# GIS Applications In Flood Forecasting Using HEC-RAS.

**Term Paper**

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# Abstract

GIS is a new technology which can be used as an effective tool at any science. It can be used in many civil engineering applications especially in water resources such as Hydrologic Modeling Delineation, Watershed, Floodplain Management, flood forecasting and other applications. Floodplain management is a recently new and applied method at the river engineering and is essential for prediction of flood hazards. This term paper discusses the applications of GIS in flood forecasting using HEC-RAS model. It presents the applications and the linking of the available GIS software (Arc info, Arcview) and the hydraulic modeling (HEC-RAS) for two cases studies. The first case study discuss creating flood plain maps, and providing 10-50 years for flood forecasting. The study area is in Thessaly plain in Greece and particularly in a zone, between both sides of the Pinios river limited by Ali-Efenti position, whereas the second case study in Zaremrood river (upstream of the Tajan River) in Iran is mainly focus about this topic by simulating steady flow and provided 2-5-10-25-50-100 years for flood forecasting . Some advantages and recommendations to improve this application with HEC-RAS are discussed. Generally using GIS for flood forecasting with other applications such as HEC-RAS will be very helpful to predict storm events which are a major concern in many regions of the world.


## 1- Introduction

GIS is a new technology which can be used as an effective tool at any science. As a civil engineer, I am interested to know how GIS can be used in my field. In this term paper I will discuss how we can use GIS with other software applications such as HEC-RAS in flood forecasting and managing, so this paper support two different cases studies to present these applications in flood forecasting. Indeed, Flood hazard is a big problem which concerns the world today.

Water has played a basic part in society improvement from the world's earliest records. It is observational both as precious resource to be protected and a violent force to be respected. In present the evolution of water a precious resource continues; as well as we develop best practices to accommodate the loss of water in the flooded their destructive. The ever-increasing population of the world, is sure that without being properly, a large number of houses will be located in areas that put them at the mercy of the flood events. In this term paper we will discuss and present to cases studies in Greece and Iran.

The first case study (floodplain mapping) is to determine flood plains and to create flood plain maps using the linking of available GIS software (Arc/info, ArcView and AVRas ) and the hydraulic modeling software HEC-RAS. The study area is the Thessaly plain and in particularly a zone, between both sides of the , Pinios river, limited by embankments with of 500m, a length about 6.5 km and a downstream limit of the Ali-Efenti position.

The second case study (flood forecasting) is to create a geometric model using ArcView 3.2 and the HEC-geoRAS extension for export into HEC-RAS and to determine a floodplain given a predetermined peak flow rate for the Zaremrood River. By comparing traditional methods of floodplain mapping and those available through computer technology, a conclusion can be reached about how new methods improve the floodplain mapping process and what is still required in order to make this new method the standard. Presently, creation of a geometric model is a labor-intensive task that must be done by hand, costing the engineer valuable resources. The addition of computer technology to such tasks can reduce both time and money spent on the project, benefiting all parties involved. (Dhital et al, 2005).

## 2- Objectives

Indeed, this paper involves connecting hydraulic modeling HEC-RAS and GIS. The primary research objectives are as following:

1. Determine flood plains and to create flood plain maps using the linking of available GIS software (Arc/info, ArcView and AVRas ) and the hydraulic modeling software HEC-RAS. The study areas are the Thessaly plain in Greece which is particularly a zone between both sides of the Pinios River in Greece, and peak flow rate for the Zaremrood River in Iran.
2. Develop a procedure to take computed water surface profiles generated from the HEC-RAS hydraulic model and draw a map of the resulting floodplain in ArcView GIS.
3. Exporting the HEC-RAS model results into ArcView GIS to create and represent floodplain maps.

# 3- Literature Review

Several studies indicate that GIS applications for flood forecasting is very essential for predicting the flood before its damage, so there are a huge of studies were used this application with HEC-RAS model. I will present here a short summary for some sources related to this topic.

- **Tate E.C, 1999, Floodplain Mapping Using HEC-RAS and ArcView GIS.**

This research is a master thesis which presents a straightforward approach for processing output of the HEC-RAS hydraulic model, to enable two- and three-dimensional floodplain mapping and analysis in the ArcView geographic information system. The methodology is applied to a reach of Waller Creek, located in Austin, Texas. A planimetric floodplain view is developed using digital orthophotography as a base map. Overall, the results of the research indicate that GI is an effective environment for floodplain mapping and analysis [1].

- **Werner MGF (2001). Impact of grid size in GIS based flood extent mapping using a 1D flow model**

Werner has found in its research that, the GeoRAS extension has simple import and export capabilities to smooth the transition between creating the geometric file, running the model and displaying the results. The end result of the process is not only quicker floodplain delineation with greater accuracy than traditional methods, but also a flow depth grid indicating to the user the level of inundation of any area in the model [2].

- **Earles TA, Wright RK, Brown C, Langan TE (2004). Los alamos forest fire impact modeling**

This paper demonstrated the utility of the HECgeoRAS model for floodplain delineation and determination of key hydraulic parameters and also, HEC-RAS capability of producing hydraulic results in Los Alamos, New Mexico, USA [3].

- **Williams TM (2006). Incorporating GIS in river hydraulic modeling: Assessing the Ability to Predict Ecological Consequences of River**

In this paper Williams carried out a study on Santee River. In this study were outlined the advantages of integration to model the impact of the Santee River rediversion. HEC-RAS 3.2 and the HEC-geoRAS extension for ARC-View were used to examine the flooding regime prior to and subsequent to red version operations. ARC-GIS 8.3 was used to reduce LIDAR elevation data and Real Time Kinematics surveys of the river bottom elevations into data usable by the program. Although the large amount of high precision data resulted in an easily calibrated model that was well validated, it strained the limitations of the GIS software [4].

- **Yang J, Townsend RD, Daneshfar B (2006). Applying the HEC-RAS model and GIS techniques in river network floodplain delineation**

The goal of this paper was to develop a direct-processing approach to river system floodplain delineation. Floodplain zones of part of the South Nation River system, located just east of Ottawa, Ontario, were mapped in two dimensions and three dimensions by integrating the hydraulic model of the choice with geographic information systems (GIS).

The first objective was to construct and validate a Hydrologic Engineering Center's River Analysis System (HEC-RAS) river network model of the system using existing HEC-2 model-generated data. Next, HECRAS simulations were performed to generate water surface profiles throughout the system for six different design storm events. The in-channel spatial data of HECRAS were then geo-referenced and mapped in the GIS domain and integrated with digital elevation model (DEM) over-bank data to build a triangular irregular network (TIN) terrain model. In the final step, floodplain zones for the six design storms were reproduced in three dimensions by overlaying the integrated terrain model for the region with the corresponding water surface TIN [5].

- **Chuan T, Jing Z (2006). Torrent risk zonation in the Upstream Red River Basin based on GIS**

Chuan and Jing explored in 2006 the methodology for compiling the torrent hazard and risk zonation map by means of GIS technique for the Red River Basin in Yunnan province of China, where was prone to torrent. The risk evaluation result in the upper Red River Basin showed that the extremely high risk area of 13,150 km2 takes up 17.9% of the total inundated area, the high risk area of 33,783 km2 is 45.9%, the moderate risk area of 18,563 km2 was 25.2% and the low risk area of 8115 km2 is 11 % [6].

- **Walker WS, Maidment DR (2006). Geodatabase Design for FEMA Flood Hazard Studies.**

Indeed Walker and Maidment demonstrated that Flooding is a hazard with serious socioeconomic consequences for all activities and infrastructure within an affected floodplain, then accurate delineation of flood extents and depths within the floodplain is essential for flood management officials to make sensible and fair decisions regarding construction, insurance and other regulated practices on land and property potentially affected by flooding (Noman et al., 2003) [7].

- **Alho P, Roberts MJ, Käyhkö J (2007). Estimating the inundation area of a massive**

In this paper Alho et al. investigated Jökulhlaups that are the consequence of a sudden and significant release of melt water from the edge of a glacier. Such floods are sourced commonly from ice-dammed lakes, but occasional volcanic eruptions beneath ice can produce intense jökulhlaups due to prodigious rates of melt water release. in this study it was presented the results of one-dimensional hydraulic modeling of the inundation area of a massive, hypothetical jökulhlaup on the Jökulsá á Fjöllum River in northeast Iceland. Remotely sensed data were used to derive a digital elevation model and to assign surface-roughness parameters. Also it was used a HEC-RAS/HEC-GeoRAS system to host the hydraulic model; to calculate the steady water-surface elevation; to visualize the flooded area; and to assess flood hazards [8].

## 4- Flooding: Cause And Effect

Indeed flooding is a big problem which causes and effect because of many factors, so in this section I will introduce the most important factors causeing flooding which are river flooding and storm surge.
First, the causes of river flooding can divided into two factors; the size of the surface or near the surface runoff and the nature of runoff, specifically bind and change in the runoff within a catchment. There are two main factors that modify or initiate floods [9]:

Enter the water fast as a result of heavy rain, snow or ice melting fast or breaches of glacial lakes. This can lead to river flooding, which in turn could lead to estuarine floods

❖ Bottlenecks and obstacles, which are caused by breaking the ice, wood, plants and landslides.

Another form of flooding is called a storm surge, which can be caused by high tides in combination with very strong winds on the beach and low pressure systems. Floods can be modified by human interventions, especially through the three main categories [9]:

- Water Supply Engineering: construction of dams and dam operating rules and the failure of the dam; adjust the river, and the use of groundwater, inter-basin water transfer; water extraction for industry and irrigation.
- Changes in the Earth's surface: Urbanization; deforestation / reforestation, agriculture and animal husbandry.
- Channel Modified: exchange of land; channel straightening; flood protection works..

# 5- Methodology

This section provides the concepts and expressions associated with it, which are often referred to from this point forward. The discussion includes geographic information system GIS , the HEC-RAS hydraulic model, and digital data sources.

## *5-1 Geographic Information Systems*

"GISs are defined as computer systems capable of assembling, storing, manipulating, and displaying geographically referenced information." [5, 11]. Formerly developed as a tool for mapping, GIS has recently gained widespread use in engineering design and analysis, particularly in the fields of hydrology, hydraulics, and water quality. GIS provides a setting in which to cover the data layers and the achievement of spatial queries, and thus create new spatial data. The results can be set digitally and scheduling, and to facilitate efficient analysis and decision-making. Structurally, GIS consists of a computer environment that joins the graphic elements (points, lines, polygons) with associated tabular attribute descriptions. This feature sets GIS apart from both computer-aided design software and databases [5]. For instance, in the view of GIS to the river network, and graphical elements represent the location and form of rivers, while the attributes may describe the name of the stream, and length, and flow rate. This one-to-one relationship between each feature and its associated attributes makes the GIS environment exclusive. In order to provide a conceptual framework, it is necessary to first define some basic GIS constructs [11].

## *5-2 ArcView GIS*

"ArcView is geographic information system (GIS) software for visualizing, managing, creating, and analyzing geographic data. Using ArcView, the user can understand the geographic context of his data, allowing him to see the  relationships and identify patterns in new ways" [5, 13]. The ArcView GIS software package, developed by the Environmental Systems Research Institute, was used as the computer development environment for this research. Many years ago, ArcView has emerged as the industry leader in desktop GIS software. All activities within ArcView are organized with a project, which may contain a number of  tables, views, layouts, charts, and 33 scripts [13]. Files created in ArcView are called projects and are denoted by an ".apr" file extension. Vector data files in ArcView are called shapefiles. The functions of ArcView include: displaying shapefiles in a view, viewing and editing the related attribute tables of this view, plotting charts to display spatial information, and creating layouts of the view and related tables and charts. Specialized ArcView software, called extensions, are required to manipulate and analyze raster and TIN data [13]. The ArcView Spatial Analyst extension is designed for creating, querying, mapping, and analyzing raster data, whereas the 3D Analyst extension is intended for creating, analyzing, and visualizing TINs and three-dimensional vector data as shown in figure 1 [14]. GIS data in ArcView can be manipulated using Avenue, a customization and development programming language embedded in the software package [13].

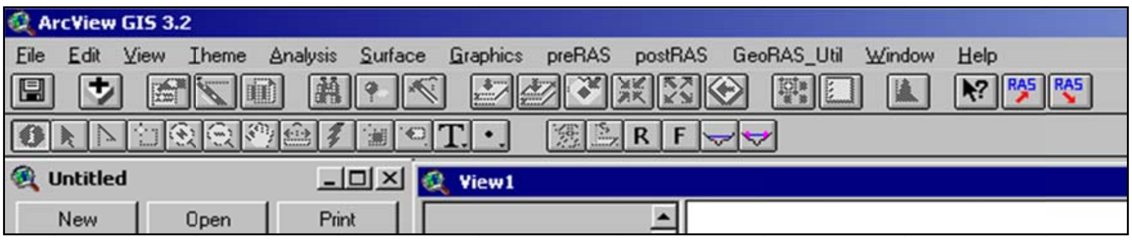


Figure 1. ArcView GIS 3.2 software main view adapted from ( ESRI, 1999)

### 5-3 HEC-RAS.

"HEC-RAS is a hydraulic model developed by the Hydrologic Engineering Center (HEC) of the U.S. Army Corps of Engineers for rivers analysis system (RAS)". According to (Tate E.C, 1999). In 1964, HEC released the HEC-2 computer model to aid hydraulic engineers in stream channel analysis and floodplain determination. HEC-2 quickly became the standard stream hydraulic analysis program, and its capabilities were expanded in the ensuing years to provide for, among other things, bridge, weir, and culvert analyses. Although HEC-2 was originally developed for mainframe computer use, it can currently operate on personal computers (in DOS mode) and workstations [15].

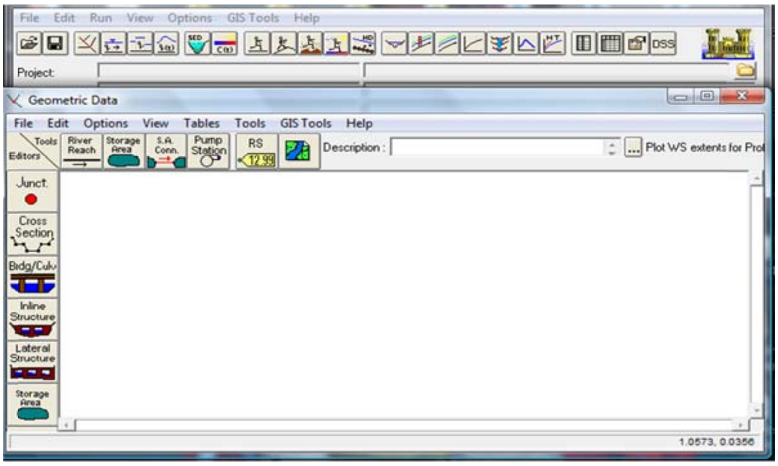


Figure 2. HEC-RAS model program main view adapted from (HEC, 2008)

Due to the increased use of Windows-based personal computing software, in the early 1990's HEC released a Windows-compatible counterpart to HEC-2 called the River Analysis System (RAS) as shown in figure 2. HEC-RAS has a graphical user interface programmed in Visual Basic, to which are attached flow computation algorithms programmed in FORTRAN, many of which were derived from the HEC-2 model. HEC-RAS is a one-dimensional steady flow model, intended for computation of water surface profile computations. Modules for unsteady flow simulation and movable-boundary sediment transport calculations are scheduled to be included. The system is capable of modeling subcritical, supercritical, and mixed-flow regimes for streams consisting of a full network of channels, a dendritic system, or a single river reach. The model results are typically applied in floodplain management and flood insurance studies in order to evaluate the effects of floodway encroachments [5, 16].

## 6- Procedure Of Application

This part details the procedure developed to process GIS application using ArcView GIS with HEC-RAS output for two main cases studies. Application of the methodology improves the accuracy and reduces analysis time by integrating spatial flow geometry with hydraulic analysis. The approach is based on conveying map coordinates to stream cross-sections and computed water surface profile data stored in HEC-RAS model coordinates. The procedure consists of five primary steps [5]:

1 Estimation of flood discharges

2. Generation of HEC-RAS input file using AVRAS pre-processor.

3. Hydraulic simulation.

4. Export of HEC-RAS results to ARCview using AVRAS post-processor.

5. Floodplain mapping.

These steps are discussed in greater detail in the following paragraphs. HEC-RAS and GIS data for floodplain mapping in Thessaly plain,Greece and Flood forecasting in Zaremrood River, Iran study areas are used to illustrate the procedures.

### *6-1 GIS-Based Floodplain Mapping In Greece – Case Study (1)*

Anastasia , et al., 2003 were developed this work to deal with the linking of the available GIS software (Arc info, Arcview and AVRas) and the hydraulic modeling (HEC-RAS), in order to create flood plain maps. The study area is in Thessaly plain in Greece and particularly in a zone, between both sides of the Pinios River limited by Ali-Efenti position. It was obtained as following procedure.

## 6-1-1 Study Area

The study area is the Thessaly plain and in particularly a zone, between both sides of the Pinios river, limited by embankments with a width of 500m, a length of approximately 6.5 km and a downstream limit of the Ali-Efenti position. Study of the annual peak flows (ie, daily data), determine the best distribution is the appropriate value and disposal of extreme flood return periods (T) of 10 and 50 are expected.

## 6-1-2 Estimation Of Flood Discharges

In this study they have used the sample of the annual maximum values of daily mean flows for the period 1959-1960 to 1993-1994 at Ali-Efenti . it was used for the estimation of the 10-year and 50-year return period flood discharge. Using the kolmogorov – Smirnov test and the x2, the Gumbel, Log-Normal and Log-Pearson type III distributions were examined, during the regularity analysis [10, 17]. The Log-Pearson type III distribution was the best fitting distribution is, as expected due to the negatve skewness (g = -0.038) of the sample according to the previous examinations. Then, the 10-year and 50-year return periods flood discharges are estimated based on the Log-Pearson type III distribution [10, 18]. The values of flood discharges are shown in Figure 3, limits with 95% confidence level along the upper and lower confidence.

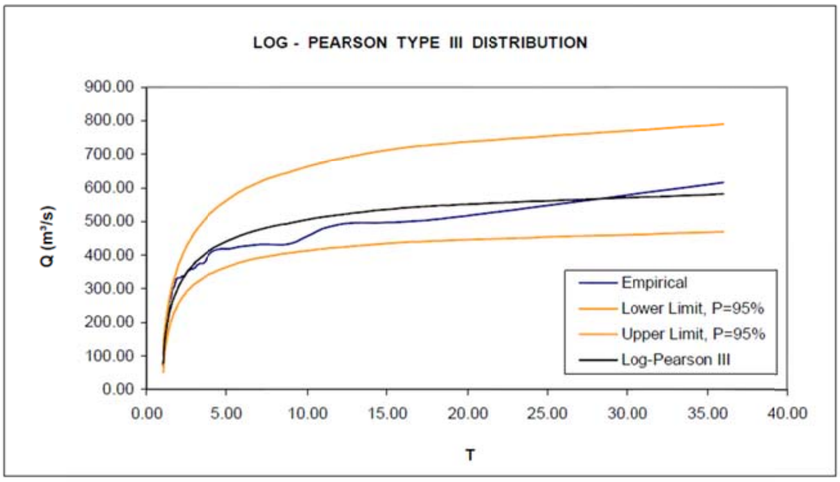


Figure 3. Log Pearson type III distribution adapted from (Anastasia , et al., 2003)

### 6-1-3 Generation Of HEC-RAS Input File Using AVRAS Pre-processor.

In the beginning, the available data in the study area topographic maps of terrain, four maps with scale 1:5000. The digital elevation map was created (DEM) with the use of Topogrid tool after the completion of the digitization, provided by Arcinfo [10, 19]. They used AVRas Pre-Processor functions to extract all the needed geographic data from the digital terrain model and to create the input file for the hydraulic model HEC-RAS [11]. There are Several spatial data were required for the application of the AVRas Pre-Processor model, , such as river centerline, cross-sections perpendicular to the flow lines river banks and flow path lines. In this case study, they have started from the Ali-Efenti position and proceeding upstream, 31 cross-sections were defined at characteristic positions along the Pinios River. the attributes of the stream centerline and cross-section themes were extracted using the AVRas Pre-Processor model at the TIN digital terrain model, the 3D versions of stream centerline and cross-section themes were also created and finally the input file for HEC-RAS was generated [20]. The parameters needed to describe channel geometry were river centerline, banks and cross sections, such as shape, elevation and relative locations along the river.all these data was used as input file. Figure 4 shows the spatial data used for the generation of HEC-RAS input file which determine the study area [10, 21].


Figure 4. Study area in Thessaly plain adapted from
(Anastasia , et al., 2003)

### 6-1-4 Hydraulic Simulation

The hydraulic model HEC-RAS was implemented after the preparation of the input file AVRas Pre-Processor. The HEC-RAS model can be used to calculate the water surface elevation in the cross sections, for one dimensional steady gradually varied flow [10]. The direct step method and the energy equation can be used for computational procedure for the given flow and water surface elevation at one cross section. The water surface elevation of the adjacent cross section was computed. On the other hand, for the application of HEC-RAS, geometric and flow data are required [10]. For example, geometric data include the input data from AVRas Pre-Processor, contraction or expansion coefficient, Manning's roughness coefficient and levees [1, 10]. As well as, flow data consist of flow rate values and boundary conditions, The subcritical flows which occurs in the reach of the Pinios river, the hydraulic computations begin at the downstream boundary, where the water surface elevation must be known and proceed upstream. The downstream water surface elevation for the 10 and 50 year return periods are estimated by the corresponding flood discharge combined with the rating curve at Ali-Efenti position. The results for the 10-year (PF 1) and 50-year (PF 3) water surface profiles are presented in figure 5and 6 respectively [10].

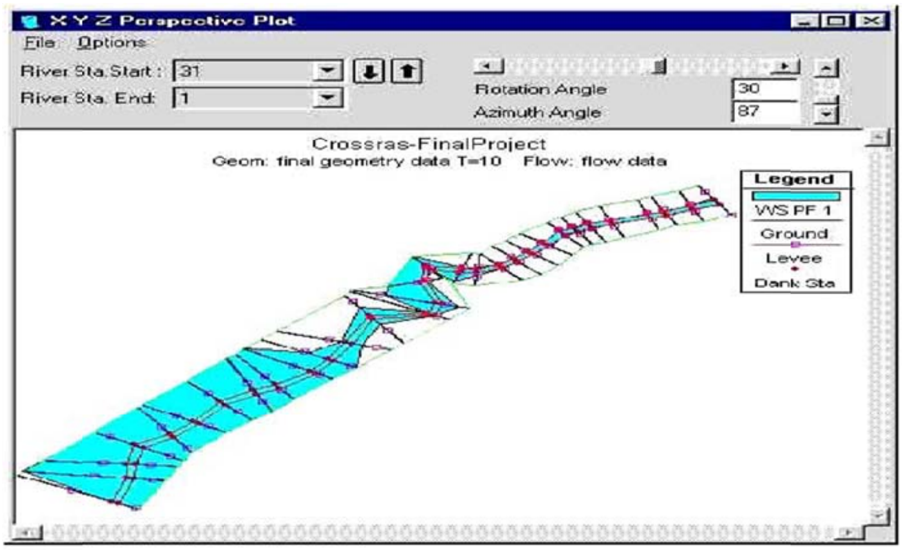


Fig. 5 Water surface extents for the 10 - year return period adapted from (Anastasia , et al., 2003)

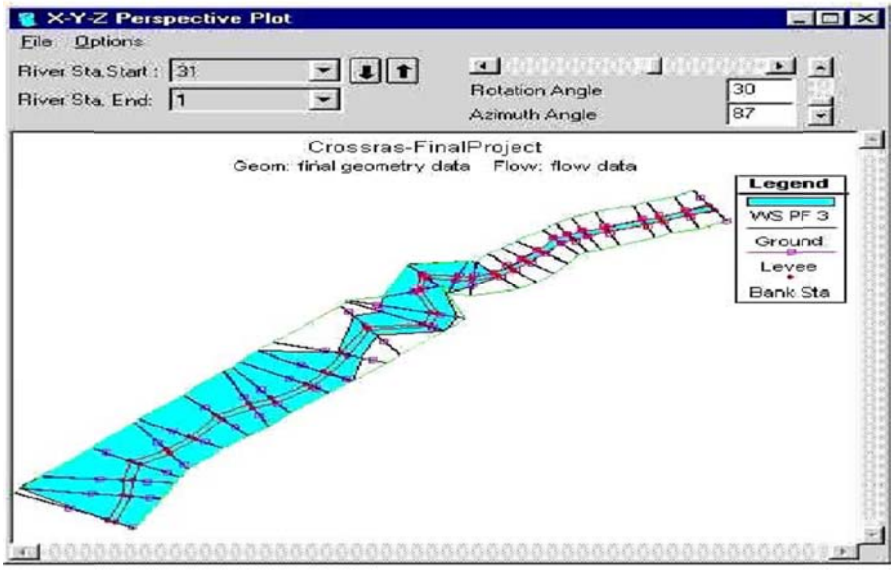


Fig. 6 Water surface extents for the 50- year return period adapted from (Anastasia , et al., 2003)

## 6-1-5 Export Of HEC-RAS Results To ARCview Using AVRAS Post-processor.

Using the AVRas Post-Processor, the computed water surface elevation at cross sections along the water surface extents generated from the HEC-RAS was exported to ArcView. Then, the water surface extents from a polygon describe the floodplain extents. Knowing the water surface elevation theme to GRID [10]. The flood plain map was created for the 10 and 50 year return periods and the results are shown in the figures 7and 8 respectively, where the grid themes Wstin-10 and Wstin-50 represent the water surface elevations for the aforesaid return periods [10].

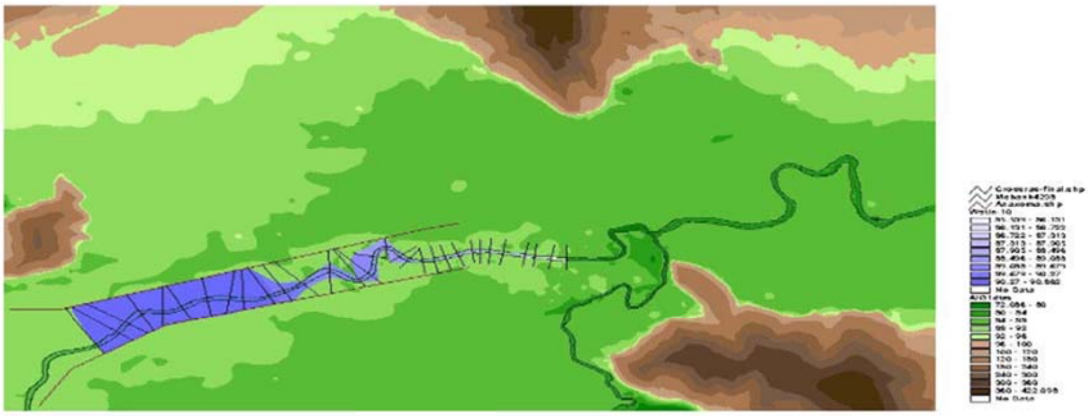

Fig. 7 Water surface elevations for the 10- year return period adapted from (Anastasia , et al., 2003)

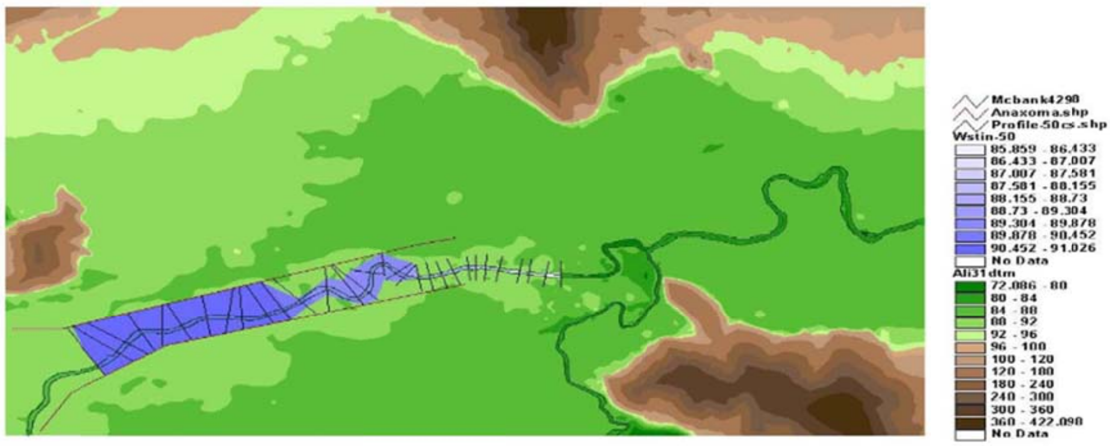


Fig. 8 Water surface elevations for the 50- year return period adapted from (Anastasia , et al., 2003)

## *6-2 Flood Forecasting In Zaremrood River, Iran – Case Study (2).*

Indeed, flooding makes by storm events is a major concern in many regions of the world, it should be predict before occurring, so the second case study in Zaremrood river (upstream of the Tajan River) in Iran is mainly focus about this topic flood forecasting based on geographical information system which was as a case study done by Karim Solaimani in 2009. The main goal was simulating steady flow and provided 2-5-10-25-50-100 years for flood forecasting as flowing procedure.

## 6-2-1 Study Area

The length of Zaremrood River in the study area is approximately 15 Km which located in southeast of Sari, Mazandaran, Iran between " 36° 26′ 15″ to 36° 26′ 44″ N latitude and 53° 8′ 23″ to 53° 9′ 52″ E longitude" whereas, the length of river is approximately 95 km that it flows eastward to westward to join Tajan River and ultimately draining in to the Khazar (Casrian Sea) Lake. The climate in this area is a supper humid climate with a mean annual rainfall about 987.5 mm. As well as, the maximum rainfall occurs in autumn and minimum in summer [22]. The maximum and minimum temperature in Zaremrood Catchment is 20.4 and 8.95C°, respectively and the mean annual temperature is about 14.5 C°. The length of river in this study is terminal 3 Km of Zaremrood River. According to this study and the report from Mazandaran Jahad Agricultural organization the hazardous floods of this river caused lots of losses such as breaking down two bridge openings of river and damage of Garmrood hydrometric station and some similar cases at recent years; in addition the river stream causes bank undercutting that may cause land sliding some parts of village in the long term [22].

## 6-2-2 Datasets

The analysis of this research depends on two types of data which are the annual peak discharge and river plan concluded surveyed elevation points and topographic map. The station named Garmrood with 24 years annual peak flow data was used Only in analyses of this research. After the peak of the annual flow of data was evaluation accuracy import to the SMADA for statistical analysis. Then choose the best statistical distribution and estimate 2, 5, 10, 25, 50, 100- years flood discharge using SMADA. GPS must be used for determining absolute and correct positioning of them, whereas the surveyed points of the Zaremrood River plan have relative elevation [22].

## 6-2-3 GIS Data And Analysis

For the past two decades progress in the field of geographic information system (GIS) for the planning process easy flood a lot and flood risk assessment. Is clear that GIS has a great role to play in risk management of natural hazards because natural component of a multi-dimensional and spatial inherent [22, 23]. In fact, GIS is a tool useful for the assimilation and processing of information that are useful, not only for technical principles but also to communicate more easily with the municipal. In order to take advantage of this tool it is important to assimilate the same amount of data and models for the purposes. [26].

The most important method for hydraulic modeling process for floodplain mapping is addition of the HEC-geoRAS extension for ArcView 3.x. it is one of several methods using in this process. It is available free of charge from the Hydrologic Engineering Center of the U.S. Army Corps of Engineers and works directly with the HEC-RAS to create a geometric data file for the desired hydraulic simulation [22, 27]. The use of accurate terrain data is the most important element of any hydraulic model [22, 28].

The data used in this case study were topographic map of area with scale of 1:25000 and river plan with scale of 1:1000. They were applied for TIN generation, using 3D analyst capability of ArcView. Then, TIN was used for preparation of required data for hydraulic simulation in HEC-RAS. Using the preRAS drop-down menu for prepared the stream centerline and left and right channel banks, flowpath and cross section cut lines themes and then generate RAS GIS import file for HEC-RAS modeling [22].

## 6-2-4 Hydraulic Simulation

The procedure of hydraulic simulation for this case study was the same as the previous in Greece. As a result I will only present the difference simulation which I found in this case study. The steady flow analysis was applied and calculating water surface profiles for steady gradually varied flow using representation of terms in the energy equation as shown in figure 9. In addition the steady flow component is capable of modeling sub critical, supercritical and mixed flow regime water surface profiles [30].

The results that HEC-geoRAS extracted from TIN in ArcView, import to the HEC-RAS model for simulation. Then some additional required data that HEC-RAS needs for running, like steady flow data and boundary condition. Selection of a suitable value for Manning's n is very significant to the accuracy of the computed water surface profiles. In the end after completing of all essential data, model runned [22].

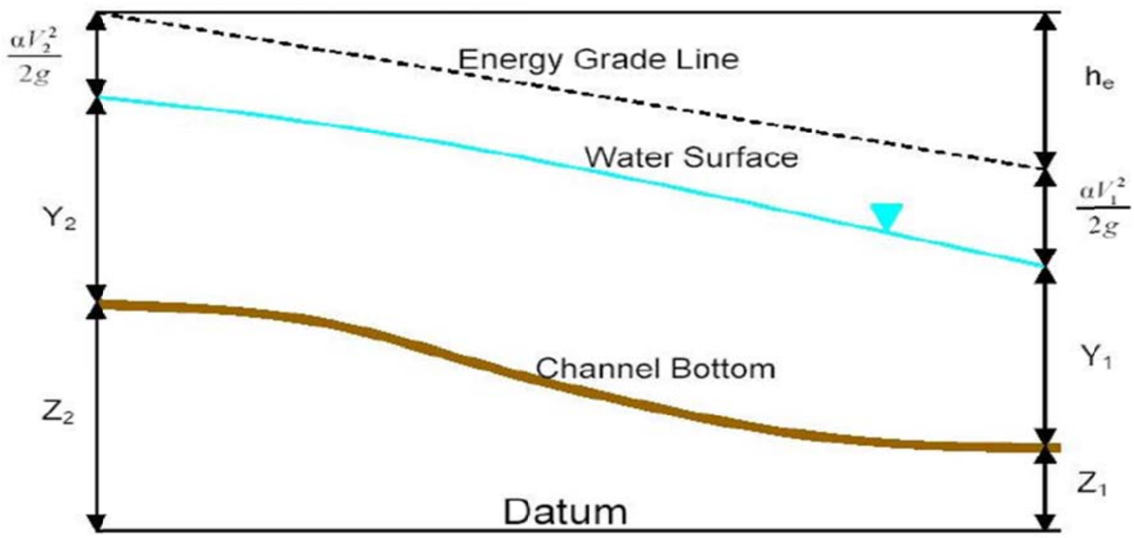


Figure 9. Representation of terms in the energy equation adapted from (Karim Solaimani, 2009)

## 6-2-5 Results And Discussion

The analysis was completed. On the other hand, the annual peak flow was only for 24 years which was imported to the SMADA software. Then, Pearson type III statistical distribution was selected for estimating 2, 5, 10, 25, 50, 100-years flood discharges (Figure 10). Using 3D analyst capability of ArcView, the topographic map with scale of 1:25000 and river plan with scale of 1:1000 were applied for TIN generation, (Figure 11) [22].

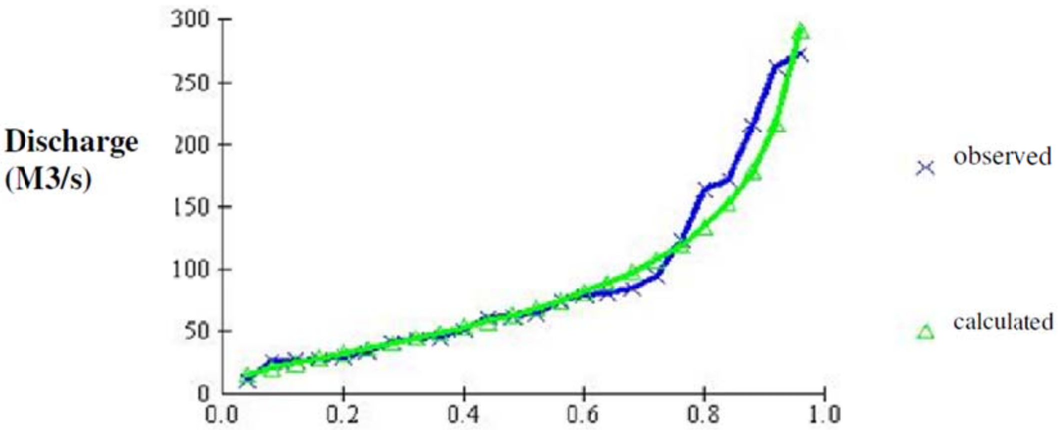


Figure 10. Estimation of flood discharge for 2, 5, 10, 25, 50,100years flood using SMADA software and Person type III adapted from (Karim Solaimani, 2009)

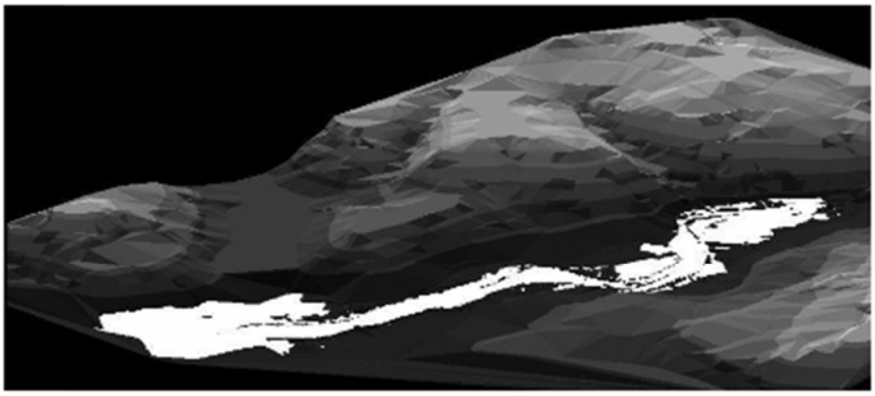

Figure 11. River plan at 1:1000 are applied for TIN generation, using ArcView adapted from (Karim Solaimani, 2009)

The final procedure was imported essential data to the HEC-RAS such as a RAS GIS. Finally, other data such as river system schematic, contraction and expansion coefficients, steady flow data, Manning's n value, flow system entered to model and in the end runned HEC-RAS model for steady flow and mixed flow regime [22]. By comparing Figures 12, 13and 14,15 we can see differences between two cross section plots of 2 and 100 year flood levels in a sample of Zaremrood cross section. One of the most important results of HEC-RAS simulation is preparing different water surface profiles of different T-year floods. Figure 16 shows 100-year water surface profile of Zaremrood River [22].

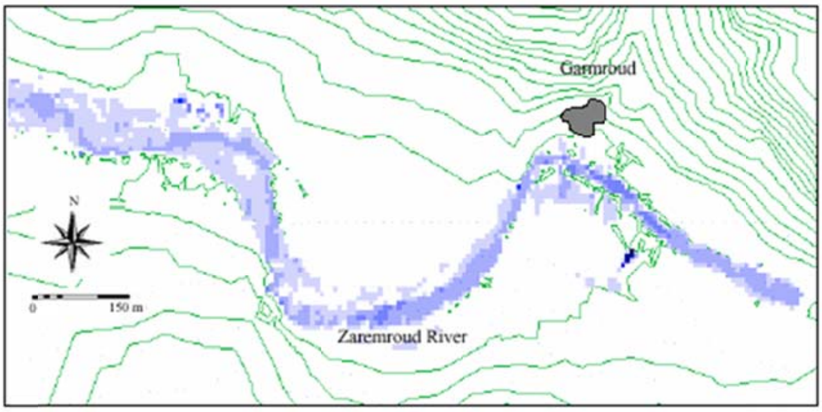


Figure 12. Flood affected area for 2 years flood events using ArcView, adapted from (Shokoufeh Salimi)

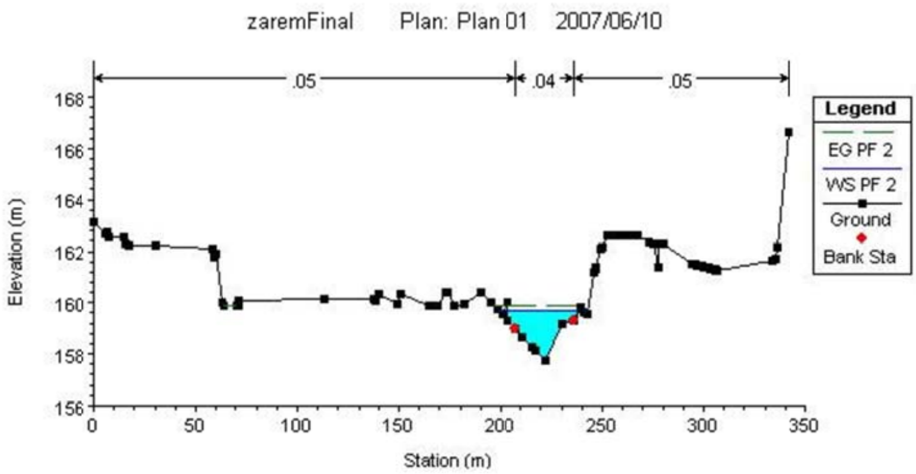


Figure13. Cross section plots of 2 years flood level, using HEC-RAS Model adapted from (Karim Solaimani, 2009)

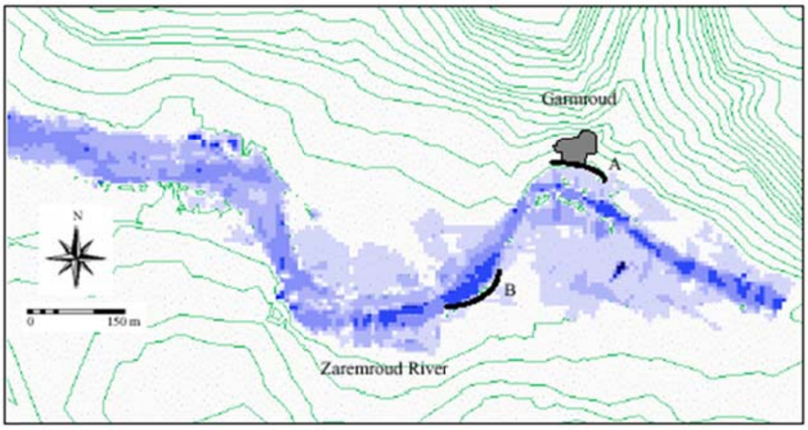


Figure 14. Flood affected area for 100 years flood events using ArcView, adapted from (Shokoufeh Salimi)

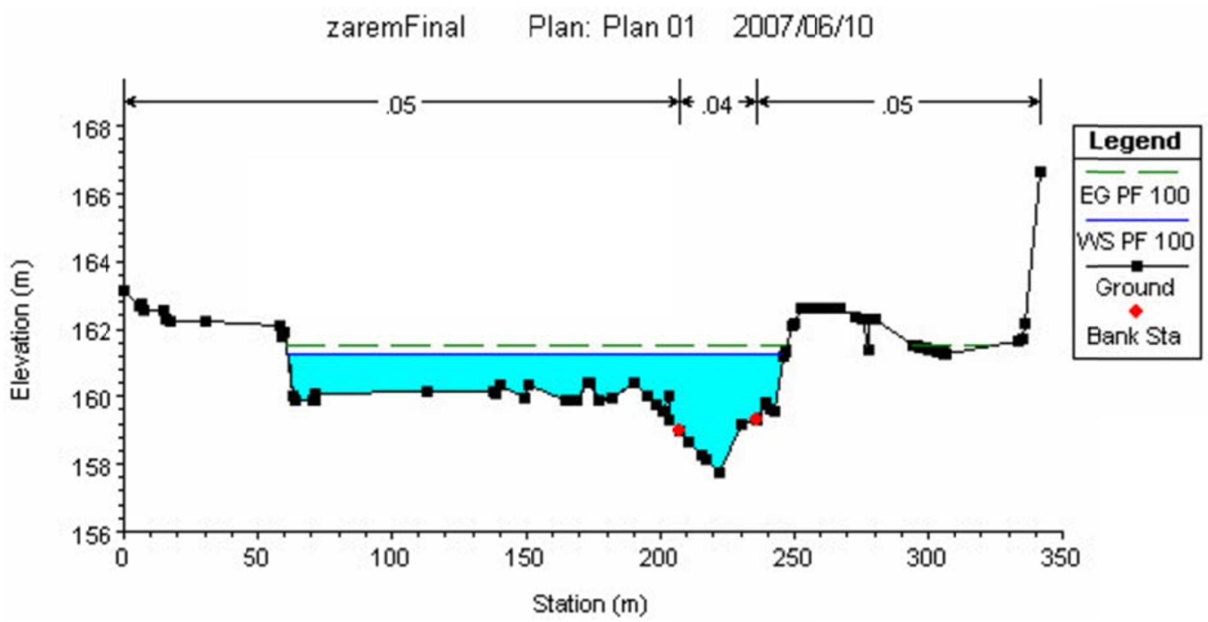


Figure 15. Cross section plots of 100 years flood level, using HEC-RAS Model adapted from (Karim Solaimani, 2009)

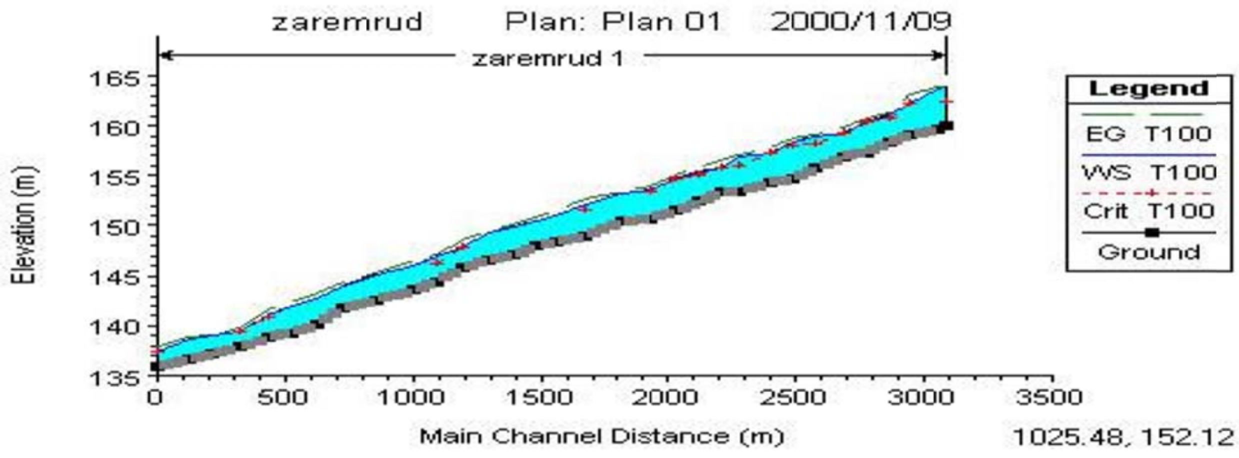


Figure16. 100-year water surface profile of Zaremrood River adapted from (Karim Solaimani, 2009)

# 7- Benefits Of GIS With HEC-RAS In Flood Forecasting

There are many advantages of using GIS with HEC-RAS as following:

- The potential for extracting topographically correct cross-section data from a DTM that can be used to determine river stage and floodplain extent as calculated in hydraulic modelling software package.
- The saving in time and cost.
- It gives a complete flood hydrograph and this allows making a realistic determination of the moderating effect while passing through a reservoir or a river area.
- It lies in the possibility of deriving the model structure and the parameters on the basis of digital elevation maps, soil maps, land use maps etc.
- It is essential to provide early warning by forecasting magnitude, location and time of any likely event.
- managing and understanding flooding

On the other hand the process developed for automating terrain modeling and floodplain delineation has several important benefits:

- User interface: Through the use of menu items and sample exercises, floodplain mapping is automated and simplified. The user need not be a GIS expert to quickly and easily produce detailed floodplain maps. In addition to showing the aerial extent of flooding, the floodplain delineation includes flood depth information.

- Digital output: Rendering the floodplain in digital GIS format allows the floodplain data to be easily compared with other digital data, such as digital orthophotography and GIS coverage's of infrastructure, buildings, and land parcels.
- Integrated terrain model: Currently, there are no available methods with which to combine hydraulic model data with a DEM. The terrain models produced by the procedure are detailed in the stream channel, but also represent the general landscape. The integrated terrain model is comparable in quality to terrain model data acquired solely through aerial photogrammetry. The integrated terrain modeling approach could be used to prepare input data for hydraulic modeling.
- Resource savings: floodplain maps can be updated more frequently, as changes in hydrologic and hydraulic conditions warrant

## 8- Conclusion

In fact this term paper focused on GIS applications tools in flood forecasting with other applications such as Hydraulic analysis HEC-RAS. I have presented and discussed determination flood plains and creating flood plain maps using the linking of available GIS software (Arc/info, ArcView and AVRas ) and the hydraulic modeling software HEC-RAS. The study areas were the Thessaly plain in Greece which is particularly a zone between both sides of the Pinios River in Greece, and peak flow rate for the Zaremrood River in Iran. Also I have presented the procedure of how to develop a procedure to take computed water surface profiles generated from the HEC-RAS hydraulic model and draw a map of the resulting floodplain in ArcView GIS. As well as exporting the HEC-RAS model results into ArcView GIS to create and represent floodplain maps. The most important result from discussing this term paper is that engineers could reduce time to prepare geometric data using GIS and it could be coupled with hydraulic models HEC-RAS that are able to predict flooded areas for different scenarios of storm events and catchments land usethat are able to predict flooded areas for different scenarios of storm events and catchments land use. Also one of the most important conclusions made from these two cases studies is that use of GIS for the undertaking of a hydraulic analysis has the potential to be both an accuracy improving and cost-saving addition to the civil engineers available tools.

## 9- Recommendations

The success of a flood forecasting system depends more than anything else on the availability of quality data in good time to allow running of the model and dissemination of information before actual flooding occurs to save life and property. These two studies have done a lot to improve on the data collection network in their locations. It would however be recommended that:

- More rain gauges should be installed in the upper and middle catchments. The additional rain gauge data would allow the use of rainfall runoff models.
- The HECRAS model should be further refined using data from aerial photography to better capture flows in magnitude and timing.
- Establish local flood forecasting centers with managers and administrative to research maps, building addresses in the 100-year floodplain, providing early warning by forecasting magnitude.
- Improve communication between the National Weather Service and emergency management personnel and other "spotters" identifying where flooding is occurring.
- Establish a formal training program for local building officials relevant to flood related building codes.
- Improve geographic information system (GIS) and LIDAR data for the state to help identify potential flood inundation areas for different size flood events; initiate a flood inundation mapping program for the state.
- Finally, establish the flood forecasting system which would connect different components of the flood forecasting system and automate processes such as data retrieval and initializing running of the model after receiving new data.

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# Appendix 1 (case study 1)

# Appendix 2 (case study 2)