

# Floodplain Modeling and Mapping Using The Geographical Information Systems (GIS) and Hec-RAS/Hec-GeoRAS Applications. Case of Edirne, Turkey.

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March 30, 2017

## Summary

The present study aims to produce flood inundation maps of different recurrent periods of the Meric (Maritza) and Tundja (Tundzha) rivers in the area of Edirne city, Turkey. The case study area situates in the intersection point of the Meric, Tundja and Arda rivers, which are at the same time transboundary water channels that run through the territories of three countries; Turkey, Bulgaria and Greece. Edirne city and its vicinities have been historically affected by natural flash floods which had negative impacts on socio-economic dimensions of the settlement as well as on agricultural areas. The current study aims for combined application of Geographical Information Systems (GIS) and hydraulic modeling in order to determine flood extents as well as to analyze role of existing levee system. For this purpose, ArcMap (ArcGIS) software of Environmental Systems Research Institute (ESRI) is set to be used for main operations with the geographical data of the case study area, such as area topography. The necessity of ArcMap is especially high, when developing the geometry of the area for further 1D steady flow simulation. For this purpose, HEC-GeoRAS for ArcMap extension is used, whereas the major hydraulic modeling and calculations are set to be done in river analysis system software HEC-RAS, which is the product of US Army Corps of Engineers. Besides 1D steady flow, the study also develops 2D unsteady flow analysis, based on the 2D mesh.

**KEYWORDS:** Edirne, Floods, Floodplain, GIS, HEC-RAS.

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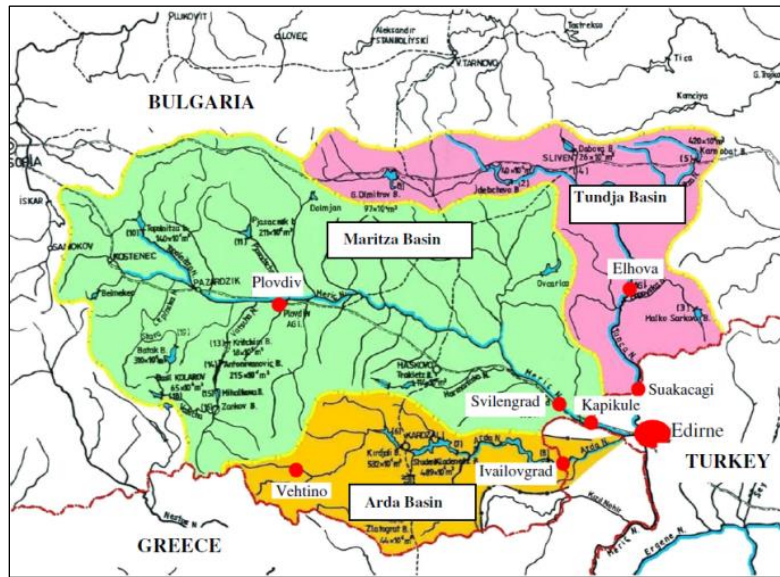
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## 1. Introduction

Turkey is one of the countries where natural disasters had a great negative impact on social and economic dimensions throughout history. Thus, floods are considered to possess significant threat along with earthquakes that occur in the country. Current study concentrates on Edirne city which is located in Thrace region, the northwestern part of Turkey. Historically, the city and its neighborhood areas have been affected by floods that occur due to the water overflow in the Meric and Tundja rivers. The Meric river flows into Turkey from Bulgaria and continues to flow along the Turkish border with Greece until it finally reaches the Aegean sea. Tundja river also flows from Bulgaria to Turkey, where it unites with the Meric river in the area close to the center of Edirne city. The Arda river enters the Turkish territory from the Greek side and flows approximately 1km., until it unites with the Meric.



**Figure 1** The Meric, Tundja and Arda basins location (Tuncok, 2015).

As shown in the **Figure 1** the Meric, Tundja and Arda river basins are mostly located on the Bulgarian territory. Therefore, Turkey and Greece are considered as the downstream countries of these basins. It is notable that even though the flood events cause damage for all of the three neighboring countries, the downstream countries experience greater negative impacts (UNECE, 2011). This is the result of topographic characteristics of the region, however the dams that are located on the rivers' streams within the Bulgarian side increase the natural flash character of floods, as they are usually opened during severe rainfalls or snow melt periods. Hence, the cooperation of three neighbor countries in terms of natural risk mitigation becomes especially important.

## 2. Methodology and data

The current study is set to develop two different types of hydraulic modeling, which are 1D and 2D. This method will allow to test various approaches on the example of the selected case study area, as well as to conduct analysis using the different software environments, such as ESRI's ArcGIS and the HEC-RAS software (Gary W. Brunner & CEIWR-HEC, 2016). Thus, 1D approach is set to be realized through the combined application of ArcGIS and HEC-RAS programs, whereas the connectivity between the software packages is to be provided through the use of HEC-GeoRAS extension (Cameron & Ackerman, 2009) for ArcMap 10.3. HEC-GeoRAS is used to develop georeferenced geometrical data within the ArcMap environment, as well as for further export/import of the data to/from HEC-RAS. At the same time, during

the 1D modeling the steady flow analysis is going to be applied, which means that the amount of water flow ( $Q=m^3/s$ ) will be considered as constant throughout the simulation period. This approach will delineate flood extents and determine areas that are projected to be affected by water in case of a natural disaster. The second methodology type is set to be based on 2D hydraulic modeling and will implement unsteady flow, according to which water discharges ( $Q$ ) change throughout the simulation time. This part will mainly be developed in HEC-RAS software, whereas this time not only hydraulic calculations, but GIS features of the program will be used as well. Still, final results of the simulation are set to be mapped and visualized in ArcMap.

The main data type required for the analysis/simulation development is data regarding the topography of the area. Topography data has to be represented in a digital format, which can be either Triangulated Irregular Network (TIN), or Digital Elevation Model (DEM). In other words, tools and features available in ArcGIS and HEC-RAS/HEC-GeoRAS provide a researcher with an opportunity of using data that best fits requirements and necessities of a study. However, the most important point here is the accuracy of the topography data, as more detailed terrain model will outcome in more accurate and reliable simulation results. Thus, the present research aims to implement 1:1000 scaled topography data, obtained from the local authorities, which are the Edirne City Municipality and State Hydraulic Works of Edirne (SHW). Besides topography information, flow data plays an important role in terms of hydraulic analysis. Thus, the present study uses flow data obtained from the SHW, which represents a real-world flood event that took place between 1-10<sup>th</sup> February, 2015 in Edirne.

### 3. Analysis

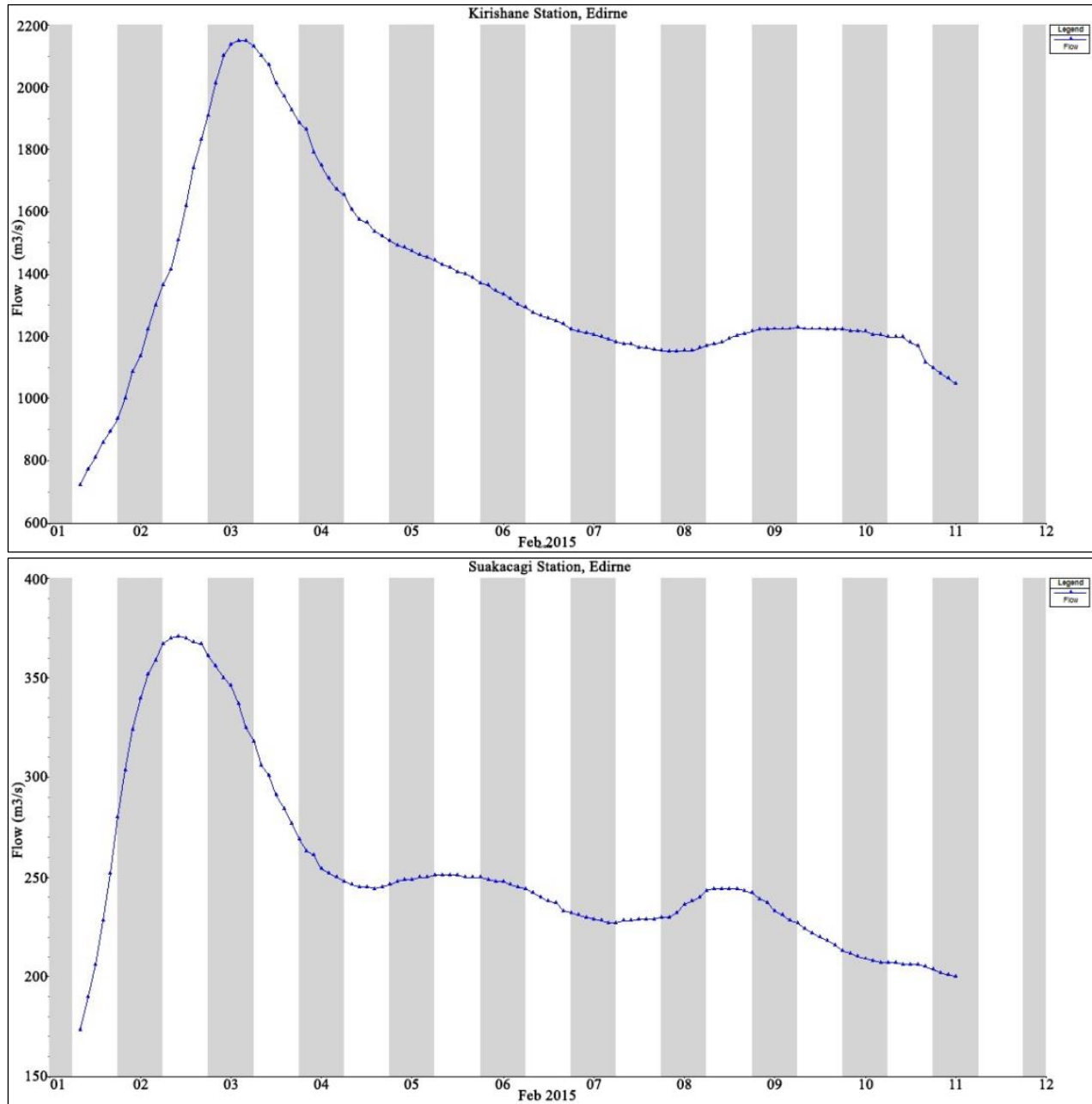
Besides implementation of different modeling techniques (1D, 2D) and flow types (steady, unsteady), developed analysis also includes scenarios where currently existing flood protection levees are either taken, or not taken into consideration. Thus, it would be possible to determine levees' significance degree by comparing floodplains of two different cases.

1D modeling begins with DEM and geometry layers' setup required for data development using ArcMap and HEC-GeoRAS. The geometry data includes stream centerlines, river banks, flow paths, cross sections and land use information. Stream centerlines and banks are needed to georeference the location of rivers and river banks, whereas the flow path layer contains the information about water flow direction. The cross section layer can be considered as one of the prior data source as it gathers the information about area topography from DEM. Finally, land use is used for generation of Manning's numbers. Manning's N value is the surface roughness coefficient that differs according to the particular type of a land cover. In terms of the present study, Manning's values have been applied to each of the land use type according to the values provided in the Hec-RAS reference manual (Gary W. Brunner, 2016). After these steps are completed, data is exported to Hec-RAS using the Hec-GeoRAS extension, where the GIS geometry is checked and flow data represented in the **Table 1** is added.

<b>Table 1</b> Water Discharge Values for Steady Flow Analysis				
Year	5yrs	10yrs	25yrs	100yrs
Meric river	1137	1415	1833	2149
Tundja river	340	370	367	325

Each column represented in the **Table 1**, contributes to a particular steady flow profile used for floodplain delineation of floods with 5, 10, 25 and 100 years of recurrence periods. Thus, obtained results of the 1D steady flow modeling are shown on the **Figure 3**. At the same time, 2D unsteady flow is developed in HEC-RAS, where two-dimensional computation mesh has been generated with common cell size of

40x40 m., and with more sensitive grid formats in river bed and levee system areas. Furthermore, flow hydrograph (**Figure 2**) has been created for each studied river based on the data from SHW.

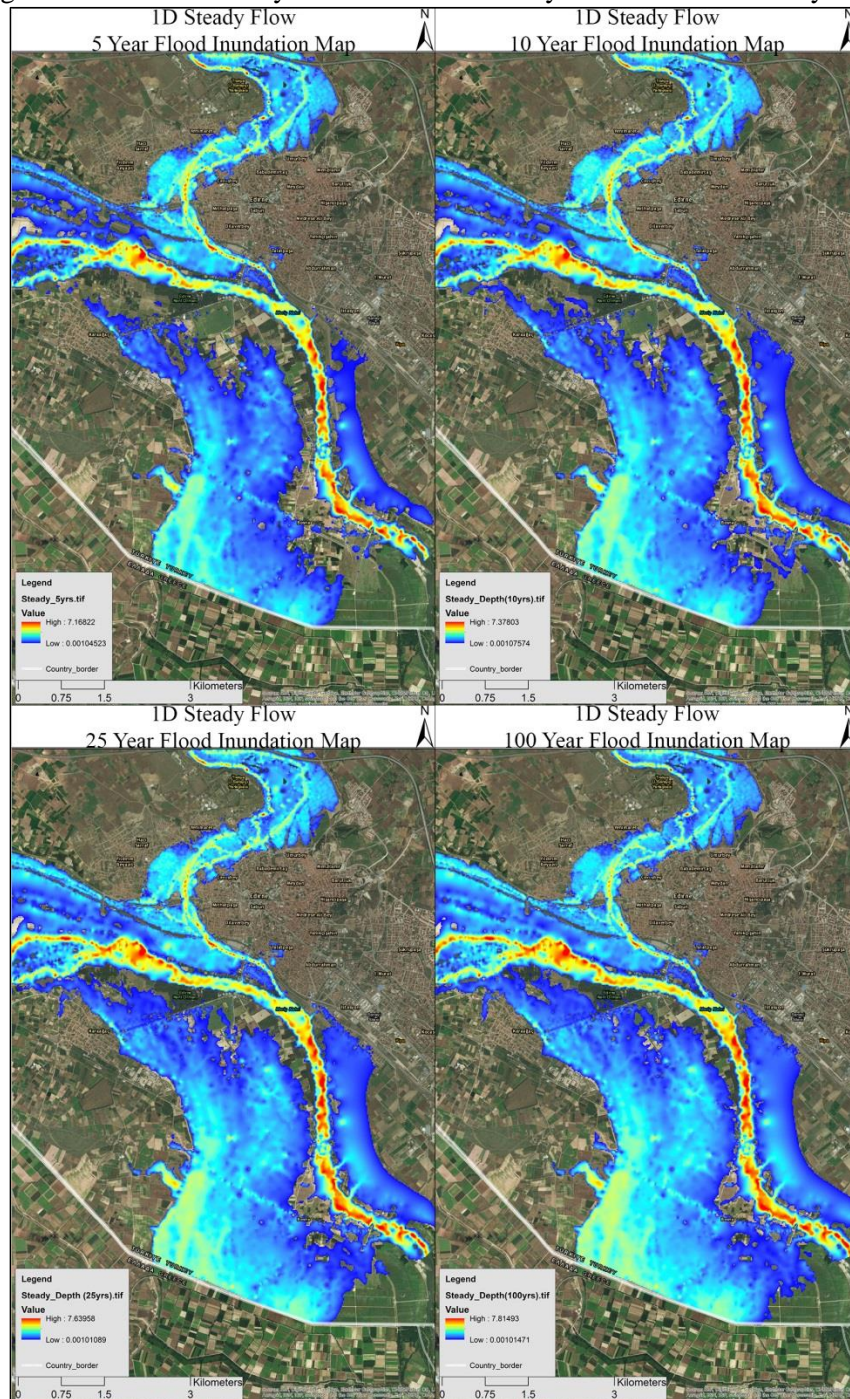


**Figure 2** Flow data registered in Kirishane (upper graph) and Suakacagi (bottom graph) hydrometric stations between 1-10<sup>th</sup> February, 2015.



#### 4. Results

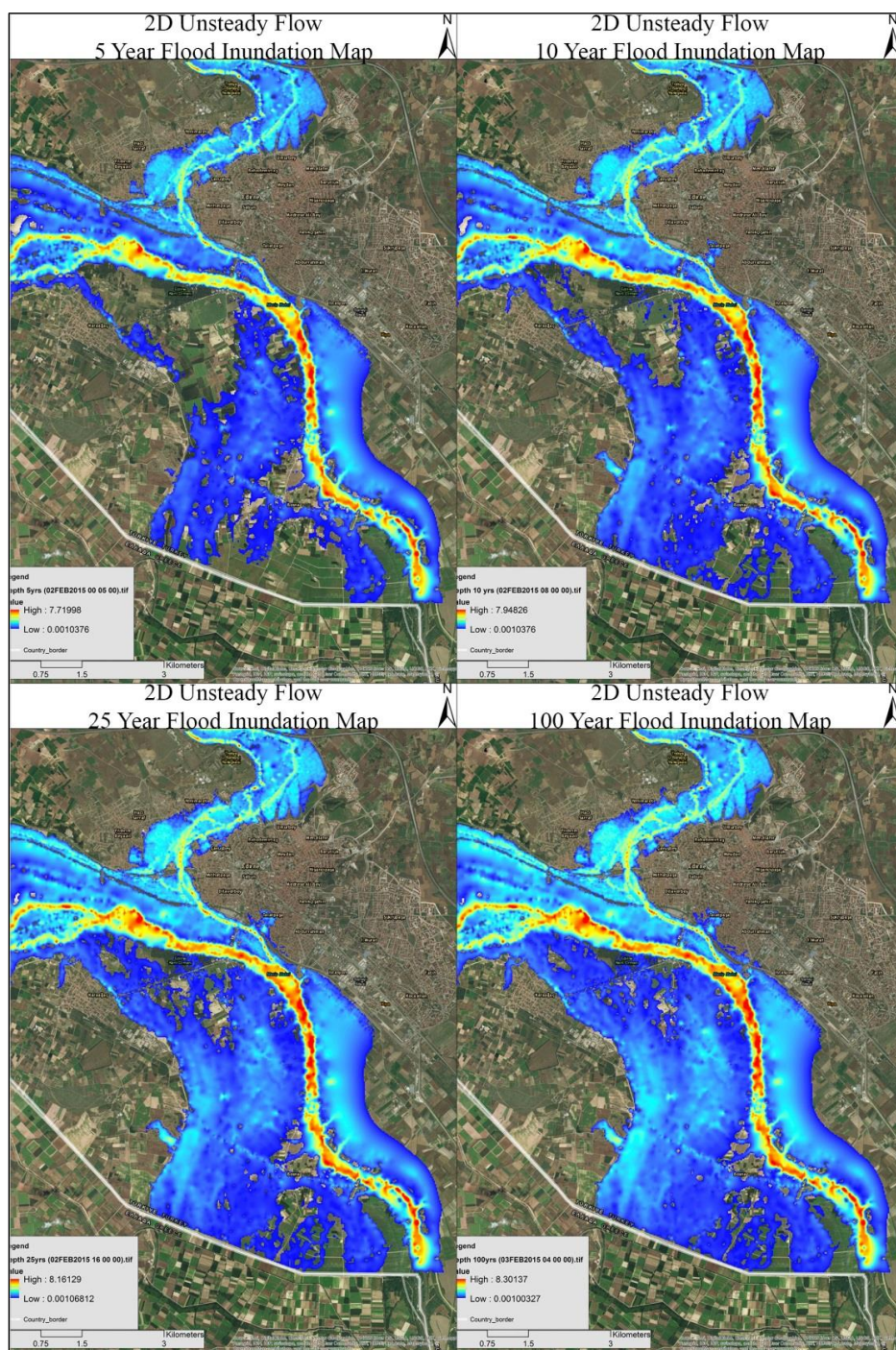
The following figures illustrate the analysis results of 1D steady flow and 2D unsteady flow modeling.



**Figure 3** 1D Steady Flow Inundation Maps of Floods with Different Return Periods (Without Levees).

The 1D steady flow analysis results show the simulated floodplain area, derived from steady flow profiles, in scenario which does not implement any levee system.

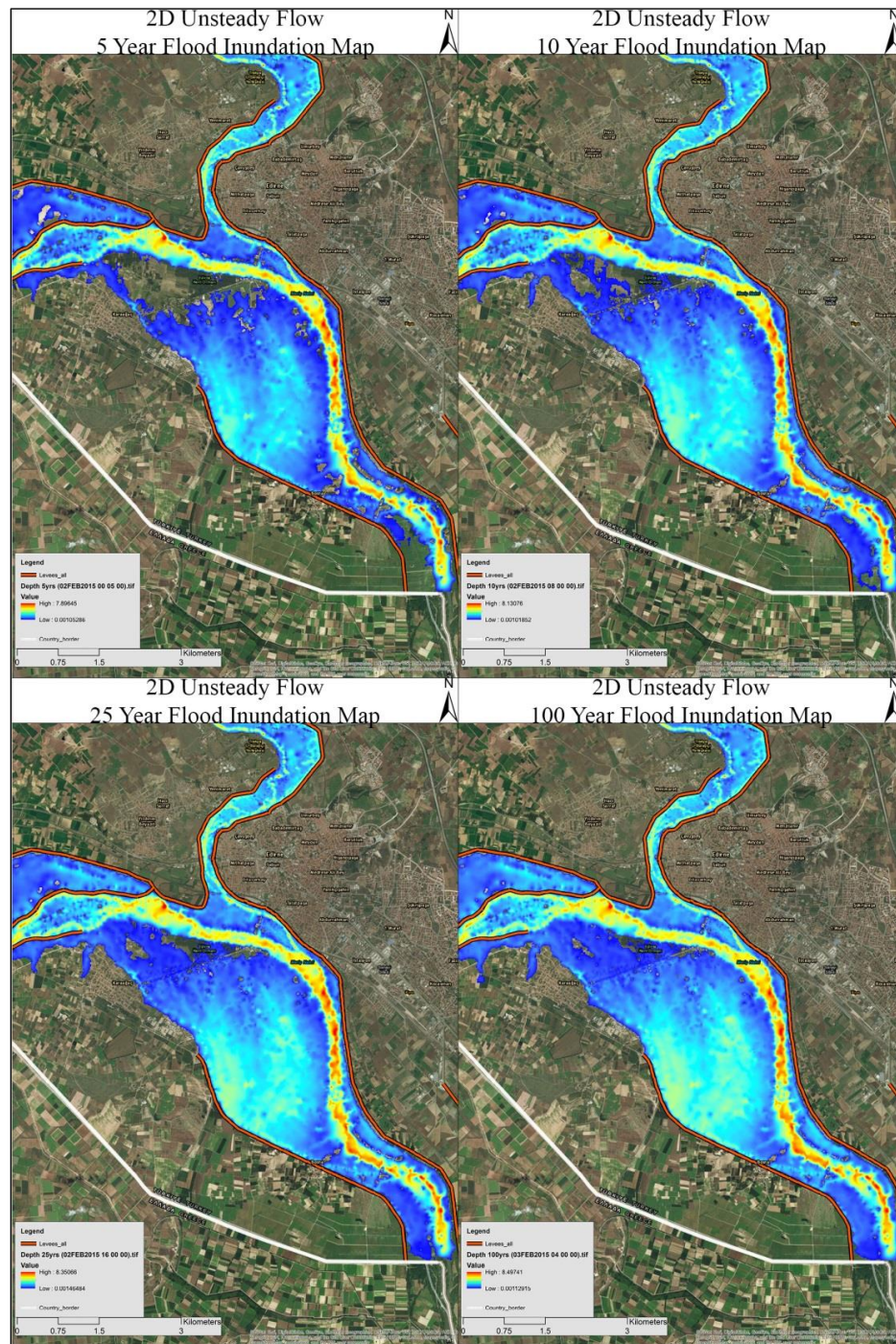




**Figure** 2D Unsteady Flow Inundation Maps of Floods with Different Return Periods (Without Levees).

Results on 2D unsteady flow inundation maps of scenario which does not implement levees. As can be seen, there are some differences in the flood extent pattern comparing to the 1D steady flow results, however common floodplain areas remain in the same zones.





**Figure 2D Unsteady Flow Inundation Maps of Floods with Different Return Periods (With Levees).**

Results on 2D unsteady flow inundation maps of scenario which implements levees. As can be seen, levees play an important role in terms of protecting urban areas from floods.

## 5. Conclusion

Combined application of GIS and hydraulic modeling provides a researcher with significant number of tools and opportunities for testing different outcomes and scenarios using the real-world/georeferenced data. The present research tested two modeling approaches using the ArcGIS and HEC-RAS/HEC-GeoRAS applications. Thus, 1D steady and 2D unsteady flow analysis have been realized which tested scenarios that either included or not included existing levee system. The presented outcomes illustrate floodplain maps of flood events with 5, 10, 25 and 100 year return periods. Applied approaches provided mainly similar results, however unsteady flow, which has been calculated using the 2D mesh, represents more relevant outcomes comparing to the 1D steady flow analysis. This is related to differences between steady and unsteady flow regimes, as well as to computational approach that is applied in 1D and 2D methods. Still, both methods can provide reliable results, while at the same time, the use of a particular technique can depend on a channel type itself. The same point is relevant for unsteady and steady flow regimes, as necessary flow type can be selected according to a dominant flow of an investigated hydraulic system. For most of the river streams, unsteady might be a relevant option, especially in terms of that it can provide a step-by-step simulation and its consecutive visualization. Finally, developed scenarios allow to see the importance of the levee system in terms of floods in Edirne city, as well as to determine areas that still get affected by water, even if they are protected by a levee. Therefore, the presented research is expected to serve as a valuable reference for further studies related to the flood natural disaster in the case study area, as well as for researches regarding the joint application of hydraulic modeling and GIS.

## 6. Biographies

### ***Fuad Hajibayov***

*Fuad is currently a Master student at Istanbul Technical University, program of Urban Planning. He also holds the Bachelor degree in Architecture. His fields of interests include modeling and simulations of natural disasters and their consecutive impacts on urban form, as well as modeling using the advanced planning techniques and GIS.*

### ***Asst. Prof. Dr. Basak Demires Ozkul***

*Basak Demires Ozkul is a Professor at Istanbul Technical University. At the same time, Dr. Basak is the advisor of Fuad Hajibayov in his Master thesis titled as "Evaluating the Impacts of Floods on Planning in Edirne City in Terms of Climate Change". Dr. Basak's research interests are related to the mobilities and socio-economic transformation in terms of urban planning.*

### ***Assoc. Prof. Dr. Fatih Terzi***

*Fatih Terzi is a Professor at Istanbul Technical University. His past academic activities also include teaching in Department of Landscape Architecture at Clemson University, USA, as well as a visit to the Center of Advanced Spatial Analysis (CASA) at University College London as an Academic Affiliate. The research interests of Dr. Terzi are related to housing and site planning, spatial development, GIS and urban modeling.*



## 7. References

- Cameron, T., & Ackerman, P. E. (2009). *HEC-GeoRAS GIS Tools for Support of HEC-RAS using ArcGIS*. Institute for Water Resources Hydrologic Engineering Center (HEC) 609 Second Street Davis, CA 95616-4687: US Army Corps of Engineers Hydrologic Engineering Center.
- Gary W. Brunner. (2016). *HecRAS Hydraulic Reference Manual*. Institute for Water Resources Hydrologic Engineering Center (HEC) 609 Second Street Davis, CA 95616-4687: US Army Corps of Engineers Hydrologic Engineering Center.
- Gary W. Brunner, & CEIWR-HEC. (2016). *HecRAS River Analysis System*. Institute for Water Resources Hydrologic Engineering Center (HEC) 609 Second Street Davis, CA 95616-4687: US Army Corps of Engineers Hydrologic Engineering Center.
- Tuncok, I. K. (2015). Transboundary river basin flood forecasting and early warning system experience in Maritza River basin between Bulgaria and Turkey. *Natural Hazards*, 75(1), 191-214.
- UNECE. (2011). *Second Assessment of transboundary rivers, lakes and groundwaters* (Vol. 1). United Nations, Geneva: United Nations Publications.