QUANTITATIVE FLOOD RISK ASSESSMENT WITH APPLICATION IN TURKEY

A THESIS SUBMITTED TO
THE GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES
OF
MIDDLE EAST TECHNICAL UNIVERSITY

BY

FATİH KESKİN

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR
THE DEGREE OF DOCTOR OF PHILOSOPHY
IN
GEODETIC AND GEOGRAPHIC INFORMATION TECHNOLOGIES

SEPTEMBER 2012

Approval of the thesis:

QUANTITATIVE FLOOD RISK ASSESSMENT WITH APPLICATION IN TURKEY

Submitted by **FATİH KESKİN** in partial fulfillment of the requirements for the degree of **Doctor of Philosophy in Geodetic and Geographic Information Technologies, Middle East Technical University** by,

Prof. Dr. Canan Özgen
Dean, Graduate School of **Natural and Applied Sciences** _______________________

Doç. Dr. Ahmet Çoşar
Head of Department, **Computer Eng. Dept., METU** _______________________

Prof. Dr. Ali Ünal Şorman
Supervisor, **Civil Engineering Dept., METU** _______________________

Examining Committee Members:

Prof. Dr. Alparslan Arıkan Hydrogeology Dept., Hacettepe University _______________________

Prof. Dr. Ali Ünal Şorman
Civil Engineering Dept., METU _______________________

Assoc. Prof. Dr. Sevda Zuhal Akyürek
Civil Enginnering Dept., METU _______________________

Assoc. Prof. Dr. İsmail Yücel
Civil Enginnering Dept., METU _______________________

Assoc. Prof. Dr. Yakup Darama
Civil Enginnering Dept., METU _______________________

Date: *07.09.2012*

I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

Name, Last name : Fatih Keskin

Signature :

ÖZ

NİCEL TAŞKIN RİSK DEĞERLENDİRMESİ, TÜRKİYE UYGULAMASI

Keskin, Fatih
Doktora, Jeodezi ve Cografi Bilgi Teknolojileri
Tez Yöneticisi : Prof. Dr. Ali Ünal Şorman

Eylül 2012,105 Sayfa

Şehir merkezlerinde ve kırsal alanlarda meydana gelen taşkınlar çok büyük can ve mal kayıplarına sebep olabilmektedir. Oluşan zararların incelenmesinde, son yıllarda risk analizi ve değerlendirmesi taşkın olaylarındaki belirsizlik analizlerinde önemli bir araç olmuştur. Taşkın anında su genişliği, su derinliği, su hısı ve olası zarar hakkında fazla bilgi olmaması bölgede yaşayan insanları taşkın akarşı daha kırılgan kılmaktadır. Özellikle bu tür bilgiler Şehir plancıları ve karar vericiler açısından büyük öenme arz etmektedir. Bu tür bilgi ile yeni bir yerleşim alanı seçiminde doğru kararlar alınabilmekte ve bu bilgiler 1 ve 2 boyutlu hidrolik modellerden elde edilebilmektedir. Bununla birlikte, son yıllarda çok hızlı bilgisayar ve modellerdeki hızlı artış iki boyutlu modellere olan ihtiyacı ortaya koymaktadır. Çok kısa zamanda karmaşık sistemlerin çözümü dalga etkili iki boyutlu modelleri desteklemektedir. Belirsizliğin değerlendirmesinde, taşkın genişliği, derinliği ve kırılganlık hususlarının birleştirilmesi ve nicel taşkın riskinin ortaya konmasında CBS çok önemli bir araçtır. Bu çalışmada, Dalaman ovasında tek ve iki boyutlu modelleme sonucundan elde edilecek taşkın yayılım ve derinlik haritaları nicel kırılganlık faktörleri ile birleştirilmiştir. Yapılan çalışma neticesinde ovanın taşkına karşı kırılgan olduğunu ortaya koymuş olup olası bir taşkında büyük parasal zararların oluşabileceğini göstermiştir.

Anahtar Kelimeler: Taşkın, Dalaman, HEC-RAS, FLO2D, model

ABSTRACT

QUANTITATIVE FLOOD RISK ASSESSMENT WITH APPLICATION IN TURKEY

Keskin, Fatih
Phd., Geodetic and Geographic Information Technologies
Supervisor : Prof. Dr. Ali Ünal Şorman

September 2012,105 pages

Floods can result in enormous causalities and huge economic losses in urban and rural regions. In recent years, while assessing the damage, risk analysis and assessment has become an important tool in addressing uncertainty in flood hazards. The lack of knowledge about the water extend, water depth, water velocity and potential damage in case of flood increase the vulnerability of the people to disasters in the flood region. Especially this information is valuable for city planners and decision makers. In case of new settlement area selection, correct decision can be taken by the help of this information. This type of information can be taken from hydraulic models as 1D or 2D. On the other hand, two dimensional (2D) hydraulic modeling becomes a need with increasing trends of very high speed computers and models instead of one dimensional (1D) ones. The ability of solving complex structures within few minutes enhances the use of 2D modeling with the integration of wave motion. In addressing the uncertainty, GIS becomes an important tool in risk assessment by integrating the flood depth, extend and vulnerability issues for definition of the quantitative risk. In this study, 1D and 2D hydraulic modeling is applied and combined with the quantitative vulnerability factors in Dalaman Plain-Turkey. Results show that the area is vulnerable to flood and high monetary damages can be seen in case a flood in the region.

Keywords: Flood, Dalaman, HEC-RAS, FLO2D, model

To My Family

ACKNOWLEDGEMENTS

I would especially like to thank to my family, my wife Songül, my son Eren and my daughter Elif, whose love gave me the strength to cope with all kinds of difficulties that I faced throughout my doctoral study.

I wish to express my deepest gratitude to Prof. Dr. Ali Ünal Şorman, my supervisor, from his wisdom, insight, kindness, invaluable encouragement and support. Without his guidance I could not have completed this thesis work.

I also wish my deepest gratitude to Prof. Dr. Alparslan Arıkan and Assoc. Prof. Dr. Sevda Zuhal Akyürek for their continuous guidance, advice, critism and patience during the study.

I owe special thanks to Assoc. Prof. Dr. İsmail Yücel and Assoc. Prof. Dr. Yakup Darama for their kind helping and valuable suggestions.

The thanks are extended to Mr. Kemal Seyrek and Mrs. Aylin Kübra Onur who helped me in writing the thesis and preparing the model data.

The thanks are extended to Karen Obrien who help me in modeling and also providing an academic version of FLO-2D program

Moreover, sincere thanks are extended to Government Organizations: State Hydraulic Works for gage data and cross section data.

TABLE OF CONTENTS

LIST OF TABLES

TABLES

LIST OF FIGURES

FIGURES

CHAPTER 1

INTRODUCTION

1.1. Importance of the study

Natural Disasters such as flood, earthquake, landslide, etc., are among the main disasters in Turkey that lead to high damage to communities. However, the lack of knowledge to respond to these types of disasters increases the vulnerability of people to disasters within the region. Though people know that they are under risk, they continue to live in the risky zones because of economic and social problems. Of course this type of approach increases the possible consequences of a probable disaster.

When the economic damages resulting from natural disasters for the period between 1991-2005 are examined (Figure 1.1), it can be seen that, United States (USA) ranks first with about 364 billion USD damage, then follows Japan with 209 billion USD damage. Turkey is the 11th one with 21 billion USD damage totally. Within this 21 USD billion damage due to natural disasters in Turkey we can see that the most damaging disaster is the earthquakes and then followed by flood events. More than 20 flood events causing at least 30 deaths per year.

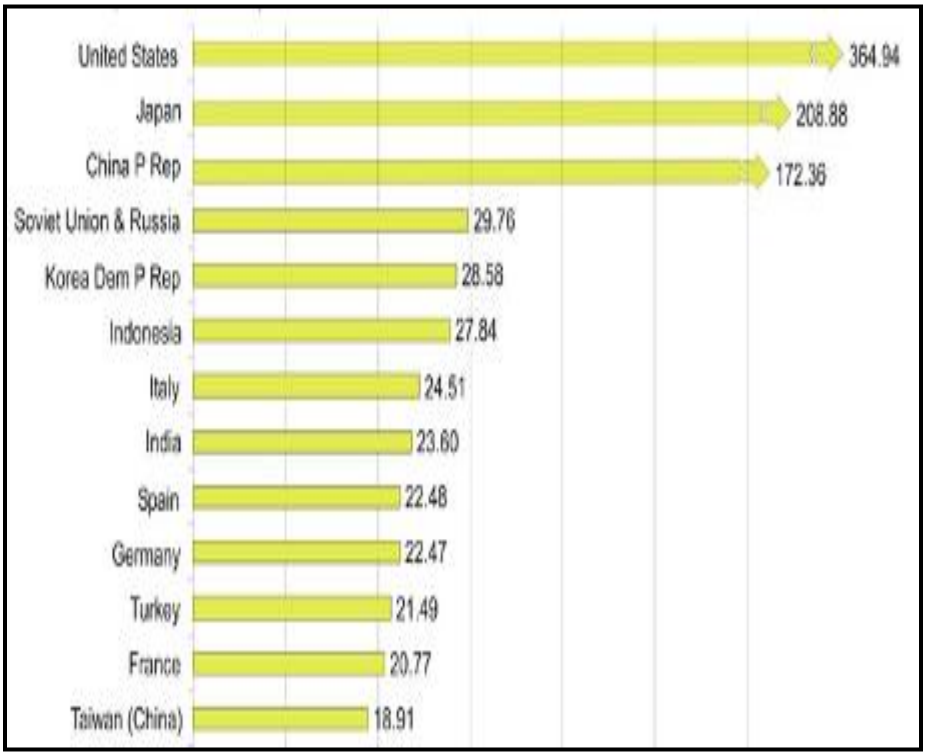


Figure 1.1 Total amount of reported economic damages: all natural disasters 1991-2005 (US$ Billion) (Source: UN-ISDR)

In addition, flood events are the main hazardous events within the meteorological disasters. Long Term Occurrence Distribution of meteorological disasters in Turkey for the period 1940 to 2002 is depicted in Figure 1.2. It can be seen that flooding is the main disaster within the meteorological disaster events. The main cause for this is the geographic location and the complexity of orography of Turkey which gives origin to an irregular rainfall taking place in some cases, resulting to the huge damages.

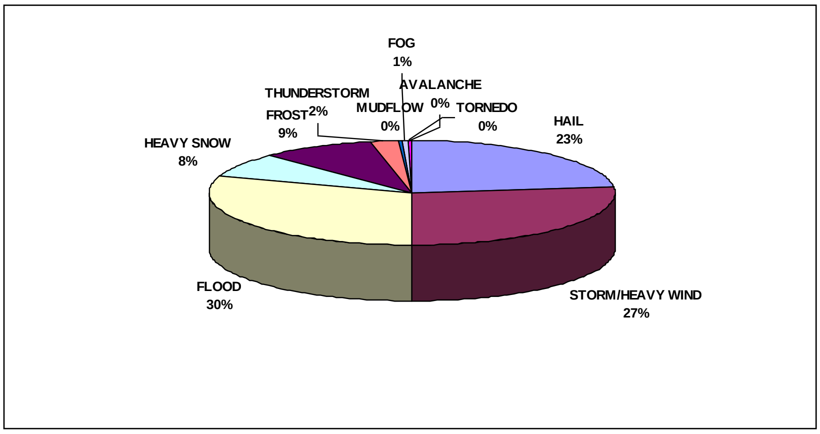


Figure 1.2 Long Term Occurrence Distribution of meteorological disasters in Turkey for the period of 1940-2002 (DMI, 2006)

In Turkey, floods are recorded as river floods and urban floods. River floods are considered as one of the most devastating natural disasters with a yearly damage of 100 million dollars over the period 1974 to 2009. Moreover, it has now been widely accepted that the frequency and magnitude of river floods may increase because of climate change (Figure 1.3). In recent years, great attention has been paid to the consequences of floods and measures to reduce its effects. This has been triggered by the observation that economic and insured losses due to “extreme” floods have drastically increased during the last two decades. Mostly in recent years although structural measures were being taken in order to decrease the flood damages, flood protection investments have also increased. The main explanation for this trend can be found in socioeconomic developments and spatial planning policies, as it appears that wealth and exposure have increased in flood-prone areas. Even in areas where the overall population growth is slowing down (like the cities in East Anatolia region) population growth in cities along rivers tends to be increasing. Flood-prone areas remain attractive for socioeconomic activities and it is therefore likely that the damage potential (as in the amount of assets in flood-prone areas) will continue to increase in the future.

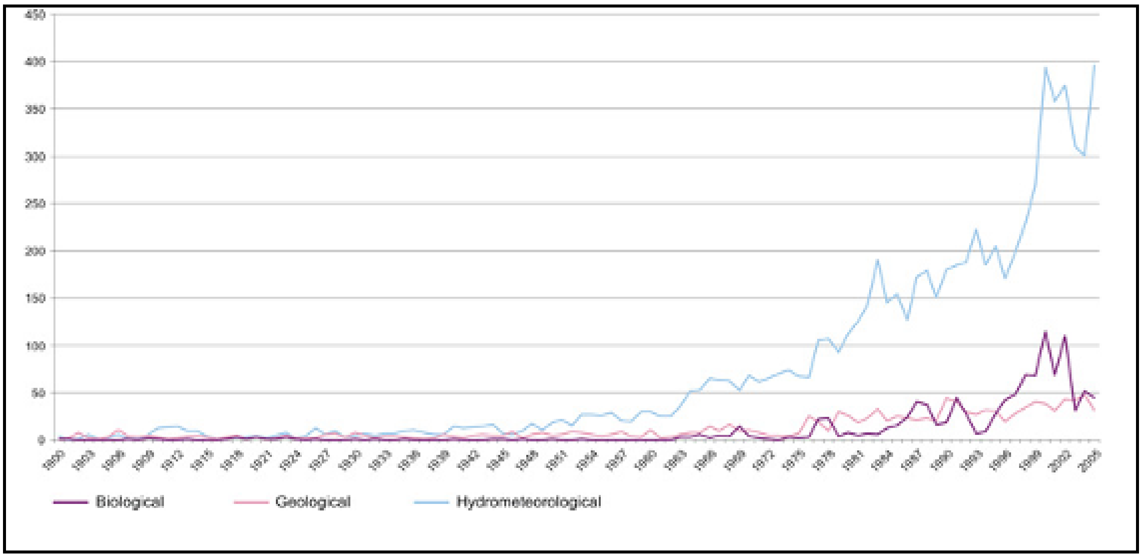


Figure 1.3 Number of natural disasters for the period of 1900-2005 Source: EM-DAT

1.2. Historical Floods:

Turkey with its change in topography and change in precipitation rate is highly prone to flooding. The historical floods and their damages (loss of life, economic loss) is depicted in Table 1.1. According to the table, there are 216 flood events and the total human loss is 415. In case of 2009 September flood event around Istanbul, 31 human losses is recorded and high economic damage to industries within the region. Also in 2011 and 2012 many big flood events had occurred which results high damages for the national economy. Some examples are the events occurred in East Black sea Region. Most of the damages occurred from the wrong city planning and road construction.

Table 1.1 Historical flood events and their damages in Turkey

Years	# of floods	# of human loss	Agricultural Damage(ha)
1989	10	1	9 500
1990	26	57	7 450
1991	23	23	15 770
1992	14	1	690
1993	2	-	60
1994	9	4	1 680
1995	20	164	201 100
1996	4	1	11 000
1997	1	---	1 390
1998	2	57	7 000
1999	1	3	----
2000	4	---	8 066
2001	6	8	43 297
2002	2	27	510
2003	21	7	64 200
2004	19	3	25 750
2005	33	14	13 855
2006	19	45	85 810
2007	15	11	1 050
Total	**216**	**415**	**497 128**

(DSI, 2011)

1.3. Data and software used in the study

The runoff data for the basin was obtained from General Directorate of State Hydraulic Works (DSI) and General Directorate of Electric Power Resources Survey and Development Administration (EIEI), and used to calculate the probable flood discharges. Digital Elevation Model (DEM) of the study area was obtained from the 1:25.000 scaled topographic maps, which were obtained from the DSI. The 1:5000 scale maps was produced from the field measurements carried out in the study area. To include important rainfall events, the precipitation data in and near the basin were obtained from State Meteorological Service (DMI) and DSI.

In this study, ArcGIS software of Environmental Systems Research Institute (ESRI) is used as the main GIS software. HEC-RAS and HEC-GeoRAS are used for 1D hydraulic modeling purpose. Floo2D is use for 2D hydraulic modeling within the river and flood plain. Additionally, ArcGIS Hydro Data Model (ArcHydro) is used for delineation of the river network and drainage basins.

The subjects described in the following chapters are briefly reviewed below:

In Chapter 2, introductory information about flood risk, hydraulic modeling and calculation of flood damages with a detailed literature review are presented.

In Chapter 3, study area with the hydrometric and meteorological data network is described. The surface characteristics (topography, vegetative cover, land use, soil and geology) of the basin are produced. In addition to the hydro meteorological data, the surface information of the basin is obtained and determination steps of basin characteristics are followed.

In Chapter 4, the detailed explanation of flood frequency analysis for the drainage basin aand flood routing is explained.

In Chapter 5, with the detailed explanation of the 1D and 2D hydraulic model, the model setup and results for the study basin are depicted. The resulting maps and effect to the settlement areas are discussed. At the end of this chapter, a discussion part is added to compare 1D and 2D hydraulic models.

In Chapter 6, the methodology for calculating flood damage and possible effects is explained. The damage is divided into three categories as settlements, agriculture and tourism. Flood damage for three categories is calculated and depicted in figures. The effect of a possible flood in different seasons and conditions is discussed and supported with model results.

In the last chapter, Chapter 7, the conclusions of the study and recommendations for the future studies are given.

1.4. Objective of the study

In the last years, Turkey had many big flood events such as Istanbul, Samsun, Batman, Antalya flood events. When the damages are analyzed, it was seen that most of them were from the wrong city planning. Especially city planners or governors, when they are planning a new place for settlement, they just collect the information from the governmental organizations and with the help of the information they select the settlement area. For the flood risk case, they do not apply any modeling issues in planning. But if modeling issues is used, it can be seen that most of the settlement areas in or near the rivers are vulnerable to floods. For some locations, like east black sea region settlements near the rivers is a must because people living there do not have large areas for settlements. But if the vulnerabilities of the locations could be identified, then the damages for these locations can be minimized. Even in a flood case, most of the governors don't have enough information to which location that should be firstly interfere. If they have enough information about the flood extend, flood depth, flood velocity and flood damages with vulnarabilities, a better interfere could be done in order to minimize the flood events and minimize the loss of life in flood events. Because of these circumstances, this study is focused on modeling flood events with 1D and 2D hydraulic models and identify the risk zones for a probable flood event. Also tangible damages are calculated for the case study.

So the objective of the study can be listed as ;

- 1D and 2D hydraulic modeling in Dalaman basin.
- Comparison of the 1D and 2D models.
- Collecting the necessary information for flood risk and modeling.
- Calculating the quantitative flood damages and identifying quantitative and qualitative flood risk.
- Generating the qualitative and quantitative flood risk maps.

CHAPTER 2

LITERATURE REVIEW

2.1. General

Risk is defined as a function of probability of occurrence, vulnerability, exposure to hazard. The flood risk is the probability of occurrence of a flood, vulnerability to flood and exposure to flood. If there are enough measurement periods for flood occurrence, it is easy to generate the probability of occurrence of flood. Even if there is enough record for peak flows, the probability can be generated by a simple peak discharge frequency analysis. Vulnerability relates to potential consequences in case of an event and in flood case, the potential consequences can be missing people, agricultural damage, building damage, loss of agricultural land, river fisheries, dams etc. Vulnerability had been discussed in several papers (Vlek 1996, UN-ISDR 2007, Smith 2001). Also, vulnerability is a reflection of the state of the individual and collective physical social, economic and environmental conditions at hand.

2.2 Hydraulic Models

There are different quantitative and spatially explicit model approaches exist in order to calculate the flood exposure and inundation areas that show the flood extend. Additionally, there are also other types of physical based models that are generally fully supported by GIS. The models can be divided into 3 types;

- Models work with storage cell functionality,
- 1D-models, and

- 2D-models.

The models are different from each other according to how the channels are routed, the discretization/incorporation of the topography data and reproduction of the surface roughness. The surface roughness has a great importance when discussing urban areas with a heterogeneous built-up surface (Messner and Meyer 2005).

According to Paperberger (2005), the storage cell models are generally considered as the least complex approaches. The models split the valley or the floodplain into single cells (Cunge et al. 1976) or the more co*m*plex representations such as polygonal shaped cells (Estrela, 1994) or Triangular Irregular Networks (TINs). The size of the model and the amount of detail depend on the grain of the Digital Topography Model (DTM) and the software resources that are available (Messner and Meyer 2005). Examples for developed models are: FloodWatch (DHI 2010), FLOODSIM (Bechteler et al. 1994), Lisflood (Bates & De Roo 2000).

The second type of model is the 1D-models that are used for flood and inundation modeling: The examples for these models are the most famous examples according to a summary by Paperberger (2005) are ISIS, Mike11 or Mike Flood from the SHI-family or HEC-RAS (Bonner et al. 1999, Brunner 2001, Van Looveren et al. 2000). Some of the 1D-models may be downloaded from the Internet and have to be implemented in connection with a GIS-system such as ArcGIS (Bechteler et al. 1994, Bonner et al. 1999, Paperberger 2005).

1D-models calculate one dimensional flows between different cross sections of a floodplain by solving the full St. Vernant equation. The cross-sections can be available in GIS format or in data format recorded in the field measurements. The data should include the floodplain in order to model the inundation in the plain. The model does not use the areas between the cross-sections, it just calculates the area within the cross-section. So, the cross sections should be taken in a good manner in order to represent the topography of the study area. 1D model is relatively simple and not extremely data-intensive (required data on cross-sections rather than a full DTM, upstream and downstream boundaries, surface roughness data for both channel and floodplain).

2D-models are the most complicated and time consuming models and they represent the most complicated approach of flood or inundation modeling. Examples are Telemac2, Mike 21, FLO2D, BASEMENT, RisoSurf (Neunzert et al., 2003), TrimR2D which all solve the 2D St. Venant equation including turbulence processes (Anderson and Bates, 1994, eldhaus et al., 1992). 2D-models permit a complex and highly detailed description of flow process, but therefore need a relatively long time for the model run and in most cases they need a considerable number of input parameters concerning the event, the water flow and the surface of the area where the flood occurs. Important results of the different inundation models which will be used for the preparation of risk maps or assessment schemes are water level height, low velocity and flood extent (2D in the spatial representation).

2.3 Flood Maps

Flood maps are useful maps that can be used within a disaster for decreasing the flood damages. With the increase of occurrence of most damaging type of disaster “flood”, especially in urbanized areas, assessment of economic loss and estimating potential losses has become an urgent necessity for disaster risk management. Flood affects socio-economic activities of people and damages to human settlements and developments. Loss estimation methodology can evaluate the risk and facilitate in taking flood disaster mitigation measures at the local, regional, state and national levels of government.

Moreover, flood mapping is an important aspect for European Union (EU) Member States in order to meet the requirements of the new Flood Directive. Though, Turkey being a candidate country for EU is not obliged to apply new Flood Directive in the near future, but the recent flood disasters show that Turkey needs flood maps immediately in order to use them correctly in city planning and decrease the flood damages.

Flood maps exist in many different forms, but in general it is possible to distinguish between flood hazard and flood risk maps. Flood hazard maps contain information about the probability and/or magnitude of an event whereas flood risk maps contain additional information about the consequences (e.g. economic damage, number of people affected). Within these two general types, however, there are different methods available to quantify hazards and risks, resulting in different types of flood maps such as flood extend, flood depth, flood danger and historical flood maps.

The most common flood hazard maps are flood extent maps. They are generally used in DSI in order to confirm the flood plain in the study area. These are maps displaying the inundated areas of a specific event. This can be a historical event, but also a hypothetical event with a specific return period (for example: once every 100-500 years). The extent of a single flood event, or of multiple events, can be depicted and also the extent of historical floods can be shown. In Turkey, generally, flood extend models are prepared by using the simple manning formula with 100 or 500 return period discharge.

When flood extents are calculated for specific return periods, flood depths can also be easily calculated. Depicting the water depths on a separate map gives a flood depth map. A different type of water depth map is created in areas where flooding is not the result of overtopping but rather of failing structures (for example, dams). In such cases it is not possible to calculate general flood extents and depth for a specific return period as the flooded area is determined by the location of a breach, which is not known before hand, and scenarios are often used. In order to generate a general picture of the flood hazard, the results of these scenarios can be combined into a single map showing the maximum (or average) flood depth per pixel.

Historical flood maps can be obtained by looking at historical flood occurrences and magnitudes. These can be mapped as point events or extents of historical floods can be depicted on a flood extent map. With the advent of remote sensing imagery, flood extents of current (or very recent) floods can easily and accurately be determined.

This opens up possibilities to calibrate or validate flood extents simulated by computer models.

Flood maps usually show only one out of several flood parameters, though in some cases flood depth information of a specific return period is added to a flood extent. In order to get an impression of the overall flood hazard, aggregation of the parameters results in a map so called flood danger map. This is commonly done using matrices or formulas to relate different flood parameters into a single measure for the “danger”. In such matrices, two axes are used to relate flood parameters such as depth, velocity, and return period or a grouped parameter such as intensity (i.e., combination of water depth and flow velocity) into qualitative danger categories. These types of maps are called flood danger maps.

When information on the consequences of a flood is combined with the hazard information, risk maps can be created. As most indicators for exposure and coping capacity are qualitative, this results in qualitative risk maps. The main quantifiable indicator for exposure is direct economic damage. A common method to calculate direct damage is by using stage-damage functions which represent the relationship between inundation depth (and/or some other flood parameter) and the resulting damage of an object or land-use type. These types of maps are called qualitative and quantitative flood maps respectively.

2.4 Flood Damage Calculation

2.4.1. Flood Damage:

Flood Damage calculation is not an easy issue, because you have to consider all the affected things such as buildings, people, land, business etc. So it is needed to define the categories that could be involved in this study. Flood damage means damage on people, their houses and belongings, on ecology, on industry, and of course on economy. The economy of the flooded area is directly affected by the flood occurrence in the region.

There are different terminology (Parker et al. 1987; Smith & Ward 1998; Penning-Rowsell et al. 2003; Messner and Meyer 2005) used in categorization of the flood damage. The first categorization is direct and indirect damages and second is the tangible and intangible damages (San and Keskin, 2009, Floodsite 2006) (Table 2.1).

Table 2.1 Categorization flood damage and example

		Monetary terms	
		Tangible	**Intangible**
Damage Form	**Direct**	Physical damage to assets - buildings - contents - infrastructure	- Loss of life - health effects - Loss of ecological goods
	Indirect	- Loss of industrial production - Traffic disruption - Emergency costs	- Inconvenience of post-flood recovery - Increased vulnerability of survivors

(Penning and Rowsell et al. 2003; Smith & Ward 1998, San and Keskin 2009)

Direct Damages: This type of damage occurs when the flood hits the people, property, and the ecology. Examples for this type of damage are damage to buildings, economic assets, effect on agricultural crops and livestock, loss of human life etc.

Indirect Damages: this type of damage occurs as a result of direct damages. Examples for this type of damage are loss in business, loss of production of the industry, cost of affected traffic etc.

Tangible Damages: Damages which can be specified as money. Examples for this type of damage are damage on property, loss of production etc.

Intangible Damages: Damages which cannot be specified as money. Examples for this type of damage are loss of life, health effects etc.

2.4.2. Calculation of Direct Tangible Damages:

As mentioned above, direct tangible damages are the damages that can be expressed as monetary terms and can be measured after the flood. In order to calculate the damage, some knowledge about the flood and the region also about the study must be known. If the information is good than the result of the damage calculation will be more precise. According to the (floodsite, 2006) there are four basic steps in order to calculate the direct tangible damages.

Size of the Area

The size of the area is important, because the way of calculation of damage changes with the spatial extend of the flood. The methodology differs when dealing with a regional flood and national flood. One can use a very precise methodology when dealing with a flood that is local because there can be more data in local scale. But this is not the case for a national flood. In order to calculate the damage of a national flood, one should use global parameters.

Objective of the study

The objective of the study whether if it will be examined in macro or micro scale is also an important parameter in flood calculation. If the aim is to obtain an approximate value for the damage, one could use global values. But in case of prioritization of an investment on flood protection, more precise methods should be used. One should check the effect of the globalization or being more precise on the methodology on the flood damage calculation.

Availability of the resources

The resources can be money and time and every study must be analyzed with an available resource. If the resource is enough to carry out a detailed investigation, then the resulting flood damage calculation should be more precise. Also if the time period for investigation is large enough than more precise results could be obtained.

Availability of the existing information

It would be better if after a flood there is enough information for the region to define the flood damage. Or if a flood-damage curve is available, one could calculate the flood damage easily. This is also valid while dealing with a national or regional flood event.

Also direct tangible damages can expressed with different assets, but building damages and inventories damages usually form the total amount of damage. So while dealing with flood damage calculation, if the time is limited, then most important damages can included in the study to obtain a damage.

2.4.3. Important factors in calculating the flood damage:

Flood damage is not an easy issue, especially it is difficult to explain in financial terms. After a flood several reports have been formed in order to identify the flood damage. Several events have been recorded and reported after the flood in order to analyze the damage of flood. Especially human losses have been first reported so that everything can be done for the human security. After human losses, loss of animals, loss of property has been recorded. Even wrong information from the people recorded but then tested after the flood event. Because normally people in the flooded area think that if they report high damages, they can get high amount of money from the government.

In the world economic evaluations have calculated in different terms. For example financial evaluations focus on the damage as a single person or company, and not focusing as public affairs which means that they focus on the actual financial burden. But in other terms, the impact of flood on national welfare that includes the impacts on intangible property and services. This type of economic evaluation is used when the calculations on flood damage is focused for the public policy decisions. Whether the flood damage is calculated as a single person or as wider calculations, there are some important principles for the calculation of flood damage. The principles are listed as below;

2.4.3.1 Time of Flood and spatial boundary of flood

It is important to know the spatial boundary and time of flood (with the duration) in order to calculate the flood damage properly. Just to know the spatial extend of flood is not sufficient all the times because you may have needed the information for the disruptions of transportation. This is an indirect effect but should be known in order to calculate the damage of flood.

2.4.3.2 Land Use data of the floodplain

In case of a possible flood, the information about the location, type and number of properties should be known if flood damage assessment should be carried. This type of information can be obtained from the land use data or field survey. This information can be detailed (information about the every single property) or aggregated (settlement, agriculture etc.). Field survey is very advantageous because the information can be collected in the needed detail for the flood damage calculation. The disadvantage part of field survey is that it needs too much time.

2.4.3.3 Inundation characteristics:

Inundation characteristics are also important when dealing with flood and damage. In order to calculate the flood damage, one should know the spatial extend of the flood as explained above. But additional information could help to calculate and refine the flood damage calculation such as flood depth. Additionally if information about the duration, velocity is available then they will be more helpful.

2.4.3.4 Monetary Terms:

In order to measure damage in monetary terms, information on the value of assets at risk needs to be quantified. This information can be integrated in the process of damage evaluation in different ways such as a transfer of approximate values of land use unit from other studies, spatial modeling of aggregated data from official statistics or information about the historical floods. Another model can be mixing the different methodologies in order to have a more accurate result.

2.4.3.5 Duration of Flood

The effect of the flood duration is also important factor when dealing with damages on buildings or agricultural areas. In a study done by Penning-Rowsell et al. (2003), it was shown that there is a difference between the floods with duration greater and smaller than 12 hours in calculating the damage. The damage can increase depending on the type of the building. This is also valid when dealing with agricultural products. Some agricultural products suffer from the flooding with a duration longer than 5 hours, while it is opposite for others.

2.4.4 Flood Damage Calculation in Turkey

Flood damage calculation is similar that was mentioned in the previous sections. The damage calculation is explained as follows;

Flood damages are analyzed under three different categories depending on the means of occurrence. These are given below as headlines and these headlines are explained in detail in the following pages.

2.4.4.1 Damage types;

a) Direct damage

b) Indirect Damage

c) Intangible Damages

a) Direct damage: The damage done by the floods to various values. This kind of floods can be categorized as below:

- The damage done by the mass effect of water: The force of water collapses buildings, artistic structures, trees etc., drags vehicles.
- Sedimentation damages: Fertile lands covered by stone and rubble with various sizes, the main river bed is filled and water flow changes direction, vehicles become unusable temporarily or permanently because of sediments.
- Erosion Damages: Bank scouring, dragging of fertile surface soil and bed changes of the stream

- Damage done by water contact and ponding: Materials like plaster, flour, sugar etc. loses their properties, tools corrode, roots of plants rot and choke, agricultural lands cannot be processed in time, drainage spoils, desertification occurs, etc.

b) Indirect damages: It is a natural cause of direct damages. For example: the damage done in the agricultural areas causing a decrease of production in the relative factories is an indirect damage and these are not taken into account in the calculations.

c) Intangible Damages: These damages are unemployment, social insecurity, deaths, and health problems etc. which are caused by direct or indirect damages.

2.4.4.2 Flood Damage Study

In flood damage calculation step, there are needed information which can be collected by site visits and assessment papers. The main steps are explained below;

a) Collecting data: Data collection with the purpose of detecting the flood damages usually must be done in two stages. As soon as the flood occurs, field analyses are done with a team (Agricultural Engineer, Civil Engineer, Hydrologist, hydrology technician) regardless of the work schedule. With this work, the discharge of flood, borders of flood field, water level on the field, the season in which the flood came, and the planting status of the area under water are marked on a map with a scale of 1/25000 or smaller. If the discharge of the flood studied is not known, it can be determined by investigations and flood marks on the upstream.

b) Determination of the families who are got harmed by the flood: After the marking of the flood field on the map, all the entities that have been damaged are recorded to the questionnaire forms already prepared.

c) Sample assessment: Samples are chosen among the population which are damaged by the flood by using possibility sampling method. Questionnaire studies are made with the entities chosen for the sample.

d) Filling in the questionnaires on the flood field: On the area that is damaged by the flood, many questionnaires are filled for the assessment of the damage done and the possible damage that can be done by a flood with the same magnitude and possibility to occur. Besides the questionnaires, connections are made with the relative public enterprises and individuals in order to get information. The damages that must be determined with the studies on the flood area can be divided into eight groups:

- Damages in the centers of population: Flood damages are determined in population centers such as houses, schools, mosques, hospitals, barns, lofts etc.
- Structure and facility damages: Flood damages done to roads, railroads, bridges, irrigation facilities, and other facilities are determined.
- Damages done to the wares and vehicles: Damages caused by dragging, sediment accumulation, contact with water (machines, vehicles, foods, home stuff etc.) are determined.
- Traffic failure damages: Damages caused by the flood with the failure, lag etc. in passenger and goods transportation are calculated.
- Human damages: Casualties and injuries caused by the flood are determined.
- Animal damages: Animals lost or dead in the flood, their kinds and unit prices are determined.
- Field damages: The amount and unit prices of land that became useless because of the scours on the banks, field gains or losses caused by a change in the riverbed and silting up.
- Agricultural Damages: The questionnaires are filled in order to determine the plant pattern on the field before and after the flood. The efficiency loss on the agricultural areas due to the flood is detected. The base information used for production income and expense on the flood field are compiled. The physical and chemical damages that the flood caused on the field are determined. The changes in the usage of the agricultural fields because of the flood are investigated. The amounts, ages and unit prices of the fruitful and fruitless trees damaged by the flood are determined. The similar field study (adjacent field) is made in an area similar to the flood area in terms of ecology and economy. The necessary information for the calculation of production income and expense of plants that are planted on the similar field is compiled.

2.4.4.3 Office Studies and Calculation of Flood Damages

All the raw information collected during flood studies are analyzed in the office. Flood damages are calculated in the light of the information gathered.In order to calculate the damages, the obtained information is categorized and analyzed under eight categories as described below;

- Damages in the centers of population: The updated values of the structures; types and shapes of which are determined during the researches is evaluated. If that information is not available, the rebuilding expenses of these structures are determined.
- Structure and facility damages: The present values of roads, railroads, bridges, headwalls etc. are calculated. If that information is not available, the rebuilding expenses of these structures are determined.
- Damages done to the wares and vehicles: The damage in the wares and vehicles which became useless because of the flood is calculated by their present sale prices.
- Traffic failure damages: These damages are evaluated and reflected to the total damages as much as they can be calculated in the light of the information determined on the field.
- Casualties: Casualties are given just in numbers.
- Animal loss and damages: The numbers of animals lost or dead are counted and multiplied by the unit prices of each in order to calculate the loss and damage of animals.
- Field damages: Evaluations are made due to the amount and unit prices of land that became useless because of the scours on the banks or a change in the riverbed.
- Agricultural damages: Agricultural damages are calculated by determining the plant pattern before and after the flood that is obtained during the field studies. The production income and expense on a unit field after and before the flood is calculated and NET INCOME/NATIONAL AGRICULTURAL INCOME is determined. The project properties being taken into account and according to the design of the planner net income or national agricultural

income can be used. Based on the plant pattern on a similar field that is not affected by the flood, the production income and expense on a unit field is determined and NET INCOME/NATIONAL AGRICULTURAL INCOME is calculated. The difference between the incomes of flood field and the similar field gives us the flood damage, thus the protection benefit.

2.4.4.4 Calculation of Flood Protection Benefits

The damages caused by the floods are lost values. Since it is not possible to protect lost values, flood protection benefit is possible only as a result of prevention of floods with the same magnitude and possibility. In other words, when demonstrating realized damage done by a flood, flood protection benefit shows the value of the damage done by the flood with the same possibility.

Flood protection benefits are calculated by utilizing the compiled data during the studies in accordance with the disposition in which the damage is determined.

The safe bed calculation by using the section profiles of the riverbed with the section profiles from the riverbed and the stream slope calculated on the field, the safe bed capacity of riverbed and the discharge of the water that generates the flood can be calculated.

The economic analysis of the flood protection structures within the flood protection projects, the flood which causes the most damage and the most economic project must be given priority instead of preventing all floods. The essence of annual flood damage calculation methods is determining the one –year amount of damage done by the repetitive floods that may occur in specified times.

The frequency method used in measuring the flood protection benefits depends on the connection between the flood protection benefit and the possibility of occurrence.

a) Flood recurrence connection:

This connection is calculated by making the frequency analysis of annual, daily maximum discharges if there is a Discharge-Observation Station (DOS) nearby. If not, synthetic approaches are used.

b) Flood recurrence - damage connection:

After the calculation of the benefits gained by the prevention of studied floods with specified discharges, flood recurrence – damage graph must be drawn on a milimetric or semi-logarithmic paper. In order to do so, flood protection benefits must be drawn to ordinate, and recurrence possibility to the axis and middle values are read from the graph. The essence of this graph which aims to obtain the amount of flood protection benefits for a specified year is to calculate the areas of triangles and trapezoids formed by straight lines that are drawn starting from marked recurrence possibilities on the axis to cut the curve. The graphic becomes more reliable as the number of different recursive flood studies done increases. When the graph is being constructed, the damage done by the recurrence possibility (discharge) corresponds to the safe bed capacity is taken as zero.

After these two connections (discharge – recurrence and flood – recurrence damage connection) are established, the expected annual flood protection benefits obtained by controlling different flood discharges can be calculated. Moreover, by calculating the investment expenses done for flood control of those discharges, benefit-expense curves can be drawn and the most economic flood discharge that must be controlled can be determined. In order to have the flood recurrence-damage graphic drawn more reliably, the equation of flood recurrence – damage connection with the help of a software called “Taşkın” is determined, and annual protection benefits for the discharge that is considered to be protected from can be calculated.

CHAPTER 3

STUDY AREA AND METHODOLOGY

3.1. Location of the study area

In this study, the Dalaman Plain (Figure 3.1) was selected because it is considered to be a potential flood risk zone (DSI, 2009) and data availability. The Dalaman River which passes through Dalaman Plain is located in the south-west part of Turkey and has a drainage area of 5344 km^2. It starts from the down part of Güntutan Mountain and has the name “Horzum”. The main tributaries of the river are the Hüsniye, Kilcan, Gökçay, Cehennem in downstream and Çavdır, Aksu, Kocacay in the upstream parts of the river. Forming from the springs, the river first flow north-north west direction, then flows to the south west direction. The river crosses the Dalaman plain from North to South direction for about 25 kilometers and discharges to the Mediterranean Sea near Dalaman district. There are several towns in the Dalaman plain namely; Akıncı, Güzelyurt, Fevziye, Mergenli, Karadonlar, Osmaniye and Yeşilyurt. The plain is generally used for agricultural purposes and there are no industrial facilities within the plain. However, there exist Dalaman International Airport located in lower eastern part of the plain and protected with high deposits. The annual average flow runoff of the river is about 1,627.4 million m^3. The river has a high potential of storage capacity, so the construction of a dam named as Akköprü dam has been started in 1994 and it is under construction. The Akköprü dam acts as a retention dam for flood events for the plain. It has a flood routing capacity of 60 million m^3. The level between 200-204 meters is used flood routing purposes. The dam has three purposes as flood, irrigation and energy. The characteristics of the dam are given in table 3.1.

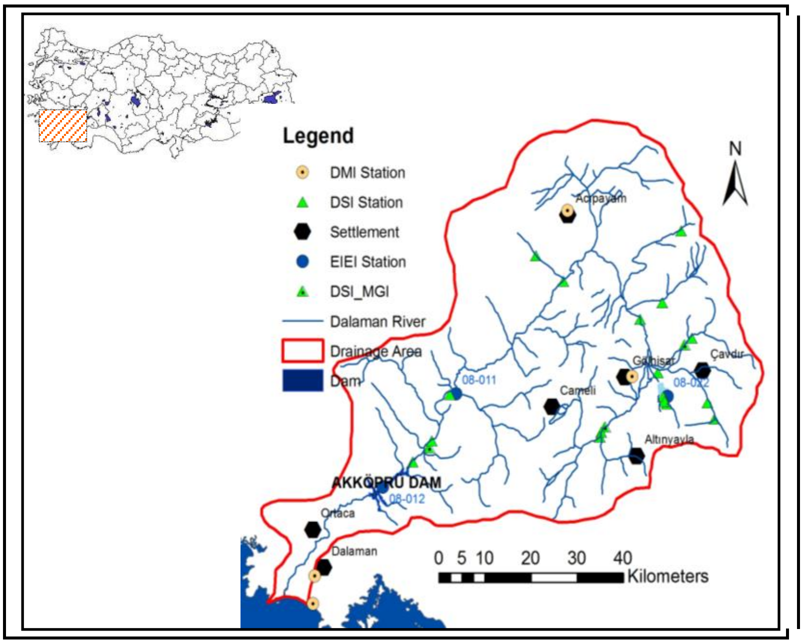


Figure 3.1 Location of the study area and hydro meteorological network

Table 3.1: Characteristics of Akköprü dam

Drainage Area (km2)	5344
Annual Average Flow (hm3)	1627.4
Regulation percent (%)	52
Dam Type	Zoned rock fill
Height (m)	112.5
Total Body Volume (hm3)	12.3
Minimum Water Level (m)	200
Maximum Water Level (m)	204
Active Volume (hm3)	188.7
Total Volume (hm3)	384.5
Total Energy (GWh)	343

3.2. Data collected for this study

The hydro meteorological network is shown in figure 3.1. The discharge stations are operated by EIEI and DSI. The rain gauge stations are operated by DMI. The Digital Elevation Model (DEM) is produced from 1/25000 scaled topographic maps and 1/5000 scale maps with cross sections from the field and all of the data layers are transformed into UTM-35N projection on ED-50 datum.

3.2.1. Hydro meteorological data

There are 6 meteorological stations and 16 discharge measurement stations in the basin. Some of the stations are in the very upstream part of the basin, where the stations do not represent specific basin characteristics. The measured maximum discharges by EIEI stations represent the basin better than the DSI stations. They have a long record period and located in specific locations in the basin. The elevations of EIEI stations in the basin change between 128 to 945 meters, whereas DSI stations lie between 205 to 1565 meters. After the analyses of the meteorological stations in the basin, it was seen that the elevation changes between 941 to 990 meters. After the analyses of the values of the stations, data produced in DMI and EIEI stations were used in the modeling of the basin for flood frequency analyses. The annual maximum discharge values are used for the calculation of different return period discharges changing from 2 years to probable maximum flood time. The stations within the basin is depicted in figure 3.1

3.2.2. Soil data

The soil map is generated from the soil maps created by General Directorate of Rural Works under the Ministry of Agriculture and Rural Affairs. The resulting map is depicted in figure 3.2. There are five types of main soil in the study area namely: rendzinas, alluvial soils, brown forest soils without lime, kolivual soils, and red brown Mediterranean soils. As seen from the figure the study area is mostly covered by the alluvial soils which show that the inundation area is porosive and could not hold the water for a long time.

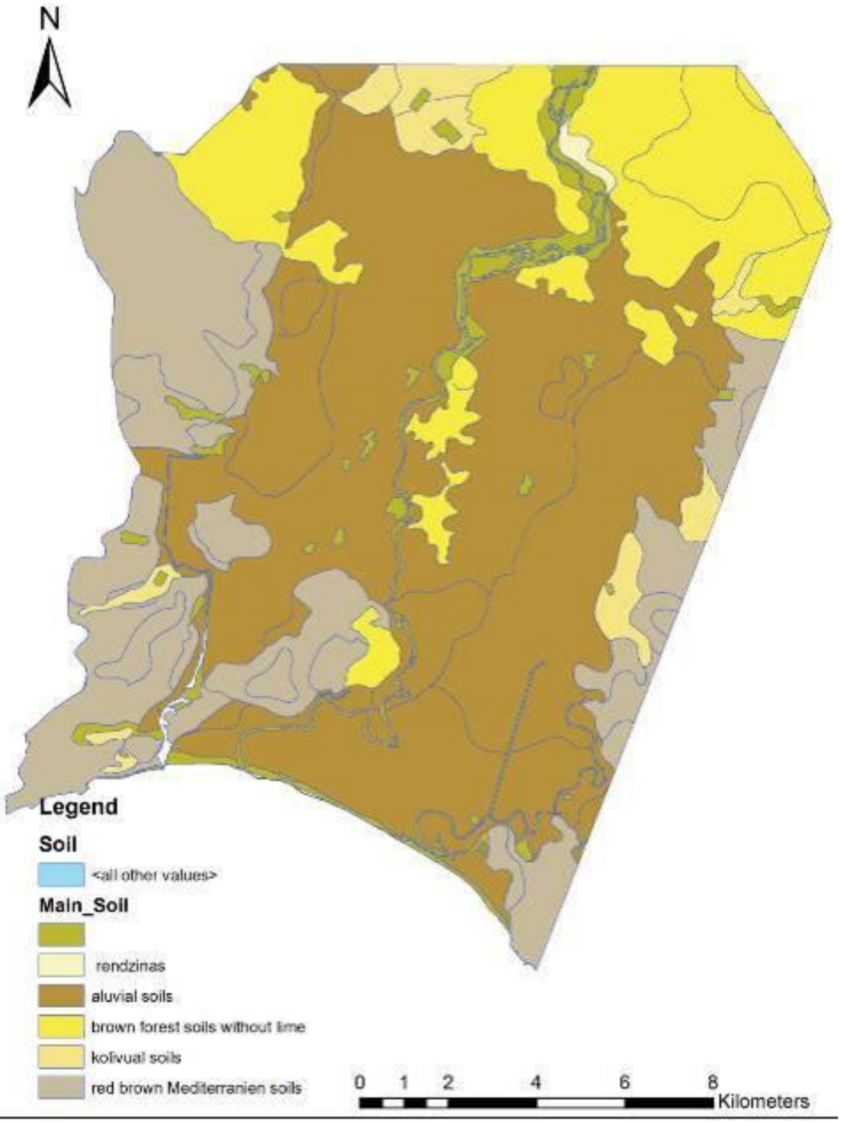


Figure 3.2 Soil map of Dalaman plain

Table 3.2 Percentage of the soil types in the drainage basin

Soil Type	Percentage (%)
Rendzinas	3.74
Aluvial Soils	63.26
Brown Forest Without Lime	13.28
Kolivual Soils	6.78
Red Brown Mediterranien Soils	12.94

3.2.3. Land use data

The land use map is shown in Figure 3.3. The map is generated from the soil data collected by General Directorate of Rural Affairs under the Ministry of Agriculture and Rural Affairs in 2003 with a scale of 1/25000. The summary of the map is shown in table 3.3. As seen from the Table 3.3, 41.64% of the basin, which is the largest part, is covered by irrigated area. This type of characteristics can be used better in the flooding times for sediment load. The higher elevations in the plain is covered by forest (36.67%). and 9.98% of the plain is covered by not intensively irrigated area. The settlement areas cover 0.65% of the plain which represents the 2003 year case.

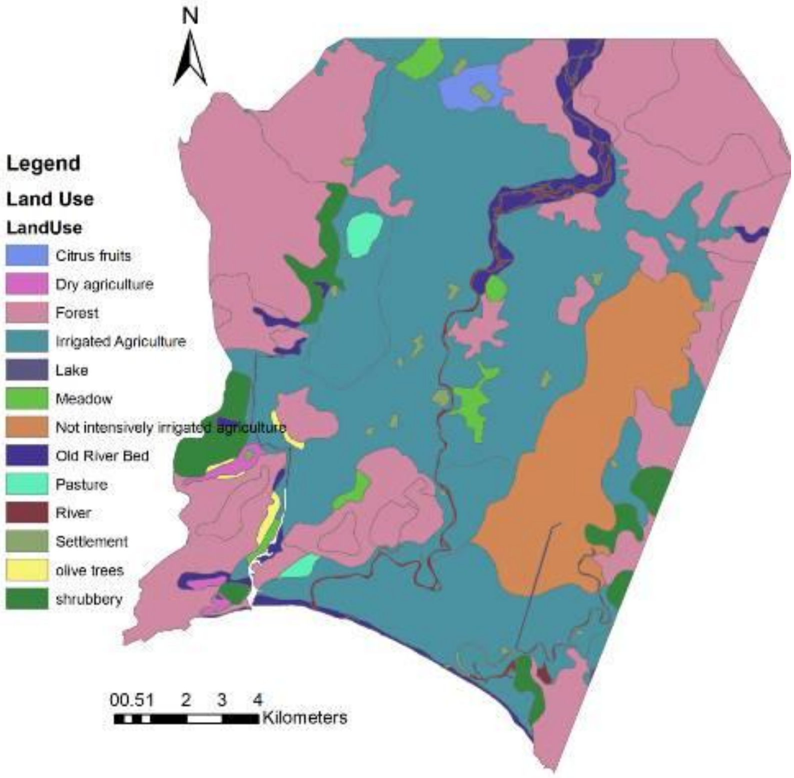


Figure 3.3. Land use map of Dalaman plain

From this land use map, it can be observed that most of the area is irrigated agriculture settled in the middle of the plain. There are some non-intensively irrigated agricultural areas in the east of the plain. Also the river bed is changing in the upper parts of the plain.

Table 3.3. Land use types and their areas within the plain

Land Use Class	**Percentage (%)**
Citrus fruits	0.69
Dry agriculture	0.46
Forest	36.67
Irrigated Agriculture	41.64
Lake	0.03
Meadow	1.24
Not intensively irrigated agriculture	9.98
Old River Bed	3.03
olive trees	0.32
Pasture	0.57
River	1.08
Settlement	0.65
shrubbery	3.63
TOTAL	**100.00**

3.2.4. Geology data

The geology map is obtained from the 1/25000 scaled geology map and by the help of land capability map, slope groups and soil map. The information about geological formations such as their areas with respect to the basin and their catchment is given in table 3.4.

Table 3.4. Dalaman Plain main rock types and their areas

Geologic Formations	**Area (%)**
Alluvium	72.1
Dolomite-Limestone	17.3
Peridodit	4.3
Dolomit	2.9
Basalt	1.3
Sandrock	2.1
Total	**100.0**

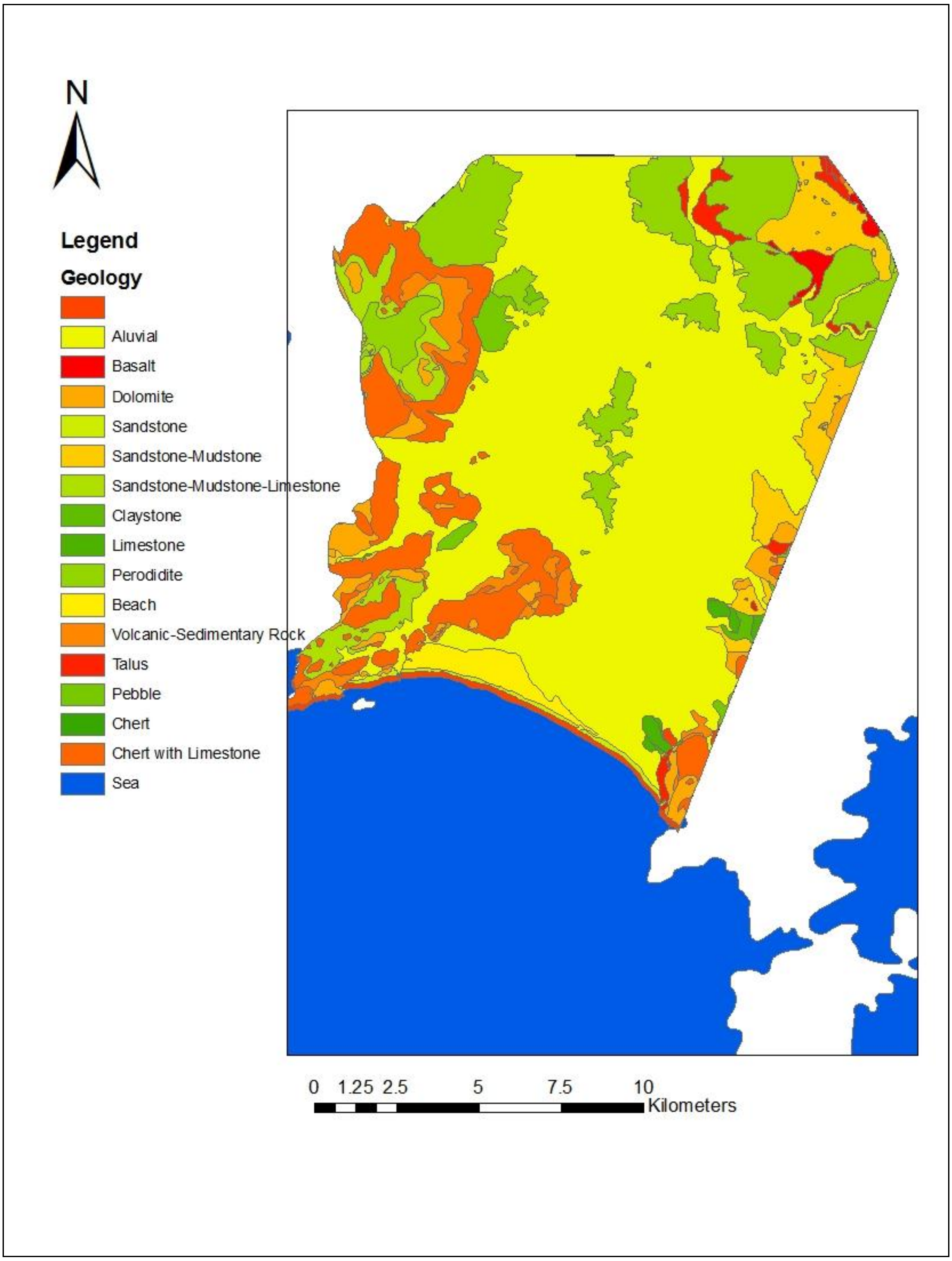


Figure 3.4 Main rock types map

Dalaman plain is mainly composed of alluvium (72.1 %) of the basin and dolomite limestone (17.3 %). In addition, the plague areas which constitute 6.4 % spread to shore of the basin as shown in Figure 3.4.

3.2.5. DEM construction

The required digital contour map for DEM creation was obtained from DSI with scale of 1/25000. This scaled map is used for the formation of the DEM of the drainage area of the plain. Estimation of elevations for each point of the defined grid is needed for the DEM construction. The gaps and unknown elevations which exist in the map should be filled with estimated values for satisfying the needed desired solution. Here we can use the ability of spatial interpolation. There are several methods for interpolation used in GIS but Kriging is used in this study for the interpolation because it accounts for the spatial continuity inherent in the data set. Spatial continuity implies that two points located close together more likely have similar values than two separated points. Kriging differs from the more conventional methods, such as inverse distance to a power that uses a strictly mathematical expression to weight known points and estimate an unknown value. In other words, kriging utilizes the statistical, rather than geometrical, distance between points. Unlike ordinary interpolators, kriging also accounts for clustering of sample values by redistributing weights from neighboring clustered sample values to points farther a field but less redundant (Isaaks and Srivastava, 1989). The spatial resolution was selected as 30 m which is feasible for 1/25000 scale. The resulting DEM is visualized and shown in Figure 3.5.

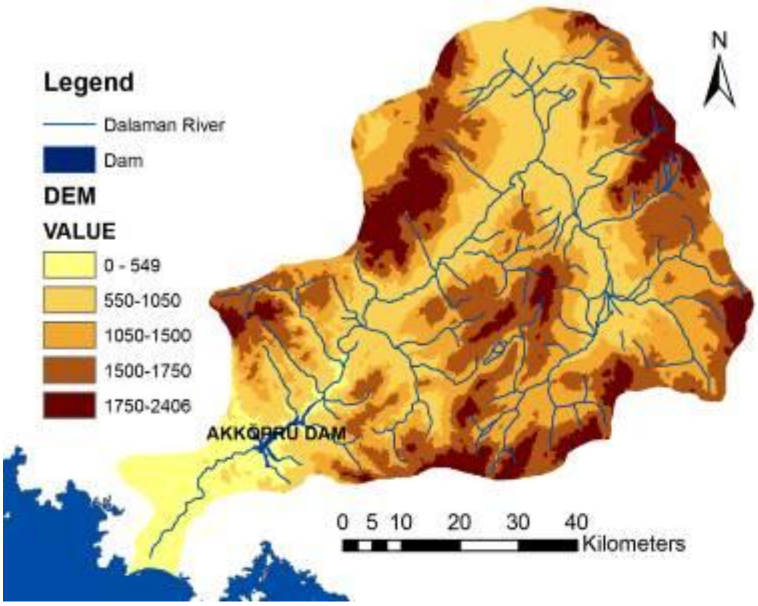


Figure 3.5 DEM of the Akköprü dam basin

The river is discharging to the Mediterranean Sea, so the minimum elevation for the basin is zero meters, while the maximum elevation is 2,406 meters and the mean elevation is 1,141 meters. Elevation classes (per 600 meters) and corresponding percentage areas of the basin are given in table 3.5. The lower (75-400 meters) and the upper (1200-1547) elevation classes contain only small portion of the basin: 8.16% and 6.99%, respectively. The majority of the basin (84.86%) is within 400 to 1,200 meters.

Table 3.5 Elevation classes and corresponding areas

Elevation (m)	**Area (km²)**	**Area (%)**
0-600	2.939	8.16
600-1200	29.493	28.91
1200-1800	81.692	55.95
1800-2406	16.81	6.99
Total	**5344**	**100**

3.2.5. DEM of the flood plain

As mentioned above, 1/25000 scale topographic maps is used in the watershed delineation of the flood plain drainage area. This area is used for representation of the upstream part of the plain. Also this information is used to gather the characteristics for the upstream of the plain.

1/25000 scale maps can be used for a macro scale modeling study, but in a case similar to this study, normally 1/5000 scale maps and river bathymetry should be included. The surface that the modeling studies will be carried must be a continuous surface. Also for 1D and 2D modeling studies, representation of the surface together with the river bathymetry and surrounding topography (flood plain) is required. Accuracy of such a surface will affect the accuracy of the floodplain modeling studies.

Normally, cross section data is retrieved by the field survey. The distance between the cross sections depends on the surface topographic change and manning coefficients change. Due to the economic cost of cross section surveying, the distance is selected for the region for the case of being as far as possible. This type of surveying results with missing information between the cross sections. The cross sections can be interpolated by GIS tools such as interpolation techniques but, they do not consider river flow direction and anisotropy. So, in order to generate a continuous surface, custom tools are required. After the generation of the surface, this generated surface will be combined with the flood plain surface.

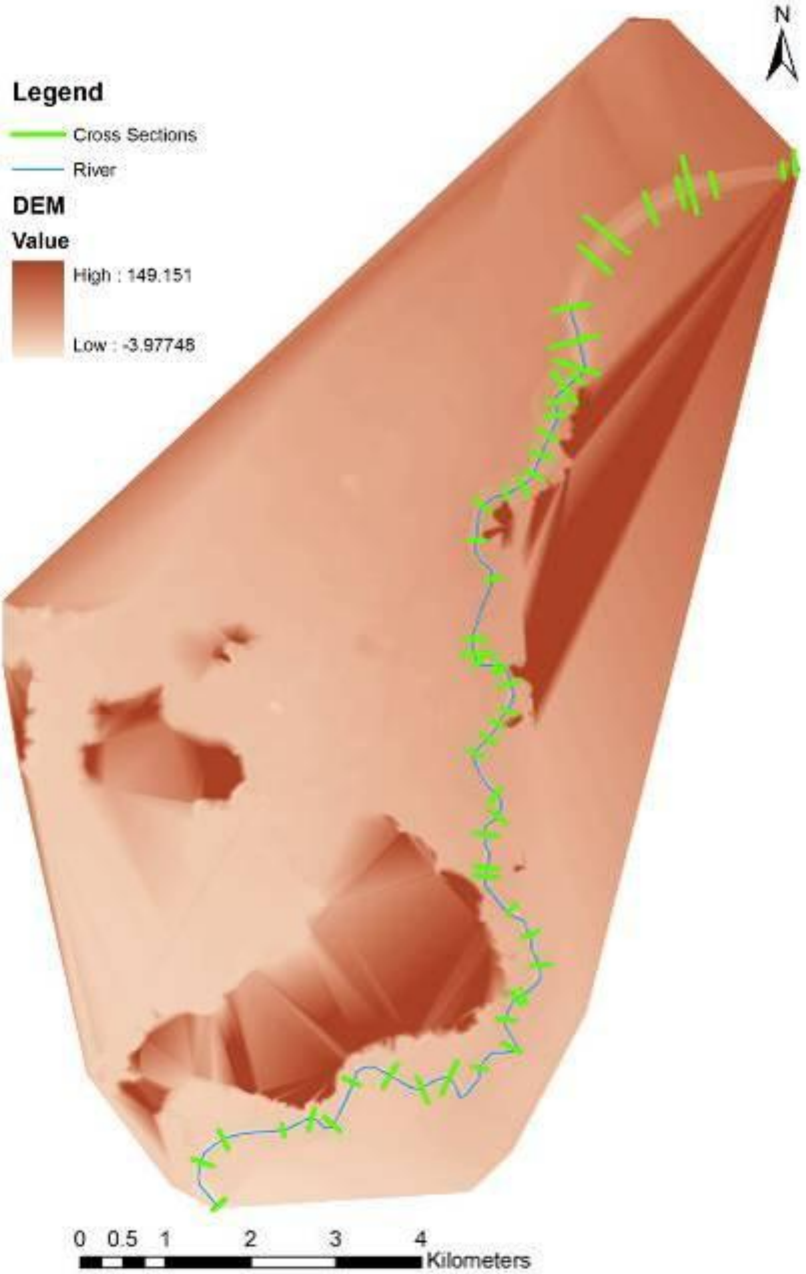


Figure 3.6 DEM and the cross sections of the flood plain

In this study, for the interpolation of river cross sections, a GIS tool (Mervade, 2009) is used. The cross sections and river line (Figure 3.6) is imported in ArcGIS 9.3 and interpolation technique is applied by the help of the tool. The resulting mesh is shown in figure 3.7.

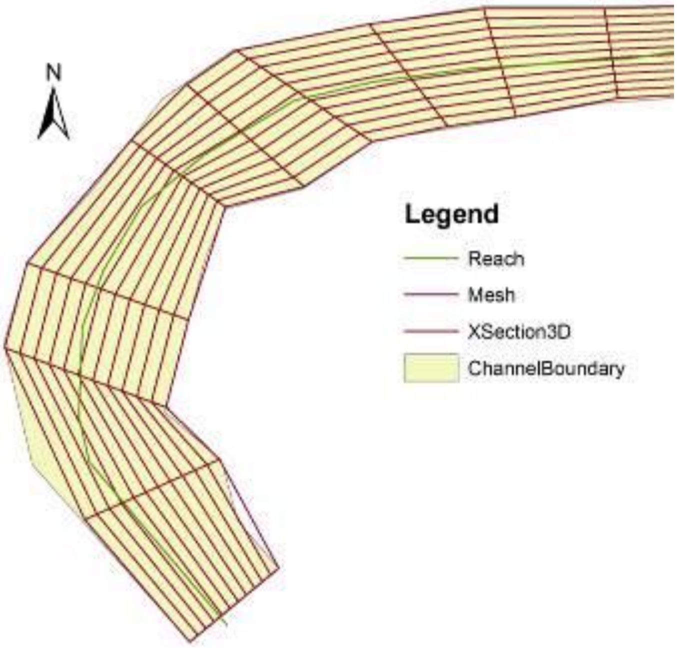


Figure 3.7 Mesh of the river cross sections.

After the creation of river bathymetry, it is combined with the 1/25000 scaled topographic maps and 1/5000 scaled topographic maps.

The 1/5000 scaled maps were not in digital format, so points values on this maps is digitized and used in ArcGIS. Examples of the maps are shown in figures 3.8 and 3.9. Red and green points represent the digitized points.

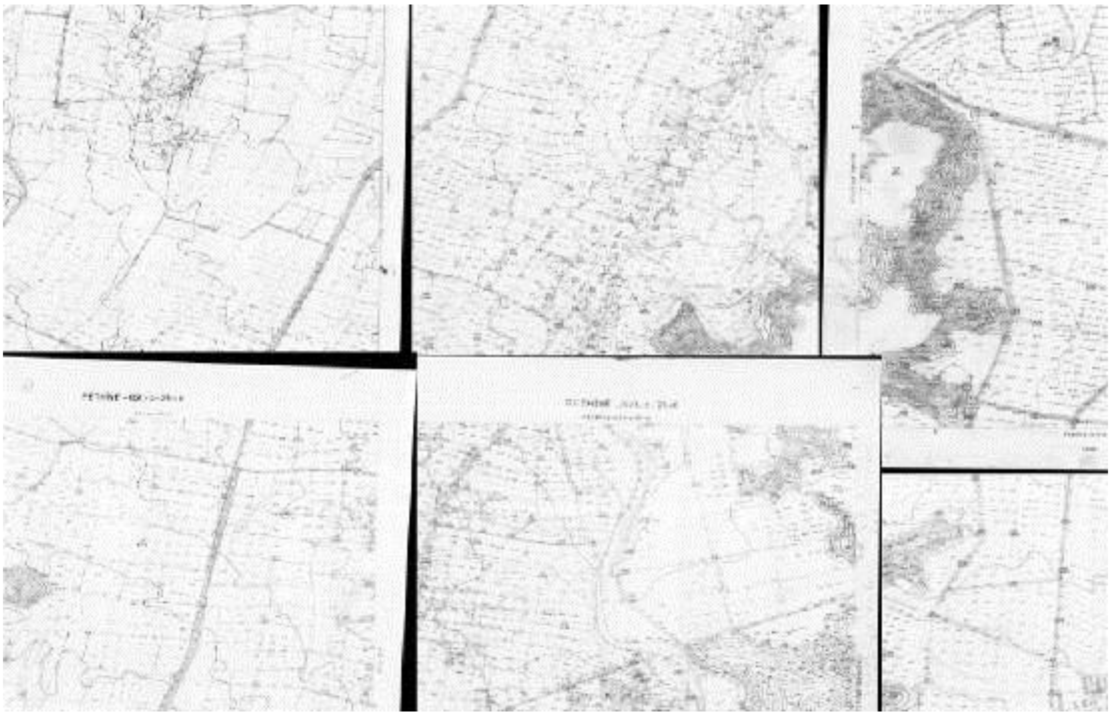


Figure3.8 Examples from 1/5000 scaled maps.

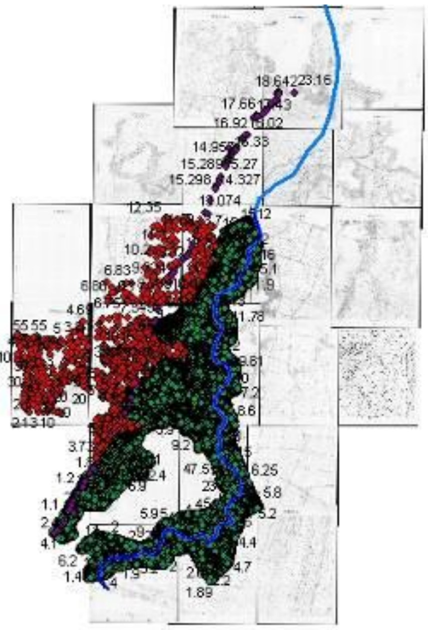


Figure 3.9 Digitizing results of 1/5000 scaled maps (green and red points digitized points).

After the combination of the maps, the z-values in the maps are used to form a continuous surface. 3D-analyst of ArcGIS is used to form a Triangulated Irregular Network (TIN). In modeling studies this generated TIN and Digital Elevation Model (DEM) which is generated from TIN are used. The TIN and raster are depicted in figure 3.10.

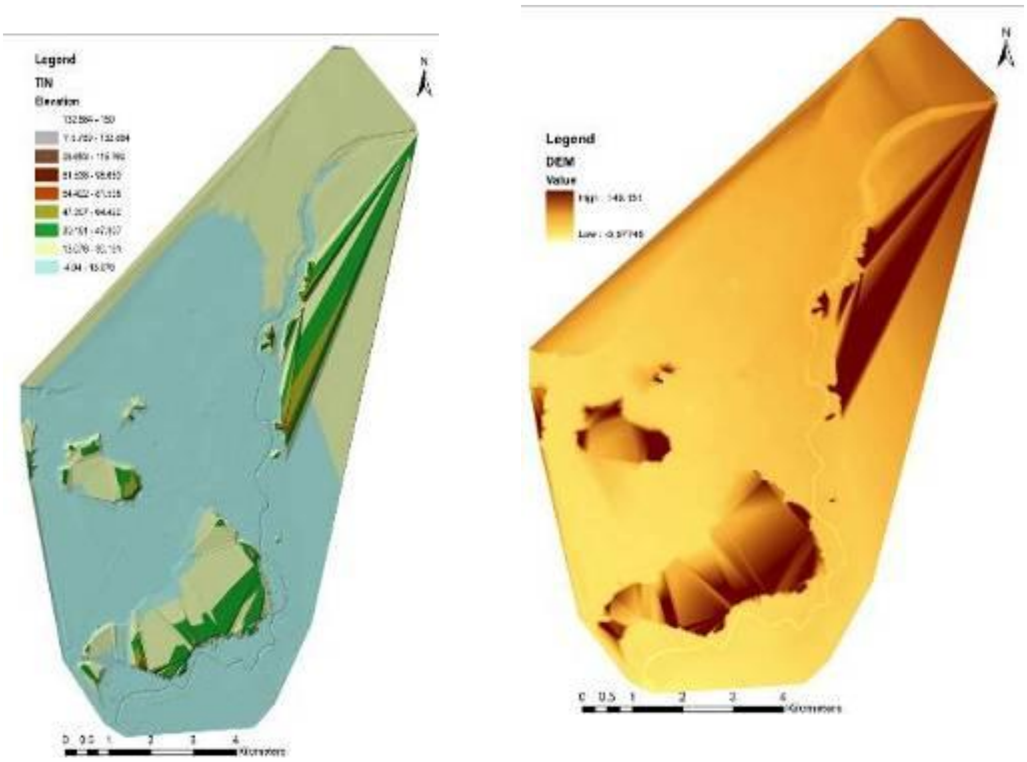


Figure 3.10 Generated TIN and Raster map for the flood plain.

3.2.6. Aspect and slope map

The slope (Figures 3.11 & 3.12) and aspect (Figure 3.13) maps of the basin which are the two important characteristics of the basin are determined from the DEM. When we look at Table 3.6, it can be seen that 83% of Dalaman plain has a slope less than 7 degrees and nearly 10% of the basin has slopes between 7 to 20 degrees. Steep regions (slopes more than 15 degrees) are accumulated around the stream branches (Figure 3.11 and 3.12).

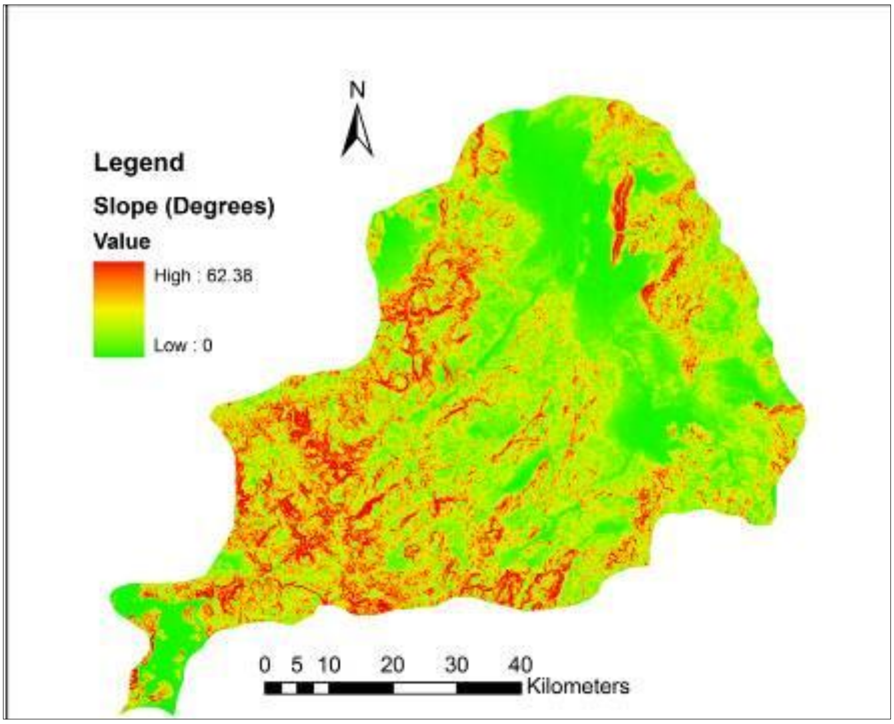


Figure 3.11 Slope map of basin

.

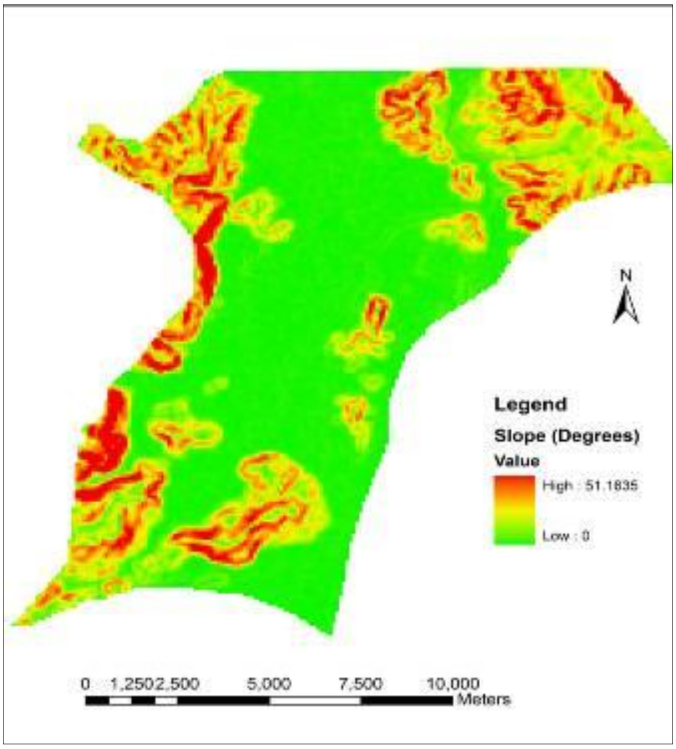


Figure 3.12 Slope map of flood plain

Table 3.6. Dalaman plain slope classes and their areas

Slope (degrees)	Area (%)
0 – 7.42	83.11
7.42-19.86	9.82
19.86 – 28.89	4.33
28.89 – 36.71	2.16
36.71 – 51.16	1.45
Total	**100.0**

Aspect classes which are an important characteristic for the snowmelt in the basin is given in table 3.7. As can be observed from the table 3.7, 10.38% of the basin faces north and 11% of the basin faces south. The portion of the basin facing west is 14.22% and facing east is 13.1%. The aspect map of the basin is given in figure 3.13.

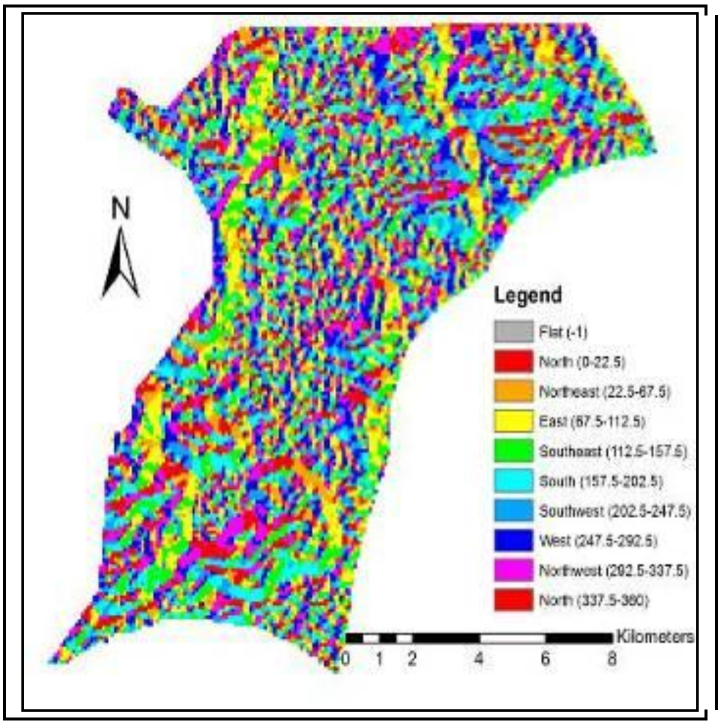


Figure 3.13 Aspect map of flood plain

Table 3.7. Dalaman plain aspect classes and their areas

Aspect	Area (%)
North (0 - 22.5)	3.26
Northeast (22.5 - 67.5)	11.13
East (67.5 - 112.5)	15.01
Southeast (112.5 - 157.5)	9.86
South (157.5 - 202.5)	12.99
Southwest (202.5 - 247.5)	11.55
West (247.5 - 292.5)	17.27
Northwest (292.5 - 337.5)	10.86
North (337.5 - 360)	7.07
Total	**100.0**

3.2.7. Digitizing the Houses and Land Parcels

The possibility of a flood is very dangerous to the houses and parcels as well as for the people in the region. The house locations can be retrieved from remote sensing data. For this reason, the Google Maps are used in order to digitize the houses and parcels in the region. The images belong to year 2009 summer season. In order to digitize the houses and parcels, a small application is used which is developed by Islem Company in Ankara. The name of the tool is called as ArctoGoogle. The tool is installed on Arc map and it directly imports the Google images to Arc map for digitizing. By this, houses and land parcels are digitized. Google map uses Landsat ETM+ Images with resolution 29.7 meters, also some other satellite images (Ikonos, Quickbird etc.) are being used.. Google map images are useful images which can be used for digitizing but Google maps have some positional accuracy errors. There are many articles (Potere 2008, Web 2011) related with positional accuracy of Google maps. In these articles, positional accuracy was investigated in terms of horizontal and vertical accuracy. The horizontal positional accuracy was found as 39.7 meters as an overall accuracy with a range of 0.4 to 171.6 meters. The image of the road and river on Google Maps is shown in figure 3.14. The locations of the villages Akıncı, Güzelyurt and Fevziye can be seen in the same figure. Also, the Dalaman International Airport can be seen on the lower right part of the figure. The digitizing operation is done one by one for the whole houses and parcels in the area. An example image of the digitizing is given in figures 3.15 and 3.16 below. The resulting images, digitized parcels and agricultural areas as well as roads and houses are depicted in the figures 3.17 to 3.20 respectively.

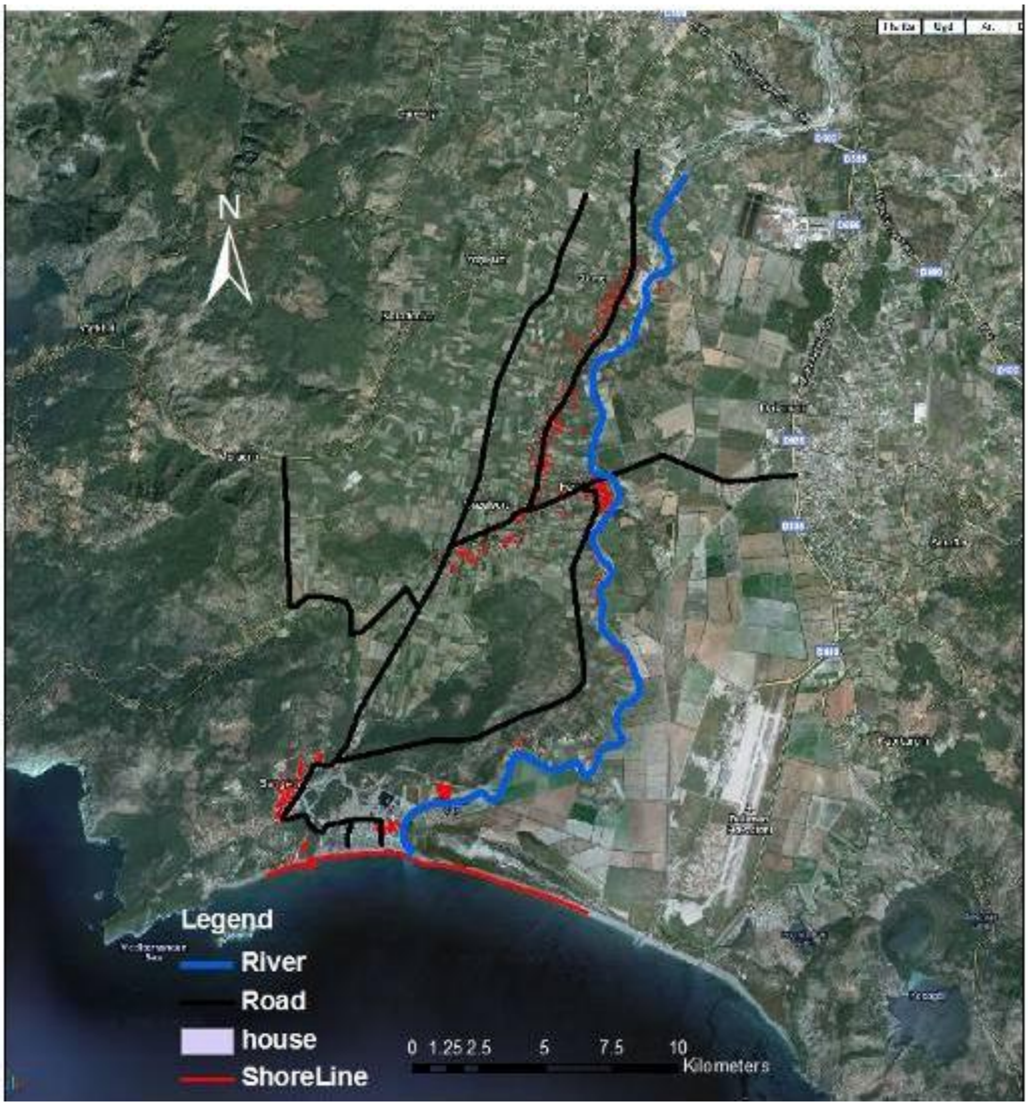


Figure 3.14 Layout of the area with Google

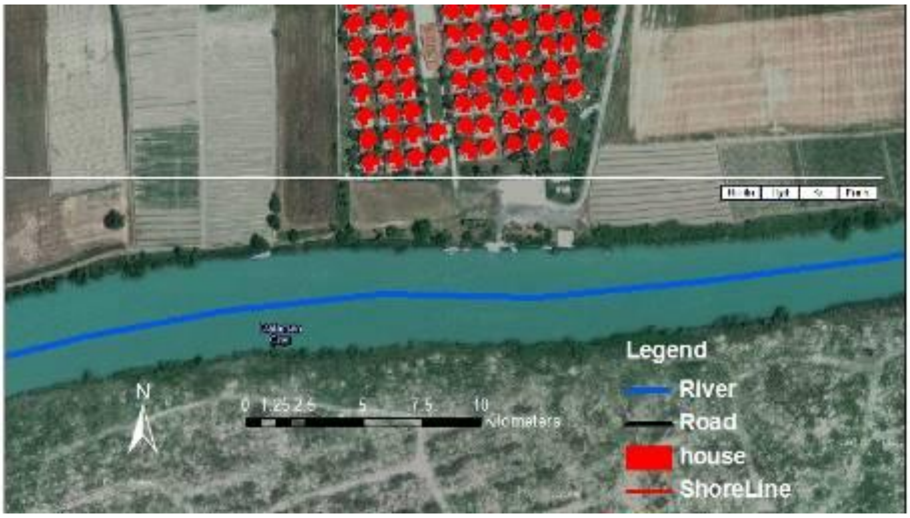


Figure 3.15 Digitizing example of the houses from Google (Akdeniz Houses)

Figure 3.16 Google view of the area with river and houses

The house data is transformed to point data for distance calculation (proximity) to river. The centroids of the polygons are assigned as the location of the points. An example of the point data is shown in figure 3.17.

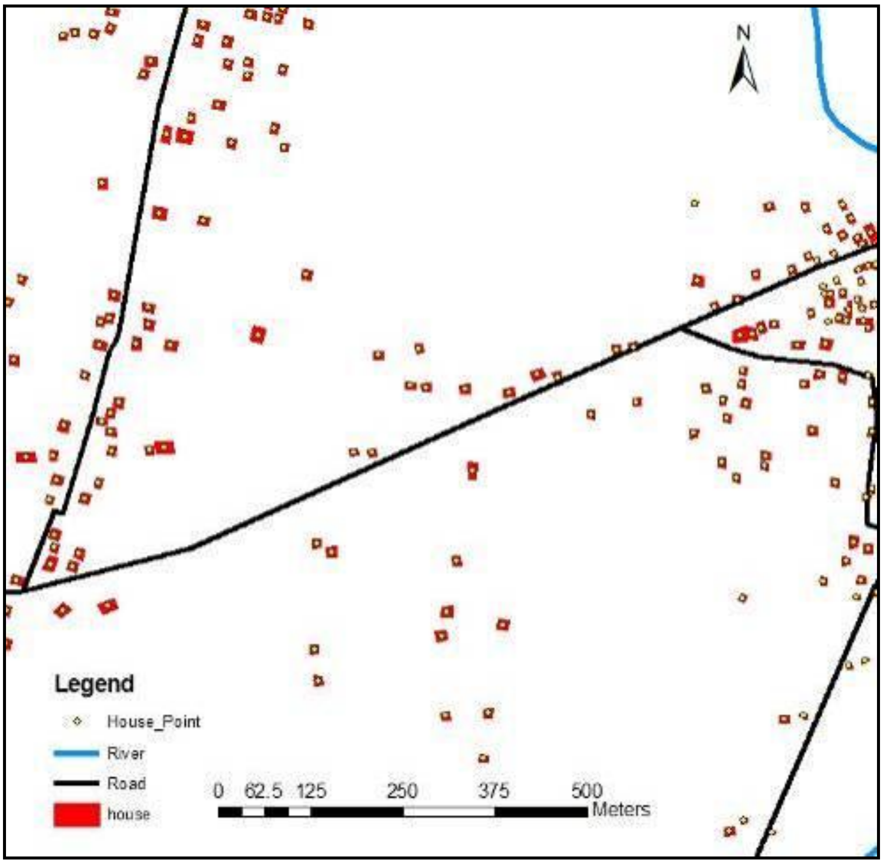


Figure 3.17 Point locations of houses

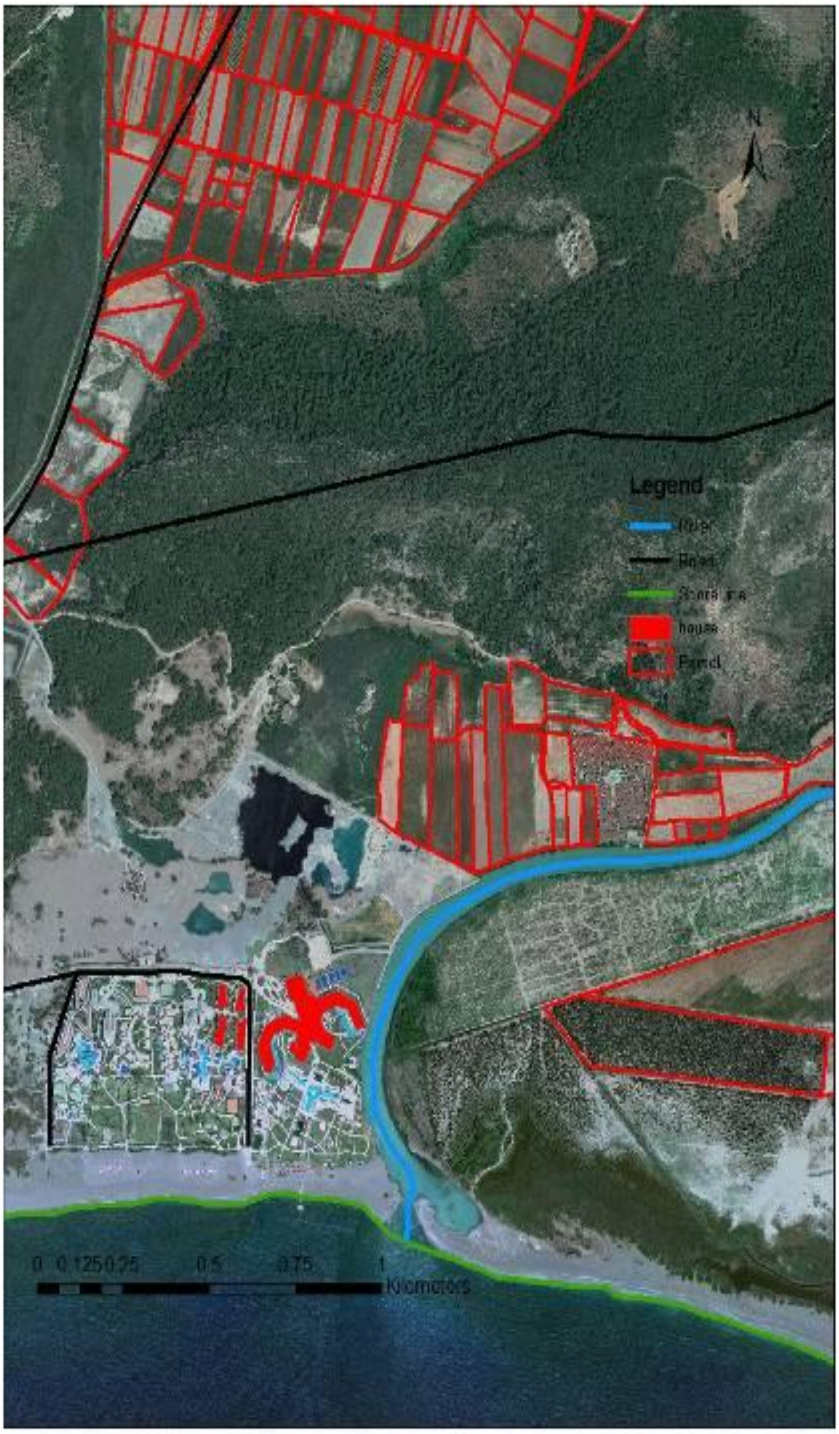


Figure 3.18 Agricultural parcels

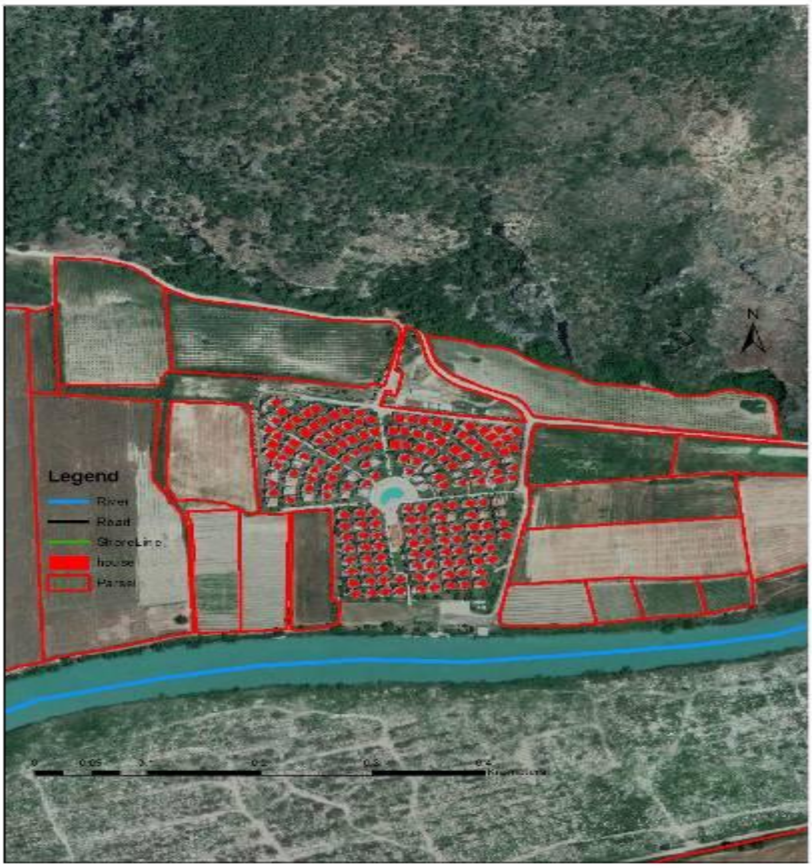


Figure 3.19 Akdeniz houses and their digitized polygons

The digitized parcels are covered with different type of agricultural products whereas some of them are empty. The trend for agricultural production in the region is that mostly long term plants such as orange, pomegranate etc. The reason for this is to earn more money on the same farm. When the farmers in the area recognized that long term plants have more benefit, the long term plants start to be more after the year 2001-2002. The agricultural pattern change is given in table 3.8. The long term plants are more resistant in terms of flood. In addition, if the season is dry, the flood has positive effects on production. On the other hand, flood can have negative effects on short term plants if the flood stays more than 2-3 days. So, the parcels are categorized into two regions such as long term and short term plant parcels. An example of categorization is shown in figure 3.20 and 3.21.

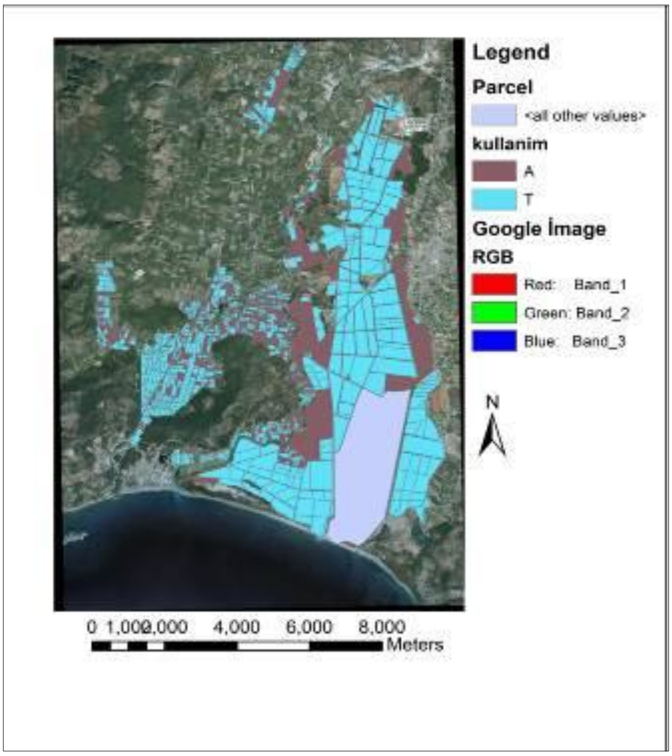


Figure 3.20 Digitized parcels and classification of parcels (A is for long-term, T is short term products)

Table 3.8 Agricultural pattern change in the region

Pattern	Old (Percentage)	New(Percentage)
Cereal	40	25
Corn	15	10
Citrus Fruits	25	27
Pomegranate	10	23
Green House	3	7
Other	7	8

According to the Turkish Statistics Organization (TİE), the population of the towns in the study area is shown in table 3.9 for the year 2008. This population is not valid for the summer season, because in summer this population increases 2-3 times with the relatives of the resident people. Also the population of the hotels in the region is not included in the table. The population of the hotels changes between 800-4500 persons. The sea coast and weather of the plain make this place very popular.

Table 3.9 Population of towns in 2008

Town	Population (person)
Guzelyurt	1691
Fevziye	906
Sarigerme	594
Akinci	618

Figure 3.21 Categorization of land use (Long-term and Short-term products)

3.2.8. Proximity to River and Road

The house data is used for the calculation of the distance of the houses to rivers and to roads. The river has a flooding potential and the houses which are near to the river is prone to more flooding. On the other hand, the roads can be used for moving away from the flood plain. So, both proximity to river and road is important data for the flood risk. The proximity bands for river and road are generated by forming the buffer regions from the river and road. The resulting maps are shown in figures 3.22 and 3.23

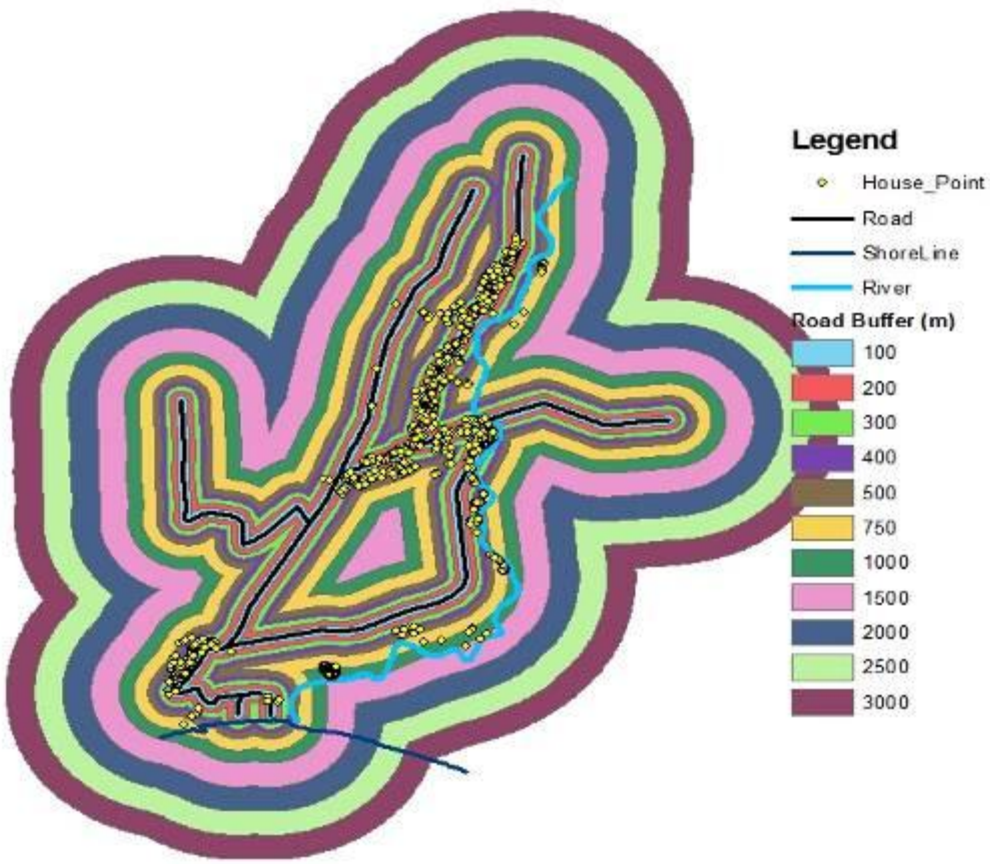


Figure 3.22 The Proximity of the houses to the river

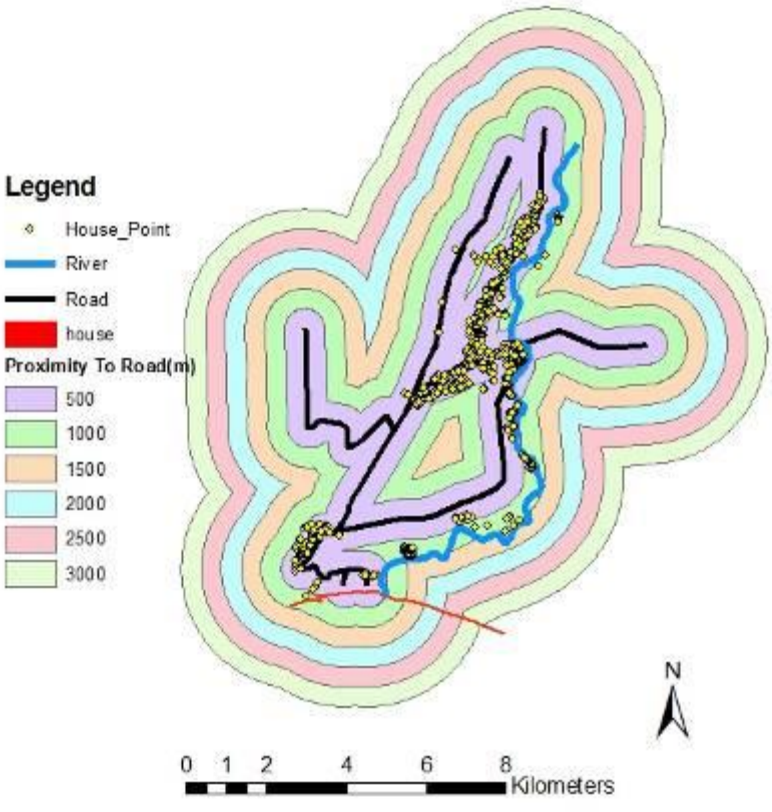


Figure 3.23 The Proximity of the houses to the road

3.2.9 Creating the 3D image of the study area

Arc scene is used in order to create the 3D image of the area. The building heights are assigned to each building. After then by using the created DEM as base layer (figure 3.24 (a)) and the heights of the buildings, the 3D image is formed as depicted in figure 3.24 (b and c)

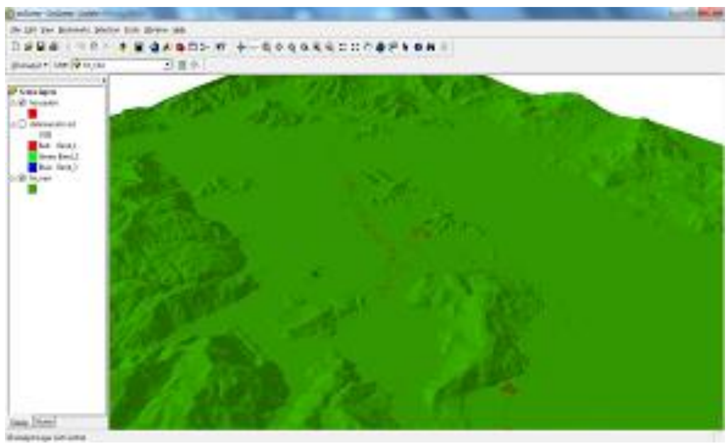


Figure 3.24 (a) DEM of the plain produced by ArcScene

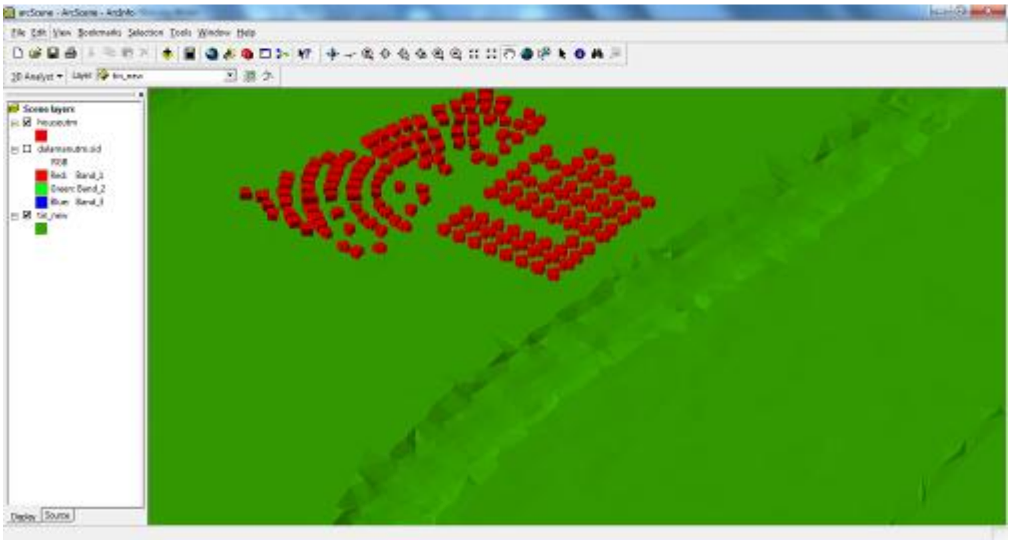


Figure 3.24 (b) 3D images of the study area with 3D buildings

Figure 3.24 (c) Google image of the Akdeniz Houses

3.3. Methodology used in this study

Flood risk is a combination of physical characteristics of flood event (extend, discharge, depth etc.) and its consequences. So, the definition of the flood risk explains the methodology of the study to some extent. In the first step, the physical characteristics of flood event should be calculated or determined. Observed discharge is one of the characteristics which can be directly measured on the field in a flood event. But generally, Turkey has sparse discharge measurement stations, generally, peak discharges or flood discharges are calculated by the help of a near station's discharge values. If there will be no measuring station nearby, discharges can be calculated by the help of rainfall-runoff model with the available meteorological data such as precipitation, temperature, evaporation etc. After having the discharges, the next step is to calculate the discharge exceeding probability (for different return periods). This can be done by the maximum recorded discharge values in the flooded areas or in the nearby stations. For steady flow state, only peak discharge values for different return periods are enough, but for unsteady flow state, the inflow hydrographs should be calculated. The return periods can be selected from 2.33 years to probable maximum flood case. Normally, from discharge values, the 1000 years return period discharge can be calculated, but after 1000 years, the peak discharge should be calculated with the meteorological data (precipitation).

After the peak discharges for different return periods are calculated, the next step is to calculate the water levels and water depths in the flood plain. This can be done with the help of hydraulic models. In the calculation of water depth, and water levels, several different models could be used. This can be 1D or 2D models depending on the physical characteristics of the study area and available data. In the calculation of water levels, cross sections could be used or terrain data (DEM) of the area could be included. When the calculated water level is combined with the land-use information of the area, the qualitative risk map is developed. If this map is combined with physical characteristics of the area such as height of the buildings, crop pattern, seasonal changes, population to obtain the damage, we obtain the quantitative flood risk maps. The flowchart of the methodology is also depicted in figure 3.25

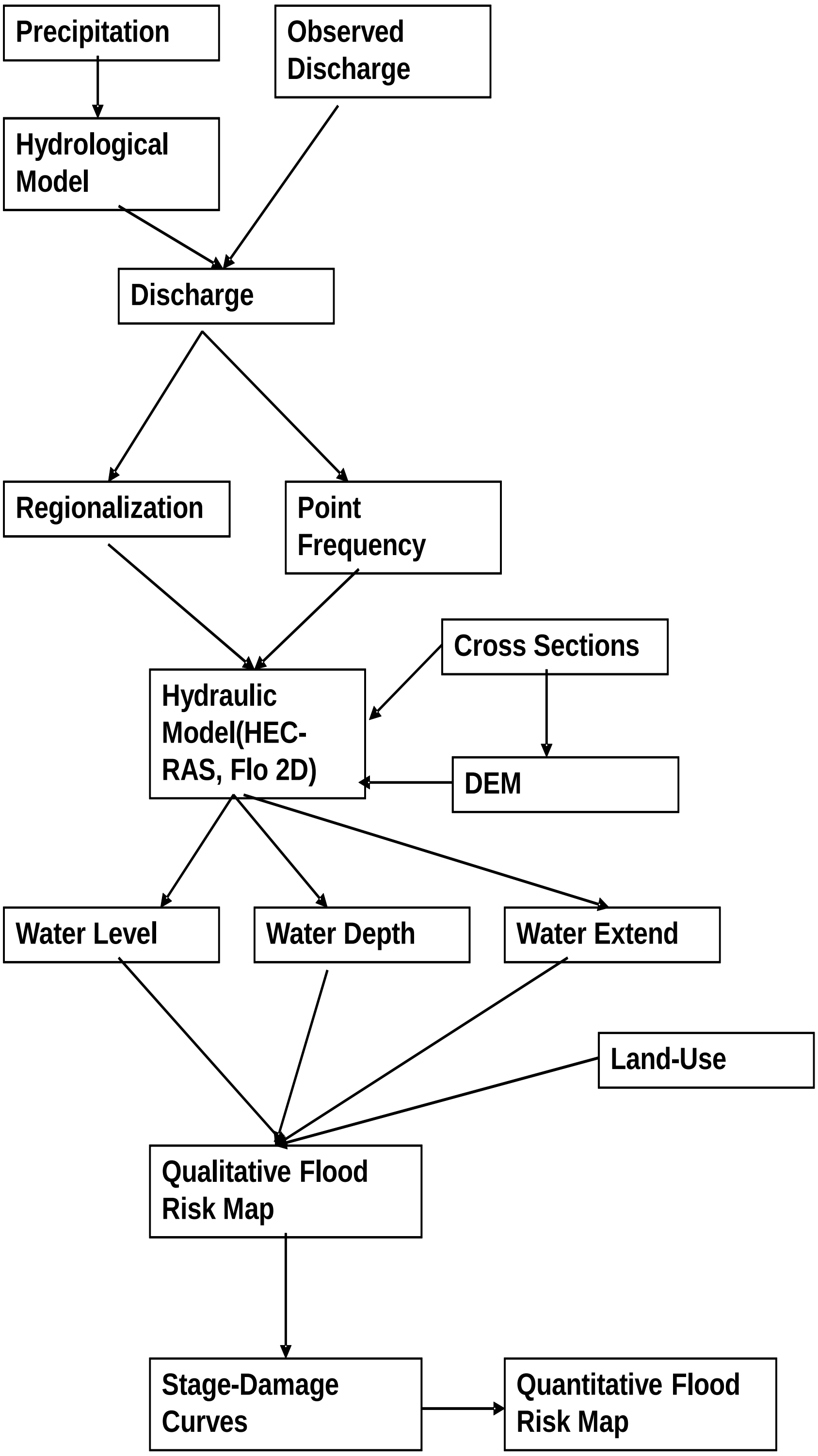


Figure 3.25 Flowchart diagram of methodology

CHAPTER 4

FLOOD FREQUENCY ANALYSIS AND FLOOD ROUTING

4.1 Flood Frequency Analysis

Probability of an event is used in the definition of risk. That is, flood inundation tendency needs to be analyzed to examine the flooding potential of the Dalaman basin. Flooding potential, that is to say probability of a flooding event can be calculated by the flood frequency analysis. The annual maximum discharge values of the study area can be used in this type of calculation. The data formed from the series arranged in descending order of value and probability (P) of each value being equal or exceeding in the related data. The return period is calculated by

$$T=1/P \qquad (4.1)$$

Simple best fitting curve method can be used for small return periods, but for large return periods theoretical probability distributions should be used. Some examples of these distributions are Normal (N), 2-parameter lognormal (LN2), 3-parameter lognormal (LN3), Pearson Type 3 (Gamma Type 3, PT3), log Pearson Type 3 (LPT3) and Gumbel (EV1).

In this study, necessary information was gathered from the maximum annual floods of the stream gauging station No: 0812 (See Figure 3.1). A total number of 10 stream gauging stations were installed to the project area in May 2010. However, the record lengths of these stations are very short and discharges measured at these stations are relatively small. That is why the flow data obtained from these stations were not taken into consideration. The drainage area of Station 0822 is 340 km^2. This station was opened on 01.06.1963 at a location shown in figure 4.1. The mean daily discharge of this station is 4.55 m^3/s. The Akköprü dam is on the downstream of the station location. The drainage area of the station (0812) is about 4954.8 km^2 and the drainage area of the dam location is about 5132.44 km^2. The maximum annual discharge values of the station are converted to the dam location values by the ratio obtained from their drainage area size. The flow data of this station submitted to the project team covers the period of water years, 1964-2008. To determine the observed frequencies, annual maximum discharges (Q) were sorted and ranked in increasing order. The probability of non-exceedence was then determined according to Weibull's plotting position. The computations are shown in Table 4.1

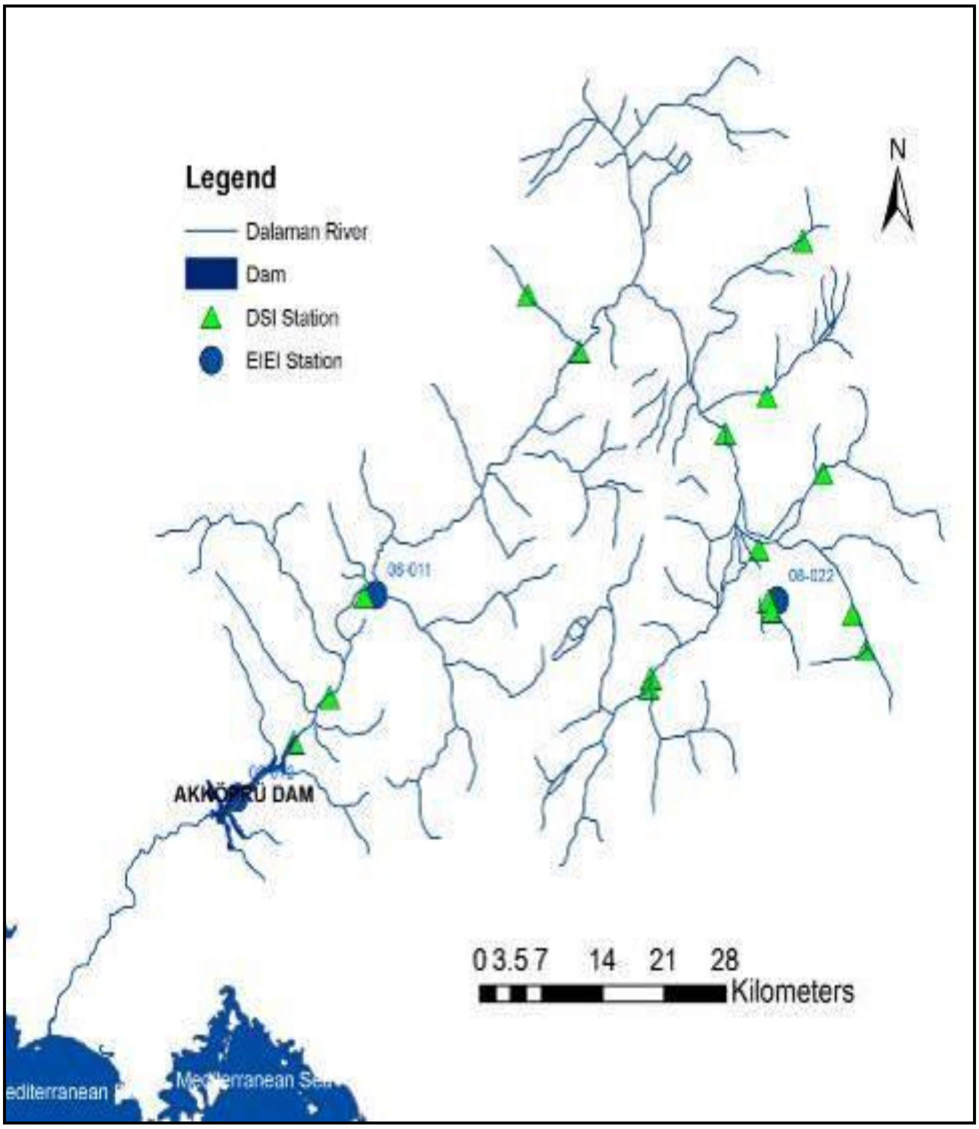


Figure 4.1 Stream gauging stations in Dalaman plain basin

Table 4.1 Frequency analysis of maximum annual flows

Rank	Water year	Q (m^3/s)	Sorted Q (m^3/s)
1	1964	249	162
2	1965	481	205
3	1966	731	227
4	1967	736	245
5	1968	720	249
6	1969	494	269
7	1970	786	289
8	1971	370	296
9	1972	372	370
10	1973	449	372
11	1974	162	400
12	1975	489	424
13	1976	595	445
14	1977	978	445
15	1978	568	449
16	1979	621	454
17	1980	1028	481
18	1981	1008	489
19	1982	1050	494
20	1983	424	562
21	1984	900	568
22	1985	626	595
23	1986	445	617
24	1987	658	621
25	1988	445	626
26	1989	702	644
27	1990	644	656
28	1991	205	658
29	1992	269	702
30	1993	227	720
31	1994	296	731
32	1995	913	736
33	1996	656	786
34	1997	617	900
35	1998	454	913
36	1999	*1128*	978
37	2000	400	1008
38	2001	289	1028
39	2002	562	1050
40	2003	245	*1128*

Statistical properties of the flow data given in Table 4.1 are presented in Table 4.2. As can be seen from Table 4.2, the linear skewness coefficient is about 0.685. This shows that the data is in acceptable limits. However, to be on the conservative side, an outlier test was not applied and all the data presented in Table 4.1 were taken into account in the frequency analysis.

Table 4.2 Statistical properties of the flow series

Number of years	40
Linear skewness coefficient	0.685
Logarithmic skewness coefficient	-0.454
Linear mean (m^3/s)	667.375
Linear standard deviation (m^3/s)	352.250
Logarithmic mean (m^3/s)	2.759
Logarithmic standard deviation (m^3/s)	0.252

In the frequency analysis, the following probability distributions, which are widely used in hydrologic analyses, were considered: N, LN2, LN3, Gamma Type 3, PT3, LPT3 and EV1. Kolmogorov-Smirnov test was applied for checking the goodness of each fit for significance levels ranging between 1% and 20%, in which cumulative non-exceedence probabilities were computed. No computations were carried out for PT3 distribution because of having greater skewness of the data. The results of the goodness tests are given in Table 4.3

Table 4.3 The results of goodness tests

Type of distribution	Significance levels				
	0.80	0.85	0.90	0.95	0.99
N	Accept	Accept	Accept	Accept	Accept
LN2	Accept	Accept	Accept	Accept	Accept
LN3	Accept	Accept	Accept	Accept	Accept
PT3 (Gamma Tip-3)	Accept	Accept	Accept	Accept	Accept
LPT3	Accept	Accept	Accept	Accept	Accept
EV1	Accept	Accept	Accept	Accept	Accept

To make a decision on the best distribution, the frequency, P(x), and the theoretical probability, F(x), of the data points were computed, and the absolute value of their difference is obtained as D_{max} for Kolmogorov Simirnov test. The probability distribution function giving the minimum value of D_{max} should be selected as the best distribution representing the annual flow series of the Station 0812. To this end, log Pearson Type 3 distribution was selected (See Table 4.3).

Using LPT3 distribution, the peak discharges of floods corresponding to various return periods were then obtained and presented in m^3/s units in table 4.5. These peak discharges were used in water surface profile computations, which are required for determining flood inundation maps of the basin. Since the record length of the aforementioned station is limited to only 40 years, it will not be reliable to carry out frequency computations for very long return periods. That is why the maximum return period is taken as 500 years in this study.

Table 4.4 The results of goodness tests for each distribution

Type of distribution	P(x)	F(x)	D_{max}
N	0.522	0.610	**0.087**
LN2	0.918	0.171	**0.089**
LN3	0.947	0.878	**0.069**
PT3 (Gamma Tip-3)	0.940	0.878	**0.062**
LPT3	0.518	0.463	**0.055**
EV1	0.925	0.878	**0.047**

Table 4.5 Peak discharges of floods for various return periods (m^3/s)

Distribution Type	**Q2**	**Q5**	**Q10**	**Q25**	**Q50**	**Q100**	**Q200**	**Q500**
N	707.108	1021.212	1185.430	1360.657	1473.632	1575.372	1668.155	1780.122
LN2	625.346	949.104	1180.441	1489.794	1730.998	1981.465	2241.348	2600.748
LN3	668.106	1000.632	1199.817	1434.075	1598.066	1755.115	1906.541	2100.325
PT3 (Gamma Tip-3)	664.766	1002.513	1204.333	1439.669	1602.767	1757.225	1904.909	2052.593
LPT3	636.033	1000.841	1238.880	1528.733	1735.285	1932.953	2123.196	2332.163
EV1	649.192	1019.835	1265.233	1575.294	1805.315	2033.637	2261.127	2561.256

The next step is to plot the flood hydrographs for different return periods. The calculated peak discharges is used in order to plot the unit hydrograph. There are different methods for plotting the unit hydrographs, but in this study SCS Dimensionless Unit Hydrograph which is the best known method for deriving synthetic unit hydrograph is used in this study (SCS, 1972). There are also other methods for plotting the unit hydrographs and some examples can be found in Web, 2010. The resulting hydrograph is depicted in figure 4.2.

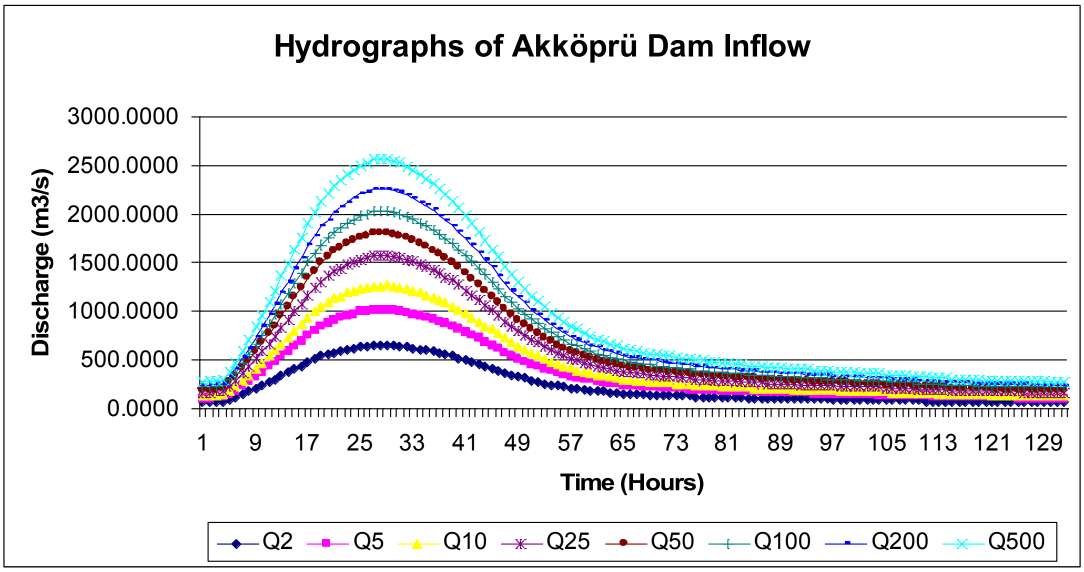


Figure 4.2 Unit hydrographs for different return periods.

The plotted unit hydrographs are used as an input to the Akköprü dam for calculating the peak discharges after flood routing from the dam. The characteristics of the dam were already given in chapter 3. The volume change with respect to height within the dam reservoir is depicted in figure 4.7. The dam has a flood volume of 60 hm^3 for reducing the impacts of a possible flood in the downstream.

The above hydrographs and peak flood values are calculated from the peak discharge values recorded in the study area. There are also different return periods above 500 years, such as 1000, 10000 and Probable Maximum Flood (PMF) discharge. In the calculation of these discharges mostly recorded precipitation values are used. The 1000 year return period of discharge can be calculated by extending the obtained distribution function graph for 500 year return period. For example PMF is calculated for the greatest depth of precipitation for a probable storm event. It is generally the combination of most critical hydrological and meteorological conditions over the basin. The calculation details of PMF can be found in Ozdemir (1978). In the calculation of PMF, precipitation values of Acıpayam, Dalaman and Gölhisar are used (figure 3.1).

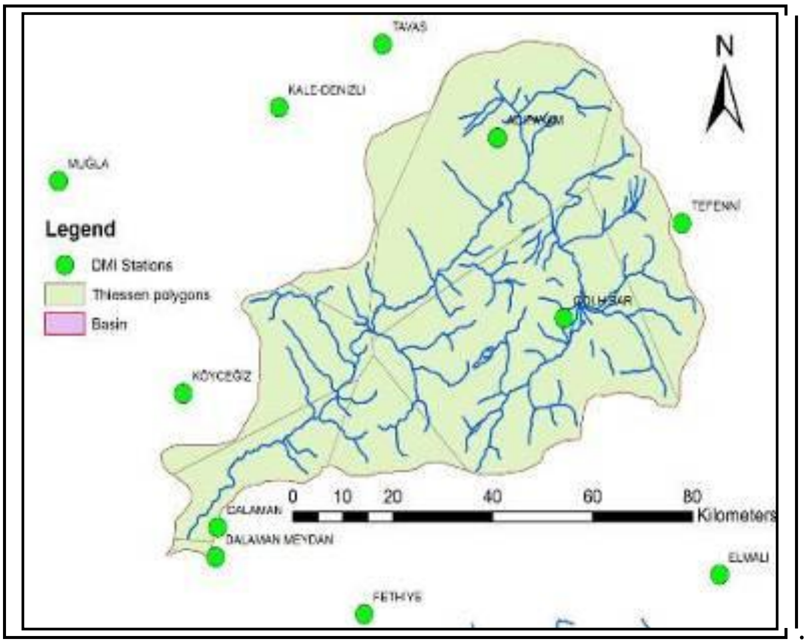


Figure 4.3 Thiessen polygons of the basin with DMI stations.

The calculated peak discharges is given in table 4.6, and unit hydrographs of these peak discharges are depicted in figure 4.4. In order to compare the peak discharges that were calculated before the construction of dam, Q1000 was compared. When we compare the two discharges, it can be said that peak discharges are increasing within the area, by being 2873 m3/s before.

Table 4.6 Peak discharge values for 1000, 10000 and PMF

Q1000 (m3/s)	Q10000 (m3/s)	PMF (m3/s)
3017.38	3683.51	5332.01

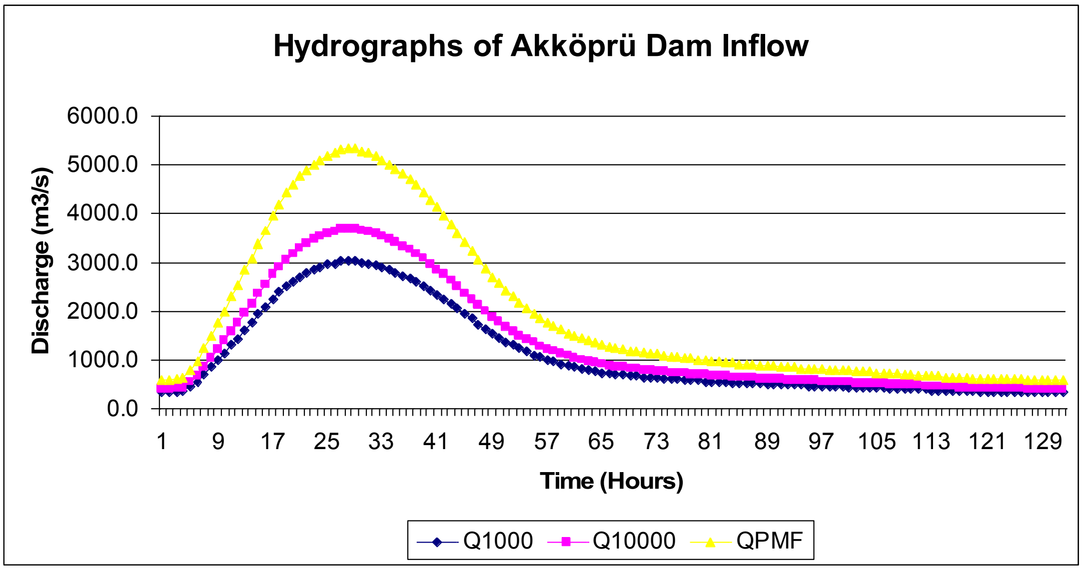


Figure 4.4 Input hydrographs for 1000, 10000 and PMF

The peak discharges and hydrographs are the inflow to the Akköprü dam in case of a flood event. The dam has a flood volume of 60 hm^3, so the inflow should be converted to the outflow by applying the flood routing at the dam body location with the dam's spillway characteristics. The calculation of the outflow is explained in the next section.

4.2 Flood Routing at Akköprü Dam

The calculated hydrographs above are the representation of a typical wave. The shape of the wave can change with respect to channel storage manning coefficient, and discharge. The change in the peaks of inflows and outflows is analyzed with flood routing. The idea is that the input will be equal to the output with a change in the peak and shift in the peak time. This type of change in the typical wave when entering the dam is called flood routing.

The passage of a flood hydrograph through a reservoir or a channel reach is gradually varied unsteady flow. If we consider some hydrologic system with input I(t), output O(t), and storage S(t), then the equation of continuity in hydrologic routing methods is the following:

$$I - O = dS/dt$$

In order to apply the flood routing techniques in this study, The height-area-volume curve is generated (figure 4.5). With this figure, it is easy to get information about the volume of the reservoir for every elevation change within the reservoir.

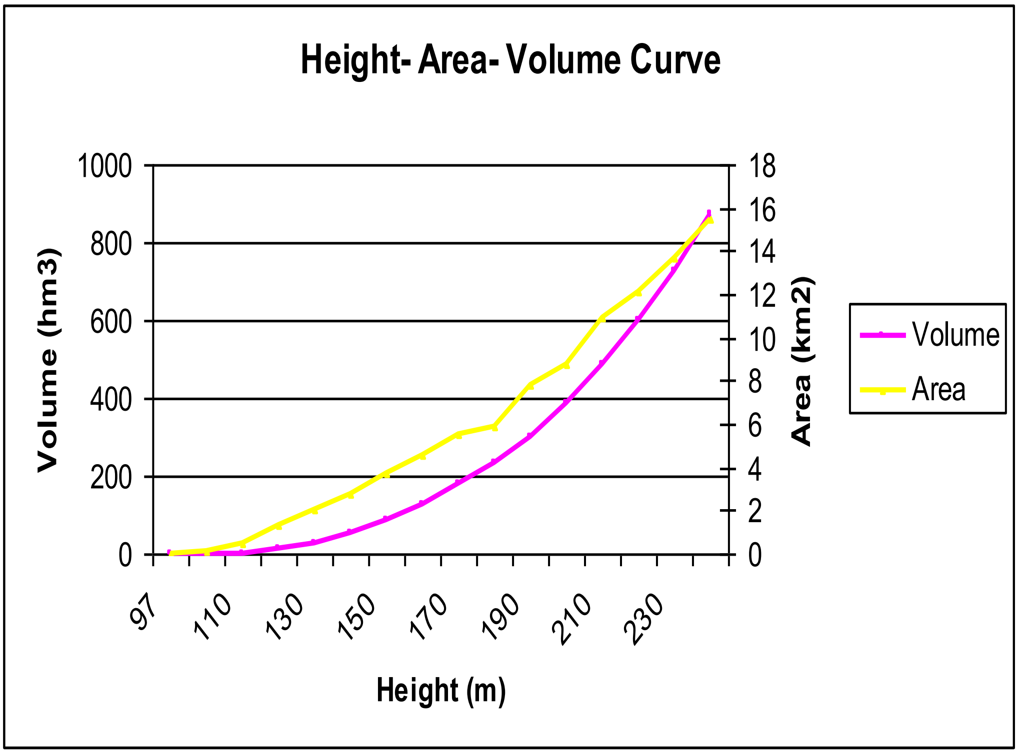


Figure 4.5 Height-Area-Volume curve of Akköprü dam.

In this study, a small macro is written in Microsoft Excel in order to calculate the result of flood routing by using the equations given above. The result of this calculation is given in table 4.7.

Table 4.7 Flood routing results

Return period	Inflow peak to the dam (m3/s)	Outflow peak from the dam (m3/s)	Percent Reduction (%)
Q2	664,8	132,5	80,07
Q5	1002,5	173,2	82,72
Q10	1204,3	189,7	84,25
Q25	1439,7	230,1	84,02
Q50	1602,8	430,5	73,14
Q100	1757,2	510,9	70,93
Q200	1904,9	743,2	60,98
Q500	2052,6	1017,8	50,41
Q1000	3017,4	1365,1	54,76
Q10000	3683,5	1593,4	56,74
QPMF	5332	2436,9	54,3

The above calculated outflow hydrographs are a result of flood routing. The flood volume existing in the dam is one of the main effective elements to reduce the inflow to the dam. When the maximum recorded discharges in the basin are analyzed, it can be seen that the maximum peak arrived to the station 08-12 is in 1998 and corresponds to 452 year return period. So, the above return period was not seen and the acceptability of these values is not known. As regards to the acceptability of these values there are some studies showing the upper and lower confidence limits for each return period (Adamowski 1985, Arora and singh 1989, Arora and RAO 1985).

CHAPTER 5

HYDRAULIC MODELING

5.1 1D Hydraulic Modeling (HEC-RAS)

In Turkey, floods generally occur due to heavy rainfall in coastal areas of northern, southern and western parts of Anatolia or on account of a sudden increase in air temperature, resulting in snow melt in the eastern and mountainous part of Southeastern Anatolia. In the northern and central parts of the country, both factors may prevail depending on the time of the year. In addition, there are other important factors which have to be considered during flood assessment. These are the factors reducing the flood plain capacity, artificially decreasing the available safe wetted area, and increasing the devastation effect of the floods; and the ones of the unauthorized use of the flood plains by construction of local barriers and settlements, construction of inappropriate bridges, culverts, and creating new agricultural plots, as in the case of the Izmir flood disaster in 1995. This is very common application, however, especially in fertile river flood plains.

In the process of preparation of development plans for the municipalities, DSI is the main executive governmental organization that is responsible for identifying the floodplain. Investigations for flood risk of planning areas are conducted in order to be used as data for preparatory period of planning. These investigations are realized considering the demands come from municipalities or other related public agencies. They are also done for the circumstances whereby the location of settlements depends on an upper scale municipal plan or on wider extent regional plans. The results of these investigations are presented to demanding organizations and institutions. (Keskin and Darama, 2008)

Generally, DSI uses a discharge of 500 year return period for the floodplain delineation in case of dense settlements in downstream. Identification of real flood risk is not so easy in traditional methods since real dynamism of the river basin cannot be shown due to limitations in these methods.

Estimation of flood inundation and its risk is increasingly a major task in relevant national and local government bodies world-wide. When river flow depth is reached in a flood event, water ceases to be contained solely in the main river channel and water spreads onto adjacent floodplains. This consists of a 1D hydraulic routing procedure for channel flow, 2D or 3D over floodplain to enable simulation of flood water depth and hence inundation extent. These make the flood prediction a very complex process in both spatial and temporal contexts. Traditional engineering methods are not easy to apply, and visual representation of the plan for a catchment is very simple.

These problems can be partially overcome by the integration of a hydraulic modeling tool such as HEC-RAS with GIS. Thus the outputs from model can be used in GIS along with other spatial data for analysis and visualization. Incorporating HEC-RAS's capabilities with a GIS allow for analysis of the full impacts on flood extents, flood depths. Flood damage assessment from a cost/benefit analysis can also be linked to an optimization module with a graphical user interface (GUI). At all stages of the integrated process model results can be presented to decision-makers in a clear and easily understandable formats. (Keskin and Darama,2008)

In this section, the flood zones that are under risk will be identified and beneficiaries of which new houses will be supplied will be selected. The settlement areas in the flood inundation areas were classified by its flooding risk using HEC-RAS where HEC-RAS simulations were performed to generate water surface profile throughout the system. Flood plain zones for the several design storms were reproduced in 3D with HEC-GeoRAS by integrating the terrain model for the area with the corresponding water surface level. At the end of the study, three different zones are generated as the level of flood risk.

5.1.1. HEC-RAS Modeling

The model package "River Analysis System" (RAS) developed by the US Army Corps of Engineers – Hydrologic Engineering Center (HEC) includes (USACE,1997,2001,2005) :

- A steady flow model
- An unsteady flow model
- The consideration of a wide range of hydraulic structures
- Structures for hydraulic design such as computation of localized scour at the bridge piers. Because of the capability of defining wide range of physical processes it has proven very helpful in supporting all phases of flood management. The description is given in (USACE, 1997, 2001, 2005). The water levels are determined from one cross-section to the other by using the energy equation (Eq. 1) with iterative procedure.

$$Y_2 + Z_2 + \frac{\alpha_2 V_2^2}{2g} = Y_1 + Z_1 + \frac{\alpha_1 V_1^2}{2g} + h_e \qquad \text{(Eq. 5.1)}$$

Where;

Y_1,Y_2 : Depth of water at cross sections

Z_1,Z_2 : Elevation of the main channel inverts

V_1,V_2 : Average velocities

a_1,a_2 : Velocity weighting coefficients

g : Gravitational acceleration

h_e : Energy loss head

In flood simulations with HEC-RAS the following input data are required:

- channel geometry;
- Boundary conditions;
- Tributary inflows if any; and
- Manning roughness coefficient.

The output data is the water level for each cross-section which was found after flood routing process.

HEC-RAS is developed for 1D hydraulic river analysis. In previous versions it is called as HEC-2, but after new additions to the program and new interface to HEC-2 formed the basis of HEC-RAS. Other than the hydraulic routing, HEC-RAS could perform sediment transport and water quality modeling. In the basic form of HEC-RAS, four types of files are needed which are a project file (".prj"), geometric file (".g01"), flow file (either ".f01" for steady or ".f01" for steady flow) and a plan file (".p01"). There may be many geometry, flow and plan files to select from to perform hydraulic computations for each project file. The ability to use various geometry, flow and plan files help to perform several different scenarios with the available data.

In order to calculate an inundation map with HEC-RAS, several different geometries are needed such as river centerlines, cross sections, bank lines and flow path lines. River centerlines represent the centerline of flow for the flow level within the river banks. In digitizing or input of river centerline, river flow direction is also assigned. In order to perform a hydraulic routing, cross sections are needed. These cross sections not only represent the channel through which flow is passed, but also describe the friction factors that HEC-RAS uses in modeling. The two bank lines (left and right) for a given river reach define the main channel and the right and left overbank areas which also defines the river bed (bathymetry) and flood plain (inundation). The three flow path lines (main, left and right) for a given river reach define the centerline of the flow path and the flow path lengths within the main channel and left and right overbank areas. As mentioned above, cross sections define the friction within the river, but it is not enough alone. The manning's coefficients (n values) are needed in order to define the friction along the cross sections and within the river. Cross sections can be used alone for defining the river geometry, but in order to get a continous flood inundation map, continuous surface must be given to the model. The generation of continuous model is explained in chapter 3.

One of the main inputs for HEC-RAS model is the river cross section. The cross section survey was done at different intervals ranging between 250 to 890 meters which sometimes extent up to 3 km each side of the river bank. About 59 cross-sections of the river were used for the modeling. To reduce the big transformation effect from one cross section to another, cross section data was converted to as 20 meter intervals. This decreases the number of critical points in the longitudinal cross-section because of the smoothened passing from one cross section to another. The acquired cross sections were transferred to HEC-GeoRAS program for the modeling as 3D. The obtained model is shown in figure 5.1.

In the previous versions of HEC-RAS (HEC2), cross sections and other geometric data are given to the model as an input file generated in DOS (ASCII) format. But with the HEC-RAS new versions, in order to generate the geometric files and viewing the resulting maps from HEC-RAS, the software package HEC-GeoRAS was created.

HEC-GeoRAS is a functional toolbar added to ArcGIS program and can be downloaded free from the HEC website (www.hec.usace.army.mil/software/hec-ras). HEC-GeoRAS eases to input the geometric files and store the input and output files as GIS files. The geometric layers are added in ArcGIS and exported to HEC-RAS for hydraulic modeling. Then the result of hydraulic modeling is also imported to GIS format in order to analyze and show the water surface extents, velocity grids, and depth grids. If continous surfaces are used in GIS layers such as a DEM, then the river path, cross sections, bank lines are created easily. Then the resulting maps created after hydraulic modeling can be easily shown on DEM or satellite imagery for representation. An example image of the study area with the cross sections and river is depicted in figure 5.1.

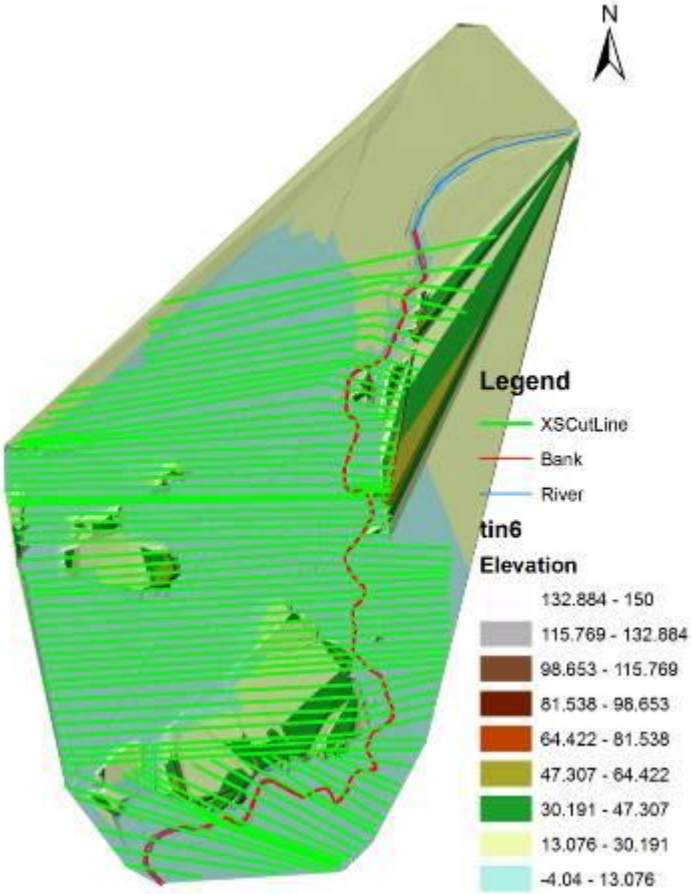


Figure 5.1 HEC-GeoRAS layout of the study area

5.1.2 Model calibration process

The model was calibrated by taking the constructed cross-sectional model and the computed backwater water levels were calibrated by comparing them with observed water levels for various flows. The key parameter that was adjusted in the calibration phase is the hydraulic roughness or Manning's "n" of the cross section to enable a match between observed and computed water surface profiles for a given flow event. Roughness coefficients are an indication of the relative channel roughness. Channel roughness is considered for calculating frictional energy loss between cross sections. If the model does not calibrate with a reasonable roughness factor, the model is reviewed to determine whether there are errors in the construct of the model such as the physical cross sections or in the observed data that is being used to calibrate the model. The 1998 dataset was critical to model calibration and reviewed previously to determine whether there were any anomalies with the data.

The hydraulic roughness of the cross section is not typically uniform across the cross section. For flows that are contained within the normal summer channel cross section, the channel roughness is typically defined as one value. In the case of the floodway channel the “n” value for bank full conditions has been determined to be around 0.039. The resistance parameter which is known to vary with water level, decreasing with increasing water level by decreasing the effective relative roughness, and then increasing again as the flow spills over bank, since floodplain roughness is usually higher than the channel roughness (Chow, 1959). So floodplain “n” value is taken as bigger than the river bed. Several simulations were done for calibration. As there will be varying hydraulic roughness or “n” values depending on the conveyance area of the cross section, the model was initially calibrated for flows in the 500 m^3/s to 1000 m^3/s range. This range defines flows just above normal summer stage. The discharge value that was used for modeling in HEC-RAS is 1350 m^3/s which corresponds to a value more than 100 year return period discharge.

Boundary conditions must be defined to make the model produce accurate results. The downstream of the river is discharging to the sea, so the downstream end boundary condition for the river is given as high sea level (2,5 meters). The upstream boundary condition is given as the slope of the river bed where there is no other known value. HEC-RAS model was run for ‘mixed flow regime’, ‘known water level’ as the downstream boundary conditions and “known slope” for the upstream boundary condition. An example cross section is shown in figure 5.2. with 100 year discharge occurrence.

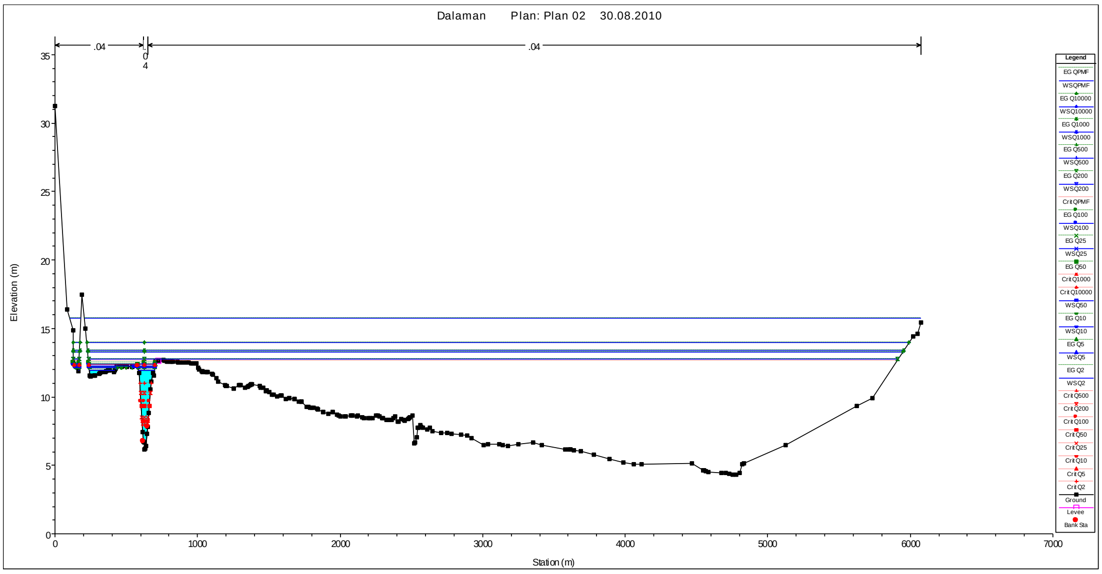


Figure 5.2 Example cross section of the study area (Km 10+645.29)

5.1.3 Flood risk mapping

Cross-sections were extracted at 59 locations to accurately simulate the hydraulic characteristics and to delineate the floodplains. Figure 5.3 shows the HEC-RAS scheme of the imported river network. For 500 year return period, the flood extend was computed using water levels for the given discharge were estimated by developing stage discharge relationships at several locations. The effect of the bridges was included by applying several reduction scenarios that could happen in a flood event. Flood hazard mapping was developed by transferring the results of HEC-RAS to the digital elevation model. In the previous versions of HEC-RAS, the water surface profile data and cross-section data from HEC-RAS were exported as a GIS file using HEC-GeoRAS. Floodplain polygons were created from the intersection of water surface and terrain surface. But in newer versions of HEC-RAS, a new module Ras Mapper is added to form the inundation mapping in the program without the help of ArcGIS. The extent of 500 year return period flood is shown in figure 5.4. Floodplain delineation for each scenario was performed resulting in an inundation depth grid and floodplain polygon. The polygon can be used as boundary region and inundation depth can be used for the determination of the real flood risk. It may also seen that the extent of flood is wider in upper part of the study reach as compared to lower reach due to variation in channel geometry and reduction in slope of the area.

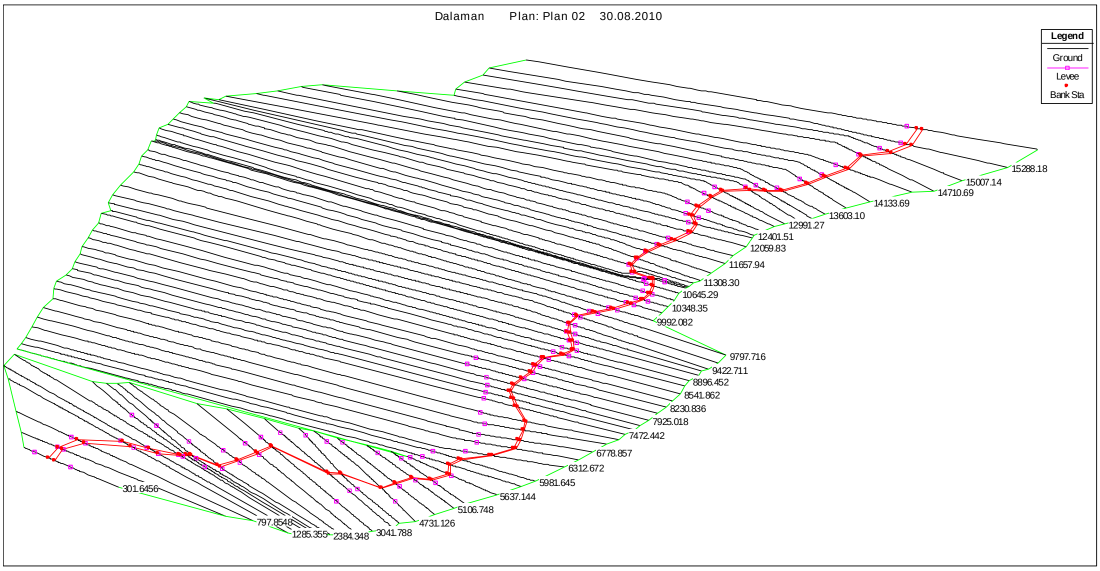


Figure 5.3 HEC-RAS scheme of the imported river network

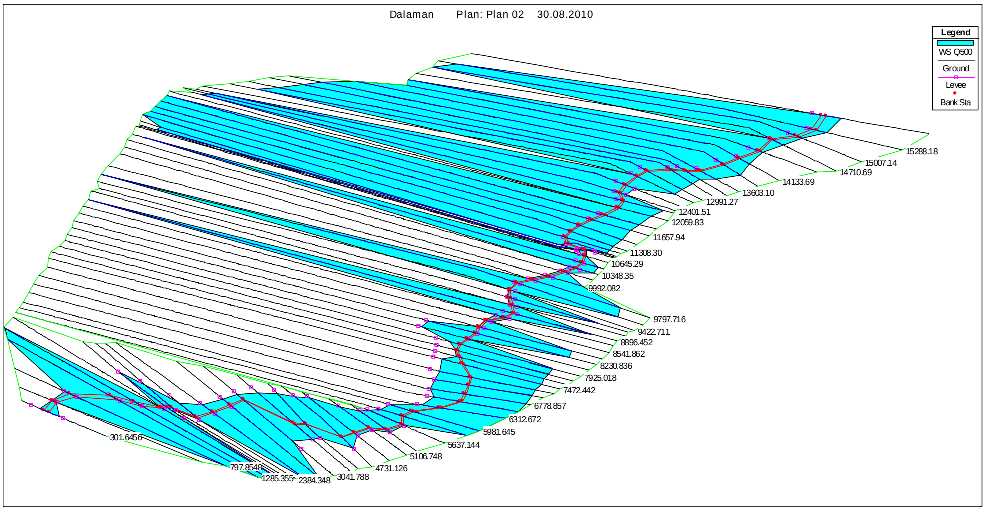


Figure 5.4 Extent of 500 year return period flood

5.2 2D Hydraulic modeling (FLO-2D)

In the previous section, the results of a 1D hydraulic model were depicted. In some areas where the flow is not one dimensional, 1D model is not enough to model the study area. In this type of study area, 2D models which include the two dimensional flow equation and wave motion can be used. To define the flow direction and inundation, a two–dimensional hydraulic model named as FLO-2D model (O'Brein et al., 1993) was applied in the study.

In two dimensional models, flow velocity and direction can be extracted. The flow velocity with the flow depth can give the information about the vulnerability of the buildings and also it can help to predict the resulting damage.

FLO-2D is a two dimensional finite difference model that simulates clear water, flood hazards, mud flows, and debris flows. The objective of this model is to estimate the probable range of flow properties in terms of velocity and depth to predict a reasonable area of inundation (O'Brein et. al., 1993). In the calibration process, the 1998 event is used same with the HEC-RAS model.

Two-dimensional governing equations include the continuity equation and the equation of motion. For the application of equations, a finite difference model was used. More details about the algorithm and the implementation can be found in FLO-2D user manual 2003. In order to start a simulation, DEM and inflow hydrograph must be defined correctly. In addition to these, data channel geometry, study region limits (coordinates), if available land-use shape files and tables and floodplain roughness of Manning's Roughness (n-value)which is a must are required. By using the flow depth, the discharge flow was routed through the grid system. For each grid element and time step, the discharge across each of the four boundaries was computed and summed. The resultant volume change is uniformly distributed over the available flow area in the element (O'Brein et al., 1993). At each time step, the model computes the change in water.

The FLO-2D software package includes a Grid Developer System (GDS) program that overlays a grid system on a set of random digital terrain model (DTM) points and that interpolates and assigns elevations to grid elements. Then, the shape file slide boundary was imported to the system and the simulation area (computational domain) for the FLO-2D model was determined based on this boundary. The elevation data was interpolated and FLO-2D grid element elevations were assigned to each grid cells. The Manning's roughness (n value) is assigned as the same values for HEC-RAS modeling.

After the determination of outflow nodes, the FLO-2D simulated the flooding by routing the flood hydrograph. With the strategy of conservation of volume in the system, the flow depths and velocities were predicted for every grid element in eight potential flow directions for a time step in the order of seconds (Garcia et al., 2004).

FLO-2D have a module named as MAPPER that can process and show water depth and velocity files that can be imported, which graphically displays the output such as maximum flow depth and velocity contours to assist in the interpretation of the results. For each cell of the analyzed data, FLO-2D returns volume, water velocity, discharge amount and water depth during all times in the simulation.

The flowchart for FLO-2D modeling is also given in figure 5.12

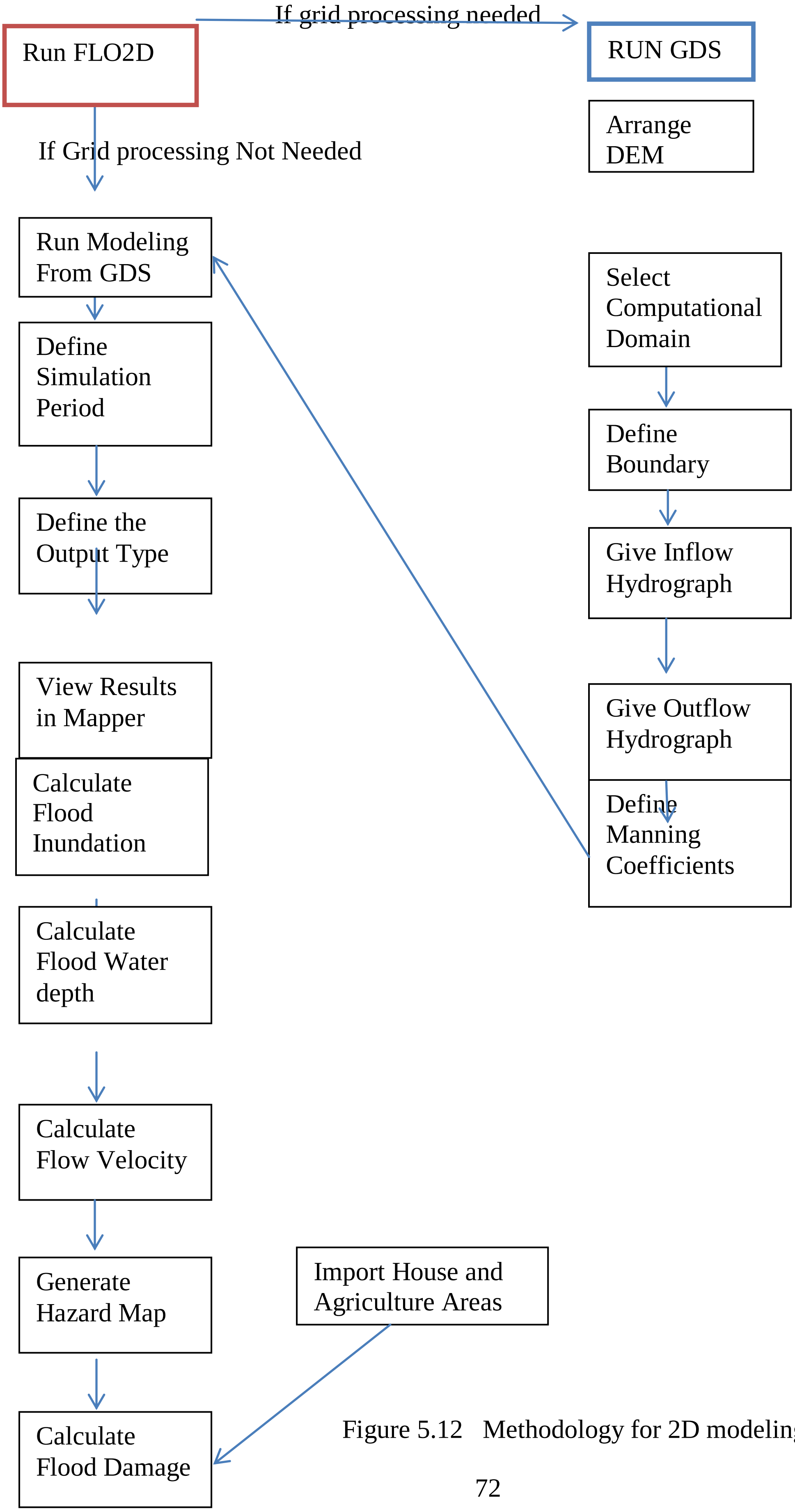


Figure 5.12 Methodology for 2D modeling

5.2.1 Calibration and Validation of the model

Calibration of the hydraulic model is the most important issue in modeling. Without calibration the results will be misleading. The flood event in 2001 is used for calibration process. In this event the location of the Akdeniz Houses which are near the sea (near Hilton Hotel) is the most known location that can be used for calibration process. From the interviews with the local people, it is understood that the water level at Akdeniz Houses is about 2.50 meters high. A discharge value for 500 year return period is used for calibration. And the sea level which is about 2.50 meters is given for the downstream boundary condition. The water level from the 1D model is used for the upstream boundary condition. After the calibration process, the simulations for 25,50,100 and 1000 years return period is done and the resulting values after calibration process is depicted in table 5.1

Table 5.1 Water depth at Akdeniz Houses location after calibration process

Return Period (Years)	Water Depth (meters)
25	-
50	-
100	1.10
500	2.45
1000	3.15

The calibration process is not done just for Akdeni Houses water depth but it is also done by comparing the inundation area of two events of which one of them is the inundation area for 2001 flood event and one of them from the simulation of 500 year return period discharge. The resulting inundation area is depicted in figure 5.13 and results showed that the simulation area is about 7,23% greater than the 2001 flood event area.

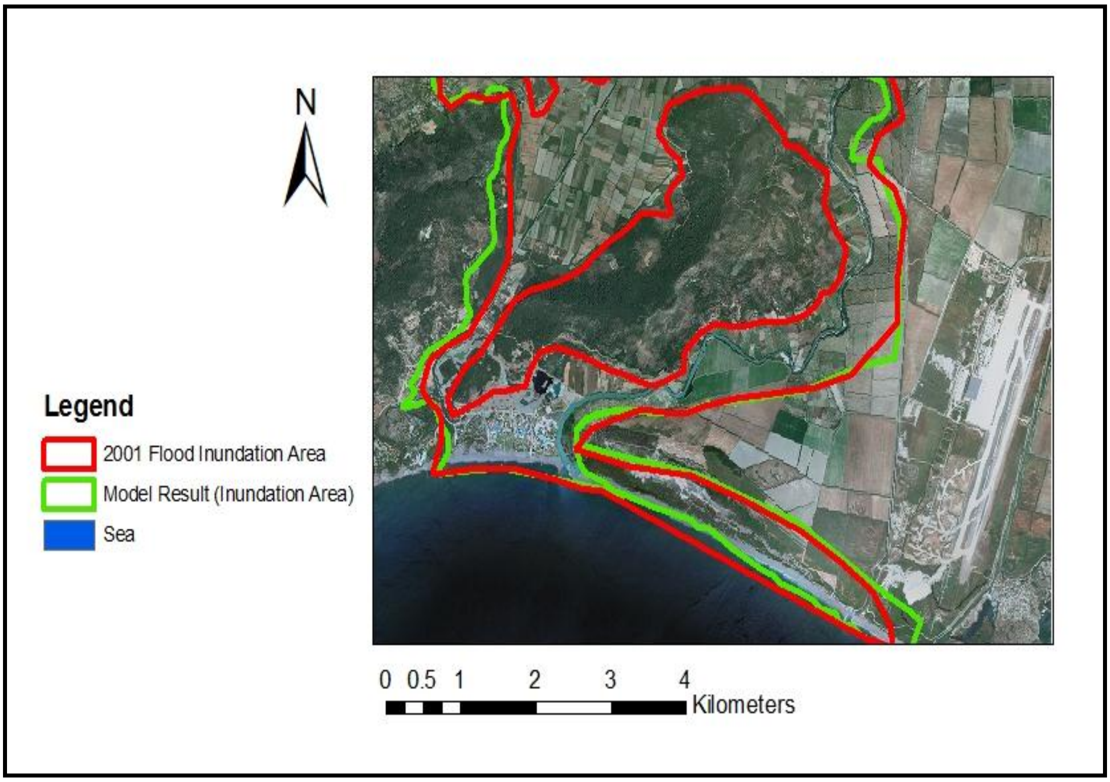


Figure 5.13 Inundation areas for the 2001 event and simulation

5.2.2 Effect of Grid resolution on flood mapping

In this section, different DEM resolutions have been studied in order to analyze the effect of the resolution on flood inundation. Many model studies have been performed on this subject.

An example is the study (Haile and Rientjes, 2005) with 1D and 2D SOBEK model with 7.5 m, 12.5 m, and 15 meters DEM resolution, whereas the results showed that the lowest resolution produced the largest inundation area.

The computation time for different DEM resolution on the whole study area by using 2D model is depicted in table 5.2. The values are for a 25 years return priod flood. As the return period increases, the simulation time increases also.

Table 5.2 Computation time for different grid resolution

DEM Resolution (Meters)	Number of Grids	Computation Time(*)
1	251279861	> 18 days
5	10051194	>11 days
25	402047	4.5 days
50	100511	2.5 Days
100	25127	17 Hours
500	1005	2 Hours

* Computation time is taken from the simulation of 100 hours hydrograph

As mentioned above simulation time for 1 meter resolution DEM is too much for the whole study area. So in order to see the effect of DEM on inundation mapping, the test for DEM resolution on flood inundation mapping is applied on a small region near the Akıncı village. The time needed for the whole area is too much, so an area of 15,8 km^2 is selected for the study. The test area is depicted in figure 5.14. A discharge value for the 500 years return period is used as input for the study. The selected area is the location where most flooding events have been recorded and because of the topography is changing more than the other locations (there is a decrease in the elevation from east to left). By the help of the topography change, the change in the inundation area is realized.

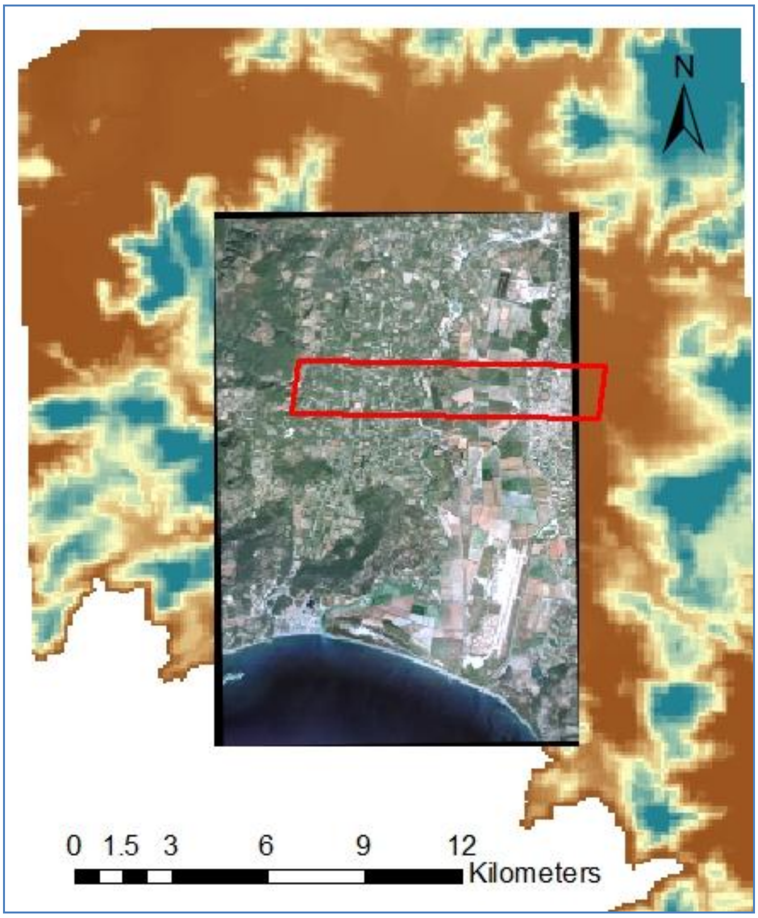
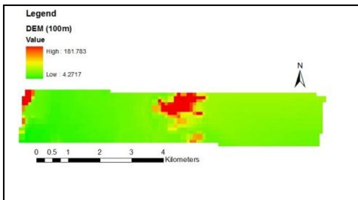
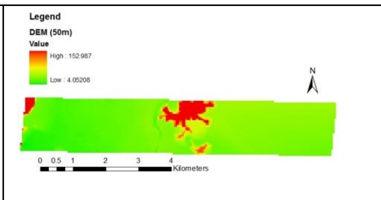


Figure 5.14 Study area(red polygon)

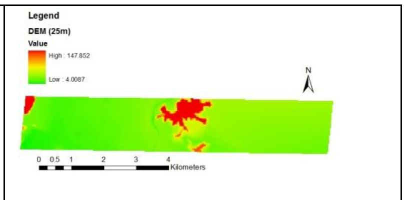
DEM resolution of 100 m., 50m. and 25 meters is selected and DEM' are shown in the figure 5.15.



100 m



50 m



25 m

Figure 5.15 DEM for different grid resolution

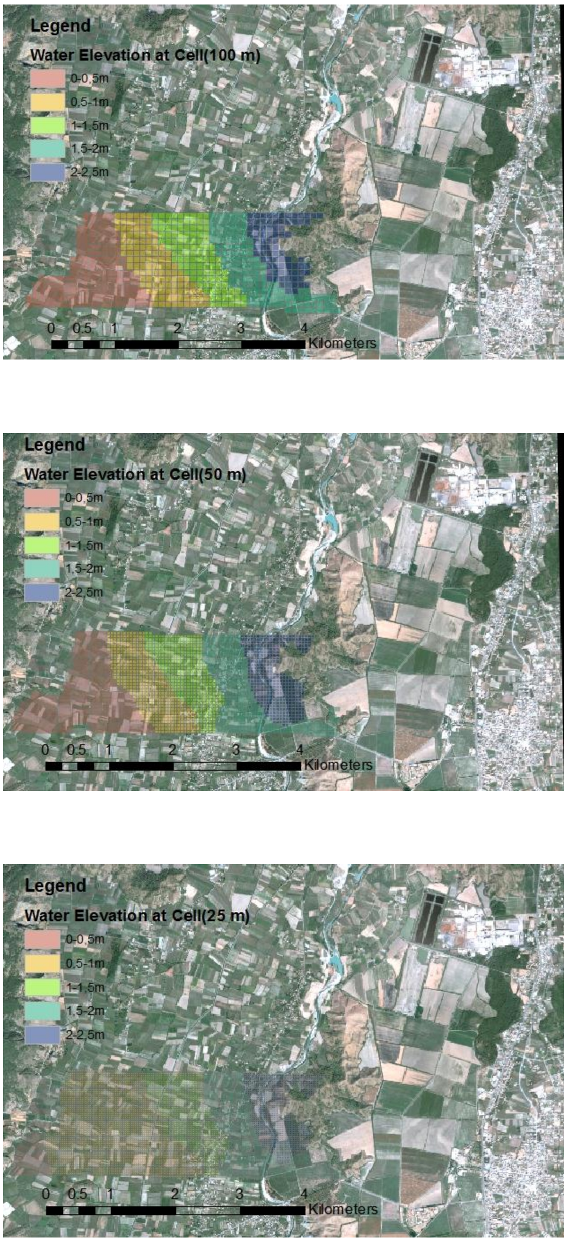


Figure 5.16 Water depth in each cell for the study area.(a) 100m, (b) 50m, (c) 25m

The main channel configuration becomes less important in 100 meter resolution DEM and serves like an inundation area. But in 25 meters resolution DEM, the channel can be more clearly recognized. Also high resolution DEM can be more clearly seen than low resolution DEM image (figure 5.16).

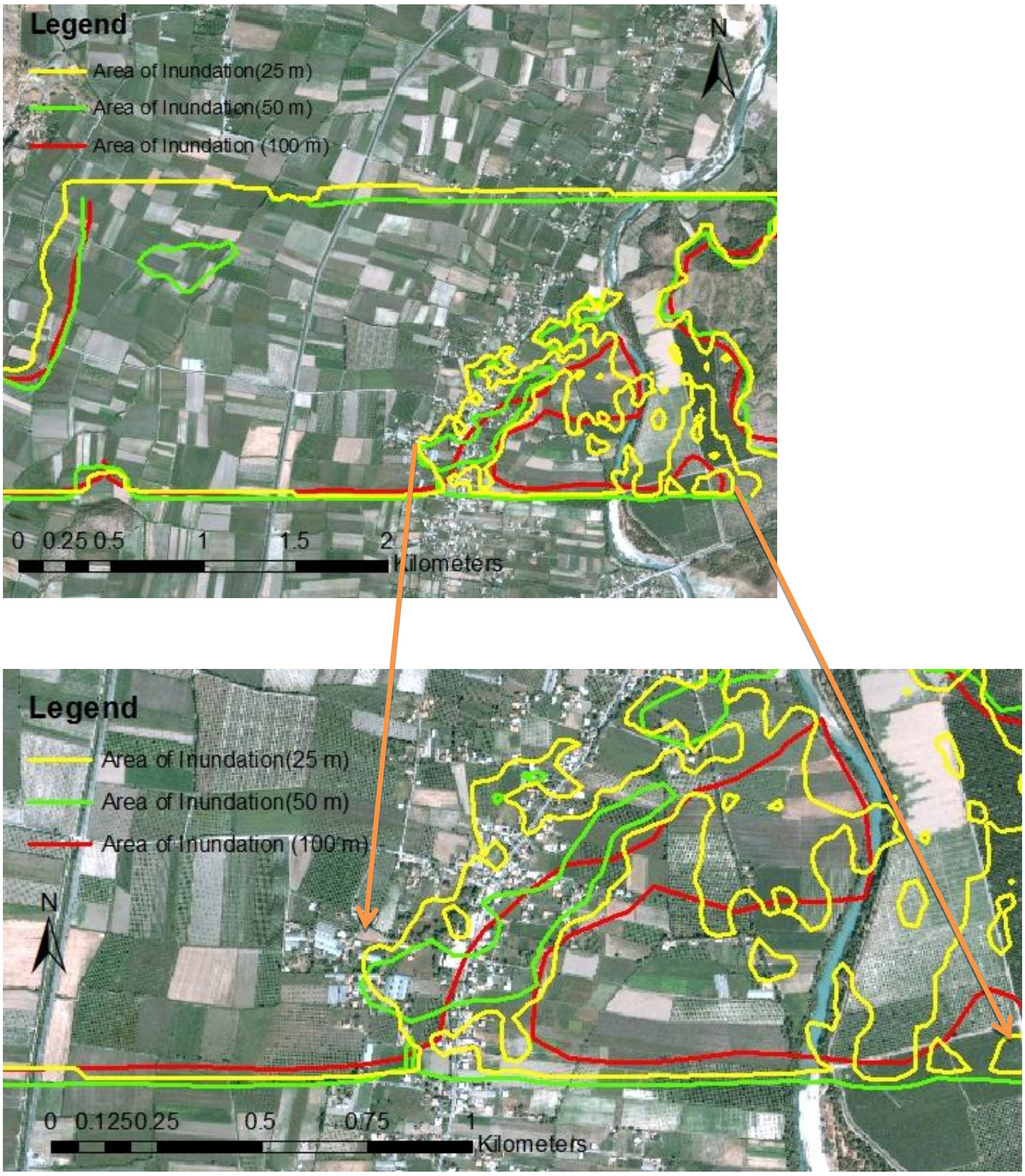


Figure 5.17 Area of inundation for 25,50,100 meters DEM resolution

When figure 5.17 is analyzed, it can be seen that area of inundation is increasing by increasing the DEM resolution. Also table 5.3 shows that if the DEM resolution is increased, least inundation area is obtained. When the DEM resolution is increased, there is a decrease in flood inundation area. When the resolution is increased from 25 meters to 100 meters, the inundation area also increases about 25%.

Table 5.3 Area of Inundation with respect to DEM resolution

DEM resolution	100 meter	50 meter	25 meter
Area of Inundation (km2)	9,96	8,72	7,99

5.2.3 Effect of settlements on flood inundation mapping

In this section, effects of the settlements have been studied in order to see the effect on flood inundation. The test for the effect of settlements on flood inundation mapping is applied on a small region near the Akıncı village. As mentioned before the time needed for the whole area is too much, so an area of 15,8 km^2 is selected for the study. The test area is depicted in figure 5.14. A discharge value for the 500 years return period is used for the study with a resolution of 25 meters.

First the effect of settlement on flood inundation areas is tested. The resulting map is depicted below in figure 5.18. In this figure, the settlement is shown with black squares. When the figure is analyzed it can be seen that, settlement increases the amount area of inundation in the study area. In the locations where there is no inundation without houses can change to location of inundation with houses. The houses decrease the velocity of the water and it results to inundation in new locations. In the study area, just with the effect of settlements an increase of %4 is observed in the amount of inundation area in the locations of the settlements. In the test area, the houses are small village houses so the amount of inundation can increase when new big industrial settlements (houses) are constructed or they can result new inundation areas where no inundation is observed before.

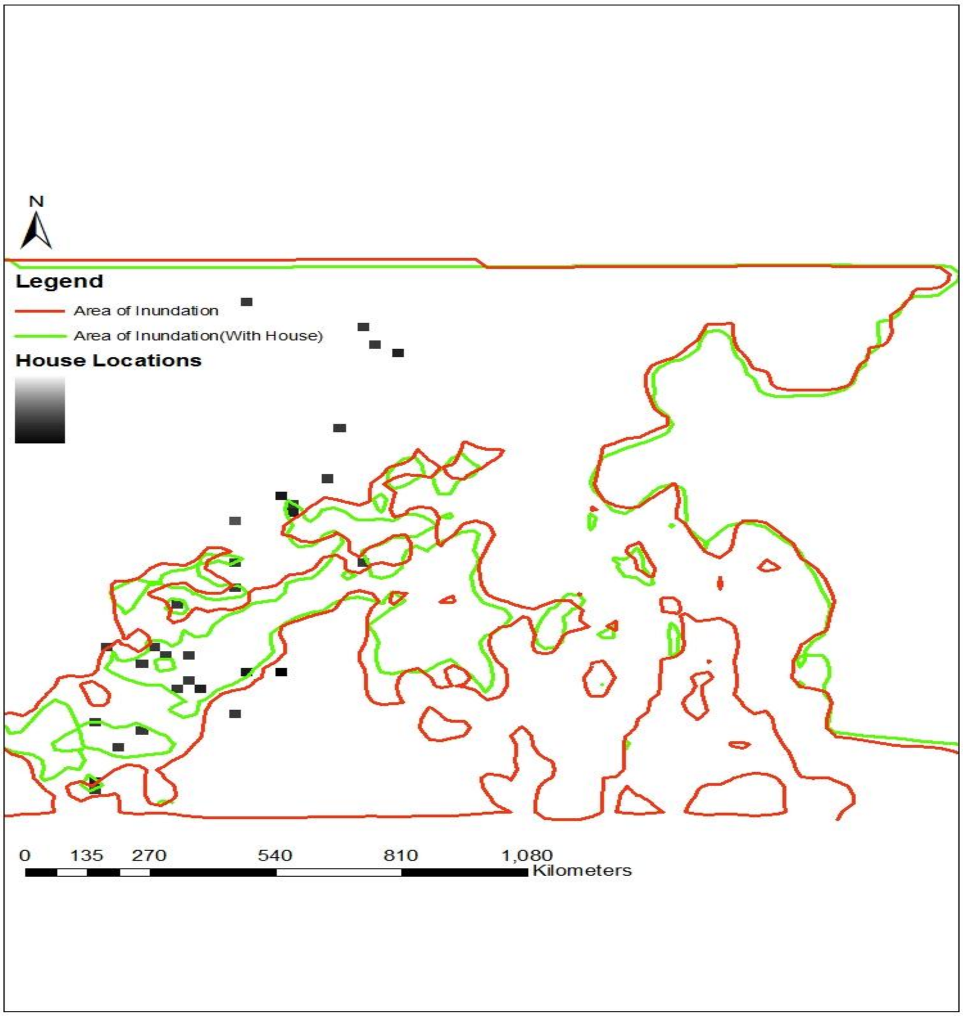


Figure 5.18 Flood Inundation areas with and without settlements in the plain

The velocity vectors are the main factor to form the inundation areas. Also they have too much effect on preparing flood danger maps. So in the study, the velocity vectors are depicted in the figure 5.20 below.

Figure 5.19 is a combination of the resulting velocity vectors with and without houses. When the figure is analyzed, it can be seen that the velocity vectors are highly changing near the houses. As expected, their directions are also changing when the water hit the houses.

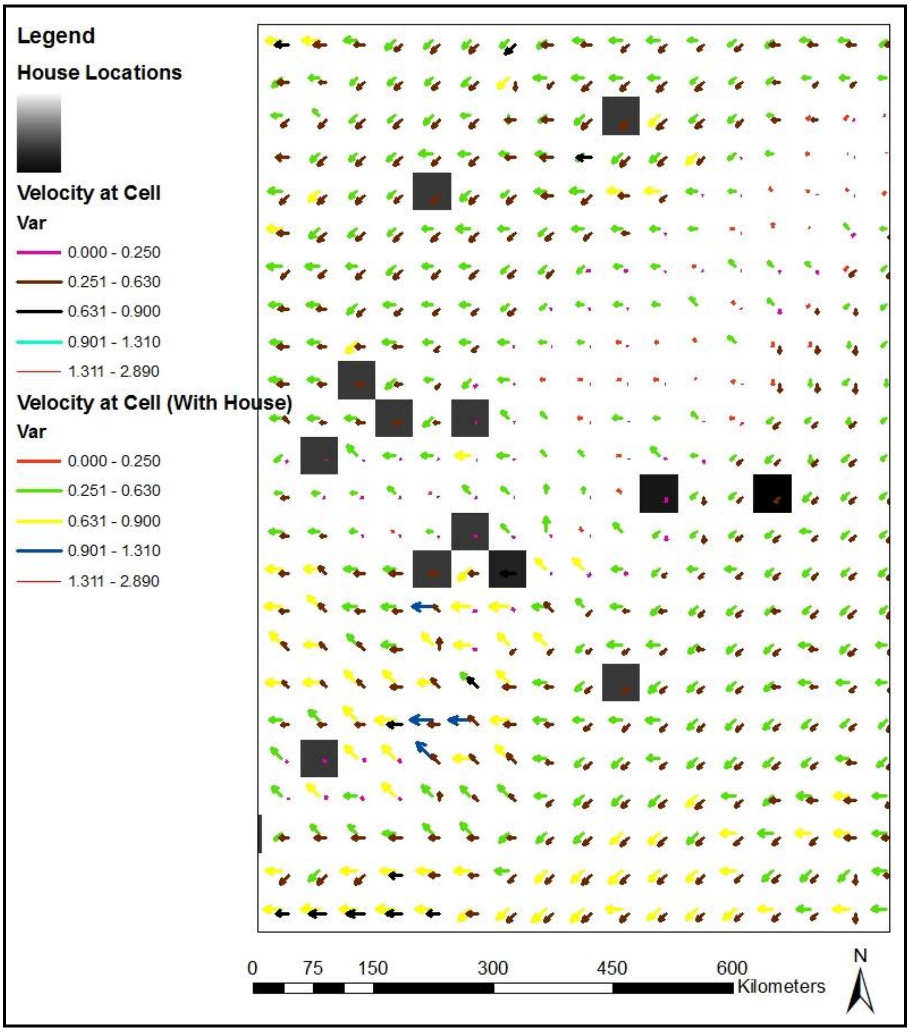


Figure 5.19 Flow velocity vectors with and without houses

5.3 Comparison of Results of 1D and 2D Models

In this section, results for 1D model HEC-RAS and 2D model FLO-2D are compared. When the data input part of the both models is compared, 1D models are simpler than 2D models. The data needed in 1D model is less than the 2D model. For a 1D model, the input is the cross sections in the needed parts, but in 2D model, a whole surface must be created first in order to simulate the flood. The preparation time for the inputs in 2D model is longer than the 1D model. The 1D model requirement is easier than 2D model.

The computer simulation time is longer in 2D models. So in order to perform a large area with high resolution DEM data, a group of computers are needed for a better result. For Dalaman plain model, 1D models runs in a few seconds, but 2D models run time is a few hours or maybe days.

1D model runs and simulates from cross section to cross section, so the resulting inundation area can be discontinuous and sometimes disregards the topographic changes between cross sections. The 2D model can produce a continous inundation area which is more useful in floodplain determination and damage calculation.
By the help of continous DEM and mesh in modeling, 2D model can simulate the floodplain in both longitudinal and lateral directions which can result more precise results for damage calculation.

When the inundation areas are compared, it can be seen that inundation depths are more or less same. But when the water depths of the 1D and 2D models are compared, it can be seen that the water depths are different for the models.

If low resolution DEM is used, the channel topography can be misleading for a 2D model. In this case it is better to use 1D model. But in 2D model water depths and velocities are available for each grid point in the 2D model.

In Dalaman plain, the flow is in two directions so because of the methodology of 1D model, the floodplain and flood depths can be misleading. The results show that usage of 2D model gives better results than 1D model in Dalaman Plain.

CHAPTER 6

FLOOD DAMAGE CALCULATION AND HAZARD MAPPING

6.1 Flood Hazard Mapping

Flood damage calculation is important especially in flood risk management. In order to decide a flood protection structure or give more importance to a specific area can be done by exploring the flood damage. That is why flood damage calculation is getting more and more importance in EU countries.

Flood damage can be expressed as hazard map or with stage-damage curves. Also stage –damage curves can be categorized for industrial, agriculture, buildings etc. This can also help in order to categorize the flood damage. Hazard maps can be prepared with several parameters, but the most important factors are the water depth and flow velocity. There are several different methodology used in EU countries. In this study, methodology developed by Garcia et al. (2003, 2005) is used . The method was first used by PREVENE, 2001 project, where it was applied to two alluvial fans in Caracas, Venezuela and later adapted and applied to other urbanized alluvial fan Garcia et al. (2003, 2005). The method is also applicable with the Swiss and Austrian standards that establish three zones to delineate the flood hazard level .(Floodsite,2005).

In this method, flood hazard level at a specific location is a function of both flood intensity and probability. Flood intensity is defined by the flow depth and velocity. Flood probability is inversely related to flood magnitude. Large flood events occur less frequently. Flood hazard level is then defined as a discrete combined function of the event intensity (severity of the event) and return period (frequency) as shown in figure 6.1.

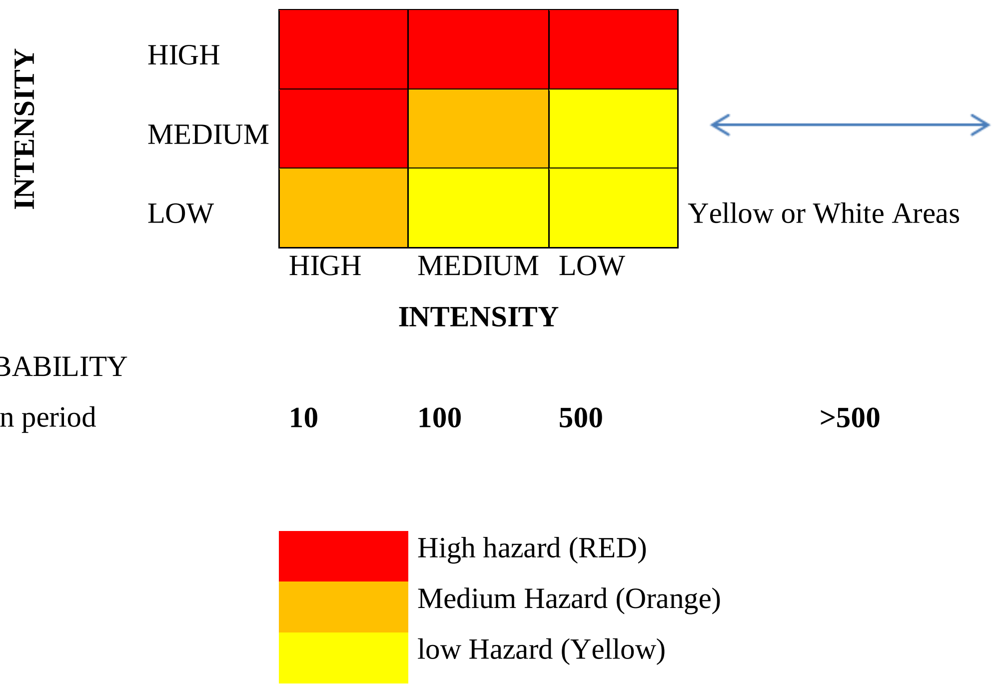


Figure 6.1 Flood Hazard Level Definition(Garcia et al. 2003, 2005)

In the above figure 6.1, the probability limits are defined for return periods of 10, 100 and 500 years. The user can select other return periods to construct the flood hazard map. A flood hazard map is based on the three color levels to define high (red), medium (orange) and low (yellow) level. These map colors translate into specific potential hazard areas as shown in the following table 6.1.

Table 6.1 Color description of hazard level

Flood Hazard Definition		
Hazard Level	Map color	Description
High	Red	Persons are in danger both inside and outside their houses. Structures are in danger of being destroyed.
Medium	Orange	Persons are in danger outside their houses. Buildings may suffer damage and possible destruction depending on construction characteristics.
Low	Yellow	Danger to persons is low or non-existent. Buildings may suffer little damages, but flooding or sedimentation may affect structure interiors.

In Flo2D program , the results can be mapped with a module named as MAPPER. The module MAPPER can use the same method in order to form the hazard map. But considering the specific conditions in different methodologies, it may be necessary to change the hazard level thresholds. In MAPPER the user can input values for flow depth and velocities that define the intensity thresholds.(table 6.2)

Table 6.2 Definition of Water Flood Intensity

Flood Intensity	Maximum depth h (m)		Product of maximum depth h times maximum velocity v (m^2/s)
High	h > 1.5 m	OR	v h > 1.5 m^2/s
Medium	0.5 m < h < 1.5 m	OR	0.5 m^2/s < v h < 1.5 m^2/s
Low	0.1 m < h < 0.5 m	AND	0.1 m^2/s < v h < 0.5 m^2/s

Flood hazard map for 500 years return period is produced and depicted in the figure 6.2. When the flood hazard map of the plain is examined, it can be seen that most of the areas for high hazard level (red color) are formed in the locations near the shore line. These locations are the areas where high population is living in the resort hotels. Also most of the village houses is located in the zone 1(yellow) and zone 2 (Orange) This result indicates that the water is passing through village houses and deposited in the shoreline.

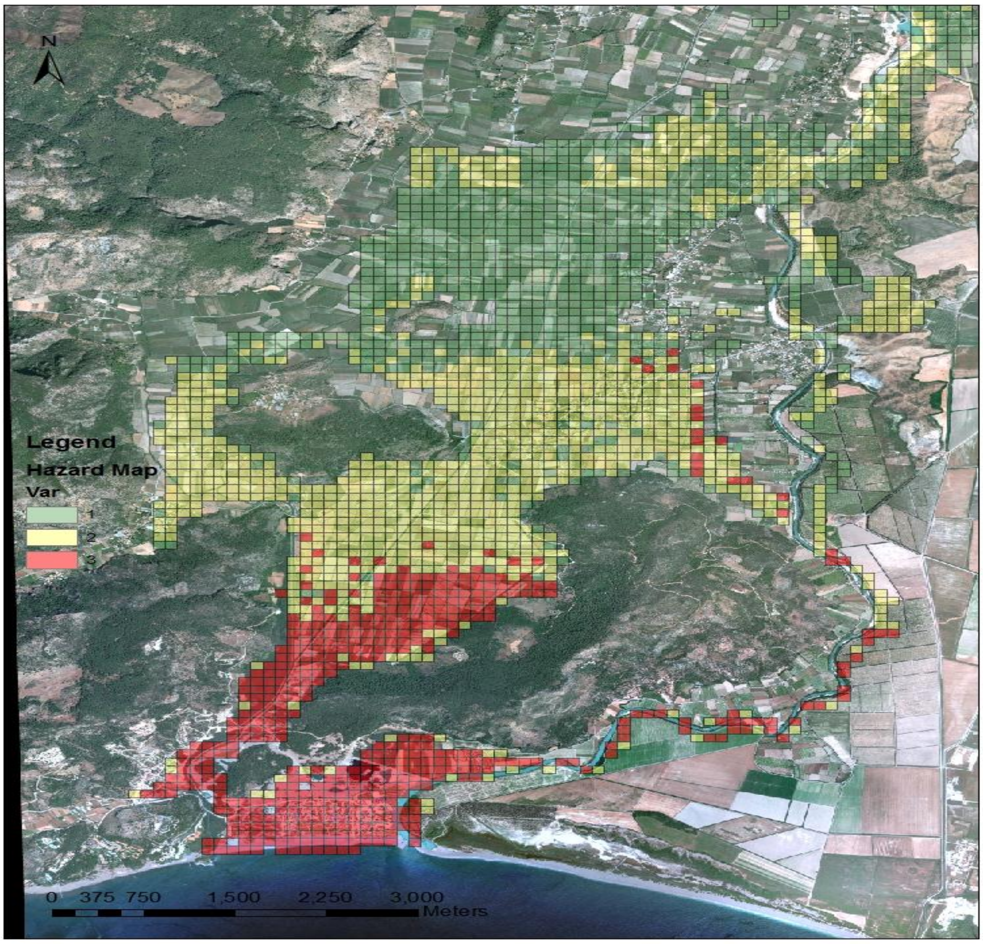


Figure 6.2 Flood hazard map of Dalaman Plain for 500 Years Return Period

6.2 Flood Damage Calculation

6.2.1 Flood Damage Calculation for buildings

In the previous section, flood hazard map of the valley is produced and depicted for the 500 years return period. In order to calculate the flood hazard map, Model and the assets which are at risk is enough. But in order to calculate the flood damage, model results are not sufficient. First the assets at risk must be identified and then their values must be defined and finally their damage with respect to flood depth must be calculated. After these values, finally flood damage calculation can be done with spatially joining the asset values and modeling results.

The module MAPPER is used for the calculation of flood damage in the valley. But the damage with respect to flood depth must be considered first. In Turkey, there is no database which can show the damages with respect to flood depth. For this reason, past flood events are processed and from these events, a table has tried to be formed. There are actually 1258 buildings in the study area and most of the buildings have sub-basements. In table 6.3, the number of houses and height of the sub-basements is shown. When the table is analyzed, it can be understood that people in the area know that they are in an area that is under flooding. Because of this most reason most of the houses have sub-basements with a height of 0.5 meters or more. The buildings that do not have sub-basements are mostly new constructed buildings.

Table 6.3 Number of the houses depending on their sub-basement height

House Sub-basement Type	**Count**
Houses having no sub-basement	203
Houses having 0.5 meter sub-basement	903
Houses having 1 meter sub-basement	89
Houses having 1.25 meter sub-basement	47
Houses having 1.50 meter sub-basement	11
Houses having 2 meter sub-basement	5

The below photos is the examples from the buildings that have different sub-basement heights.

Figure 6.3 Photo for the mosque in the study area

Figure 6.4 Photo for Akdeniz Houses near the sea

Figure 6.5 Example house photo for the basement used for temporary usage

Figure 6.6 Example photo for the small pensions in the study area

Figure 6.7 Example photo for the old houses in the study area

After the assessment of the building types, flood damage with respect to flood depth is generated and presented in tabular form. While generating this table, values of the buildings are taken from the Ministry of Public Works for a town house and cost of the house materials is taken from the representative houses. The town houses are classified into 6 categories with respect to their sub-basement heights. The hotels are grouped in to 3 categories and primary school is taken as one category. The golf area and other valuable locations for the hotels are also included in the cost estimation. The resulting table are depicted in table 6.4.

Table 6.4 Proposed Damage for 1 m^2 of Building depending on the type and sub-basement height (TL)

Type	Water Depth					Explanation
	1 m.	2 m.	3 m.	4 m.	5 m.	
Village House No1	220	330	374	440	484	Houses having no sub-basement
Village House No2	185	275	315	370	407	Houses having 0.5 meter sub-basement
Village House No3	150	185	255	300	330	Houses having 1 meter sub-basement
Village House No4	100	125	170	200	220	Houses having 1.25 meter sub-basement
Village House No5	50	75	85	100	110	Houses having 1.50 meter sub-basement
Village House No6	25	38	56	71	85	Houses having 2 meter sub-basement
Hotel No 1	1120	1680	1904	2016	2240	Hotels having no sub-basement
Hotel No 2	700	1050	1190	1260	1400	Hotels Having 0.5 meters sub-basement
Hotel No 3	420	630	714	756	840	Hotels having 1 meters sub-basement
Primary School	170	225	270	324	374	Sub-basement=0.50 meters

For different return periods from two years to cadastrophal, the damages are calculated and depicted in the figure 6.3. The school damage is very low because there is only one school and because of being old building, its value is taken as low value. The number of hotels is very limited than the number of houses and the resulting graph is also showing the same results as hotels cost is less than the house costs.

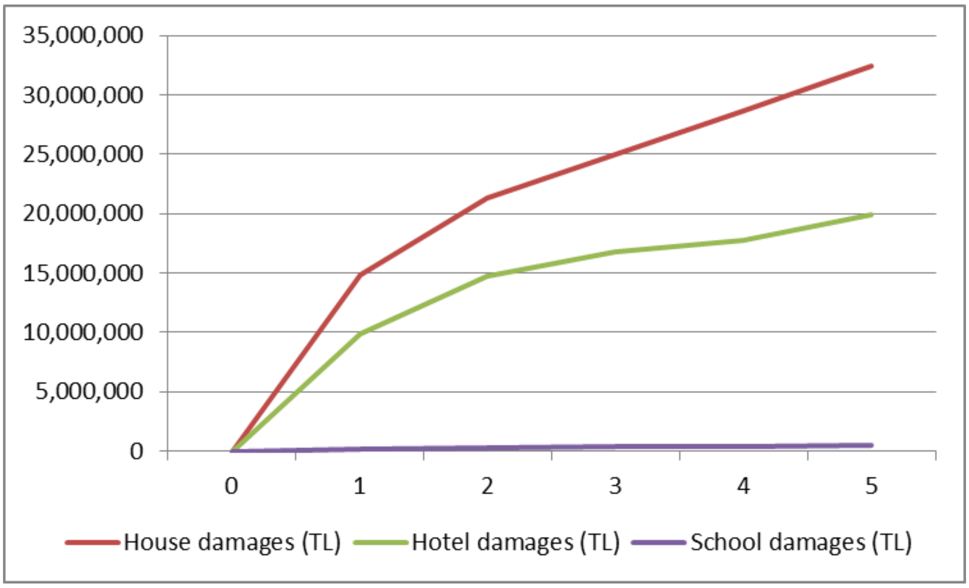


Figure 6.8 Calculated Damages for different building types (TL)

6.2.2 Flood Damage Calculation for Agricultural Areas

Agricultural damages are very different from the house damages. The type of the agriculture, season, soil type or the age of the product effects the agricultural damage calculation. For example, for cereals, if the flood is in the winter season and the crop is under the soil, then there will be no damage to the crop. The flood will form damage if the water retain over the area longer than 1-2 days. For long term agricultural products, a flood case of 0,5 meters water height will not affect the product. There will be a damage for the re-spreading the soil in the farm. There will be damages in the greenhouses. The greenhouse damages composed of structural damages and agricultural damages. Of course for some types of agricultural products, they benefit from the flood for the sediment load which is very useful for agriculture. This is valid if the crop is in the correct agricultural period. For a better flood damage study for agricultural products, it will be better if investigation is done just after occurred flood. The damage can be seen by agricultural engineers and damage can be calculated more precisely.

As mentioned in chapter 3, there are different types of agricultural crops in the study area. They are cereal, corn, citrus fruit, pomegranate and other types (table 3.8). In this pattern the long term crops will be affected less than the short term crops. So a case study is done for a case that 1000 year flood has occurred in the area and the crops are in bad condition. In this case, it is assumed that long-term products effect about %25, and short term products effected as %100. For year 2012, the agricultural income for long-term products (citrus fruit, pomegranate etc.) is about 840 Turkish Lira per 1000 m^2 area. For short term products it is about 110 Turkish lira per 1000 m^2 area.(DSI ,2012)

According to the specific case the inundated area is about 14866933.9 m^2 (figure 6.4). About this area 9,513,971.97 m^2 area is used for short term products 5,347,394.80 m^2 area is long term products. As a result the total damage for this case is 1,533,369.383 TL.

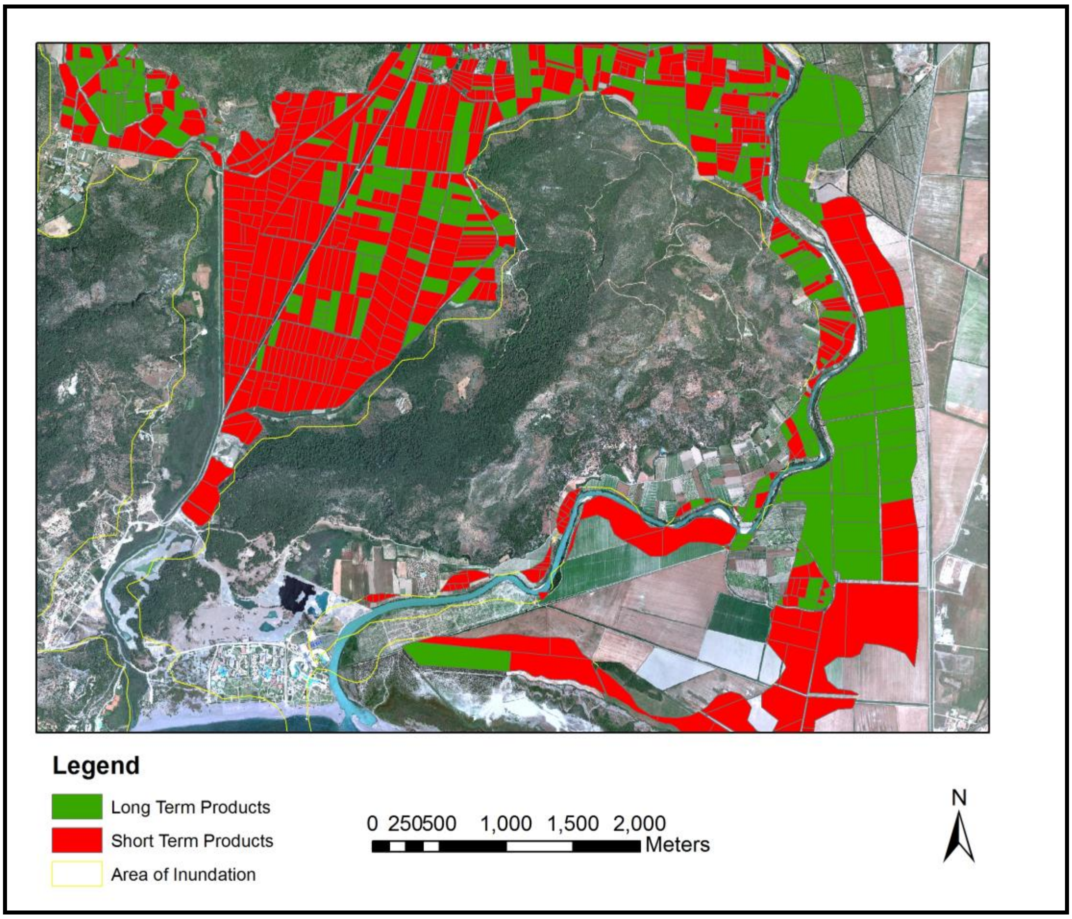


Figure 6.9 Parcels that are inundated.

CHAPTER 7

CONCLUSIONS AND RECOMMENDATIONS

In this study, comparison of 1D hydraulic model HEC-RAS and 2D hydraulic model FLO-2D is done in order to compare the efficiency and ability of different models in Dalaman plain. Then the results of 2D model are used for assessing the flood risk and calculation of quantitative flood damage is carried out with application. Dalaman plain have both lateral and longitudinal directions flow. In normal regime cases, river is discharging in the channel geometry. But in flood regime cases both channel and flood plain are used for discharging to sea. The river becomes two separate rivers and resulting inundation areas are different in 1D and 2D modeling.

Calibration of the 2D model is done for the flood case in 2001 and after then, the modeling and verification issues have been carried out.

2D model simulation is done for different DEM resolutions and it is seen that the model is sensitive to DEM resolution. As the DEM resolution increases, the sensitivity increases but on the other hand increasing the DEM resolution increase the simulation time up to a simulation time to 3-4 days.

The topography is very important in 2D and 1D modeling approach. Especially in 2D modeling if the buildings in the study area are given as an input to 2D model, there are some results in the model. Especially velocity directions and velocity magnitude change more than the inundation depths and inundation areas. This increase the risk in the settlement areas which results as more human and animal losses.

In modeling a unit hydrograph for three days is used for the study. The results could change more if longer hydrographs is used and the damages could be more costly in terms of monetary terms.

Manning coefficient is the most important parameter in calibration and model verification. This coefficient is generated by site visits to the study area. Wrong coefficients would results misleading inundation areas and water depths. Two different manning numbers must be used for channel and floodplain separately. in many studies where the study area is large, two different numbers is not an easy issue. That is why same manning number is used for channel and floodplain.

The study area has settlements of which most of them have subbasements higher than 0,5 meters. It means that people in the flooding zone knows that they are in flood zone and take some small precautions for floods. These result to minimize the damage in small flood events.

Comparison of two models shows that;

- 2D model data needs and preparation time is more than 1D models
- Simulation time takes longer in 2D model than 1D model.
- Resulting inundation area is continuous in 2d model where in 1D model there are discontinuous areas.
- 2D model makes calculations in both longitudinal and lateral directions where 1D model makes just in longitudinal direction.
- Due to the topography changes and 2D flow in the plain, resulting flow depths and inundation areas are to be different using both approaches.
- Settlement areas effect the modeling results in 2D model but in 1D model it is very small if the cross sections are taken in wide ranges (i.e. 25 meters and more)

In Dalaman plain the flow is in two directions so because of the methodology of 1D model, the floodplain and flood depths can be misleading. The results show that usage of 2D model gives better results than 1D model in Dalaman Plain.

In damage calculations, the primary damage (tangible damages) is included in the study area. But the secondary flood damages (Intangible damages) can be included. If more data is obtained for further studies in order to calculate the percentage of primary and secondary damages for the study area.

The application 1D and 2D models together is very used in nowadays. This type of application makes it easier the modeling issues and decrease the computation time for 2D modeling. 2D model use the boundary conditions of 1D model result so, it decrease the input data need also. In this thesis, it could not be done, because the applied theory of 1D and 2d models are different in nature. It can only be applicable for 1D and 2D model which are produced from the same origin and assumption.

The results of the study show that the study area is prone to flooding of which sometimes damages could occur more than 50 million Turkish Liras. Especially nowadays hotels and pensions are increasing in the region. This also increase the possible damage more than today in the future. The damages can be decreased by opening the mountainous areas for settlement and Dalaman plain for agricultural purposes.

Dalaman plain can always face with flood danger due to its location and slope. In order to decrease the flood damage and especially human loss, a flood warning system should be used. This warning system could be done with the data obtained from the dam operation unit and real time gauging station values.

The results also show that there is a big need for flood risk management in the region and the study can be used for risk management purposes. The risk management should be delivered o the people in the region and should be uptodate. Also and emergency action plan can be prepared with the study results so that the damages could be minimized.

The study focused on a location where exist less settlement areas and more agricultural areas. The needed information could not be collected for a study in an urban case. So the results of this study could be used for rural areas more than urban areas. In an urban area case, the damages could be more than urban area case.

For future as recommendation, if there will be sufficient data especially about the flood damage for each flood case, the damage calculations can be done and verified statistical model calculations.

REFERENCES

Adamowski, Kaz., "Non Parametric Kernel Estimation of Flood Frequencies", *Water Resources Research* , Vol. 21, No. 11, pp. 1585-1590, 1985.

Arora, K., and U.P. Singh, "A Comparative Evaluation of the Estimators of the Log Pearson (LP3) Distribution", *Journal of Hydrology,* Vol. 105, pp. 19-37, 1989.

Arora, P.S., and A.R. Rao. , "Fitting Probability Distributions to Flood Data", Tech. Report. CE-HSE-85-06, School of Civil Engineering, Purdue University, W. Lafayette, IN 47907, pp. 186, 1985.

Chow, V.T., Open Channel Flow. McGraw-Hill Book Company, New York, NY.,1959.

Cook A. and Merwade V., Comparison of one-dimensional HEC-RAS with two-dimensional FESWMS in flood inundation mapping. Proceedings of the American Water Resources Association 2008 Spring Specialty Conference GIS and Water Resources V, San Mateo, CA, 2008.

Cutter, S. L., Vulnerability to environmental hazards. Progress in Human Geography **20** (4), pp. 529-539, 1996.

DSI, According to the intervies with Agricultural Economist Murat SAN, 2012.

Potere D., "Horizontal Positional Accuracy of Google Earth's High resolution Imagery", Open Access Sensors, 8, 7973-7981, 2008.

Messner F. & Meyer V., “Flood damage, vulnerability and risk perception – challenges for flood damage research”, Leipzig University, Department of Economics, 2005.

FLOODsite, “Guidelines for Socio-economic Flood Damage Evaluation”, Report Number: T9-06-01, 2006.

Gemmer M., “Decision support for flood risk management at the Yangtze river by GIS/RS-based flood damage estimation” Dissertation at University of Giessen, 2004.

Glade T., “Vulnerability Assessment in Landslide Risk Analysis”, *Die Erde – Beitrag zur Erdsystemforschung* 134 (2):123-146, 2003.

Hewitt K., “Regions of risk”, A geographical introduction to disasters. Harlow, 1997.

Jonkman S. N., “*Loss of life estimation in fl ood risk assessment Theory and applications”, Phd Thesis, Delft Technic University, Nedherlands, 2007.*

Keskin F., Darama Y., “3D Flood Modeling of the Iluh River in Southeastern Turkey by Using Hec-Ras and Hec-GeoRas”, international Conference on Fluvial Hydraulics RiverFlow 2008 Conference, 3-5 September 2008, Izmir, Turkey, 2008.

Klein R.J.T., Nicholls R.J., Thomalla F., Resilience to natural hazards: how useful is this concept? *Environmental Hazards* 5: 35-45, 2003.

Merwade V., Cook A., and Coonrod J., “GIS techniques for creating river terrain models for hydrodynamic modeling and flood inundation mapping.”, Environmental Modelling & Software, Vol. 23/10-11, pp 1300-1311, 2008.

Mitchell J.K., Hazards research. In: Gaile, G.L., Willmot, C.J. (Eds), Geography in America. Columbus, OH: Merrill, pp. 410-424, 1989.

Moel et. Al., “Flood maps in Europe – methods, availability and use”, Natural Hazards and Earth System Sciences, Vol. 9, pp. 289–301. 2009.

O'Brien, J. S., Julien P.Y. And Fullerton W.T., “Two Dimensional water flood and mudflow simulation”. Journal of Hydraulic Engineering, 119(2):244-259, 1993.

O'Brien, J. S., Flo2D Users Manual Tetra Tech ISG, Nutrioso, AZ., 1999.

OFDA/CRED, EM-DAT International Disaster Database- Universite catholique de Louvain, Brussels, Belgium. 2007.

Özdemir H., “Uygulamalı Taşkın Hidrolojisi”, DSİ Genel Müdürlüğü Basım ve Foto Film İşletme Müdürlüğü, 1978.

Sayers P.B., Hall J.W., and Meadowcroft I.C., Towards risk-based flood hazard management in the UK. Proc. of ICE, *Civil Engineering* 150(May 2002):36-42, 2002.

Slovic, P., “T*he perception of risk*”, Earthscan Publications, Sterling, Virginia, 2000.

Smith K., Assessing risk and reducing disaster. London, 2001.

Freegeographytools, “http://freegeographytools.com/2007/positional-acccuracy-in-google-maps-my-maps-vs-google-earth”, Last visited on 03.01.2011.

Stevens B. K., “Increased Functionality of Floodplain Mapping Automation: UTAH İnundation Mapping System (UTIMS)”, MAster Thesis, Utah State University, 2009.

UN-ISDR, Retreived from http://www.unisdr.org/eng/media-room/facts-sheets/fs4-Understanding-nature-of-vulnerability.htm, Last visited on February 2007.

Usul, N., Engineering Hydrology, Metu Press, Ankara, ISBN:975-7064-43-2, 2005.

Vlek C.A.J. A multi-level, multi-stage and multi-attribute perspective on risk assessment, decision-making and risk control, *Risk Decision and Policy* Vol. 1 No. 1 pp.9-31, 1996.

Thompson, http://drdbthompson.net/writings/0-4193-4.pdf, Last visited on 02.08.2010.

SCS, (Soil Conservation Service). National Engineering Handbook, Section 4, U.S. Department of Agriculture, Washington, D.C. 1972.

USACE, Hydrologic Engineering Center, River Analysis System HEC-RAS, Hydraulic Reference Manual version 3.0, January 2001. www.usace.army.mil,

USACE, Hydrologic Engineering Center, River Analysis System HEC-RAS, Hydraulic Reference Manual version 3.1.3, May 2005. www.usace.army.mil

USACE, Hydrologic Engineering Center, UNET, One Dimensional Unsteady flow through a full network of open channels, User's Manual, Davis, Ca., 1997.

USACE, Hydrologic Engineering Center, Hydrologic Modeling System HEC-HMS, Technical Reference Manual, March 2000. www.usace.army.mil

USACE, HEC-RAS river analysis system users manual version 4.0. United States Army Corps of Engineers – Hydrologic Engineering Center. 747 p., 2008.

CURRICULUM VITAE

PERSONAL INFORMATION

Surname, Name: Keskin, Fatih
Nationality: Turkish (TC)
Date and Place of Birth: 27 March 1970 , Ankara
Marital Status: Married
Phone: +90 312 285 62 06
email: fatihkeskinus@yahoo.com

EDUCATION

Degree	**Institution**	**Year of Graduation**
MS	METU Geodesy and Geo.Inf. Tec.	2007
BS	METU Civil Engineering	1992
High School	Atatürk Anadolu High School, Ankara	1988

WORK EXPERIENCE

Year	**Place**	**Enrollment**
2012- Present	Palye Engineering	General Manager
2010-2012	Eser Engineering	Planning Manager
2001-2010	DSİ Genel Müdürlüğü	Civil Engineer
1992-2001	DSİ 12. Bölge Müdürlüğü	Civil Engineer

FOREIGN LANGUAGES

Advanced English, Fluent German

PUBLICATIONS

- **Keskin F.,** Şorman A.Ü., Assesment of the Drought Pattern Change in Çamlıdere Basin Using SPI Index, Balwois 2010 Conference, Turkey, 25-29 May 2010, Ohrid, Republic of Macedonia

- **Keskin F**., Şorman A.Ü., Assessment of the dry and wet period severity with hydrometeorological index, International Journal of Water Resources and Environmental Engineering Vol. 2 (2).

- Einfalt T., **Keskin F.,** Analysis of the Istanbul Flood 2009, Balwois 2010 Conference, Turkey, 25-29 May 2010, Ohrid, Republic of Macedonia

- **Keskin F.,** Yenilmez F., Çolak M., Yavuzer İ., Düzgün H. Ş., Analysis of Traffic Incidents in METU Campus, 2. Uluslararası Çoğrafya Sempozyumu, 2-5 Haziran 2010, Antalya, Turkiye.

- Yenilmez F., **Keskin F**., Aksoy A., Spatial and Temporal Analysis of Water Quality Parameters in Mogan Lake, 2. Uluslararası Çoğrafya Sempozyumu, 2-5 Haziran2010, Antalya, Turkiye.

- **Keskin F**., Yucel İ., Ani Taşkın Olaylarının Uydu temelli Verilerin Kullanımı ile İncelenmesi, 2. Ulusal Taşkın Sempozyumu, 22-24 Mart 2010, Afyonkarahisar, Türkiye

- Dinçsoy Y., **Keskin F.,** , Yukarı Havza Islah Önlemleri ve Taşkın Zararlarına Olan Etkileri, 2. Ulusal Taşkın Sempozyumu, 22-24 Mart 2010, Afyonkarahisar, Türkiye

- **Keskin F**., Darama Y., Dalaman Ovasının Taşkın Riski Açısından Değerlendirilmesi, , 2. Ulusal Taşkın Sempozyumu, 22-24 Mart 2010, Afyonkarahisar, Türkiye

- **Keskin F**. Şorman A.Ü., Akyürek S.Z., "HYDROLOGICAL MODELING IN YUVACIK DAM BASIN WITH GIS INTEGRATION: HOW CAN WE MODEL THE HYDROLOGY OF A BASIN", **Book**,VDM Verlag Publications, Germany, ISBN-10: 3639144120, ISBN-13:978-3639144123, 14 June 2009

- **Keskin F.,** Yucel İ., Utilizing precipitaition forecasts of meteorological models in a hydrological model for flood forecasting in West Black Sea region of Turkey, 8 *IAHS* Scientific Assembly / 37 IAH Congress, 6-12 September, 2009, Hyderabad, India.

- **Keskin F**., Şorman A.Ü., Effect of Drought on Groundwater Quality in Ankara, Turkey, International Symposium on Efficient Groundwater Resources Management (IGS-TH 2009), 16-21 February 2009, Bangkok, Thailand.

- **Keskin F**., Şorman A.Ü., Assessment of Hydrometeorological Drought in West Mediterrenean Basin, Turkey, 4th Conference of the Asia Pacific Association of Hydrology and Water Resources (APHW), 3-5 November 2008, Beijing, China.

- **Keskin F**., Use of Radar Data for Coupling of Mike11 with MM5 Model for Flood Forecasting in Turkey 15-18 September Hydro Predict 2008, Prague, Czech Republic.

- Sensoy A., Sorman A.A., **Keskin F.,**, Sorman A.U., Modelling and predicting daily discharges in Yuvacik Dam Reservoir using two different models, HydroPredict 2008, 15-18 September 2008, Prague, Check Republic.

- **Keskin F.,** Darama Y., 3D Flood Modeling of the Iluh River in Southeastern Turkey by Using Hec-Ras and Hec-GeoRas, International Conference on Fluvial Hydraulics RiverFlow 2008 Conference, 3-5 September 2008, Izmir, Turkey

- **Keskin F**., Einfalt T., Comparison of MM5 output to adjusted radar rainfall data for hydrological Modeling, Fifth European Conference on Radar in Meteorology and Hydrology, 30 June- 4 July 2008, Helsinki, Finland. (poster presentation)

- **Keskin F.,** Coupling of Mike11 hydrological model with MM5 model for flood forecasting in Bartin Basin, Balwois 2008 Conference, Turkey, 27-31 May 2008, Ohrid, Republic of Macedonia

- Einfalt T., **Keskin F**., Comparison of MM5 Output to Adjusted Radar Rainfall Data, International Symposium on Weather and Hydrology, 10-12 March 2008, Autrans, France

- **Keskin F**., Şensoy A., Şorman. A.A., Şorman A.Ü., Application of Mike11 Model for the Simulation of Snowmelt Runoff in Yuvacık Dam Basin, Turkey, International Congress River Basin Management, 22-24 March 2007, Antalya, Turkey.

- **Keskin F**., Rainfall Forecasting System of TEFER Project, International Congress River Basin Management, 22-24 March 2007, Antalya, Turkey.

- Hatipoğlu M.A., **Keskin F**., Seyrek K., Floodplain Delineation in Mugla-Dalaman Plain Using GIS Based River Analysis System, International Congress River Basin Management, 22-24 March 2007, Antalya, Turkey.

- **Keskin F**., Flood Forecasting System of Turkey, 3rd APHW Conference, 16-18 October 2006, Bangkok, Thailand.

- **Keskin F**., Hydrological Modeling in Yuvacik Dam Basin by Geographical Information Systems, METU, **Master Thesis**, February 2007.

HOBBIES

Computer Technologies, Running