JOURNAL OF
ENVIRONMENTAL HYDROLOGY

The Electronic Journal of the International Association for Environmental Hydrology
On the World Wide Web at http://www.hydroweb.com

VOLUME 13 2005

# FLOOD ZONING USING THE HEC-RAS HYDRAULIC MODEL IN A GIS ENVIRONMENT

A. Hossein Zadeh[1]
M.Z. Ahmadi[2]
M.B. Sharifi[3]
M. Masoudian[2]

[1]Irrigation Structure, University of Mazandaran, Iran
[2]Faculty Members, University of Mazandaran, Iran
[3]Faculty Member, University of Mashhad, Iran

*This research estimates the flood zone and economic damages over an 8.2 km reach of the perennial Laeen Soo River in the northern Khorasan Province, Iran, using HEC-GEORAS, a combination of HEC-RAS with Arcview GIS software. The 1:500 map of the Khorasan water district has been used, and the land use of the region was classified into 16 types. The roughness coefficient of each land use for four seasons of the year was estimated separately, using two general methods of the U.S. Soil Conservation Service (SCS) and standard tables. The flood zones for floods with return periods of 10 to 200 years were calculated. The results showed that the combination of GIS with the HEC-RAS model was very powerful and efficient in flood zone analysis. The studies on the Laeen Soo River showed that the zone of a flood in summer was more extensive than other seasons, and the SCS method gave a higher Manning coefficient. It is recommended that for flood zoning of the Laeen Soo River, that the summer be chosen as the design criterion and the SCS method as the method of Manning coefficient estimation.*

## INTRODUCTION

Floodplains and regions near rivers, where social and economic activities take place due to their special conditions, are always in danger of flooding. Determining the amount of flood advance and its height with respect to ground surface elevations, and finding flood characteristics with different return periods (known as "flood zoning") have tremendous importance. Flood zoning is considered a prerequisite for sustainable development within the limits of flood prone rivers, because it determines the type of development, construction criteria, basis for the ecological and environmental effects, and the amount of investment risk. The ability of some river hydraulic models to combine with Geographical Information Systems (GIS) provides a valuable tool to managers and planners.

One definition of a flood is a flow rate greater than common discharge rates in rivers. It has a limited duration and the water overflows the natural river's bed, occupies the lowlands and lands near the rivers and has financial and human damages (Ahmadi Nejad et al., 2002).

The most important factors affecting the intensity and flood return period in each region are: volume and time of upstream surface runoff and river or flood conditions, physical characteristics of watershed (area, morphology), hydrological characteristics of the watershed (rainfall, storage, evapotranspiration), and human activities causing and intensifying the flood flows. Investigations have shown that the cause of flood damages is neither the short-term flood return period or high flood intensity, but over use of flood plain around rivers.

The management methods to decrease flood hazards are divided into structural and non-structural categories. In non-structural methods, physical structures are not used for flood management or flood protection. In structural methods, structures such as dams, embankments, flood diverting dams, detention dams, and flood canals are used for storing, limiting and controlling floods.

Flood zoning using GIS as a non-structural method, is an efficient tool for flood damage mitigation management. In addition, the concerned authorities can use the method as a legal tool to control and apply management and zoning of lands, plan development, decrease flood hazards and protect the environment.

Johnson et al. (1999) used the HEC-RAS model to forecast and determine the limits of wetlands in the Wyoming-Gary Yule River in the U.S.A. Tate et al. (1999) combined HEC-RAS and Arcview to study the limits of the bed in the Vader Creek River in Austin, Texas, U.S.A. They found the flood zones with different return periods using the hydraulic model of HEC-RAS. Then, by making a TIN layer of the region, they transferred the results from HEC-RAS into a TIN of the region and provided the flood zones maps, water velocity in each region, and flood hazard of each section.

Azagra et al. (1999) used HEC-RAS with air photographs for flood zoning in the Vader River of Austin, Texas, U.S.A. Noori Shadkam (2001) studied different methods of management for flood control, then by using GIS found the flood zones of the Kameh representative flood plain in Iran. Barbad et al. (2002) made flood zoning maps of the Sepid Rood River in Gilan Province, Iran, using Iranian cartographical maps of 1: 25000, cross sections measured by Iran Rasad Consulting Engineers, and Arcview, HEC-RAS and HEC-GEORAS software. They concluded that a combination of GIS and the HEC software is feasible and makes the calculations easy. Combination of Arcview and HEC-RAS provides powerful tools for planners and decision makers.

Arhami and Salehi Nishabori (2003) produced a supplementary software called HEM-GEO which can determine the effects of flood submerged structures such as bridges, roads and buildings in flood plains. This supplementary software provides a new method for output processing of the software HEMAT. By reading the text files from output of the HEMAT model and changing it to a data station in Arcview, a digital elevation model (DEM) of the water surface is produced, providing two and three dimensional flood zoning and analysis in GIS-Arcview.

## MATERIALS AND METHODS

### Region under study

The Laeen Soo River is the last Gharaghom River flowing out of Iran where it disappears in the Gharaghom gravelly lands of Turkmenistan. The river originates from the northern portions of Hazar Masjed Mountain (3040 msl), 50 km from the southeastern of the city of Dareh Gaz in Khorasan Province, and flows in a northeastern direction. It irrigates the villages of Robat, Laeenkohneh, Laeen Soo, Hojatabad, Asadabad, Rajababad, Karimabad, Aminabad and Sangedivar and then enters Turkmenistan. Figure 1 shows the geographical locations of the region both in Khorasan Province and in Iran.


Figure 1. Location of the region under study.

These studies are in a reach of 8200 m on the Laeen Soo River, between Laeen Soo village and Sangedivar village where the river enters Turkmenistan. The geographical positions of the region are: 370 2' to 370 10' 30" north latitude and 590 22' to 590 32' 30" east longitude.

### Steps of Investigation

After basic studies on the Laeen Soo River basin and determination of parameters such as flood return periods, the region was visited and the water marks, and conditions of the guard walls were observed by walking along the river. By talking to the villagers questions were asked about floods that occurred in the river. The land use and physical and apparent characteristics of the lands were recorded. To determine soil particle size distribution, 7 samples were taken from the river bed sediments. The steps in carrying our the project are shown in Figure 2.

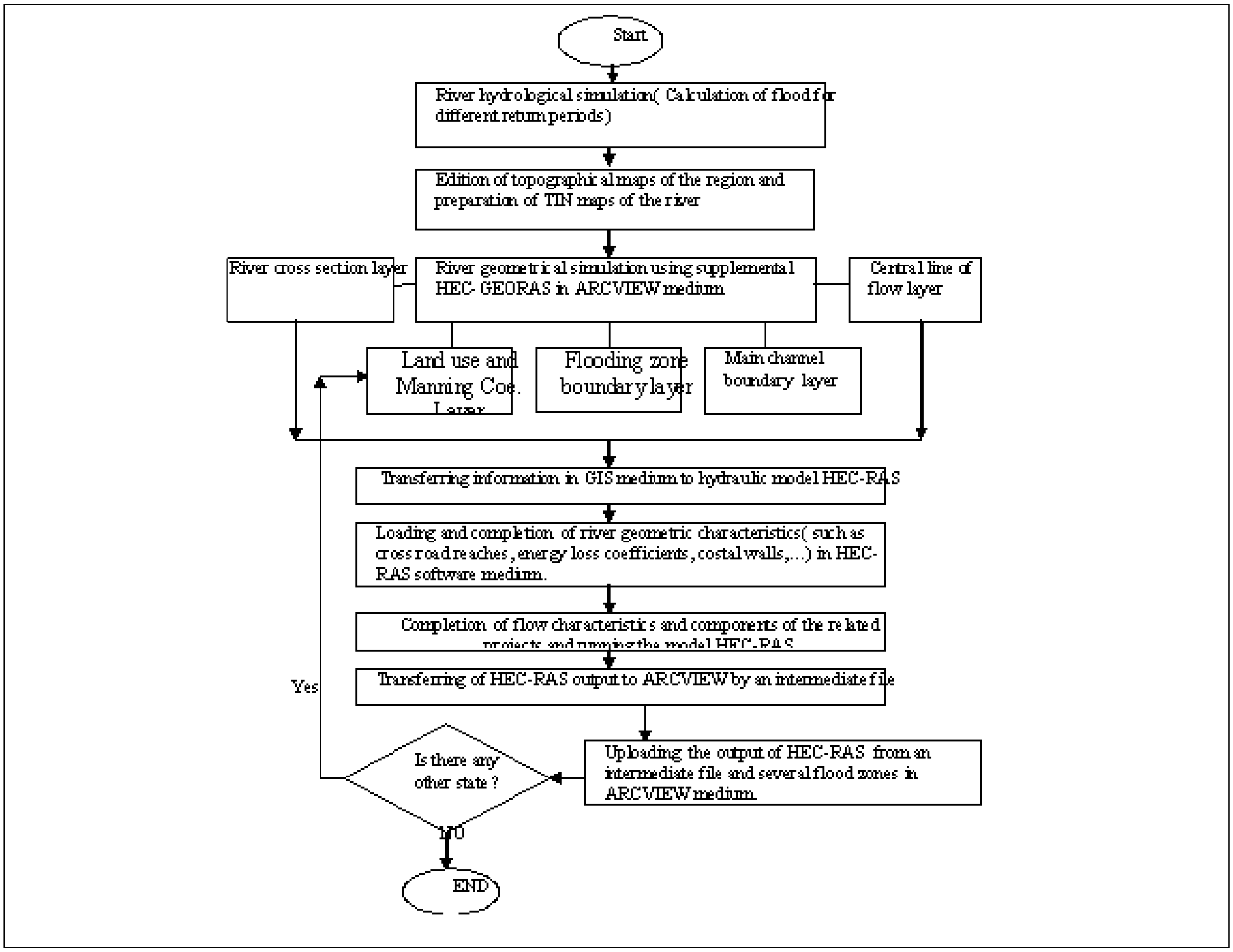



Figure 2. Steps to perform the project.

Investigation Tools

The maps used for these studies are:

-Topographic maps of 1:500

-Cadastre maps of 1:2500 of river band in the reach under study

- 1:50000 and 1:250000 maps of Iranian Cartographical Organization

To digitize the region, Arcview GIS (Version 3.2), HEC-GEORAS (Version 3.1), 3DANALYST, CADREADER, and so on were used. The flow in the reach of the river was simulated using HEC-RAS Version 3.1.1 (2003).

Local visits, expert investigation and most of all, technical judgments are all important in the determination of the nature of the design and selection of damage prone points and corrective recommendations (Hossein Zadeh, 2004).

## RESULTS AND DISCUSSIONS

### Physiography

To estimate parameters such as area, circumference, main channel length, mean height and lowest and highest elevations, the 1:50000 maps of the geographical organization of Iran have been used. The slope of the river was also estimated from longitudinal sections of the river. Table 1 shows a summary of physiographic characteristics of the Laeen Soo river watershed.

Table 1. Summary of Physiographic Characterisitcs of the Laeen Soo River Watershed

| River slope (%) | Watershed slope (%) | Dominant height (m) | Watershed mean height (m) | Watershed area ($km^2$) |
|---|---|---|---|---|
| 2.98 | 26.6 | 900 | 1647 | 228 |
| Equivalent rectangle | | Watershed circumference (km) | Gravilus coefficient | River length (km) |
| Length (km) | Width (km) | | | |
| 8 | 28.8 | 74.5 | 1.34 | 27 |
| River length inside the area (km) | Sub-watershed area 4 ($km^2$) | Sub-watershed area 3 ($km^2$) | Sub-watershed area 2 ($km^2$) | Sub-watershed area 1 ($km^2$) |
| 8.2 | 170.271 | 5.929 | 7.528 | 44.273 |
| Total time of concentration of watershed (hour) | | | | |
| Mean | Kirpich | Williams | SCS | Snyder |
| 7.8 | 2 | 8 | 5 | 16 |

### Hydrology

To obtain monthly and annual discharge rates of the Laeen Soo River, the data of the Sangedivar hydrometric Station were used. To complete the discharge rate data, the Hatam Ghalah Station data and a correlation was obtained. The best correlation is:

$$Qsa = 0.32+0.2726Qha \qquad R=0.77,\ n=23 \qquad (1)$$

where Qsa is the Sangedivar Station discharge rate in m3/s, Qha is Hatam Ghalah Station discharge rate in m3/s , R is the correlation coefficient in confidence level over 99% and n is the number of common statistical years . The Hatam Ghalah Station is on the Zangalo River in the vicinity of Laeen Soo River. The physical and hydrological characteristics of both river watersheds are alike. The total annual input of the Laeen Soo River at the Sangedivar hydrometric Station is 27.4 MCM.

In order to estimate floods with different return periods, after completion of the observed data of Hatam Ghalah Station, maximum instantaneous discharge rates were analyzed using different statistical distributions. The results showed that the Type III Pearson distribution (moment method) had the least standard errors, so this distribution was used (Table 2).

### Geometric simulation of the river

The river route in 37 topographical map sheets at a 1:500 scale, surveyed by the regional water organization of Khorasan Province in 2001, were digitally introduced into Arcview. These maps

Table 2. Frequency Analysis of Maximum Instantaneous Discharge Rates Observed in Hydrometric Stations of Sangedivar (m3/s)

| Return Periods | 5 | 10 | 25 | 50 | 100 | 200 |
|---|---|---|---|---|---|---|
| Pearson Type III (Moment method) | 61 | 95 | 140 | 182 | 222 | 263 |

were corrected, completed and combined and the topographical information was entered into Arcview. Then the TIN or three dimensional model of the river was constructed. Then, by using supplementary HEC-GEORAS in Arcview, the information layers were constructed that are necessary to obtain the geometric simulation of the river.

**Central line of flow**

This layer defines the center line of the river and is located in the lowest part of the river. This line defines the length of the river, which is 8169 m.

**The lines showing the main river channel**

These lines are determined by surveying and show the general boundary of the river. The distance between these lines, which is the main channel width, varies from 3 to 50 m.

**The lines showing maximum flood zones**

These lines determine the limits in which there are probabilities of flooding. This limit is experimental and is determined by trial and error. These lines are in the form of three lines left, right and in the center of the river. The width of the band is up to 400 m.

**Cross sections**

In general, the geometry of the river is simulated by cross sections and the distance between the cross sections. Along the river route, 558 cross sections were drawn. These cross sections are defined by drawing lines perpendicular to the flow path and from left to right. Each cross section is distinguished from another by a number or an index. Using this method, the distance of a cross section from downstream lower points is considered the index and number of each cross section. The cross section distances in the left, right and center of the river show the curvature of the river. The distances between these reaches are 2 to 60 m with an average of 15 m.

**Land use layer**

To produce the land use layer the Cadastre maps of the floodplain of the river with a scale of 1:2500 were used. As the land use map is necessary in allocation of roughness coefficient, 16 different textures were extracted from visiting of the region under study. For this purpose, the factors of vegetation, land situation, and the amount of obstacles were used.

The survey provided four textures with four roughness coefficients for the main channel of the river, three textures for the floodplain of the river which are not cultivated, two types of roads (earth and asphalt), rice fields, cotton and alfalfa fields, residential regions, orchards and rangelands (lands far from the river that are not cultivated or have rain-fed agriculture). Based on these divisions, the land use maps of the region are shown in Figure 3.

The roughness coefficient of each land use was estimated by using the standard table and the U.S. Soil Conservation Service (SCS) method. In the SCS method, the roughness coefficient is estimated in six steps by considering separately the effects of different factors of base roughness,

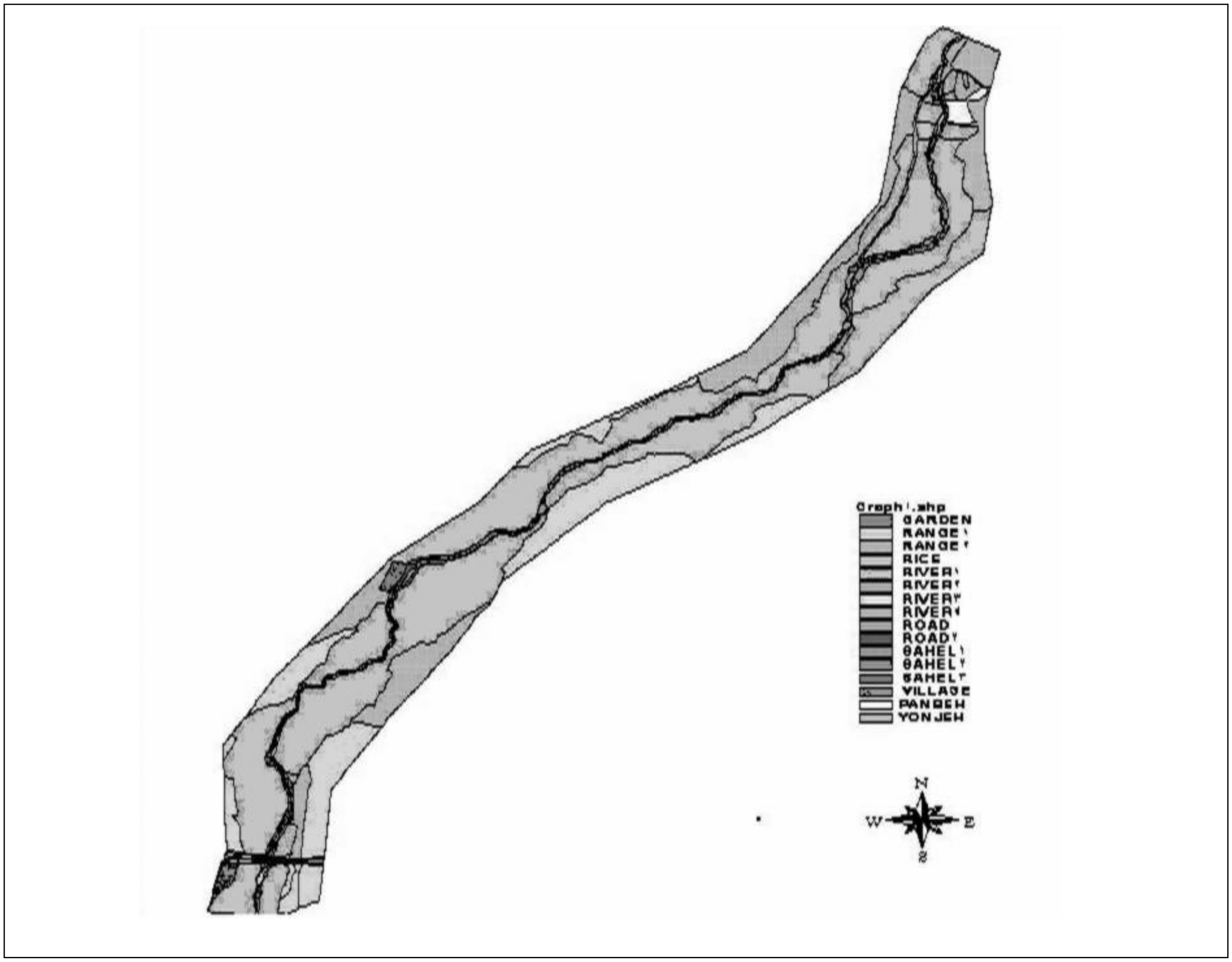



Figure 3. The land use map of the region

the effect of obstacles, effect of route curvature, effect of water depth, and effect of irregularity of cross section.

Table 3 shows roughness coefficients for each land use by the standard table method. The standard tables are those of Chow's (1959) book on Open Channel Hydraulics.

Table 4 shows the Manning roughness coefficients from SCS method, obtained in 6 steps and for different annual land uses.

**Loading intermediate file to HEC-RAS medium and its completion**

After determination of physical situation of each land use by using supplementary HEC-GEORAS software, the information layers are combined and transferred into HEC-RAS medium. When the transferred file is loaded in HEC-RAS medium, the basic geometry of the river including schematics, cross section, the distance between cross-sections in the center and banks of the river, roughness coefficient along cross section and the limits of the main channel are obtained. There may be some errors in this stage which will be mentioned in the time of running the program.

In this stage, the supplementary geometric information such as variations in Manning roughness coefficient, addition of cross structures, change in expansion and contraction loss coefficients, water uptakes near the river, etc. are added to the geometry of the river. In Laeen Soo river, the cross structure is the big Kalat-Dargaz bridge which has 7 m height and 4 opening mouths of 20 m length

Table 3. Manning Roughness Coefficients from Chow (1959)

| Season of the year | | Spring | Summer | Fall | Winter |
|---|---|---|---|---|---|
| Row | Land use | n | | | |
| 1 | Main channel type I | 0.04 | 0.04 | 0.04 | 0.04 |
| 2 | Main channel type II | 0.045 | 0.045 | 0.045 | 0.045 |
| 3 | Main channel type III | 0.055 | 0.055 | 0.055 | 0.055 |
| 4 | Main channel type IV | 0.06 | 0.06 | 0.06 | 0.06 |
| 5 | River bank type I | 0.05 | 0.05 | 0.05 | 0.05 |
| 6 | River bank type II | 0.06 | 0.06 | 0.055 | 0.055 |
| 7 | River bank type III | 0.095 | 0.095 | 0.085 | 0.085 |
| 8 | Orchard | 0.11 | 0 .11 | 0.095 | 0.095 |
| 9 | Residential areas | 0.1 | 0.1 | 0.1 | 0.1 |
| 10 | Earthly roads | 0.025 | 0.025 | 0.025 | 0.025 |
| 11 | Asphalt roads | 0.02 | 0.02 | 0.02 | 0.02 |
| 12 | Rice fields | 0.04 | 0.07 | 0.05 | 0.04 |
| 13 | Cotton fields | 0.05 | 0.08 | 0.07 | 0.05 |
| 14 | Alfalfa fields | 0.07 | 0.07 | 0.07 | 0.05 |
| 15 | Rangelands type I | 0.06 | 0.06 | 0.045 | 0.045 |
| 16 | Rangelands type II | 0.065 | 0.065 | 0.05 | 0.05 |

and 12 m width. The expansion and contraction loss coefficients were 0.1 and 0.3, respectively.

Then flow and boundary layer flow conditions were entered into the hydraulic model. The water enters the main river in 6 locations. The flow rates with different return periods for each section were obtained by Dican equations and considering the upstream watershed areas, which are shown in Table 5.

The flow regime was considered as mixed one and boundary conditions for upstream river flow discharge rating curve and downstream normal depth were introduced. The HEC-RAS model for these conditions was run.

**Transferring output results of HEC-RAS to Arcview**

After running the HEC-RAS model, the output results is transferred into Arcview by an intermediate file. These steps are carried out for four seasons and two methods of Manning coefficient determination. For eight situations, the steps are repeated. For each situation, the flood zones for return periods of 10 to 200 years were obtained. The results of this river simulation will be shown in outputs of the HEC-RAS software in the form of cross sections, longitudinal profiles, three dimensional flow schematics, hydraulic parameter tables in cross sections, and changes of hydraulic parameters along the river.

Table 4. Manning Roughness Coefficients for Different Land Uses by SCS Method

| Row | Land Use | Base Roughness Coefficients | Adjusted Vegetation | Change in Cross Section and Shape | Surface Irregularity | Effect of Obstacles | Amount ofCurvature | Total |
|---|---|---|---|---|---|---|---|---|
| 1 | Main Channel type I | 0.031 | 0.01 | 0.00 | 0.005 | 0.012 | 0.00 | 0.058 |
| 2 | Main Channel type II | 0.031 | 0.01 | 0.005 | 0.005 | 0.012 | 0.00 | 0.063 |
| 3 | Main Channel type III | 0.031 | 0.01 | 0.00 | 0.01 | 0.012 | 0.00 | 0.068 |
| 4 | Main Channel type IV | 0.031 | 0.01 | 0.00 | 0.005 | 0.012 | 0.15N | 0.073 |
| 5 | River Bank type I | 0.028 | 0.01 | 0.00 | 0.00 | 0.015 | 0.00 | 0.053 |
| 6 | River Bank type I (Spring and Summer) | 0.028 | 0.025 | 0.00 | 0.00 | 0.018 | 0.00 | 0.067 |
| | River Bank type II (Fall and Winter) | 0.028 | 0.018 | 0.00 | 0.00 | 0.018 | 0.00 | 0.06 |
| 7 | River Bank type III (Spring and Summer) | 0.024 | 0.055 | 0.00 | 0.00 | 0.025 | 0.00 | 0.104 |
| | River Bank type IV (Fall and Winter) | 0.024 | 0.04 | 0.00 | 0.00 | 0.025 | 0.00 | 0.89 |
| 8 | Orchard (Spring and Summer) | 0.024 | 0.08 | 0.00 | 0.00 | 0.01 | 0.00 | 0.114 |
| | Orchard (Fall and Winter) | 0.024 | 0.06 | 0.00 | 0.00 | 0.01 | 0.00 | 0.094 |
| 9 | Residential Areas | - | - | - | - | - | - | 0.1 |
| 10 | Earthly Roads | - | - | - | - | - | - | 0.025 |
| 11 | Asphalt Roads | - | - | - | - | - | - | 0.02 |
| 12 | Rice (Spring) | 0.02 | 0.015 | 0.00 | 0.00 | 0.01 | 0.00 | 0.045 |
| | Rice (Summer) | 0.02 | 0.05 | 0.00 | 0.00 | 0.01 | 0.00 | 0.08 |
| | Rice (Fall and Winter) | 0.02 | 0.025 | 0.00 | 0.00 | 0.01 | 0.00 | 0.055 |
| 13 | Cotton (Spring and Summer) | 0.02 | 0.05 | 0.00 | 0.00 | 0.015 | 0.00 | 0.085 |
| | Cotton (Fall and Winter) | 0.02 | 0.03 | 0.00 | 0.00 | 0.01 | 0.00 | 0.06 |
| 14 | Alfalfa (Spring, Summer, and Fall) | 0.02 | 0.045 | 0.00 | 0.00 | 0.01 | 0.00 | 0.075 |
| | Alfalfa (Winter) | 0.02 | 0.025 | 0.00 | 0.00 | 0.01 | 0.00 | 0.055 |
| 15 | Rangelands type I (Spring and Summer) | 0.023 | 0.03 | 0.00 | 0.00 | 0.005 | 0.00 | 0.058 |
| | Rangelands type I (Fall and Winter) | 0.023 | 0.01 | 0.00 | 0.00 | 0.005 | 0.00 | 0.038 |
| 16 | Rangelands type II (Spring and Summer) | 0.02 | 0.05 | 0.00 | 0.00 | 0.01 | 0.00 | 0.08 |
| | Rangelands type II (Fall and Winter) | 0.02 | 0.02 | 0.00 | 0.00 | 0.01 | 0.00 | 0.05 |

concluded that the width of the flood zone is between 30-400 m along the river. In greater floods, a wider zone was affected. Figure 6 is a sample of flood zone maps drawn for total length of the river.

Talking to the local people shows that the widths of floods of 10, 25 and 50 years are the same as estimated. In the last 40 years, few floods occurred with widths of up to 300 m. A precise analysis of high water marks confirms this information.

Table 5. Maximum Instantaneous Discharge Rates Along the River Route for Different Return Periods

| Return period / Point of crossing | Distance from downstream (m) | 10-year | 25-year | 50-year | 100-year | 200-year | 1000-year |
|---|---|---|---|---|---|---|---|
| | | Maximum instantaneous discharge rate ($m^3/s$) | | | | | |
| Point of crossing 1 | 81701 | 73.56 | 108.4 | 140.9 | 171.9 | 203.64 | 281.84 |
| Point of crossing 2 | 5304 | 75.82 | 111.73 | 145.25 | 177.18 | 209.9 | 290.5 |
| Point of crossing 3 | 4190 | 78.15 | 115.17 | 148.72 | 182.63 | 216.36 | 299.44 |
| Point of crossing 4 | 3883 | 78.57 | 115.79 | 150.53 | 183.61 | 217.52 | 301.05 |
| Point of crossing 5 | 3013 | 79.34 | 116.93 | 152.01 | 185.42 | 219.66 | 304.01 |
| Point of crossing 6 | 2641 | 93.11 | 137.22 | 178.38 | 217.59 | 257.77 | 356.76 |
| Point of crossing 7 (total watershed) | 0 | 95 | 140 | 182 | 222 | 263 | 364 |

By transferring the information to Arcview, supplemental results like water logging, depth and water velocity in each point of the flooded lands are obtained by using GIS analytical functions.

## CONCLUSIONS

The results showed that none of river main channels are adequate for flow passage and in all cases a large amount of land near the river will be waterlogged. The most important crop cultivated in the vicinity of river is rice (90 % of cultivated land).

The maximum water depth along the river varies from 0.65 to 3.5 m. The mean Froude Number in all cross sections and for all situations is 0.3 to 1.85 along the river. The water velocity in the reach under study is 1 to 2.7 m/s, but due to changes in bed slope and roughness coefficient, the velocity may locally vary up to 5 m/s. The shear stress changes between 40 to 600 N/m2, but the dominant tension for the whole river route is about 300 N/m2.

The stream power obtained by computations and simulations in HEC-RAS model was 20 to 1400 N/s, but at some points due to severe changes in topography and roughness coefficients it reached 1200 N/s.

The summary of total land being waterlogged is shown in Table 6. As can be seen in this Table and Figure 4, the total waterlogged area was 40 ha for a 10-year flood and spring time Manning roughness coefficients obtained from standard tables. The maximum waterlogged land area for a 200-year flood of was 88.1 ha and summer time Manning roughness coefficient obtained from SCS method. The rice field waterlogged areas were 28.1 and 44.6 ha for minimum and maximum conditions.

Figure 5 shows, based on the results of Table 6, that in all seasons, the waterlogged land area is more extensive with the SCS method than with other methods. Also, the waterlogged area of a specific flood is higher in summer than other seasons.

The water surface width for all cross sections was obtained for all conditions and it was

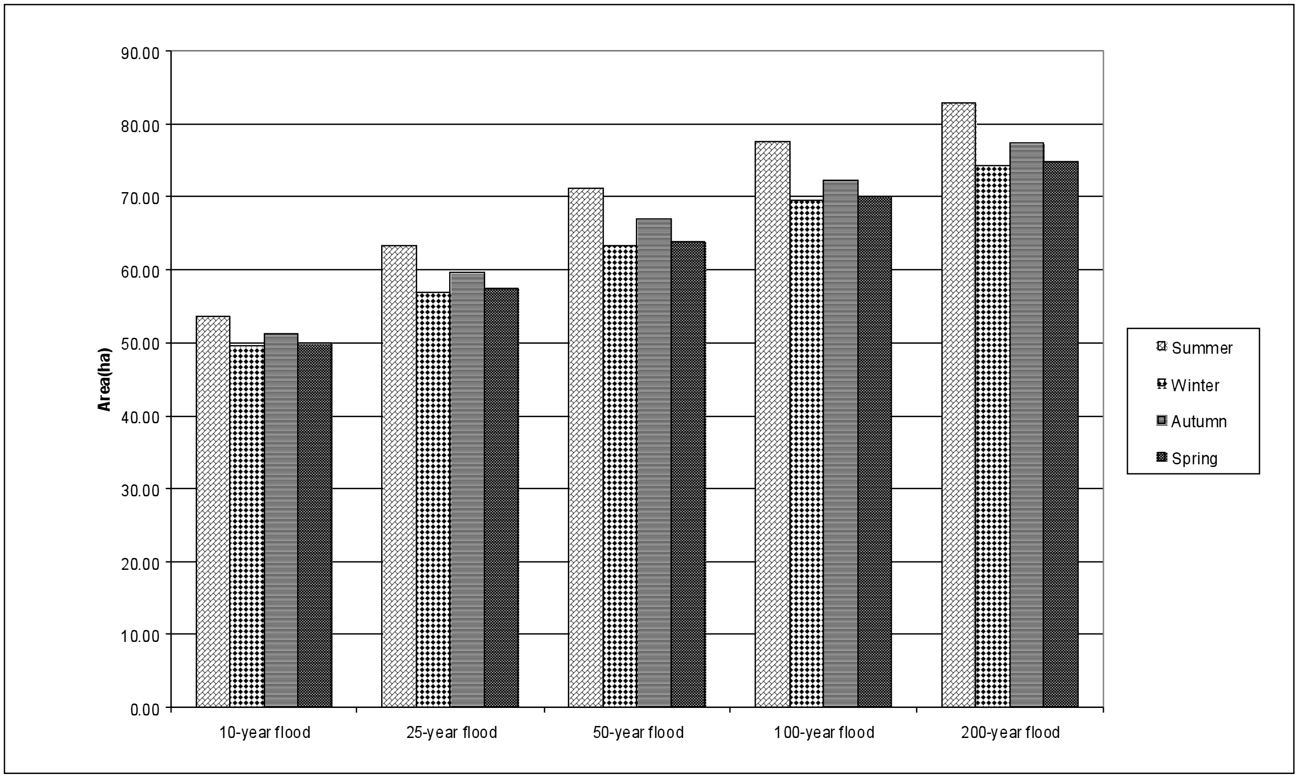



Figure 4. Comparison of total waterlogged lands in different seasons and floods.

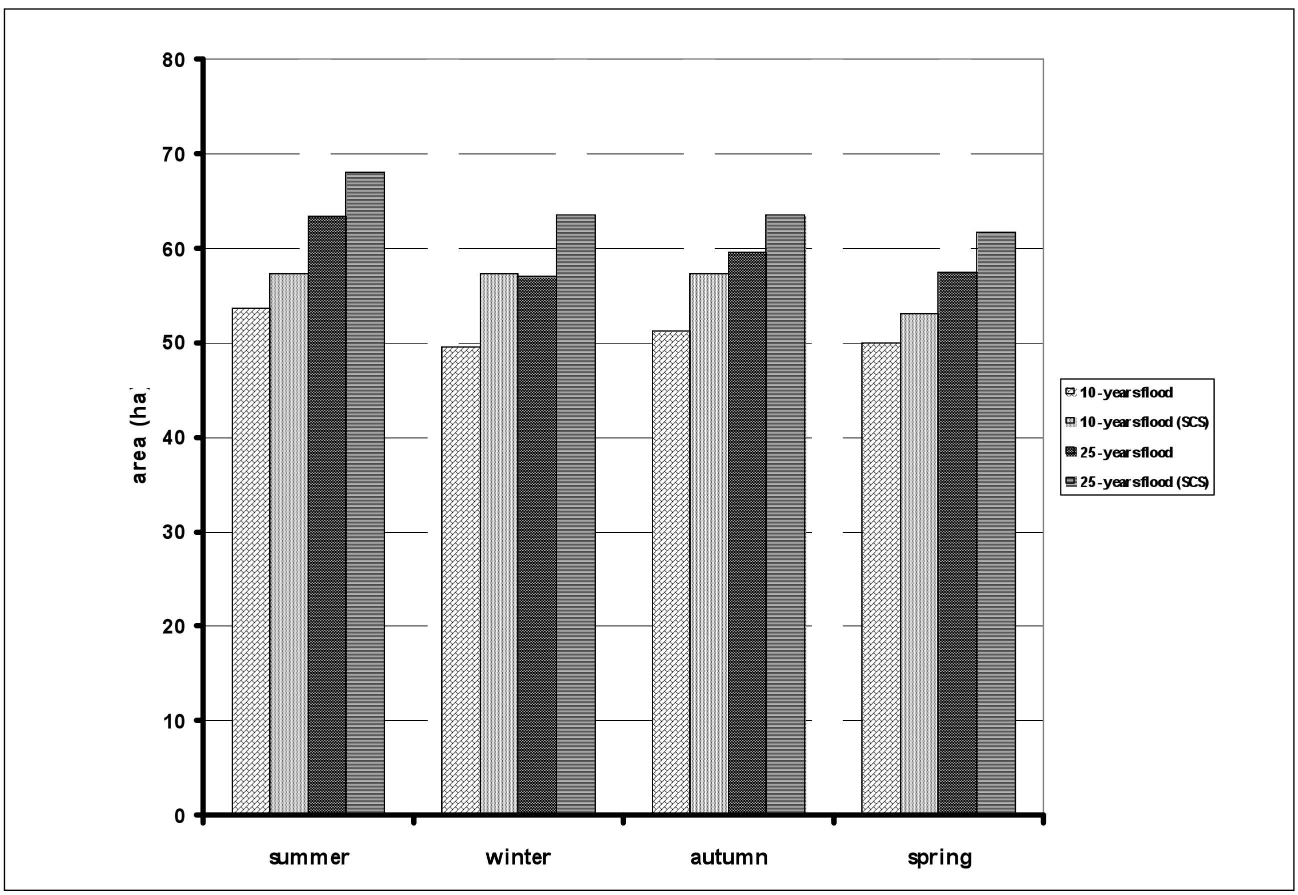



Figure 5. Comparisons of waterlogged lands in different seasons and by two methods of Manning roughness coefficients estimation.

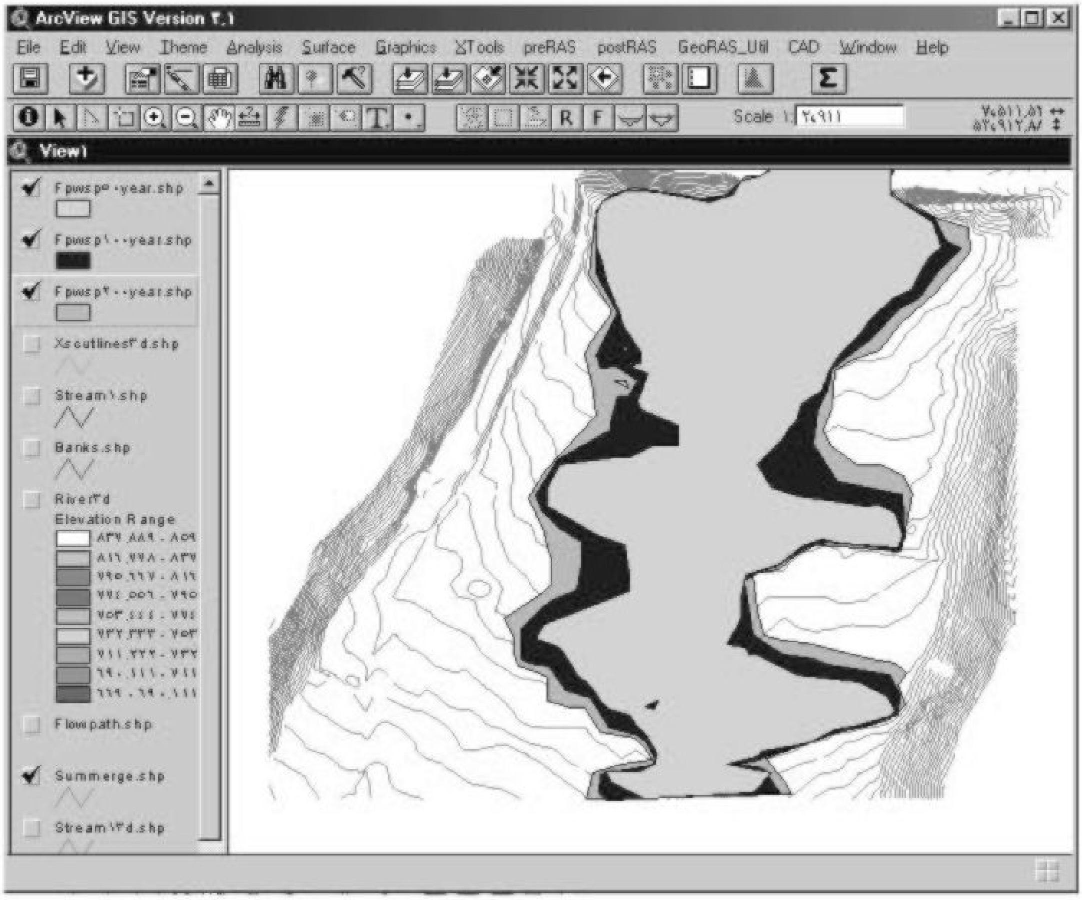



Fig. 6. Flood Zone on topography of the region

Table 6. Summary of the Results Obtained from Waterlogged Lands for all Conditions

| Flood Return Period | | | | | Characteristics | |
|---|---|---|---|---|---|---|
| 200-year flood | 100-year flood | 50-year flood | 25-year flood | 10-year flood | Manning Coefficient Calculation | Season |
| 79.62 | 74.80 | 69.11 | 61.65 | 53.07 | SCS | Spring |
| 74.90 | 70.10 | 63.90 | 57.51 | 49.95 | Standard Table | |
| 88.07 | 81.39 | 74.72 | 68.05 | 57.32 | SCS | Summer |
| 82.97 | 77.67 | 71.22 | 63.42 | 53.68 | Standard Table | |
| 82.36 | 75.75 | 69.60 | 63.46 | 57.32 | SCS | Autumn |
| 77.42 | 72.31 | 66.99 | 59.61 | 51.25 | Standard Table | |
| 82.36 | 75.75 | 69.60 | 63.46 | 57.32 | SCS | Winter |
| 74.28 | 69.60 | 63.32 | 56.98 | 49.60 | Standard Table | |

### Flood damages

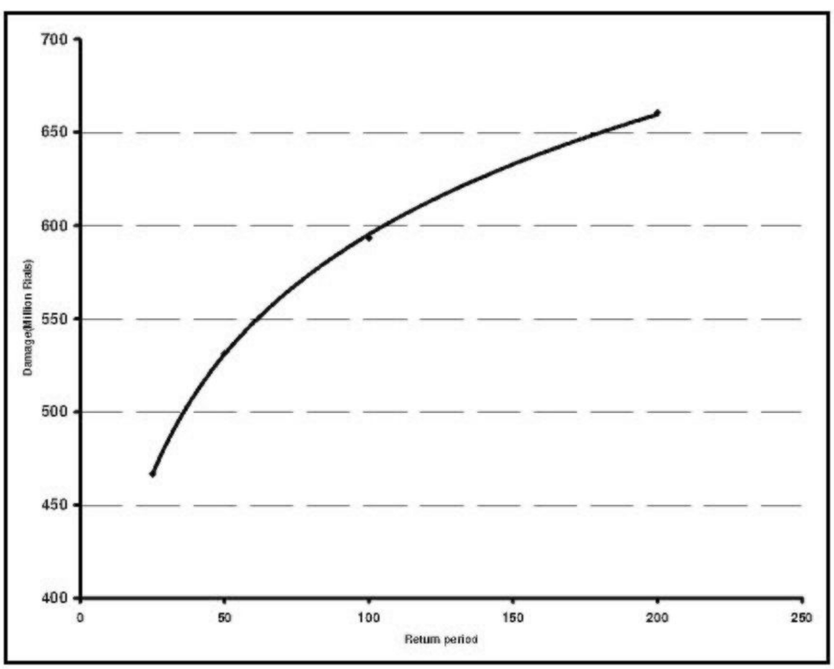
The GIS gives the opportunity to calculate the waterlogged areas of each land use. Using this area and water depth information, the amount of damage can be calculated.

Based on economic studies and local questioners and value engineering judgment of each m2 of different land uses and damage percentage of each land use was estimated. By multiplying the waterlogged area and the damage of each m2 for different floods, the total damage of the total region is obtained and is shown in Table 7.

Based on the above cases, the relationship between flood damage (X in million Rials) with different return periods (T in years) is shown in Figure 7.

Table 7. Area of the Flood Zone and Damage to the Lands for Different Return Periods (million Rials)

| Return period | 25-year | | 50-year | | 100-year | | 200-year | |
|---|---|---|---|---|---|---|---|---|
| Land use type | Area (ha) | Amount of damages | Area (ha) | Amount of damages | Area (ha) | Amount of damages | Area (ha) | Amount of damages |
| Rice | 44.67 | 446.7 | 51.05 | 510.5 | 57.43 | 574.3 | 63.81 | 638.1 |
| Orchard | .12 | 0.9 | 0.12 | 0.9 | 0.12 | 0.9 | 0.13 | 0.98 |
| Road | 0.11 | 11 | 0.12 | 12 | 0.13 | 13 | 0.13 | 13 |
| Cotton | 0.55 | 3.3 | 0.55 | 3.3 | 0.55 | 3.3 | 0.55 | 3.3 |
| Rain-fed lands | 1.95 | 4.88 | 2.01 | 5.025 | 2.07 | 5.175 | 2012 | 5.3 |
| Total amount of damages | | 466.78 | | 531.73 | | 593.4 | | 660.68 |



The relationship of Figure 7 is in the form of the following equation:

$$X = 92.862 \ln(T) + 167.6 \qquad R2 = 0.9998 \qquad (2)$$

The financial damage of a 1000-year flood is 809 million Rials.


## ACKNOWLEDGMENTS

The authors would like to thank the Universities of Mazandaran and Ferdousi Mashhad for supporting the Master of Science Project.


## REFERENCES


Ahmadi Nejad, M., M. Namjo and M. Farsi; (2002). River route management and optimum design of guard walls of Halil Rood River in Jiroft. 6th International Seminar of River Engineering. 1st edition. 7 p. In Persian.

Arhami, M. and H. Salehi Nishabori; (2003). Flood zoning by supplementary HEC-GEO. 4th Iranian Conference of Hydraulics. 1st ed. p.8. In Persian.

Azagra, E.; (1999). Flood plain visualization usingTINs. Master of ScienceThesis. University ofTexas atAustin. Austin. 135 p.

Barbad, M., A Behnia and H. Motiei; (2002). Flood zoning in watersheds by combining GIS and mathematical models. 6th International Seminar of River Engineering. 2nd edition. 7 p. In Persian.

Chow, V.; (1959). Open Channel Hydraulics. McGraw-Hill. 680 p.

Hossein Zadeh, A. 2004. Flood zoning by HEC-RAS hydraulic model in GIS medium. Master of Science Thesis at University of Mazandaran. 131 p.

Gregory D. Johnson, M. Dale Strickland, John P. Buyok, Clayton E. Derby, and David P. Young, Jr.. (1999). Quantifying impacts to riparian wetlands associated with reduced flows along the Greybull River, Wyoming Wetlands. Vol. 19, No.1, pp. 71-77.

Noori Shadkam, A.; (2001). GIS in flood warning systems. M.S. thesis of University of Ferdousi Mashhad. 123 p. In Persian.

Tate, E.C., F. Olivera and D. Maidment; (1999). Floodplain mapping using HEC-RAS and Arcview GIS. Center for Research in Water Resources. 94 p.



ADDRESS FOR CORRESPONDENCE
M.Z. Ahmadi
Uiversity of Mazandaran
Mazandaran, Iran

**E-mail:** mzahmadi@yahoo.com