Since extracted natural unit hydrographs by having similar general form have different characteristics, therefore, providing hydrograph of index unit on specified base time for area became necessary. For providing hydrograph of index unit at first characteristics of peak discharge, time of reaching up to peak and base time of index unit of hydrograph by averaging act (arithmetic average) was determined from natural unit hydrographs. The by having natural unit hydrographs and also peak discharge, peak time and time of hydrograph base of average unit, hydrograph of index unit was drawn. For confidence of accuracy of achieved hydrograph of index unit, effective rainfall height (unit) was controlled.

By having discharge with various return period, hydrograph of index unit of area and discharge of base flow with various return period, hydrograph of floods with determined return period was provided. Then discharge of base flow with various return period of year was gained. In next phase by using of S.C.S and without dimension figures related to it (Mahdavi, 1999) and discharge of peak of flood and time of reaching to peak from hydrograph of index unit of area, hydrograph of flood with various return periods was extracted. In next phase for specifying for specifying rate of reserve in river finding procedure of flood by using Maskinengam-Kanzh was performed.

Cross section in distances which considerable changes in cross section, roughness co-efficient or rive slope was made, provided. In each section by using of corrected method of S.C.S (Chow et al., 1988) and on the basis of channel observance and flood plain, amount related to Manning roughness co-efficient was determined.

2.3. DARABAD RIVER PLAIN FLOOD ZONING

In this phase for providing profile of level of water, HEC-RAS mode was used. By using of output information this software includes figures of stage of flood and its entrance to geographical information system, flood absorber in flood plain of under study area was determined which performed in two phases:

2.4. PERFORMANCE OF HEC-RAS MODEL

Performed operations in HEC-RAS environment include phases as bellow:

- Introducing river network

Since, HEC-RAS model is not able to draw route of river by really specifications on the ground, therefore, for introducing place of cross sections and other specifications related to them, at first Darabad river route was drawn as theoretical in it.

- Input information related to cross sections

After introducing under study interval to model, extracted cross sections out of river route in under study interval were introduced. Required data for each cross section include length of interval, data related to geometry and roughness coefficient of section.

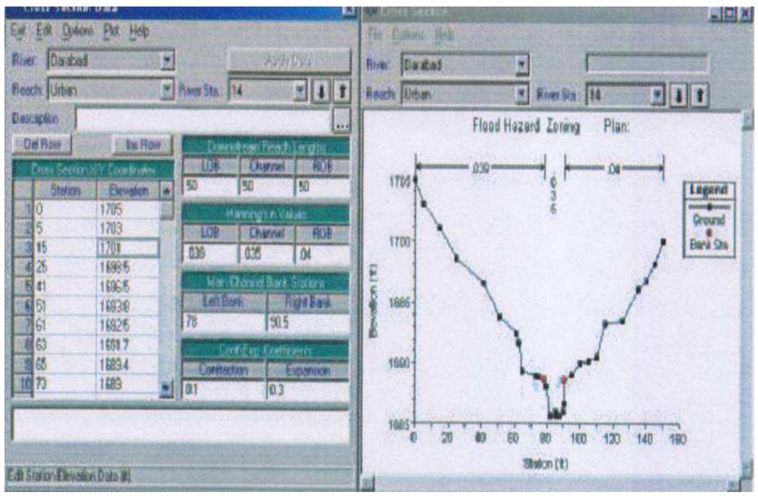

Figure 2: Cross section No. 14

- *Input Information Related to Discharge of Flow and Border Condition*

In this research, by considering Mixed flue, for upper border condition discharge rating curve and in lower section normal depth was selected. After introducing amounts of discharge and border condition, amount of flow discharge in upper and lower intervals, achieved of routing of related hydrographs was introduced to the model. Then type of flow as steady flow and mixed were introduced to the model and model against floods with return period of 25, 50, 100 and 200 years was performed. In next phase final reported of model was issued and entered into GIS environment.

2.5. SET OUT FLOOD ABSORBER ZONES BY USING GIS

For this first topography maps in the figure scale of 1:2000 and using ground control point (here longitude and latitude of some selected point which extracted from topography map), achieved map were corrected and digital elevation model (DEM) provided. The phases bellow made done in sequence:

- Introducing height position of all target points in GIS environment
- Calculation of border spaces in two sides of central line of channel and introducing Universal Transverse Mercator (UTM)
- Introducing characteristics of several point in river route
- Ground of referring cross section
- Change of digital elevation model to elevated point (vectored)
- Bordering bottom of cross sections as Peligon
- Removing points located outside of Pligon in Digital Elevation Model
- Extraction central and side point for making 3 dimension figure out of central and border points of river in each cross section and border and central lines of channel.
- Making TIN model of water level by using of three dimension model of water and Peligon bordered cross sections
- Providing TIN model by using digital, line elevation point, of cross sections and
- Production of flood elevation grid.

2.6. RESULTS AND CONDITIONS

As it was mentioned before, geometric information of Darabad River including cross sections, Manning roughness coefficient and inter specifications of channel and plain flood of that was determined by field operations. Researchers used various method for providing flood absorber areas one of which are relation of mathematic modes and GIS. Among various methods, represented method by Tate et.al (1999) had high confidence coefficient that in this research also this method is used.

2.7. RESULTS RELATED TO STATISTICAL ANALYZING OF GHALAK STATION PEAK TIME DISCHARGE DATA

After correction and renovation of annual peak time discharge of hydrometric exist in the area, the best statistic distribution between Loug Pierson type III of Galak station maximum discharge data was determined and conclusions is represented in table 3 and 4.

Table 3: Statistics parameters of series of data after correction and renovation of peak time discharges

Average	Criteria Deviation	Skew Coefficient
8.57	136.5	26

Table 4: Calculate d amount against various return period

Occurrence Probability	Return period	Calculated Amount	Standard Deviation
0.96	25	37.42	19.93
0.98	50	58.96	43.56
0.995	200	140.35	183.96
0.995	200	140.35	183.96

2.8. RESULTS OF CALCULATION AVERAGE UNIT HYDROGRAPH AND FLOODS HYDROGRAPH WITH VARIOUS RETURN PERIODS

As we said before, hydrograph of each selected events analyzed and after separation of base discharge, exceed was calculated and height of run off hydrograph and volume of flood was determined. Then hydrograph of unit was calculated after each event and then by using them hydrograph of average unit of area which could be used as hydrograph of index of area, provided (figure 3).

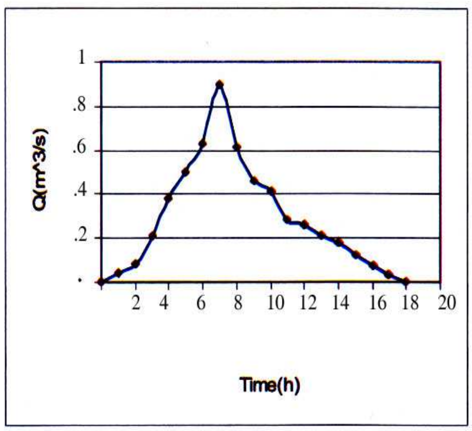

Figure 3: Hydrograph of Area Index Unit

2.9. RELATION RELATED TO TRENDING FLOODS WITH VARIOUS RETURN PERIOD

In this research, for gaining discharge of peak of mentioned floods in lower section routing of hydrographs was made (figure 4). Maskingam – Kanzh Seven coefficient was calculated as bellow:

$C_1 = 0.0098$ $C_2 = 0.9871$ $C_3 = 0.0031$

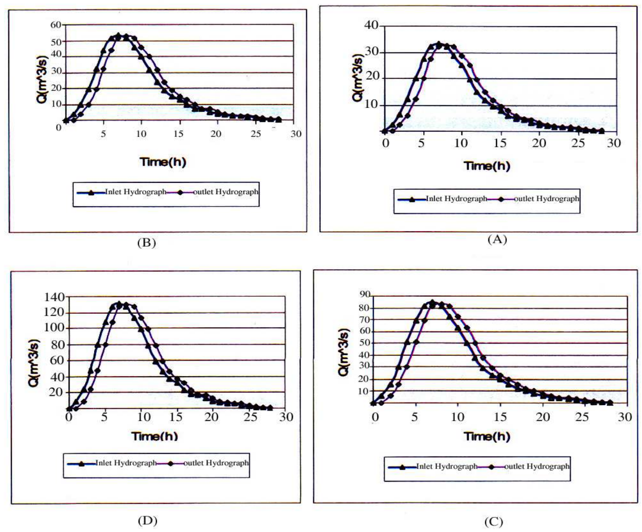

Figure 4: Routing hydrographs of floods with return period of 25 years (a), 50 years (b), 100 years (c) and 200 years (d)

2.10. RESULTS RELATED TO HEC-RAS MODEL OUTPUTS

After execution of simulation of flow in HEC-RAS model, many of its specifications in various sections such as latitude profile of river, discharge rating curves, etc. were achieved. On the basis of this outputs we can represent designs according to river training and control of flood. With regard to previous matters and capabilities of this model, all out put information of model in cross No. 12 for sample is shown in figures 5 and 6.

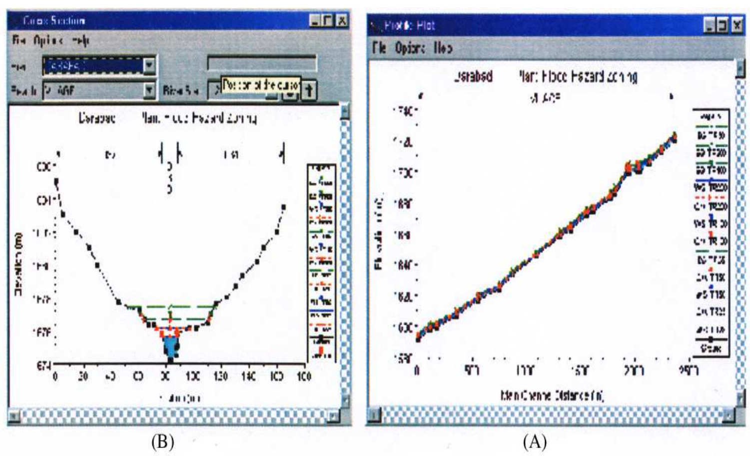

Figure 5: Under study interval latitude profile (a) and cross section No. 12 after performance of model (b)

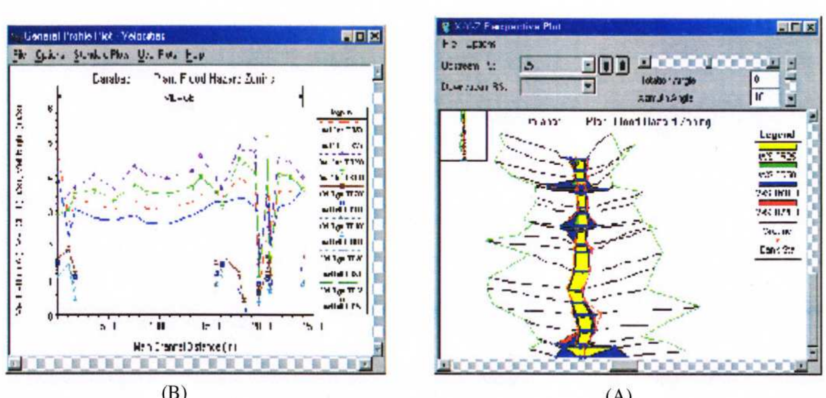

Figure 6: Chart of flood zones with various return period (a) and distribution of speed in understudy interval (b)

2.11. RESULTS RELATED TO EXTRACTION OF FLOOD ZONE IN GIS ENVIRONMENT

As it was referred in methodology of research, after entrance of data related to mean flood on various container and other information about GIS environment we acted to
Extraction and screening mentioned flood zone which is shown in figure bellow.

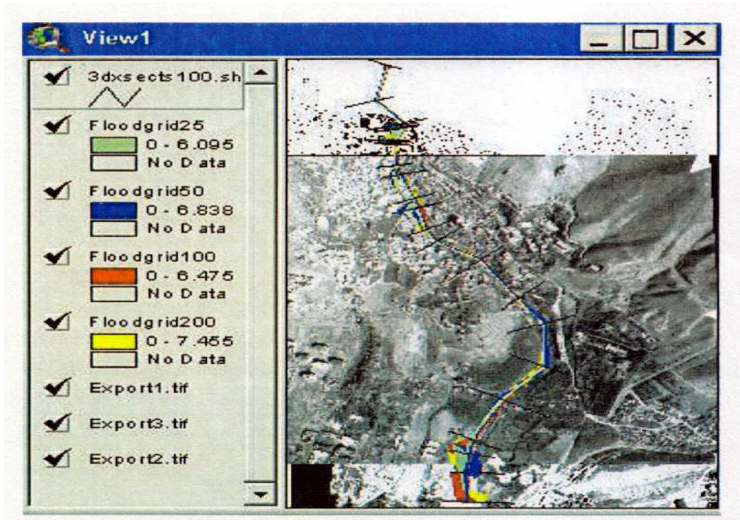

Figure 7: Flood zones with return period of 25, 50, 100 and 200 years on air picture of under study area

2.12. RESULT ABOUT AVERAGE DEPTH AND LEVEL OF ABSORBING FLOOD AGAINST VARIOUS RETURN PERIODS

Table 5: Surface and Depth of Average of Flood in each Zone Plain Flood

Return Period	25	50	100	200
Flood absorbing area (sqm.)	31769	41544	49328	57583
Average Depth (meter)	1.3	1.97	2.26	2.63

2.13. SUMMARIZATION:

HEC-RAS hydraulic model by assumption of stability perform trend of calculation and in most areas this assumption could be accurate, but as in this research also performed, by shortness of distance between crosses and performance of routing operation and to entrance of discharge in upper and lower sections, logical and accurate results was represented. Usage of geographical information system in this research in case of accuracy and speed is very high and we should consider that GIS also has capability of relation with HEC-RAS hydraulic model and in this case there was a good conclusion. With regard to Flood zoning map (figure 7), the area located in bridges and lower of river has vast flood absorber zones.

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