HASAN KALYONCU UNIVERSITY
GRADUATE SCHOOL OF
NATURAL & APPLIED SCIENCES

FLOOD HYDROGRAPH MODELING STUDIES BY USING GIS AND HEC-HMS FOR DAKAR, SENEGAL

M. Sc. THESIS
IN
CIVIL ENGINEERING

BY
ERKAN ALKAN
JANUARY 2015

Flood Hydrograph Modeling Studies by using GIS and HEC-HMS for DAKAR, Senegal

M.Sc. Thesis
In
Civil Engineering
Hasan Kalyoncu University

Supervisor
Prof. Dr. Mustafa Yılmaz KILINÇ

By
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JANUARY 2015

T. C.
UNIVERSITY OF HASAN KALYONCU
GRADUATE SCHOOL OF
NATURAL & APPLIED SCIENCES
CIVIL ENGINEERING DEPARTMENT

The name of the thesis: Flood Hydrograph Modeling Studies by Using GIS and HEC-HMS for DAKAR, Senegal.

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Exam date: January 27, 2015

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Erkan ALKAN

ABSTRACT

FLOOD HYDROGRAPH MODELING STUDIES BY USING GIS AND HEC-HMS FOR DAKAR, SENEGAL

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M.Sc. in Civil Engineering
Supervisor: Prof. Dr. Mustafa Yılmaz KILINÇ
January 2015, 56 pages

Dakar, capital city of Senegal, has a hot semi-arid climate with a short rainy season. Dakar's rainy season lasts from July to October. Floods due to rainfall during this short period of time cause destruction in residential area and loss of life and properties. Actually, the main reason of destructions and losses is not exactly the heavy rains. Houses built in the floodplain and settlements in this area destroy the nature of the floodplain and cause disasters. To avoid disasters caused by flooding, conservation and mitigation studies and activities should be performed in natural floodplains.

The main objective of this study is applying hydrological model to Dakar Basin and obtaining flood hydrographs of the basin. In the study, for determination of watershed boundaries and drainage lines, Geospatial Hydrologic Modeling Extension (HEC-GeoHMS); for hydrologic modeling studies, Hydrologic Engineering Center's Hydrologic Modeling System (HEC-HMS) software's were applied to Dakar Basin. According to the modeled hydrographs, results will try to be interpreted. Moreover, it is aimed to use obtained model parameters for Dakar's flood prevention studies.

Keywords: Dakar, GIS, HEC-HMS, HEC-GeoHMS, Hydrologic Modeling, Flood Hydrograph Modeling.

ÖZET

CBS VE HEC-HMS PROGRAMLARINI KULLANARAK SENEGAL, DAKAR ŞEHRİ İÇİN TAŞKIN HİDROGRAF MODELİNİN OLUŞTURULMASI

ALKAN, Erkan
İnşaat Mühendisliği Yüksek Lisans
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Ocak 2015, 56 sayfa

Senegal'in başkenti olan Dakar İli sıcaklık değerlerinin yüksek olduğu yarı kurak bir iklime sahiptir. Dakar'ın yağış sezonu Temmuz-Ekim ayları arasındadır. Bu kısa periyotta yağan yağışlar, yerleşim bölgelerinde tahribata, can ve mal kayıplarına sebep olmaktadır. Tahribatın ve kayıpların asıl nedeni ani yağışlardan ziyade taşkın yataklarında inşa edilen konutlar ve yerleşim birimleridir. Doğal taşkın alanlarının tahrip edilmesi neticesinde taşkın kaynaklı felaketler oluşmaktadır. Taşkın kaynaklı felaketleri önlemek için doğal taşkın alanlarında koruma ve hafifletme çalışmaları yapılmalıdır.

Bu çalışmada, Dakar havzası için hidrolojik modelleme çalışmaları yapılarak taşkın hidrografları oluşturulması amaçlanmıştır. Havza sınırlarının ve drenaj hatlarının belirlenmesinde Mekânsal Hidrolojik Modelleme Uzantısı (HEC-GeoHMS) yazılımı, hidrolojik modelleme çalışmalarında ise Hidrolojik Modelleme Sistemi (HEC-HMS) yazılımı kullanılmıştır. Çalışma neticesinde elde edilen hidrograflar yorumlanıp neticelerine yer verilecektir. Bunun yanı sıra model parametrelerinin Dakar taşkın önleme çalışmalarında kullanılabilir nitelikte olması amaçlamıştır.

Anahtar kelimeler: Dakar, CBS, HEC-HMS, HEC-GeoHMS, Hidrolojik Modelleme, Taşkın Hidrografı Modellemesi.

ACKNOWLEDGEMENT

I would like to thank to Prof. Dr. Mustafa Yılmaz KILINÇ, my supervisor, for his invaluable guidance, encouragement and support during this thesis.

I also owe special thanks to, Assist. Prof. Dr. Mehmet İshak YÜCE and Assoc. Prof. Dr. İsmail HALTAŞ for their guidance during my thesis study period.

Special thanks are reserved for Prof. Dr. Mustafa Yılmaz KILINÇ, Prof. Dr. Mehmet KARPUZCU, and Assist. Prof. Dr. Mehmet İshak YÜCE for serving on the examining committee and their contributions and suggestions to improve the quality of the thesis.

Finally, I would like to express my particular thanks to my mom (Cemile ALKAN) and my fiancée (Ayşe TANŞU) for their support during this thesis.

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LIST OF SYMBOLS/ABBREVIATIONS

ANSD	Agence Nationale de Statistique et de la Démographie
DEM	Digital Elevation Model
ESRI	Environmental Systems Research Institute
FEMA	Federal Emergency Management Agency
GeoHMS	Geospatial Hydrologic Modeling Extension
GIS	Geographic Information System
GSSHA	Gridded Surface Subsurface Hydrologic Analysis
HEC	Hydrologic Engineering Center
HMS	Hydrologic Modeling System
SCS	Soil Conservation Service
UML	University of Maryland Libraries
WMS	Watershed Modeling System

CHAPTER 1
INTRODUCTION

1.1. Definition of the Problem

Water is one of the natural resources for all man-kinds and living-beings. From smallest organism to till biggest creature, all the biological life system and human system is all up to water. 70% of our planet is covered with water but just %0.03 of this water have special of usable and potable (drinkable). Day by day water needs are increasing because world's population is increasing quite fast after all water source is been same. Therefore we need to use water resources beneficial as much as possible and waste water should be avoided.

Water shortage is a big problem for human being as well as water excess. Floods resulting from intense storm, cause loss of life and property. Flooding occurs most commonly from heavy rainfall when natural watercourses do not have the capacity to convey excess water. However, floods are not always caused by heavy rainfall. They can result from other phenomena, particularly in coastal areas where inundation can be caused by a storm surge associated with a tropical cyclone, a tsunami or a high tide coinciding with higher than normal river levels. Dam failure, triggered for example by an earthquake, will result in flooding of the downstream area, even in dry weather conditions. Other factors which may contribute to flooding include: volume, spatial distribution, intensity and duration of rainfall over a catchment; the capacity of the watercourse or stream network to convey runoff; catchment and weather conditions prior to a rainfall event; ground cover; topography; and tidal influences. Despite today's advanced technology and knowledge, floods cannot be totally controlled. However, damages caused by the floods can be minimized by taking precautions.

Water resources engineering is intended to provide balance of usage-protection between watershed (river basin) and natural resources. Wise-use of available resources according to existing technology does not harm and deteriorate the nature; as a result floods will be as minimum as possible. According water resources engineering, river basin should be planned based on watershed management methods. River and watershed management involves the rainfall-runoff model. Rainfall-runoff model aims to examine the relationship between rainfall (entering the system) and flow (leaving the system).

Senegal in West Africa is faced by both problems mentioned above (water shortage and water excess). Tropical climate that prevails in country and country is experiencing dry and rainy season both. Dakar, the capital of the country is growing very fast, and population growth is increasing quite rapidly. See the housing needs as a growing population is increasing. To meet the housing needs houses builds in river basin and that increases of loss life and property. Therefore, watershed management for fast-growing cities such as Dakar is quite important.

1.2. Purpose and Scope of the Study

In Dakar, temperatures are high throughout the year but there is a relatively cooler period from December to April during which rain is very rare. Dakar is a coastal city and its altitude is very low; therefore rainfall between July-October (rainy season) leads to flooding in Dakar basin. Population growth rate in Dakar is very high. Depending on the growing population there is a need to residential areas. To overcome this problem, houses were built in the floodplain. However, the nature of the floodplain was destroyed. In order to avoid disasters caused by flooding, conservation studies and activities should be performed in the natural floodplains.

The purpose of this study is applying hydrological model to the Dakar basin and obtain flood hydrographs by using Geospatial Hydrologic Modeling Extension (HEC-GeoHMS) and Hydrologic Engineering Center's Hydrologic Modeling System (HEC-HMS) software’s. Obtained flood hydrographs will be used to determine the floods reoccurrence intervals. This study will include stages of hydrologic modeling study that was applied to Dakar basin.

1.3. Outline of the Thesis

In Chapter 1, main problems those led to this study are tried to be explained. Purpose and scope of the study are tried to be identified.

In Chapter 2, a brief literature survey on hydrologic modeling and some of the most popular hydrologic modeling software that are widely used in the recent years is given.

In Chapter 3, the methods, software's and materials used in this study are tried to be explained and general information about the Dakar Basin (geography, claimant, geology etc) are given.

In Chapter 4, detailed analysis of the data was performed by using by using Geospatial Hydrologic Modeling Extension (HEC-GeoHMS) and Hydrologic Engineering Center's Hydrologic Modeling System (HEC-HMS) software's.

In Chapter 5, finding and results of data analysis of the study are given. It mainly includes the performance evaluation of the constructed HEC-HMS model that was applied to the Dakar Basin.

In Chapter 6, discussion of the results, conclusion of the study and recommendations for flood management studies can be done in the future are given.

CHAPTER 2
LITERATURE REVIEW

A flood occurs when water overflows or inundates land that's normally dry. There are many reasons of the floods. Most common is when rivers or streams overflow their banks. Excessive rain, a ruptured dam or levee, rapid snow melting in the mountains can cause flood. In many regions of the world, flooding originated by storm events is a major problem. (Townsend and Walsh, 1998 and Hudson and Colditz, 2003). Storm event-induced flooding causes the inundation of residential those are located in the floodplain. In many countries of the world, floods caused the loss of life and property. To minimize the damage caused by the floods, flood modeling and control studies are extremely important. Some software's (such as GIS, ArcGIS and HEC-GeoHMS) and hydrological models (such as HEC-HMS, SWMM 5 and MIKE 11) are used to for flood modeling studies.

Geographic Information System (GIS) help us visualize, question, analyze, and interpret data to understand relationships, patterns, and trends. GIS benefits organizations of all sizes and in almost every industry. In recent years, advances in GIS have opened many opportunities for enhancing hydrologic modeling of watershed systems (USACE-HEC, 2003 and Chang, 2008).

ArcGIS is a GIS software and collection of software products created by Environmental Systems Research Institute (ESRI). It includes desktop, server, mobile, hosted, and online GIS product (Hillier, 2011). ArcMap is the central application used in ArcGIS that create maps and access most of the ArcGIS functionality (Rutherford, 2008). ArcMap represents geographic information as a collection of layers and other elements in a map (UML, 2013). Common map elements include the data frame containing map layers for a given extent plus a scale bar, north arrow, title, descriptive text, a symbol legend, and so on (Rieger, 1998).

The Hydrologic Engineering Center's Geospatial Hydrologic Modeling, HEC-GeoHMS is a public domain extension of ArcGIS software. HEC-GeoHMS is a geospatial hydrology toolkit for engineers and hydrologists. HEC-GeoHMS is used to visualize spatial information, document watershed characteristics, perform spatial analysis, delineate subbasins and streams, construct inputs to hydrologic models, and assist with report preparation (Yen and Chow, 1980). Through the use of HEC-GeoHMS a user can easily and efficiently create hydrologic inputs that can be used directly with the Hydrologic Engineering Center's Hydrologic Modeling System, HEC-HMS software (USACE-HEC, 2003).

Hydrologic models are primarily used for hydrologic prediction and for understanding hydrologic processes (Refsgaard, 1996). Two major types of hydrologic models can be distinguished: stochastic models and process-based models.

- *Stochastic Models*: These models are based on data and using mathematical and statistical concepts to link a certain input (for instance rainfall) to the model output (for instance runoff). These models are designed to perform best within a limited range of time scales and for selected statistics for which they are calibrated (Paschalis etc., 2014). Stochastic models play an important role in elucidating many areas of the natural and engineering sciences (Taylor and Karlin, 1998). Commonly used techniques of stochastic models are regression, transfer functions, neural networks and system identification.

- *Process-Based Models*: These models try to represent the physical processes observed in the real world. Typically, such models contain representations of surface runoff, subsurface flow, evapotranspiration, and channel flow, but they can be far more complicated. Process-based models, derived deductively from established physical laws, can capture the underlying dynamics of watersheds and may produce better predictions across a range of scales. (Beven, 2002). These models are known as deterministic hydrology models. Deterministic hydrology models can be subdivided into single-event models and continuous simulation models (Table 2.1).

Table 2. 1 Deterministic hydrology models according U. S. Federal Emergency Management Agency (FEMA)

PROGRAM	COMMENTS
Single Event	
HEC-1 4.0.1 and up 1	Flood hydrographs at different locations along streams. Calibration runs preferred to determine model parameters (HEC, 2000).
HEC-HMS 1.1 and up	The Hydrologic Modeling System provides a variety of options for simulating precipitation-runoff processes. It now includes snowmelt and interior pond capabilities, plus enhanced reservoir options.
SWMM 5 Version 5.0.005	SWMM 5 provides an integrated environment for editing study area input data, running hydrologic simulations and viewing the results in a variety of formats. These include color-coded drainage area and conveyance system maps, time series graphs and tables, profile plots and statistical frequency analyses. Calibration or verification to the actual flood events highly recommended (James et al., 2010).
MIKE 11	Simulates flood hydrographs at different locations along streams using unit hydrograph techniques. Three methods are available for calculating infiltration losses and three methods for converting rainfall excess to runoff, including SCS Unit hydrograph method (MIKE 11, 2004).
National Weather Service FLDWAV Computer Program	FLDWAV program, developed by the National Weather Service (NWS), is a generalized flood routing program with the capability to model flood flows through a single stream or a system of interconnected waterways. For more information this program, visit the National Weather Service FLDWAV Computer Program factsheet.
XP-SWMM 8.52	Model must be calibrated to observed flows, or discharge per unit area must be shown to be reasonable in comparison to nearby gage data, regression equations or other accepted standards for 1% annual chance events. Calibration or verification to the actual flood events highly recommended (WSM, 2000).
Xpstorm 10.0	Xp storm has the same storm water modeling capability as the XP-SWMM program. Calibration or verification to the actual flood events highly recommended.
Gridded Surface Subsurface Hydrologic Analysis (GSSHA)	GSSHA is a spatially explicit, physics based hydrologic model that can simulate a wide range of runoff mechanisms, including infiltration-excess and saturation-excess runoff, snow melt, storm and tile drains, groundwater exfiltration and discharge, lakes (including non-draining lakes such as prairie potholes), detention basins, culverts and weirs.

Continuous Simulation	
HSPF 10.10 and up (Dec 1993)	Calibration to actual flood events required.
HEC-HMS 3.0 and up (Dec 2005)	The Hydrologic Modeling System (HMS) includes two different soil moisture models suitable for continuous modeling, one with five layers and one with a single layer. Two approaches to evapotranspiration are provided and snowmelt is available (Scharffenberg and Fleming, 2006).
MIKE 11 RR (2009 SP4)	The Rainfall-Runoff Module is a lumped-parameter hydrologic model capable of continuously accounting for water storage in surface and sub-surface zones. Flood hydrographs are estimated at different locations along streams. Calibration to actual flood events is required.
PRMS Version 2.1 (Jan 1996)	PRMS is a modular-designed, deterministic, distributed-parameter modeling system that can be used to estimate flood peaks and volumes for floodplain mapping studies. Calibration to actual flood events required. The program can be implemented within the Modular Modeling System that facilitates the user interface with PRMS, input and output of data, graphical display of the data and an interface with GIS.

Recent research in hydrologic modeling tries to have a more global approach to the understanding of the behavior of hydrologic systems to make better predictions and to face the major challenges in water resources management (HEC, 2000).

CHAPTER 3
METHODS AND MATERIALS

3.1. Software Used in This Study

3.1.1. General Overview

In this study, the Geographic Information System (GIS), Geospatial Hydrologic Modeling Extension (HEC-GeoHMS) and Hydrologic Engineering Center's Hydrologic Modeling System (HEC-HMS) softwares were used. These softwares are used for the hydrologic modeling studies, mostly and ordinarily. HEC-GeoHMS software is a GIS add-in used in ARC View version 3.x, uses ArcGIS and the spatial analyst extension to develop a number of hydrologic modeling inputs for the HEC-HMS (HEC, 2003). HEC-HMS software is designed to simulate the complete hydrologic processes (precipitation-runoff processes) of dendritic watershed systems (Scharffenberg and Fleming, 2006). The relationship between GIS, HEC-GeoHMS, and HEC-HMS is illustrated in Figure 3.1.

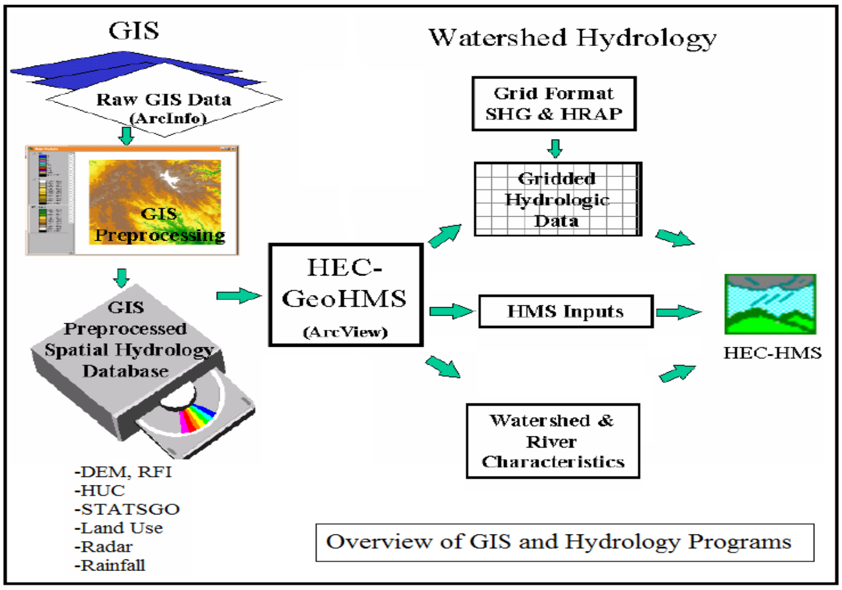


Figure 3. 1 Relationship between GIS, HEC-GeoHMS, HEC-HMS

3.1.2. Geospatial Hydrologic Modeling Extension (HEC-GeoHMS)

3.1.2.1. Overview

The Hydrologic Engineering Center's (HEC) ultimate developments in Geographic Information System (GIS) instrument for hydrologic and hydraulic modeling result from many years of interest in geospatial data usage. The Geospatial Hydrologic Modeling Extension (HEC-GeoHMS) has been developed as a geospatial hydrology toolkit for engineers and hydrologists with limited GIS experience. HEC-GeoHMS uses ArcGIS and the Spatial Analyst extension for developing the number of hydrologic modeling inputs for the Hydrologic Engineering Center's Hydrologic Modeling System, HEC-HMS. ArcGIS and its Spatial Analyst extension are susceptible from the Environmental Systems Research Institute, Inc. (ESRI). Analyzing digital terrain data, HEC-GeoHMS transforms the drainage paths and watershed boundaries into a hydrologic data structure that represents the drainage network. The program allows users to visualize spatial information, document watershed characteristics, perform spatial analysis, and delineate sub-basins and streams. Working with HEC-GeoHMS through its interfaces, menus, tools, buttons, and context-sensitive online help allows the user to pursuant to create hydrologic inputs for HEC-HMS. The menus, buttons and tools of HEC-GeoHMS are shown in Figure 3.2.

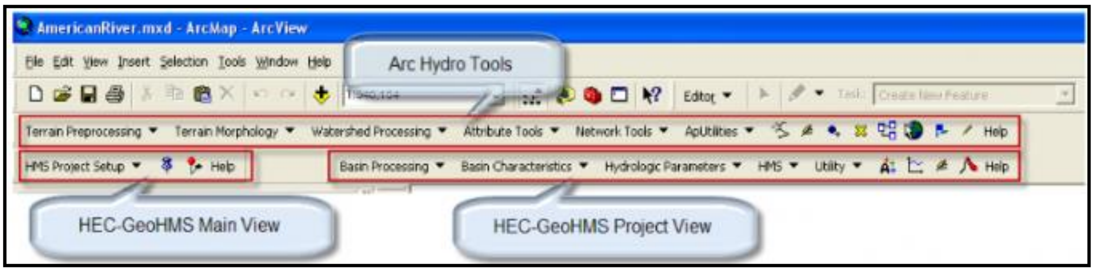


Figure 3. 2 Arc Hydro tools, main view and project view of HEC-GeoHMS software

3.1.2.2.Technical Capabilities of HEC-GeoHMS and Program Features

HEC-GeoHMS version 1.0 constitutes a background map file, lumped basin model, a grid-cell parameter file, and a disintegrate basin model, which can be used by HMS to develop a hydrologic model (Abushandi and Merkel, 2013). To assist with estimating hydrologic parameters, GeoHMS can generate tables containing physical characteristics of streams and watersheds. If the hydrologic model operates the distributive techniques for hydrograph transformation, i.e. Mod-Clark, and grid-based precipitation, then a. grid-cell parameter file and a distributed basin model can be generated. HEC-GeoHMS version 1.1 provide opportunity the user to analyze DEM's in a number of generate systems and projections, including Albers-Equal Area, Universal Transverse Mercator (UTM), Transverse Mercator, Lambert, and the State Plane Coordinate System (Kessler, 1992; Doyle, 1978). An predisposes of version 1.1 provide opportunity users to use more sophisticated "burning in" technique to impose the stream onto the terrain. This is accomplished as a gradual step-wise process to better reproduce stream networks and watershed boundaries. HEC-GeoHMS is a public property extension to the ArcView GIS and Spatial Analyst extension. HEC-GeoHMS runs on the Windows 95/98/NT/2000/XP platforms.

3.1.2.3.Data Management

GeoHMS executes a number of administrative tasks that assistant the user manage GIS data derived from the program. The data management feature tracks thematic GIS data layers and their names in a manner largely transparent to the user. Prior to performing a particular operation, the data manager will offer the appropriate sophisticated data inputs for generating, and prompt the user for confirmation. Other times, the data management feature manages the locations of various projects and also performs error checking and detection.

3.1.2.4.Terrain Preprocessing

Terrain preprocessing marks the first step to using HEC-GeoHMS. In this step, a terrain model is used as an input to derive eight additional data sets that collectively describe the drainage patterns of the watershed and allows for stream and sub-basin delineation. The first five data sets in grid representation are the flow direction, flow accumulation, stream definition, stream segmentation, and watershed delineation. The next two data sets are the vectored representation of the watersheds and streams, and they are the watershed polygons and the stream segments. The last data set, the aggregated watersheds, is used primarily to improve the performance in watershed delineation.

3.1.2.5.Basin Processing

After the terrain preprocessing is completed software gives opportunity to user to revise the sub-basins delineation. Sub-basin and routing reach delineations include points where assistant is needed, i.e., stream flow gage locations, flood damage centers, environmental concerns, and hydrologic and hydraulic controls. Basin processing allows the user to interactively combine or subdivide sub-basins as well as to delineate sub-basins to a set of points.

3.1.2.6.Hydrologic Parameter Estimation

In this step, users have opportunity to count up the Curve Number loss rate parameter based on various soil and land-use databases. The curve number can represent a lumped value for a sub-basin or an individual cell for a grid-based sub-basin. In addition, watershed and channel characteristics together with a spreadsheet template are linked to GeoHMS to assist the users with estimation of initial values of time of concentration. Also, basin and channel characteristics can be used to calculate CN Lag and simple prismatic Muskingum-Conge routing parameters.

3.1.2.7.Transition to Hydrologic Modeling System (HMS)

GeoHMS produces a number of hydrologic inputs that are used directly in HMS. In addition, the program supports the estimation of hydrologic parameters by providing tables of physical characteristics of the streams and watersheds.

3.1.3. Hydrologic Modeling System (HEC-HMS)

3.1.3.2.Overview

The Hydrologic Modeling System is designed to simulate the precipitation-runoff processes of dendritic watershed systems. It is intended to be applicable in a wide range of geographic areas for solving the widest possible range of problems. This includes large river basin water supply and flood hydrology, and small urban or natural watershed runoff (Kalin and Hantush 2006). Hydrographs designed by the program are used directly or in conjunction with other software for studies of water availability, urban drainage, flow forecasting, future urbanization impact, reservoir spillway design, flood damage reduction, floodplain regulation, and systems operation. The main HEC-HMS screen is shown in Figure 3.3.

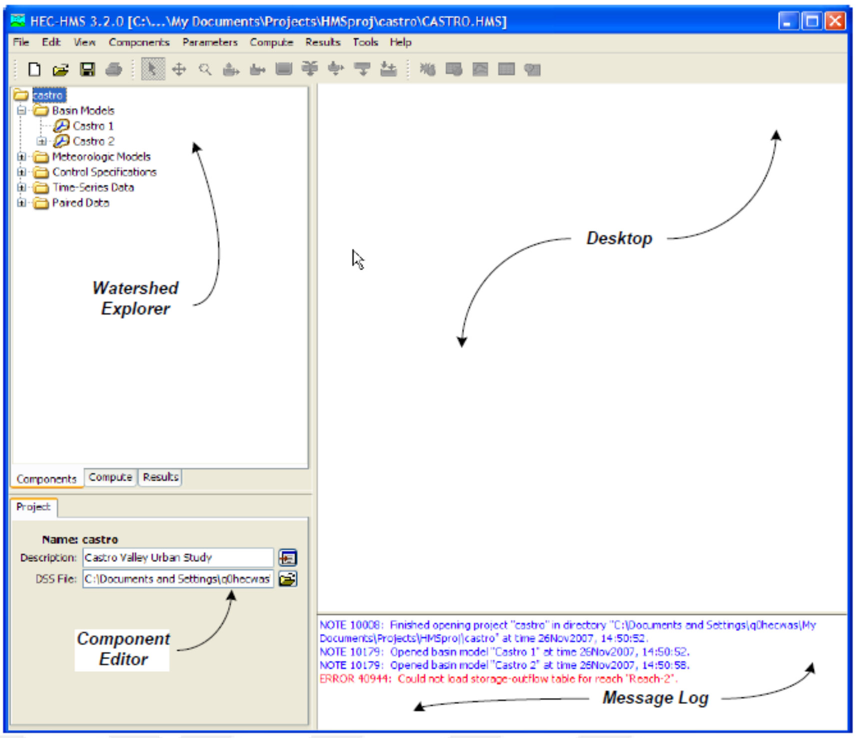


Figure 3. 3 The main HEC-HMS screen

3.1.3.3.Capabilities

The program has a capability to array of capabilities for conducting hydrologic simulation. Many of the most common methods in hydrologic engineering are included in such a way that they are easy to use. The program does the difficult work and let the user be free to concentrate on how best to represent the watershed environment.

3.1.3.4.Watershed Physical Description (Basin model)

The physical representation of a watershed is accomplished with a basin model. Hydrologic elements are connected in a dendritic network to simulate runoff processes. Accessible elements are: sub-basin, reach, junction, reservoir, diversion, source, and sink. These elements are shown in Table 3.1. Computation proceeds from upstream elements in a downstream direction.

Table 3. 1 Hydrologic elements of HEC-HMS software

Hydrologic Element	**Description**
Sub-basin 	The sub-basin is used to represent the physical watershed. Given precipitation, outflow from the sub-basin element is calculated by subtracting precipitation losses, calculating surface runoff, and adding base flow.
Reach 	The reach is used to convey stream flow in the basin model. Inflow to the reach can come from one or many upstream to elements. Outflow from the reach is calculated by accounting for translation and attenuation. Channel losses can optionally be included in the routing.
Junction 	The junction is used to combine stream-flow from elements located upstream of the junction. Inflow to the junction can come from one or many upstream elements. Outflow is calculated by summing all inflows.
Source 	The source element is used to introduce flow into the basin model. The source element has no inflow. Outflow from the source element is defined by the user.
Sink 	The sink is used to represent the outlet of the physical .4 watershed. Inflow to the sink can come from one or many upstream elements. There is no outflow from the sink.
Reservoir 	The reservoir is used to model the detention and attenuation of a hydrograph caused by a reservoir or detention pond. Inflow to the reservoir element can come from one or many upstream elements. Outflow from the reservoir can be calculated using one of three routing methods.
Diversion 	The diversion is used for modeling stream flow leaving the main channel. Inflow to the diversion can come from one or many upstream elements. Outflow from the diversion element consists of diverted flow and non-diverted flow. Diverted flow is calculated using input from the user. Both diverted and non-diverted flows can be connected to hydrologic elements downstream of the diversion element.

An assortment of different and separate methods is available to simulate infiltration losses. Opportunities for event modeling include initial constant, SCS curve number, gridded SCS curve number, exponential, Green Amps, and Smith Parlance. The one-layer deficit constant method can be chosen to use for simple continuous modeling. The five-layer soil moisture accounting method can be chosen to use for continuous designing of complex infiltration and evapotranspiration environments. Gridded methods are acceptable for both the deficit constant and soil moisture accounting methods.

Seven methods are present for transforming excess precipitation into surface runoff. Unit hydrograph methods include the Clark, Snyder, and SCS techniques. User-specified unit hydrograph or s-graph ordinates can also acceptable. The modified Clark method, Mod-Clark, is a linear quasi-distributed unit hydrograph method that can be chosen to use with gridded meteorological data. An implementation of the kinematic wave method with multiple planes and channels is also included.
Five methods are included for representing base-flow contributions to sub-basin outflow. The recession method gives an exponentially decreasing base-flow from a single event or multiple sequential events. The constant monthly method works while continuous simulating. The linear reservoir method conserves mass by routing infiltrated precipitation to the channel. The nonlinear Bossiness method provides a response similar to the recession method but the parameters are estimate from measurable qualities of the watershed.

A total of six hydrologic routing methods are included for simulating flow case of open channels. Routing with no attenuation can be modeled with the lag method. The traditional Muskingum method is included along with the straddle stagger method for simple approximations of attenuation. The modified Pulls method can be used to model a reach as a series of cascading, level pools with a user-specified storage-discharge relationship. Channels with trapezoidal, rectangular, triangular, or circular cross sections can be modeled with the kinematic wave or Muskingum-Conge methods. Channels with overbank areas can be modeled with the Muskingum-Conge method and an 8-point cross section. Additionally, channel losses alsocan be included in the routing. The constant loss method can be added to any routing method while the percolation method can be chosen to use only with the modified Pulls or Muskingum-Conge methods. The methods accessible in the sub-basin and the reach hydrologic elements are shown in Table 3.2.

Table 3. 2 Methods available in the subbasin and the reach hydrologic elements

Hydrologic Element	**Calculation Type**	**Method**
Subbasin	Canopy	Simple (also gridded)
	Surface	Simple (also gridded)
	Loss rate	Deficit and constant rate (also gridded) Exponential Green and Ampt (also gridded) Initial and constant rate SCS curve number (also gridded) Smith Padange Soil moisture accounting (also gridded)
	Trasform	Clark's unit hydrograph Kinematic wave ModClark SCS unit hydrograph Snyders unit hydrograph User-specified s-graph User-specified unit hydrograph
	Baseflow	Bounded recession Constant monthly Linear reservoir Nonlinear Boussinesq Recession
Reach	Routing	Kinematic wave Lag Modified Puls Muskingum Muskingum-Cunge Straddle stagger
	Gain/Loss	**Constant** **Percolation**

Water impoundments also can be represented. Lakes are usually described by a user-entered storage-discharge relationship. Reservoirs can be simulated by describing the physical spillway and outlet structures. Pumps can also be included as compulsory to simulate interior flood area. Control of the pumps can be linked to water depth in the collection pond and, optionally, the stage in the main channel.

3.1.3.5.Meteorology Description (Meteorologic model)

Meteorological data analysis is performed by the meteorological model and includes precipitation, evapotranspiration, and snowmelt. Six different historical and synthetic precipitation methods are included. Three evapotranspiration methods are included at this time. Currently, only two snowmelt methods are available. Precipitation methods are available for calculating basin average precipitation is shown in Table 3.3.

Table 3. 3 Precipitation methods available for describing meteorology

Precipitation Methods	**Descriptions**
Frequency Storms	Used to develop a precipitation event where depths for various durations within the storm have a consistent exceedance probability.
Gage Weights	User specified weights applied to precipitation gages.
Gridded Precipitation	Allows the use of gridded precipitation products, such as NEXRAD radar.
Inverse Distance	Calculates subbasin average precipitation by applying an inverse distance squared weighting with gages.
SCS Storm	Applies a user specified SCS time distribution to a 24-hour total storm depth.
Specified Hyetograph	Applies a user defined hyetograph to a specified subbasin element.
Standard Project Storm	Uses a time distribution to an index precipitation depth.

3.1.3.6.Hydrologic Simulation

The time span of a simulation is cooperated by control specifications. Control specifications include a starting date and time, ending date and time, and a time interval. A simulation runs out for creating a combining a basin model, meteorological model, and control specifications. Run options include a precipitation or flow ratio, ability to save all basin state information at a point in time, and ability to begin a simulation run from previously saved state information. Simulation results can be viewed from the basin map. Global and element summary tables include information on peak flow and total volume. A time-series table and graph is available for elements. Results from multiple elements and multiple simulation runs also can be viewed. All graphs and tables can be printed.

3.1.3.7.Parameter estimation

Most parameters for methods included in sub-basin and reach elements can be estimated automatically using optimization trials. Observed discharge compulsory to be available for at least one element before the optimization can be began. Parameters at any element upstream of the observed flow location can be estimated. Seven different objective functions are accessible to estimate the goodness-of-fit between the computed results and observed discharge. Two different search methods can be chosen to use for minimizing the objective function. Constraints also can be imposed to restrict the parameter space of the search method.

3.1.3.8.Analyzing Simulations

Analysis tools are designed for working with simulation runs out to provide additional information or processing. Presently, the only tool is the depth-area analysis tool. It can works with simulation runs to have a meteorological model using the frequency storm method. Given a decision of elements, the tool automatically adjusts the storm area and generates peak flows represented by the correct storm areas.

3.1.3.9.GIS Connection

The power and speed of the program makes it possible to represent watersheds with hundreds of hydrologic elements. Traditionally, these elements would be identified by inspecting a topographic map and manually identifying drainage boundaries. All with this, those methods are effective; it is prohibitively time consuming while the watershed are represented with many elements. A geographic information system (GIS) can use for elevation data and geometric algorithms to perform the same task much more rapidly. A GIS companion product has been developed for aid in the creation of basin models for such projects. It is called the Geospatial Hydrologic Modeling Extension (HEC-GeoHMS) and can be used to create basin and meteorological models for use with the program.

3.2. Study Area

3.2.1. General Overview of Study Area

Dakar is the capital and largest city of Senegal in West Africa . It is located on the Cape Verde peninsula that juts into the Atlantic Ocean. It has the coordinates of

14°41′34″N 17°26′48″W. The city has been divided into 19 administrative districts in 1996, they are: Biscuiterie, Cambérène, Dieuppeul-Derklé, Fann-Point E-Amitié, Gueule Tapée-Fass-Colobane, Gorée, Grand Yoff, Grand Dakar, Hann Bel-Air, HLM, Médina, Mermoz-Sacré-Cœur, Ngor, Ouakam, Parcelles Assainies, Patte d'Oie, Dakar-Plateau, Sicap-Liberté and Yoff (Figure 3.4). The study area mainly include Cambérène and Parcelles Assainies districts as shown in Figure 3.5.

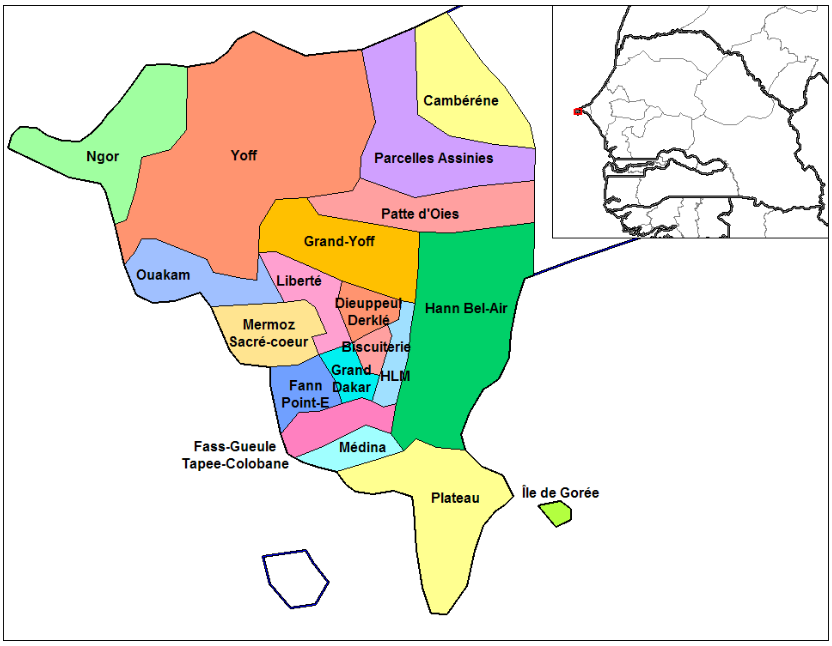


Figure 3. 4 Administrative districts map of Dakar

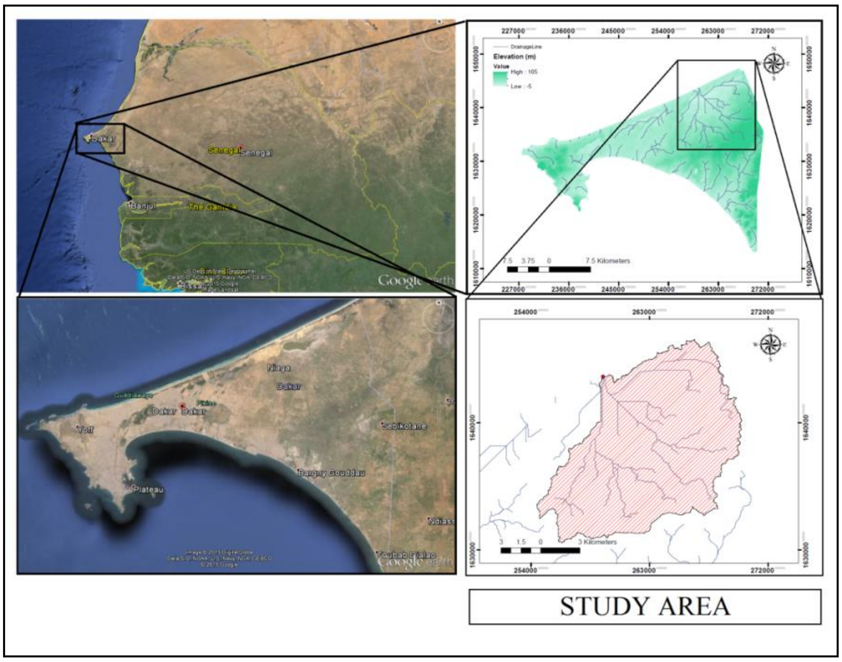


Figure 3. 5 Location of the study area

Senegal has a population of 13.635.927 and population growth rate of Senegal is 2.48% according estimation of 2014. In late 2007, according to official estimates, the total of population was 1 075 582 inhabitants and for now Dakar has a population of 3.137.196, nearly 24 % of the population of Senegal, according National Agency of Statistics and Demography of Senegal (ANSD, 2013).

3.2.2. Climatic Characteristics and Meteorological Data

The Dakarian climate is generally warm. Dakar has a hot semi-arid climate (Peel et al., 2007), with a short rainy season and a lengthy dry season. Dakar's rainy season lasts from July to October while the dry season covers the remaining eight months. The city sees approximately 495 mm of precipitation per year. Locations of the meteorological stations of Dakar are shown in Figure 3.6. Dakar between December and May is usually pleasantly warm with daily temperatures around 24–27 °C. Nights during this time of the year are comfortable, some 17–20 °C. However, between May and November the city becomes decidedly warmer with daily highs reaching 29–31 °C and night lows a little bit above 23–24 °C. Notwithstanding this hotter season Dakar's weather is far from being as hot as that of African cities inland, such as Niamey and N'Djamena, where temperatures hover above 36 °C for much of the year. It has presumably the best climate settings in all western Africa, as it is cooled year-round with sea breezes. Climatic data of Dakar is shown in Table 3.4.

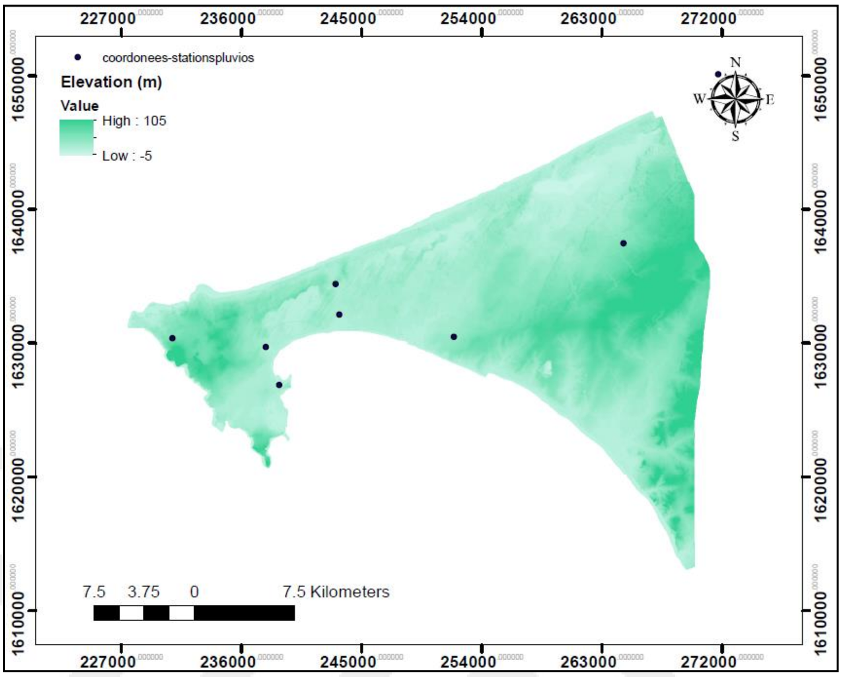


Figure 3. 6 Location of the meteorological stations of Dakar.

Table 3. 4 Climatic Data of Dakar

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Record High °C	37	40	40	39	37	39	40	40	42	40	43	39
Average High °C	25	24,6	25	25	26,3	29	30	30,1	30,4	30,4	29	26,5
Daily Mean °C	22	21,7	22,2	23	23,4	27	27,4	27,4	27,4	28,1	26,4	23,6
Average Low °C	17,4	17	17,4	18	20,2	23	24,5	24,6	24,4	24,3	22,5	19,6
Record Low °C	11	10	10	10	17	17	13	19	17	18	16	12
Precipitation mm	2,1	1,3	0	0	0	10	83,4	184	157	51,6	2,6	2,6
Avg. Precipitation Days (≥ 1 mm)	0	0	0	0	0	1	4	9	8	2	0	0
% Humidity	69	75	76	79	79	78	77	79	81	79	74	66
Mean Monthly Sunshine Hours	244.9	245.8	276	288	291.4	252	232.5	223.2	219	257.3	249	238.7
Percent Possible Sunshine	70	74	74	74	73	65	58	57	60	70	73	69

3.2.3. Topography of Study Area

Dakar is the largest city of the Senegal with an extensive seacoast, low mountains, and deserts. The average elevation of Dakar is 12 meters from sea level. Mountain height average is not so high and even some part of the city is under the sea level (the highest point in the city has 105m and deepest point of the city has -5m altitude). Therefore city has many small lakes under sea level.

Digital Elevation Model (DEM), which has 60 cm resolution (Figure 3.7), of Dakar obtained from Cheikh Anta DIOP University and Minister of Restructuring and Development of Flood Zones of Senegal (Ministre de la Restructuration et de L'aménagement des Zones D'inondation).

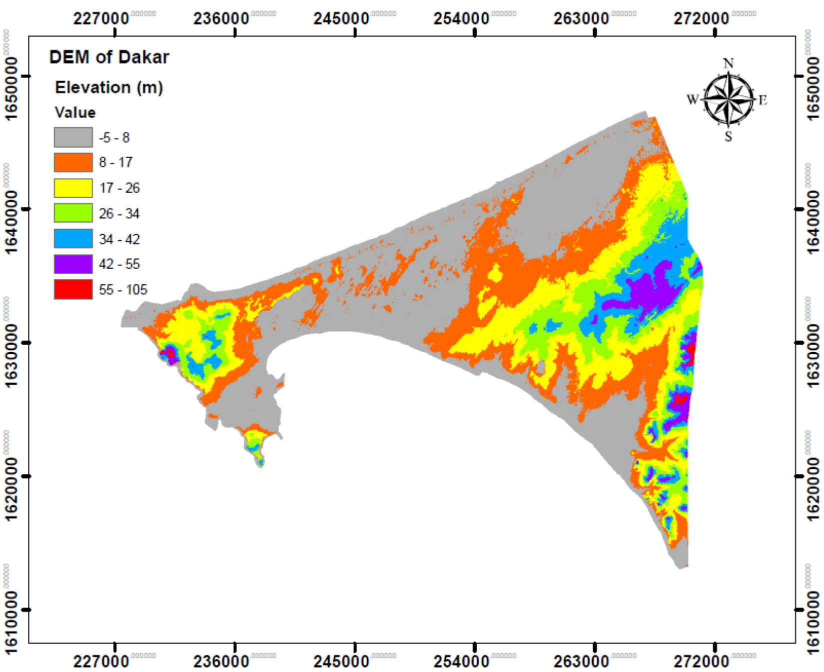


Figure 3. 7 Digital Elevation Model (DEM) of Dakar.

3.2.4. Geological Characteristics

Dakar is located on an ancient volcano. Therefore, there are many different geological formations in the study area. Geology map of Dakar is given in Figure 3.8. The information about formation of geological characteristics of the Dakar city is given below:

- Northern coast of city covered by Coastal Dunes.
- Lake regions are covered by Lagoonal Deposits.

- The coastal and central parts of the city are partially covered by Eocene Clayey.
- Eastern part of the city partially covered by medium size Eocene Limestone.
- Eastern boundary of the city covered by Eocene Miocene Phosphate soil.
- In the northern part of the city there are two large lakes.
- Southeast part of the city is covered by Maastrichtian Sandstones.
- Southern coastal part of the city is covered by Paleocene Limestone.
- Western part of the city is covered by Quaternary Volcanic soil.

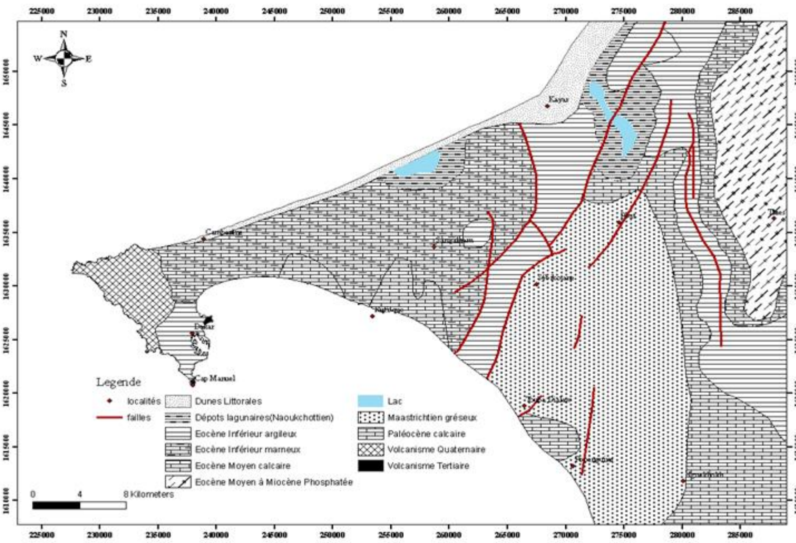


Figure 3. 8 Geology map of Dakar.

CHAPTER 4
ANALYSIS OF DATA

4.1. Basin Preprocessing

In the basin processing, the tools are used to see the delineation results, assess outcomes, and accept or deny the resulting delineation. The schematic of sub-basin model delineation is given in the Figure 4.1.

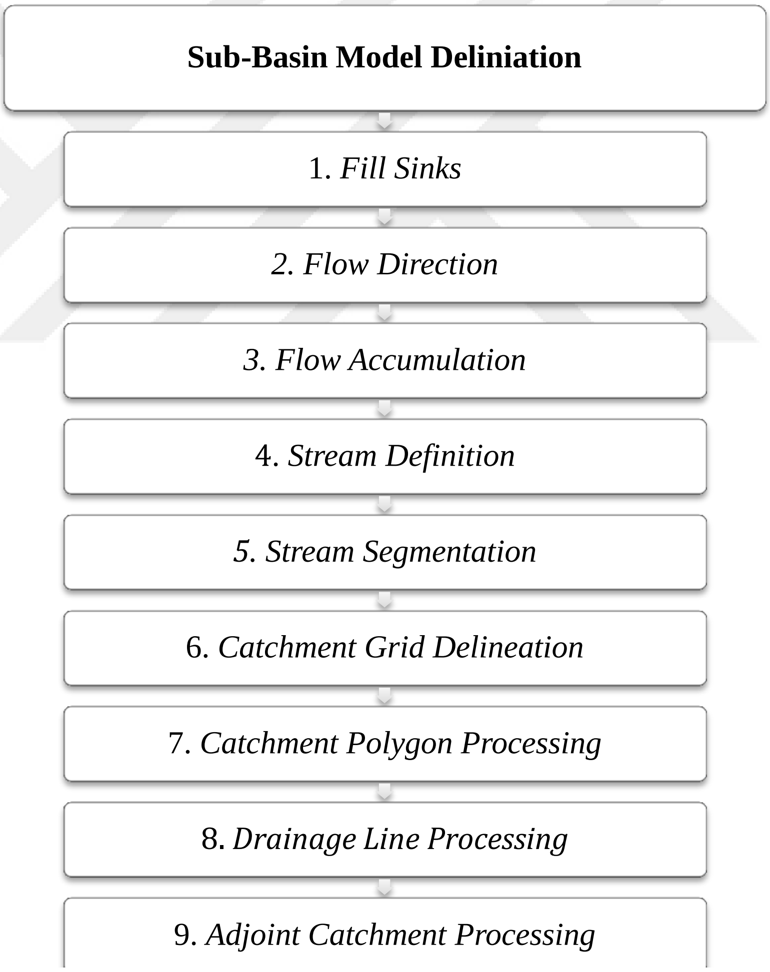


Figure 4. 1 Schematic of sub-basin model delineation

4.1.1. Fill Sinks

The depressionless DEM is created by filling the depressions or pits by increasing the elevation of the pit cells to the level of the surrounding terrain .The pits are often considered as errors in the DEM due to the re-sampling and interpolating. Profile view of a sink before and after running fill is shown in Figure 4.2.

The steps to fill the depressions are shown below:

- **Terrain Preprocessing →Fill Sinks**
- Input of the **RawDEM** should be DEM of the basin, the output of the **HydroDEM** is the **fillgrid** (Figure 4.3).

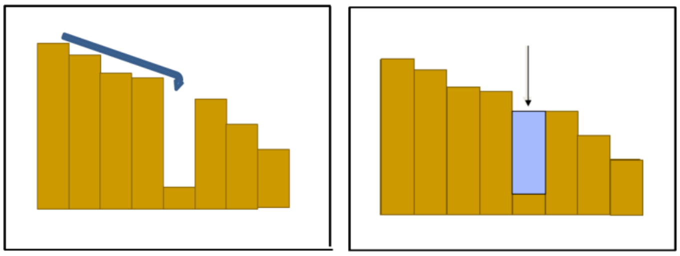


Figure 4. 2 Profile view of a sink before and after running fill

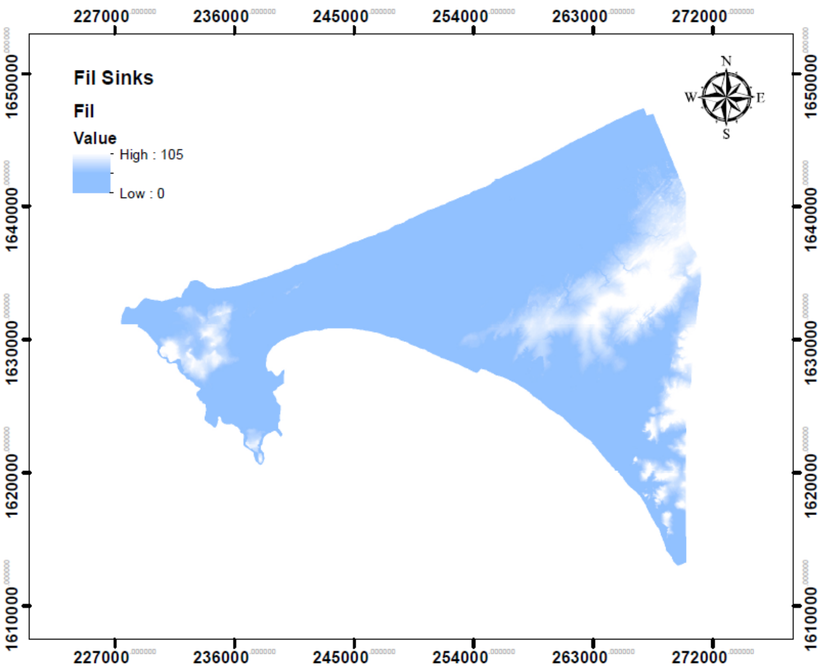


Figure 4. 3 Fill sink results of DEM

4.1.2. Flow Direction

This step defines the direction of the steepest descent for each terrain cell. Similar to a compass, the eight-point pour algorithm specifies the following eight possible directions are shown in Figure 4.4 and Figure 4.5. To get a complete version of flow direction mathematical expressions are used. Mathematical expression of flow direction is shown in Figure 4.6. The output flow direction map is shown in Figure 4.7.

The steps to compute flow directions are shown below:

- **Terrain Preprocessing →Flow Direction**
- Input of the **HydroDEM** is hydrologically corrected DEM**.**

32	64	128
16		1
8	4	2

NW	north	NE
west		east
SW	south	SE

Figure 4. 4 Flow directions

77	66	59
63	54	47
68	65	32

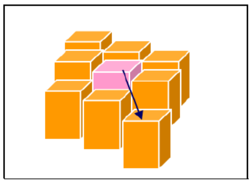


Figure 4. 5 Water flow direction

77	66	59
63	54	47
68	65	32

↘	↘	↓
→	↘	↓
↗	→	↘

2	2	4
1	2	4
128	1	2

Figure 4. 6 Mathematical expression of flow direction

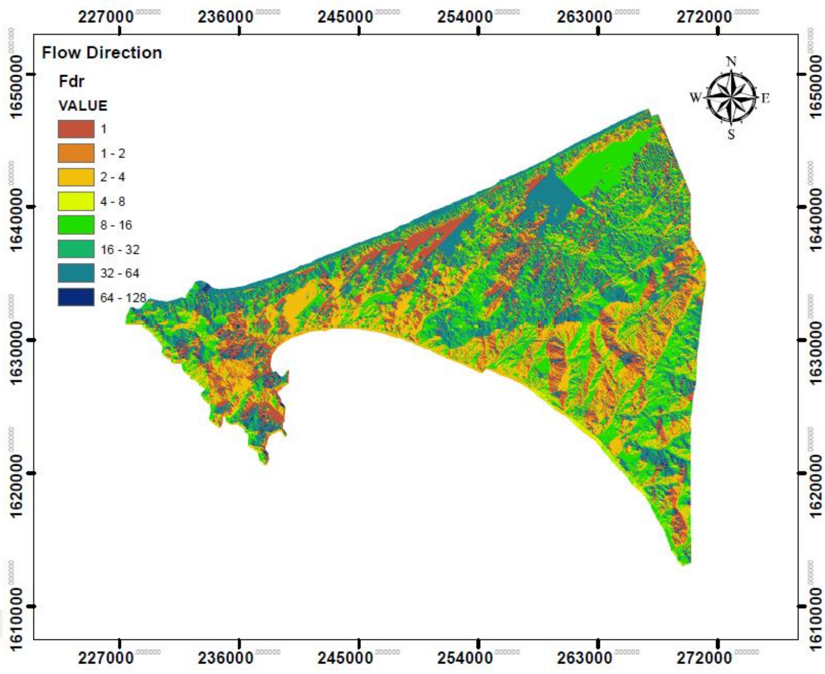


Figure 4. 7 Flow direction result.

4.1.3. Flow Accumulation

Flow Accumulation. This step determines the number of upstream cells draining to a given cell. Upstream drainage area at a given cell can be calculated by multiplying the flow accumulation value by the grid cell area.

The steps to compute flow accumulation are shown below:

- **Preprocessing →Flow Accumulation.**
- The name of the output flow accumulation grid is defined in the "Output Flow Accumulation Grid" field. The result of flow accumulation operation is shown in Figure 4.8.

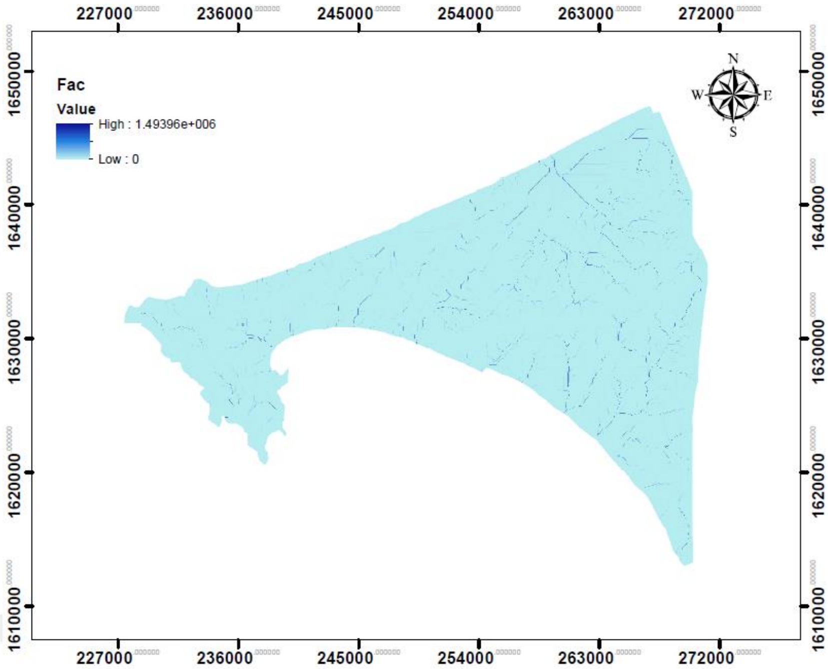


Figure 4. 8 Result of flow accumulation.

4.1.4. Stream Definition

This step classifies all cells with a flow accumulation greater than the user-defined threshold as cells belonging to the stream network. The user-specified threshold may be specified as an area in distance units squared, e.g., square kilometers, or as a. number of cells. The flow accumulation for a particular cell must exceed the user-defined threshold for a stream to be initiated. The default is one percent (1%) of the largest drainage area. in the entire DEM. The smaller the threshold chosen, the greater the number of sub-basins delineated in a. following step.

The steps to compute stream definition are shown below:

- **Preprocessing→Stream Definition.**
- Input will be **Flow Accumulation Grid**.
- The name of the output stream grid is defined in the "Output Stream Grid" field. The result of the Stream Definition operation is the "Str" grid as shown in Figure 4.9.

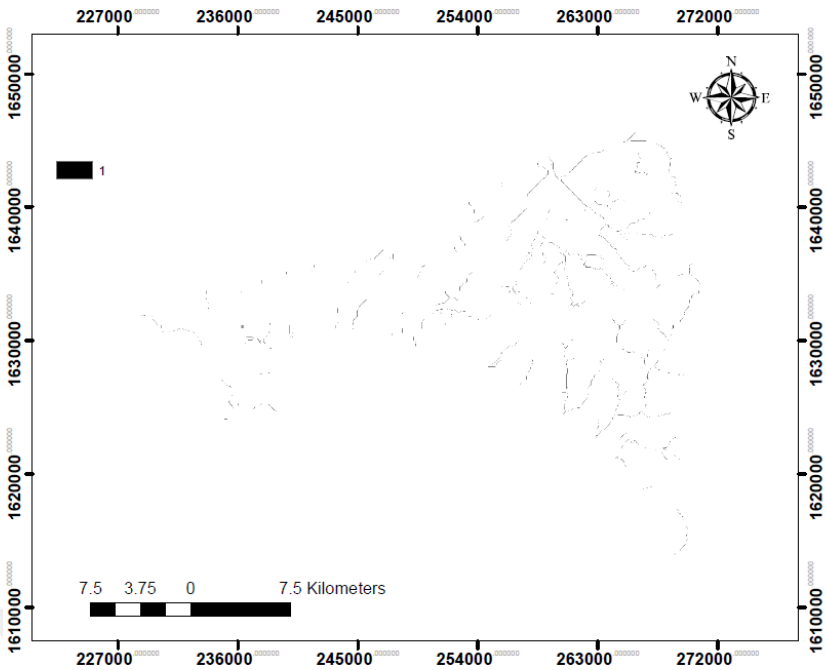


Figure 4. 9 The result of the stream definition operation

4.1.5. Stream Segmentation

This step divides the stream grid into segments. Stream segments, or links, are the sections of a. stream that connect two successive junctions, a. junction and an outlet, or a junction and the drainage divide.

The steps to compute stream segments are shown below.

- **Terrain Preprocessing →Stream Segmentation**.
- "Input Stream Grid" and "Input Flow Direction Grid" files are selected. The stream segmentation operation results in many stream segments as shown in Figure 10.

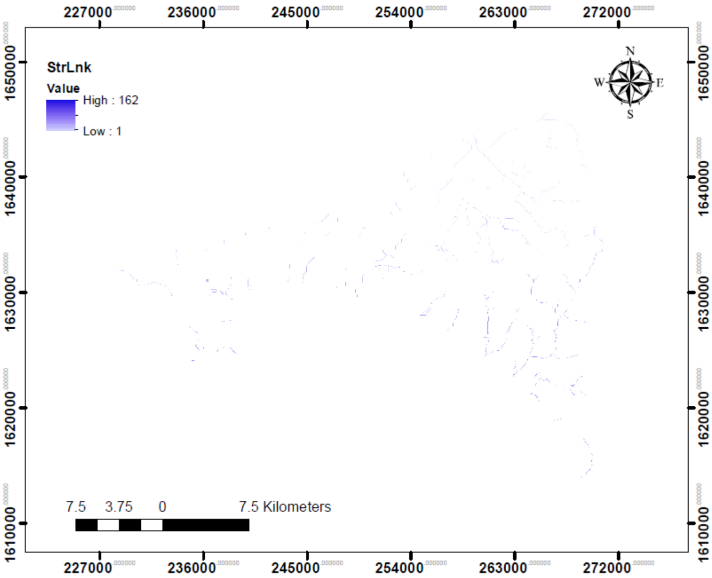


Figure 4. 10 The stream segmentation operation results

4.1.6. Catchment Grid Delineation

This step delineates a sub-basin for every stream segment. The steps to delineate watersheds are shown below:

- **Terrain Preprocessing →Catchment Grid Delineation**.
- "Input Flow Direction Grid" and the "Input Link Grid" files are selected. The watershed delineation operation result is shown in Figure 4.11.

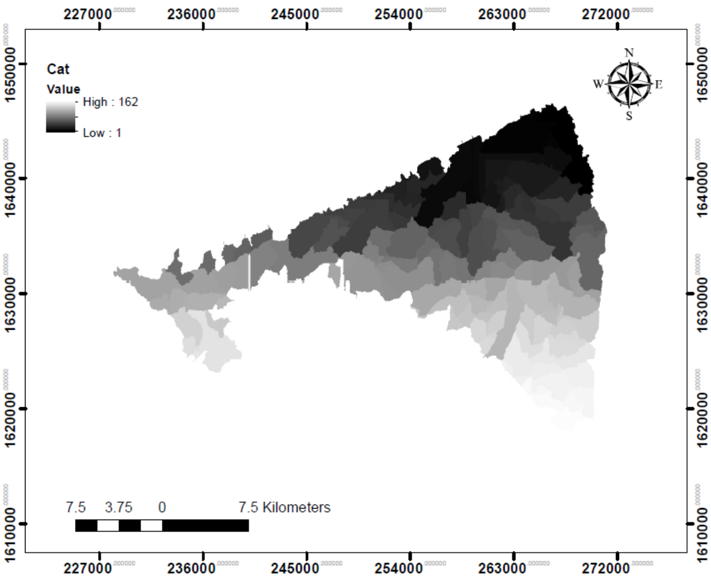


Figure 4. 11 The watershed delineation operation result

4.1.7. Watershed Polygon Processing

Catchment Polygon Processing. This step creates a. vector layer of subbasins using the catchment grid computed in the previous step. The steps to create a. polygon sub-basin layer are shown below.

- **Preprocessing →Catchment Polygon Processing.**
- Select the "Input Catchment Grid" file is selected. The catchment polygon processing operation creates a polygon sub-basin layer as shown in Figure 4.12.

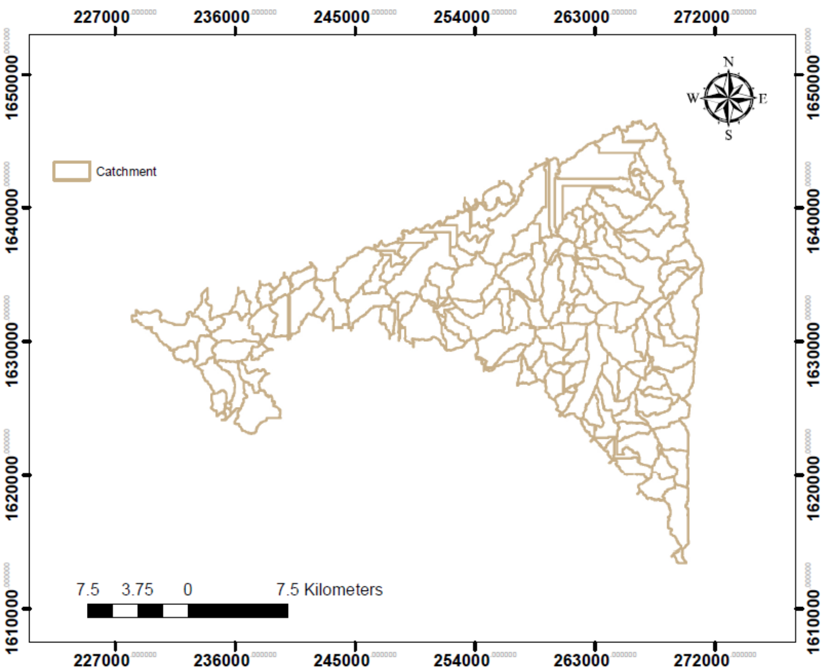


Figure 4. 12 The catchment polygon processing operation result

4.1.8. Drainage Line

This step creates a. vector stream layer. The steps to vectorize stream segments are shown below:

- **Preprocessing →Drainage Line Processing.**
- "Input Stream Link Grid" and the "Input Flow Direction Grid" are selected. The stream layer is shown in Figure 4.13.

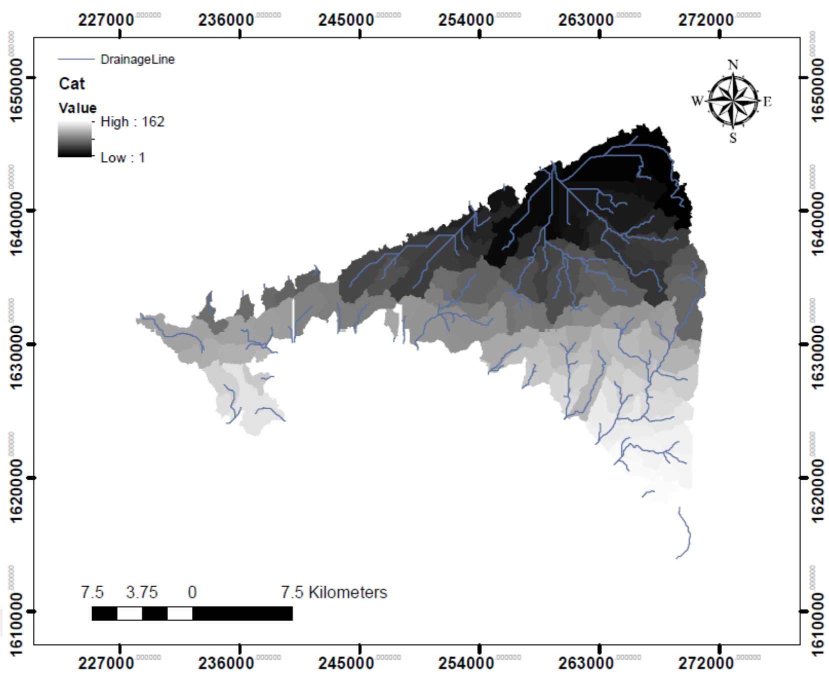


Figure 4. 13 Drainage line processing results

4.1.9. Adjoint Cathcement

This step aggregates the upstream subbasins at every stream confluence. This is a required step and is performed to improve computational performance for interactively delineating subbasins and to enhance data extraction when defining a HEC-GeoHMS project. This step does not have any hydrologic significance.

The steps to aggregate watersheds are shown below.

- **Preprocessing →Adjoint Catchment Processing.**
- "Input Drainage Line" and "Input Catchment" layers are selected. The adjoint catchment operation results are shown in Figure 4.14.

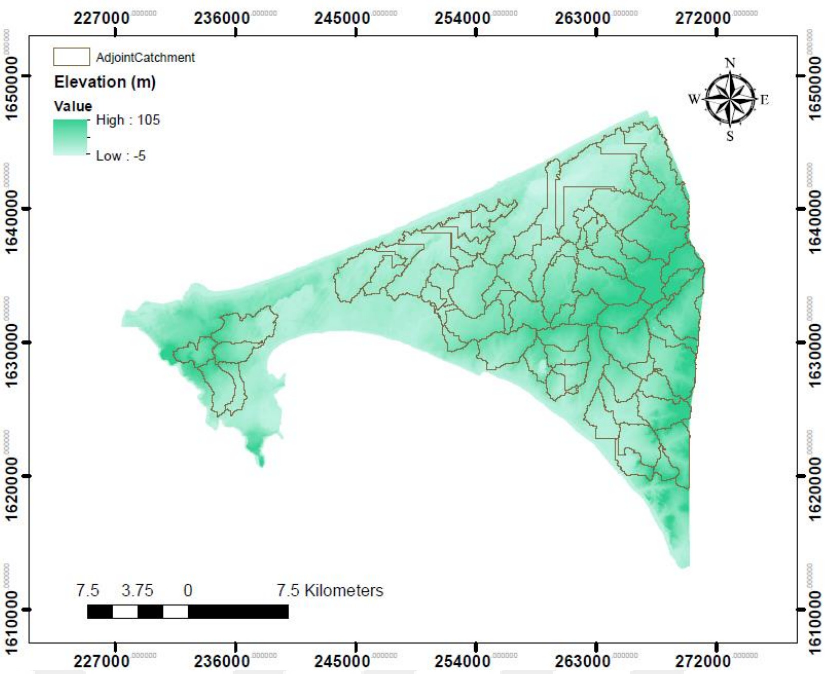


Figure 4. 14 The adjoint catchment operation results

4.2. Extracting Project Specific Data

Tools on the HEC-GeoHMS Project View toolbar were used to interactively delineate the project area and create input files for HEC-HMS project. The steps of extracting data are shown below.

4.2.1. Start a New Project

HMS Project Setup tool menu was used to start a new project. By using **Add Project Point** tool, a point selected on the cell located at the gage. The selected project point is shown in the Figure 4.15.

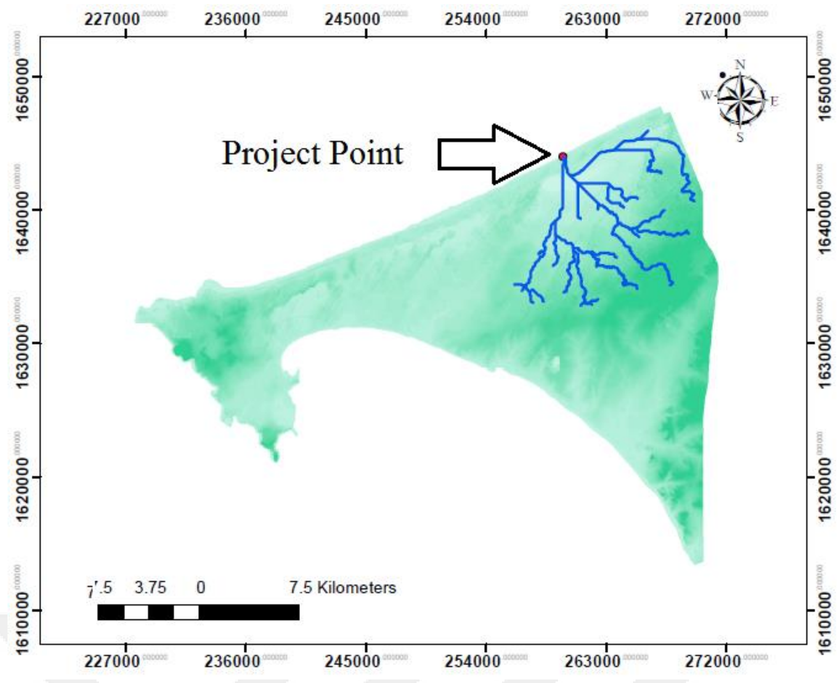


Figure 4. 15 Selected project point

4.2.2. Generate Project

The project area was obtained by using **Generate Project** process. The extracted project area is shown in the Figure 4.16.

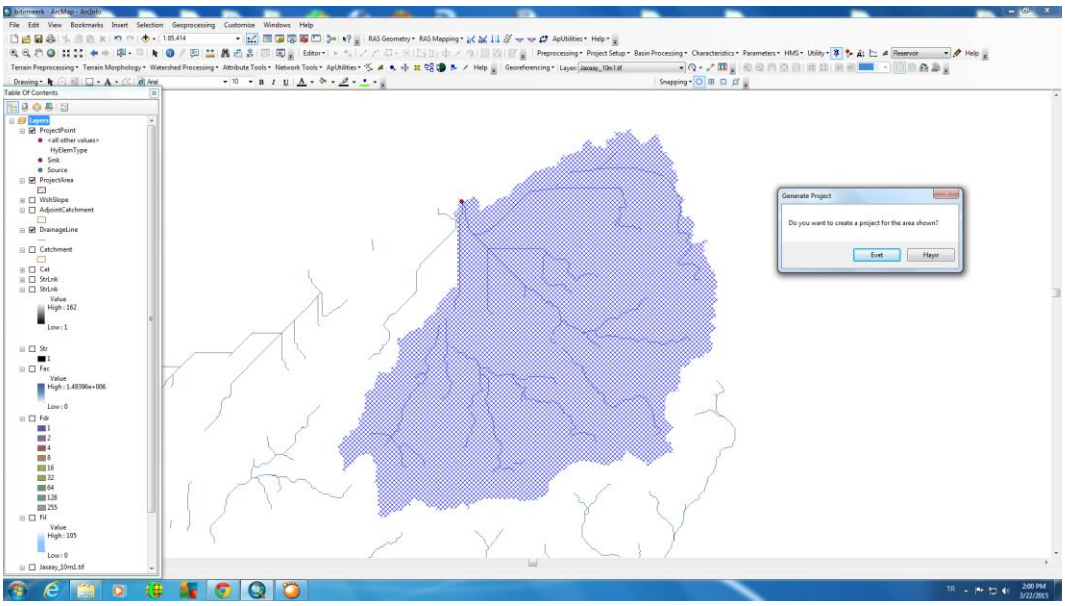


Figure 4. 16 Project Area to be extracted

The pertinent datasets are extracted for the area above the outlet and added to the project data frame (Figure 4.17). These datasets will be used for additional basin processing extracting basin characteristics, and developing HEC-HMS inputs.

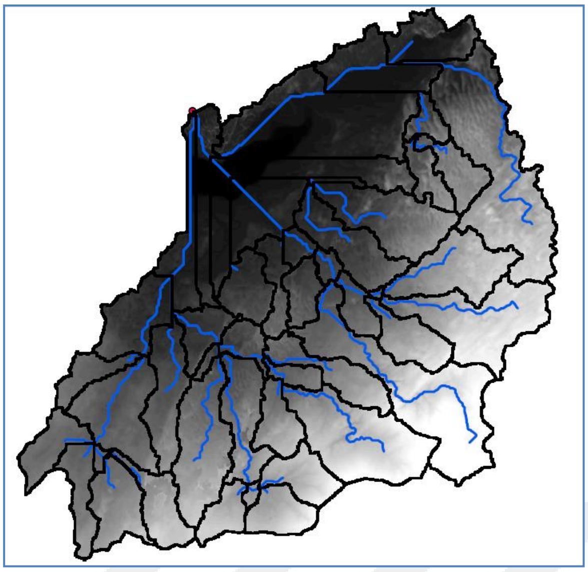


Figure 4. 17 Project frame with extracted data

4.3. Basin Processing

4.3.1. Obtain River Profile

By using **River Profile** tool, river profiles of the study area were obtained. An example of river profile is shown in the figure 18.

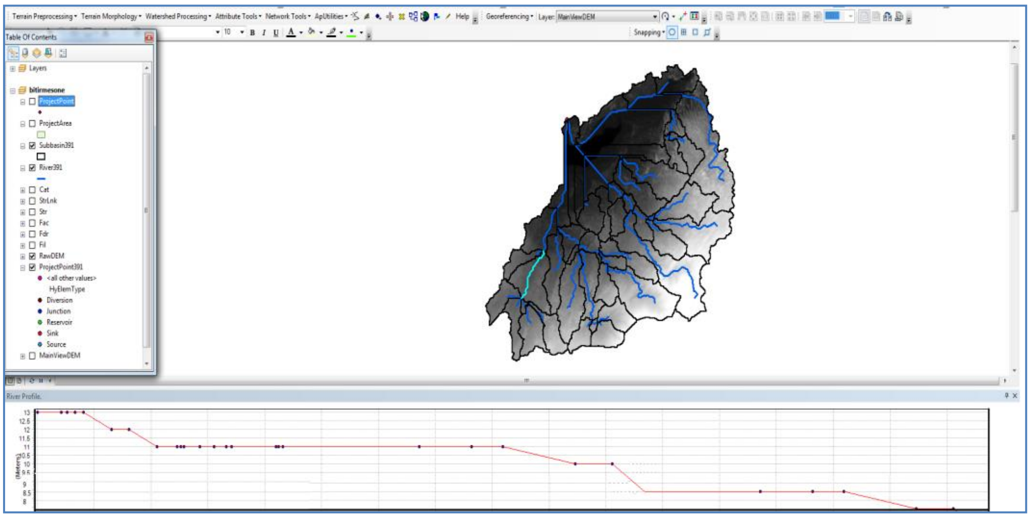


Figure 4. 18 River profile

4.3.2. River Length

Attribute table for the river layer that generated after process of **River Length** is shown in the Table 4.1.

Table 4. 1 Attribute table for the river layer

Table

River391

OBJECTID *	Shape *	arcid	grid_code	from_node	to_node	Shape_Length	HydroID	NextDownID	DrainID	RivLen
1	Polyline	1	1	1	2	1006.309883	1	2	5	1006.309883
2	Polyline	2	3	2	3	2117.228714	2	8	5	2117.228714
3	Polyline	3	6	5	4	59.497475	3	-1	5	59.497475
4	Polyline	4	5	6	3	4324.680374	4	8	5	4324.680374
5	Polyline	5	9	7	6	441.629509	5	4	5	441.629509
6	Polyline	6	10	8	6	1503.111832	6	4	6	1503.111832
7	Polyline	7	8	9	5	1476.396103	7	3	5	1476.396103
8	Polyline	8	4	3	9	4101.147904	8	7	5	4101.147904
9	Polyline	9	11	10	9	820.243866	9	7	6	820.243866
10	Polyline	10	12	11	10	2453.847763	10	9	6	2453.847763
11	Polyline	11	15	12	11	3129.629868	11	10	6	3129.629868
12	Polyline	12	2	13	2	9626.280297	12	2	5	9626.280297
13	Polyline	13	14	14	10	2149.604615	13	9	6	2149.604615
14	Polyline	14	16	15	11	2773.944443	14	10	6	2773.944443
15	Polyline	15	17	16	14	463.284271	15	13	6	463.284271
16	Polyline	16	18	18	14	1265.391052	16	13	6	1265.391052
17	Polyline	17	21	19	18	113.63961	17	16	7	113.63961
18	Polyline	18	13	20	10	2785.060967	18	9	6	2785.060967
19	Polyline	19	7	21	5	5001.665222	19	3	5	5001.665222
20	Polyline	20	20	22	18	1261.543289	20	16	7	1261.543289
21	Polyline	21	19	17	23	2808.91919	21	23	6	2808.91919
22	Polyline	22	24	24	22	1132.253967	22	20	7	1132.253967
23	Polyline	23	26	23	24	551.421356	23	22	7	551.421356
24	Polyline	24	23	26	21	1028.284271	24	19	7	1028.284271
25	Polyline	25	28	25	23	4849.812768	25	23	7	4849.812768
26	Polyline	26	27	27	24	1091.751442	26	22	7	1091.751442
27	Polyline	27	30	28	26	1908.944443	27	24	8	1908.944443
28	Polyline	28	22	29	21	2751.492783	28	19	7	2751.492783
29	Polyline	29	31	30	28	358.994949	29	27	8	358.994949
30	Polyline	30	36	31	28	1674.680374	30	27	8	1674.680374
31	Polyline	31	32	32	29	606.482323	31	28	8	606.482323
32	Polyline	32	37	33	31	2343.883476	32	30	8	2343.883476
33	Polyline	33	38	34	31	1109.827561	33	30	8	1109.827561
34	Polyline	34	29	35	26	2764.716088	34	24	7	2764.716088
35	Polyline	35	39	36	34	484.705627	35	33	8	484.705627
36	Polyline	36	25	38	22	9005.519113	36	20	7	9005.519113
37	Polyline	37	41	37	39	929.203102	37	38	9	929.203102
38	Polyline	38	33	39	29	3338.477631	38	28	8	3338.477631
39	Polyline	39	42	40	39	14.142136	39	38	9	14.142136
40	Polyline	40	40	41	34	5348.868684	40	33	9	5348.868684
41	Polyline	41	43	42	40	511.335137	41	39	9	511.335137
42	Polyline	42	44	43	40	521.837662	42	39	9	521.837662
43	Polyline	43	34	44	30	3927.975106	43	29	8	3927.975106
44	Polyline	44	45	46	43	1630.868325	44	42	9	1630.868325
45	Polyline	45	35	47	30	4619.604615	45	29	8	4619.604615
46	Polyline	46	46	48	43	1043.050865	46	42	9	1043.050865
47	Polyline	47	47	45	49	869.974747	47	48	9	869.974747
48	Polyline	48	49	49	47	440.416306	48	45	9	440.416306

(1 out of 50 Selected)

River391

4.3.3. River Slope

Slope attributes for the river layers is shown in the Table 4.2.

Table 4. 2 Slope attributes for the river layers

OBJECTID *	Shape *	arcid	grid_code	from_node	to_node	Shape_Length	HydroID	NextDownID	DrainID	RivLen	Slp	ElevUP	ElevDS
1	Polyline	1	1	1	2	1006.309883	1	2	51	1006.309883	-0.002981	0	3
2	Polyline	2	3	2	3	2117.228714	2	8	53	2117.228714	0	3	3
3	Polyline	3	6	5	4	59.497475	3	-1	56	59.497475	0.016807	3	2
4	Polyline	4	5	6	3	4324.680374	4	8	55	4324.680374	0.00185	11	3
5	Polyline	5	9	7	6	441.629509	5	4	59	441.629509	0.002264	12	11
6	Polyline	6	10	8	6	1503.111832	6	4	60	1503.111832	0.005322	19	11
7	Polyline	7	8	9	5	1476.396103	7	3	58	1476.396103	-0.001355	1	3
8	Polyline	8	4	3	9	4101.147904	8	7	54	4101.147904	0.000488	3	1
9	Polyline	9	11	10	9	820.243866	9	7	61	820.243866	-0.004877	-3	1
10	Polyline	10	12	11	10	2453.847763	10	9	62	2453.847763	0.002038	2	-3
11	Polyline	11	15	12	11	3129.629868	11	10	65	3129.629868	0.002876	11	2
12	Polyline	12	2	13	2	9626.280297	12	2	52	9626.280297	0.002493	27	3
13	Polyline	13	14	14	10	2149.604615	13	9	64	2149.604615	0.002791	3	-3
14	Polyline	14	16	15	11	2773.944443	14	10	66	2773.944443	0.001802	7	2
15	Polyline	15	17	16	14	463.284271	15	13	67	463.284271	0	3	3
16	Polyline	16	18	18	14	1265.391052	16	13	68	1265.391052	0.00079	4	3
17	Polyline	17	21	19	18	113.63961	17	16	71	113.63961	0.017599	6	4
18	Polyline	18	13	20	10	2785.060967	18	9	63	2785.060967	0.002154	3	-3
19	Polyline	19	7	21	5	5001.665222	19	3	57	5001.665222	-0.0004	1	3
20	Polyline	20	20	22	18	1261.543289	20	16	70	1261.543289	0.001585	6	4
21	Polyline	21	19	17	23	2808.91919	21	23	69	2808.91919	0.004628	26	13
22	Polyline	22	24	24	22	1132.253967	22	20	74	1132.253967	0.004416	11	6
23	Polyline	23	26	23	24	551.421356	23	22	76	551.421356	0.003627	13	11
24	Polyline	24	23	26	21	1028.284271	24	19	73	1028.284271	0.001945	3	1
25	Polyline	25	28	25	23	4849.812768	25	23	78	4849.812768	0.004536	35	13
26	Polyline	26	27	27	24	1091.751442	26	22	77	1091.751442	0.005496	17	11
27	Polyline	27	30	28	26	1908.944443	27	24	80	1908.944443	0.001048	5	3
28	Polyline	28	22	29	21	2751.492783	28	19	72	2751.492783	0.001454	5	1
29	Polyline	29	31	30	28	358.994949	29	27	81	358.994949	0.002786	6	5
30	Polyline	30	36	31	28	1674.680374	30	27	86	1674.680374	0.002986	10	5
31	Polyline	31	32	32	29	606.482323	31	28	82	606.482323	0.006595	9	5
32	Polyline	32	37	33	31	2343.883476	32	30	87	2343.883476	0.003413	18	10
33	Polyline	33	38	34	31	1109.827561	33	30	88	1109.827561	0.003604	14	10
34	Polyline	34	29	35	26	2764.716088	34	24	79	2764.716088	0.002894	11	3
35	Polyline	35	39	36	34	484.705627	35	33	89	484.705627	0.002063	15	14
36	Polyline	36	25	38	22	9005.519113	36	20	75	9005.519113	0.003998	42	6
37	Polyline	37	41	37	39	929.203102	37	38	91	929.203102	0.002152	15	13
38	Polyline	38	33	39	29	3338.477631	38	28	83	3338.477631	0.002396	13	5
39	Polyline	39	42	40	39	14.142136	39	38	92	14.142136	0	13	13
40	Polyline	40	40	41	34	5348.868684	40	33	90	5348.868684	0.003739	34	14
41	Polyline	41	43	42	40	511.335137	41	39	93	511.335137	0.001956	14	13
42	Polyline	42	44	43	40	521.837662	42	39	94	521.837662	0.001916	14	13
43	Polyline	43	34	44	30	3927.975106	43	29	84	3927.975106	0.004073	22	6
44	Polyline	44	45	46	43	1630.868325	44	42	95	1630.868325	0.004292	21	14
45	Polyline	45	35	47	30	4619.604615	45	29	85	4619.604615	0.003247	21	6
46	Polyline	46	46	48	43	1043.050865	46	42	96	1043.050865	0.003835	18	14
47	Polyline	47	47	45	49	869.974747	47	48	97	869.974747	0.004598	26	22
48	Polyline	48	49	49	47	440.416306	48	45	99	440.416306	0.002271	22	21
49	Polyline	49	50	50	49	324.705627	49	48	100	324.705627	0.006159	24	22
50	Polyline	50	48	51	47	452.340187	50	45	98	452.340187	0.004421	23	21

4.3.4. Longest Flow Path

The result of the longest flow path operation is shown in the Figure 4.19 and the physical parameters in the attribute table are shown in the Table 4.3.

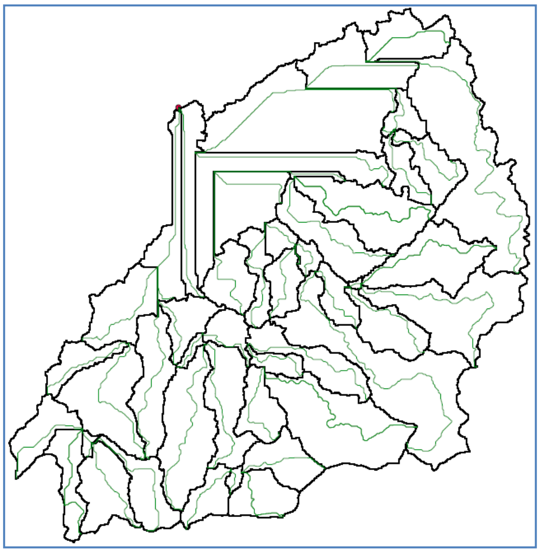


Figure 4. 19 Longest flow path layer

Table 4. 3 Attribute table fort the longest flow path

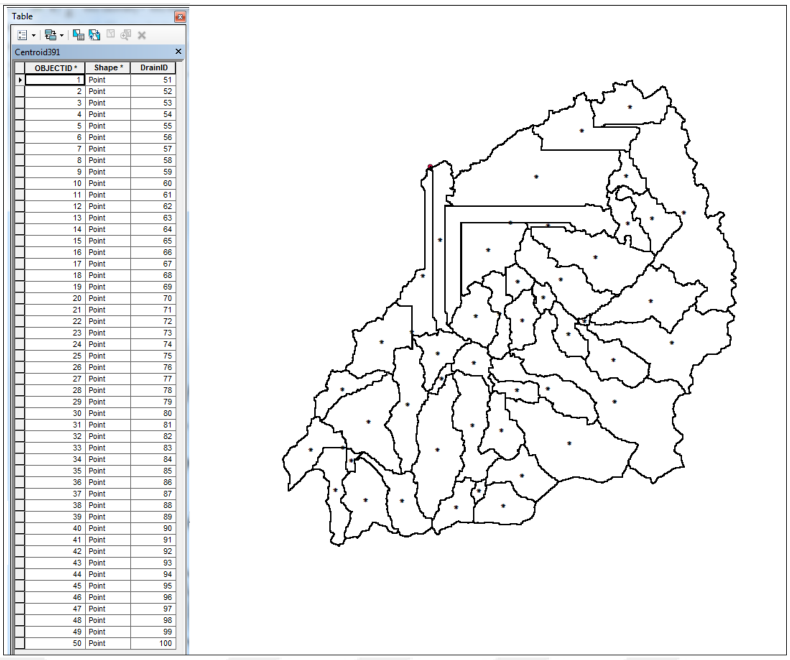
Table

LongestFlowPath391

OBJECTID *	Shape *	Shape_Length	DrainID	Slp	ElevUP	ElevDS	Slp1085	Elev10	Elev85	LengthDow	LongestFL	HYDROID
1	Polyline	3246.848122	51	0.004312	17	3	0.002053	3	8	11001.11831	3246.848122	02
2	Polyline	3246.848122	51	0.004312	17	3	0.002053	3	8	11001.11831	3246.848122	03
3	Polyline	3731.162697	53	0.001608	9	3	0	1	1	9368.20417	3731.162697	04
4	Polyline	122.426407	56	0.024505	5	2	0.010891	2	3	122.42640	122.426407	05
5	Polyline	7372.422074	54	0.00217	17	1	0	1	1	8906.24458	7372.422074	06
6	Polyline	4873.233765	55	0.003899	22	3	0.002462	0	9	10508.20417	4873.233765	07
7	Polyline	3845.904038	60	0.00364	25	11	0.003467	12	22	13805.55482	3845.904038	08
8	Polyline	4036.837662	62	0.002229	6	-3	0.002312	-4	3	6390.90403	4036.837662	09
9	Polyline	6775.721138	61	0.003394	24	1	0.002558	-4	9	8311.61471	6775.721138	10
10	Polyline	2782.46212	64	0.002875	5	-3	0.002875	-3	3	5138.59956	2782.46212	11
11	Polyline	3221.579003	59	0.004035	24	11	0.004967	11	23	13183.30085	3221.579003	12
12	Polyline	6172.777413	65	0.004698	32	3	0.004104	3	22	10982.7626	6172.777413	13
13	Polyline	6172.777413	65	0.004698	32	3	0.004104	3	22	10982.7626	6172.777413	14
14	Polyline	6172.777413	65	0.004698	32	3	0.004104	3	22	10982.7626	6172.777413	15
15	Polyline	5166.147904	69	0.004839	38	13	0.004129	17	33	13880.4285	5166.147904	16
16	Polyline	5166.147904	69	0.004646	37	13	0.004129	17	33	13880.4285	5166.147904	17
17	Polyline	5239.751801	66	0.004008	24	3	0.003817	2	17	10047.6659	5239.751801	18
18	Polyline	1963.883476	68	0.004074	11	3	0.003395	2	7	6469.62553	1963.883476	19
19	Polyline	12522.8593	52	0.002955	40	3	0.003301	1	32	20275.05842	12522.8593	20
20	Polyline	1561.396103	70	0.004483	10	3	0.00427	4	9	7330.45814	1561.396103	21
21	Polyline	727.132034	76	0.008252	17	11	0.005501	11	14	8889.99133	727.132034	22
22	Polyline	5973.883476	58	0.000837	8	3	0.000893	0	4	6033.38095	5973.883476	23
23	Polyline	6340.512986	57	0.000473	6	3	0.000421	0	2	6397.93939	6340.512986	24
24	Polyline	5312.939392	63	0.003953	18	-3	0.003262	-4	9	7667.00576	5312.939392	25
25	Polyline	1483.284271	73	0.002023	4	1	0.001798	1	3	6542.37590	1483.284271	26
26	Polyline	2801.28463	71	0.003927	16	5	0.004284	6	15	8572.41774	2801.28463	27
27	Polyline	4096.909089	67	0.004149	20	3	0.00358	3	14	8600.58003	4096.909089	28
28	Polyline	2620.452019	74	0.006869	25	7	0.006106	8	20	9653.12841	2620.452019	29
29	Polyline	3882.533547	72	0.004121	17	1	0.002747	3	11	8943.69624	3882.533547	30
30	Polyline	3772.117241	77	0.008483	43	11	0.007776	13	35	11937.04760	3772.117241	31
31	Polyline	2463.000359	80	0.005278	16	3	0.003789	3	10	8552.44732	2463.000359	32
32	Polyline	2280.09668	86	0.004386	16	6	0.003509	7	13	10276.41702	2280.09668	33
33	Polyline	7512.960313	78	0.004126	45	14	0.004082	17	40	16227.24096	7512.960313	34
34	Polyline	1529.325035	81	0.005885	15	6	0.006103	7	14	9527.71644	1529.325035	35
35	Polyline	2656.492783	88	0.004517	22	10	0.004517	10	19	12327.49350	2656.492783	36
36	Polyline	3405.548699	82	0.004405	20	5	0.004307	7	18	11218.20417	3405.548699	37
37	Polyline	4982.117241	87	0.006423	42	10	0.004817	13	31	14655.18902	4982.117241	38
38	Polyline	7263.254685	90	0.004956	50	14	0.004589	16	41	18044.08296	7263.254685	39
39	Polyline	7263.254685	90	0.004956	50	14	0.004589	16	41	18044.08296	7263.254685	40
40	Polyline	247.071068	92	0	13	13	0	13	13	11398.20417	247.071068	41
41	Polyline	3254.716088	89	0.006145	34	14	0.006964	14	31	14037.61543	3254.716088	42
42	Polyline	10721.620844	75	0.004104	51	7	0.004104	10	43	17754.29724	10721.620844	43
43	Polyline	984.827561	94	0.004062	17	13	0.004062	13	16	12148.0317	984.827561	44
44	Polyline	5009.579362	83	0.004392	27	5	0.003726	7	21	12820.16377	5009.579362	45
45	Polyline	5678.868684	79	0.00405	26	3	0.004226	3	21	11766.24458	5678.868684	46
46	Polyline	4961.528496	85	0.00524	33	7	0.003225	9	21	13318.91485	4961.528496	47
47	Polyline	2894.360749	97	0.007601	45	23	0.007831	24	41	16309.69696	2894.360749	48
48	Polyline	3146.076477	91	0.002543	21	13	0.001695	14	18	14295.13852	3146.076477	49
49	Polyline	910.979797	99	0.008782	29	21	0.008782	22	28	13885.89970	910.979797	50
50	Polyline	6410.706345	84	0.004992	38	6	0.004368	9	30	14766.02163	6410.706345	51
51	Polyline	2591.162697	100	0.007333	42	23	0.008748	23	40	16008.56997	2591.162697	52
52	Polyline	2591.162697	100	0.007333	42	23	0.008748	23	40	16008.56997	2591.162697	53
53	Polyline	3383.83297	96	0.007093	38	14	0.006699	16	33	15070.94587	3383.83297	54
54	Polyline	2545.426766	98	0.005893	36	21	0.006286	23	35	15522.41774	2545.426766	55
55	Polyline	4671.46753	95	0.004495	35	14	0.004852	16	33	16356.50937	4671.46753	56
56	Polyline	4104.543648	93	0.003167	26	13	0.002924	14	23	15269.81889	4104.543648	57
57	Polyline	4104.543648	93	0.003167	26	13	0.002924	14	23	15269.81889	4104.543648	58

4.3.5. Basin Centroid

Center of gravity method was used to find basin centroids. Attribute table and locations of the centroids are shown in the Figure 4.20.



Table

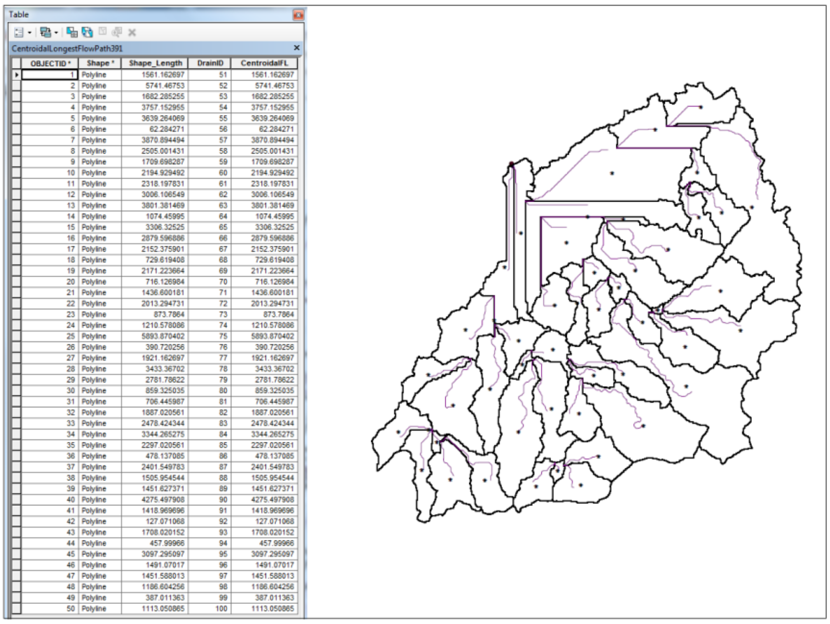
Centroid391

OBJECTID *	Shape *	DrainID
1	Point	51
2	Point	52
3	Point	53
4	Point	54
5	Point	55
6	Point	56
7	Point	57
8	Point	58
9	Point	59
10	Point	60
11	Point	61
12	Point	62
13	Point	63
14	Point	64
15	Point	65
16	Point	66
17	Point	67
18	Point	68
19	Point	69
20	Point	70
21	Point	71
22	Point	72
23	Point	73
24	Point	74
25	Point	75
26	Point	76
27	Point	77
28	Point	78
29	Point	79
30	Point	80
31	Point	81
32	Point	82
33	Point	83
34	Point	84
35	Point	85
36	Point	86
37	Point	87
38	Point	88
39	Point	89
40	Point	90
41	Point	91
42	Point	92
43	Point	93
44	Point	94
45	Point	95
46	Point	96
47	Point	97
48	Point	98
49	Point	99
50	Point	100

Figure 4. 20 Subbasin centroid layer

4.3.6. Centroid Elevation and Centroidal Flow Path

After process of **Centroid Elevation**, an elevation field is added to the cancroids layer's attribute table. Centroidal longest flow path of the study area is shown in the Figure 4.21.



Table

CentroidalLongestFlowPath391

OBJECTID *	Shape *	Shape_Length	DrainID	CentroidalFL
1	Polyline	1561.162697	51	1561.162697
2	Polyline	5741.46753	52	5741.46753
3	Polyline	1682.285255	53	1682.285255
4	Polyline	3757.152955	54	3757.152955
5	Polyline	3639.264069	55	3639.264069
6	Polyline	62.284271	56	62.284271
7	Polyline	3870.894494	57	3870.894494
8	Polyline	2505.001431	58	2505.001431
9	Polyline	1709.698287	59	1709.698287
10	Polyline	2194.929492	60	2194.929492
11	Polyline	2318.197831	61	2318.197831
12	Polyline	3006.106549	62	3006.106549
13	Polyline	3801.381469	63	3801.381469
14	Polyline	1074.45995	64	1074.45995
15	Polyline	3306.32525	65	3306.32525
16	Polyline	2879.596886	66	2879.596886
17	Polyline	2152.375901	67	2152.375901
18	Polyline	729.619408	68	729.619408
19	Polyline	2171.223664	69	2171.223664
20	Polyline	716.126984	70	716.126984
21	Polyline	1436.600181	71	1436.600181
22	Polyline	2013.294731	72	2013.294731
23	Polyline	873.7864	73	873.7864
24	Polyline	1210.578086	74	1210.578086
25	Polyline	5893.870402	75	5893.870402
26	Polyline	390.720256	76	390.720256
27	Polyline	1921.162697	77	1921.162697
28	Polyline	3433.36702	78	3433.36702
29	Polyline	2781.78622	79	2781.78622
30	Polyline	859.325035	80	859.325035
31	Polyline	706.445987	81	706.445987
32	Polyline	1887.020561	82	1887.020561
33	Polyline	2478.424344	83	2478.424344
34	Polyline	3344.265275	84	3344.265275
35	Polyline	2297.020561	85	2297.020561
36	Polyline	478.137085	86	478.137085
37	Polyline	2401.549783	87	2401.549783
38	Polyline	1505.954544	88	1505.954544
39	Polyline	1451.627371	89	1451.627371
40	Polyline	4275.497908	90	4275.497908
41	Polyline	1418.969696	91	1418.969696
42	Polyline	127.071068	92	127.071068
43	Polyline	1708.020152	93	1708.020152
44	Polyline	457.99966	94	457.99966
45	Polyline	3097.295097	95	3097.295097
46	Polyline	1491.07017	96	1491.07017
47	Polyline	1451.588013	97	1451.588013
48	Polyline	1186.604256	98	1186.604256
49	Polyline	387.011363	99	387.011363
50	Polyline	1113.050865	100	1113.050865

Figure 4. 21 Centroidal longest flow path layer

4.3.7. Selecting HMS Project and Developing the Other Hydrologic Parameters

In selecting HMS process, for Loss Method Initial+Constant Method, for transform method Clark Method, for base flow method None, and for route method Lag Method were chosen. **Auto Name** process applied to the river and basins after choosing methods (Table 4.4-4.5).

Table 4. 4 River auto name process result ‘attribute table of rivers’

Table

Subbasin391

OBJECTID *	Shape *	grid_code	Shape_Length	Shape_Area	HydroID	DrainID	Description	PrecipGage	LossMet	TransMet	BaseMe	Name	TotStormP	BasinSlope
1	Polygon	1	11260	2883600	51	51	<Null>	<Null>	Initial+Constant	Clark	<Null>	W510	<Null>	<Null>
2	Polygon	2	34080	11959700	52	52	<Null>	<Null>	Initial+Constant	Clark	<Null>	W520	<Null>	<Null>
3	Polygon	3	12700	3819200	53	53	<Null>	<Null>	Initial+Constant	Clark	<Null>	W530	<Null>	<Null>
4	Polygon	4	20920	10665500	54	54	<Null>	<Null>	Initial+Constant	Clark	<Null>	W540	<Null>	<Null>
5	Polygon	5	12660	1124900	55	55	<Null>	<Null>	Initial+Constant	Clark	<Null>	W550	<Null>	<Null>
6	Polygon	6	340	3500	56	56	<Null>	<Null>	Initial+Constant	Clark	<Null>	W560	<Null>	<Null>
7	Polygon	7	15420	2841500	57	57	<Null>	<Null>	Initial+Constant	Clark	<Null>	W570	<Null>	<Null>
8	Polygon	8	15340	2734300	58	58	<Null>	<Null>	Initial+Constant	Clark	<Null>	W580	<Null>	<Null>
9	Polygon	9	10240	1542600	59	59	<Null>	<Null>	Initial+Constant	Clark	<Null>	W590	<Null>	<Null>
10	Polygon	10	11240	2127600	60	60	<Null>	<Null>	Initial+Constant	Clark	<Null>	W600	<Null>	<Null>
11	Polygon	11	22520	5568200	61	61	<Null>	<Null>	Initial+Constant	Clark	<Null>	W610	<Null>	<Null>
12	Polygon	12	8780	297400	62	62	<Null>	<Null>	Initial+Constant	Clark	<Null>	W620	<Null>	<Null>
13	Polygon	13	14040	2425600	63	63	<Null>	<Null>	Initial+Constant	Clark	<Null>	W630	<Null>	<Null>
14	Polygon	14	10540	3736200	64	64	<Null>	<Null>	Initial+Constant	Clark	<Null>	W640	<Null>	<Null>
15	Polygon	15	16460	5370400	65	65	<Null>	<Null>	Initial+Constant	Clark	<Null>	W650	<Null>	<Null>
16	Polygon	16	15580	3901400	66	66	<Null>	<Null>	Initial+Constant	Clark	<Null>	W660	<Null>	<Null>
17	Polygon	17	11500	1682500	67	67	<Null>	<Null>	Initial+Constant	Clark	<Null>	W670	<Null>	<Null>
18	Polygon	18	6220	828200	68	68	<Null>	<Null>	Initial+Constant	Clark	<Null>	W680	<Null>	<Null>
19	Polygon	19	15820	4673900	69	69	<Null>	<Null>	Initial+Constant	Clark	<Null>	W690	<Null>	<Null>
20	Polygon	20	4700	598700	70	70	<Null>	<Null>	Initial+Constant	Clark	<Null>	W700	<Null>	<Null>
21	Polygon	21	8060	1652500	71	71	<Null>	<Null>	Initial+Constant	Clark	<Null>	W710	<Null>	<Null>
22	Polygon	22	11180	3510100	72	72	<Null>	<Null>	Initial+Constant	Clark	<Null>	W720	<Null>	<Null>
23	Polygon	23	3120	20600	73	73	<Null>	<Null>	Initial+Constant	Clark	<Null>	W730	<Null>	<Null>
24	Polygon	24	7600	1423200	74	74	<Null>	<Null>	Initial+Constant	Clark	<Null>	W740	<Null>	<Null>
25	Polygon	25	29960	10606300	75	75	<Null>	<Null>	Initial+Constant	Clark	<Null>	W750	<Null>	<Null>
26	Polygon	26	2040	97700	76	76	<Null>	<Null>	Initial+Constant	Clark	<Null>	W760	<Null>	<Null>
27	Polygon	27	10680	2626100	77	77	<Null>	<Null>	Initial+Constant	Clark	<Null>	W770	<Null>	<Null>
28	Polygon	28	20700	6763500	78	78	<Null>	<Null>	Initial+Constant	Clark	<Null>	W780	<Null>	<Null>
29	Polygon	29	14920	3765700	79	79	<Null>	<Null>	Initial+Constant	Clark	<Null>	W790	<Null>	<Null>
30	Polygon	30	9700	1905400	80	80	<Null>	<Null>	Initial+Constant	Clark	<Null>	W800	<Null>	<Null>
31	Polygon	31	4100	328800	81	81	<Null>	<Null>	Initial+Constant	Clark	<Null>	W810	<Null>	<Null>
32	Polygon	32	9840	1637000	82	82	<Null>	<Null>	Initial+Constant	Clark	<Null>	W820	<Null>	<Null>
33	Polygon	33	14780	4982500	83	83	<Null>	<Null>	Initial+Constant	Clark	<Null>	W830	<Null>	<Null>
34	Polygon	34	16300	5633400	84	84	<Null>	<Null>	Initial+Constant	Clark	<Null>	W840	<Null>	<Null>
35	Polygon	35	15280	3681900	85	85	<Null>	<Null>	Initial+Constant	Clark	<Null>	W850	<Null>	<Null>
36	Polygon	36	7620	1320600	86	86	<Null>	<Null>	Initial+Constant	Clark	<Null>	W860	<Null>	<Null>
37	Polygon	37	14680	3044700	87	87	<Null>	<Null>	Initial+Constant	Clark	<Null>	W870	<Null>	<Null>
38	Polygon	38	6500	956700	88	88	<Null>	<Null>	Initial+Constant	Clark	<Null>	W880	<Null>	<Null>
39	Polygon	39	9220	2130100	89	89	<Null>	<Null>	Initial+Constant	Clark	<Null>	W890	<Null>	<Null>
40	Polygon	40	17340	7522400	90	90	<Null>	<Null>	Initial+Constant	Clark	<Null>	W900	<Null>	<Null>
41	Polygon	41	9940	2214400	91	91	<Null>	<Null>	Initial+Constant	Clark	<Null>	W910	<Null>	<Null>
42	Polygon	42	520	2500	92	92	<Null>	<Null>	Initial+Constant	Clark	<Null>	W920	<Null>	<Null>
43	Polygon	43	11200	2183100	93	93	<Null>	<Null>	Initial+Constant	Clark	<Null>	W930	<Null>	<Null>
44	Polygon	44	3140	250200	94	94	<Null>	<Null>	Initial+Constant	Clark	<Null>	W940	<Null>	<Null>
45	Polygon	45	12720	2611300	95	95	<Null>	<Null>	Initial+Constant	Clark	<Null>	W950	<Null>	<Null>
46	Polygon	46	11760	3151300	96	96	<Null>	<Null>	Initial+Constant	Clark	<Null>	W960	<Null>	<Null>
47	Polygon	47	9800	2418400	97	97	<Null>	<Null>	Initial+Constant	Clark	<Null>	W970	<Null>	<Null>
48	Polygon	48	7760	1639300	98	98	<Null>	<Null>	Initial+Constant	Clark	<Null>	W980	<Null>	<Null>
49	Polygon	49	2960	269000	99	99	<Null>	<Null>	Initial+Constant	Clark	<Null>	W990	<Null>	<Null>
50	Polygon	50	7760	2246200	100	100	<Null>	<Null>	Initial+Constant	Clark	<Null>	W1000	<Null>	<Null>

Table 4. 5 Basin auto name process result ‘attribute table of basins’

Table

River391

OBJECTID *	Shape *	arcid	grid_code	from_node	to_node	Shape_Length	HydroID	NextDownID	DrainID	RivLen	Slp	ElevUP	ElevDS	RouteMet	Name
1	Polyline	1	1	1	2	1006.309883	1	2	51	1006.309883	-0.002981	0	3	<Null>	R10
2	Polyline	2	3	2	3	2117.228714	2	8	53	2117.228714	0	3	3	<Null>	R20
3	Polyline	3	6	5	4	59.497475	3	-1	56	59.497475	0.016807	3	2	<Null>	R30
4	Polyline	4	5	6	3	4324.680374	4	8	55	4324.680374	0.00185	11	3	<Null>	R40
5	Polyline	5	9	7	6	441.629509	5	4	59	441.629509	0.002264	12	11	<Null>	R50
6	Polyline	6	10	8	6	1503.111832	6	4	60	1503.111832	0.005322	19	11	<Null>	R60
7	Polyline	7	8	9	5	1476.396103	7	3	58	1476.396103	-0.001355	1	3	<Null>	R70
8	Polyline	8	4	3	9	4101.147904	8	7	54	4101.147904	0.000488	3	1	<Null>	R80
9	Polyline	9	11	10	9	820.243866	9	7	61	820.243866	-0.004877	-3	1	<Null>	R90
10	Polyline	10	12	11	10	2453.847763	10	9	62	2453.847763	0.002038	2	-3	<Null>	R100
11	Polyline	11	15	12	11	3129.629868	11	10	65	3129.629868	0.002876	11	2	<Null>	R110
12	Polyline	12	2	13	2	9626.280297	12	2	52	9626.280297	0.002493	27	3	<Null>	R120
13	Polyline	13	14	14	10	2149.604615	13	9	64	2149.604615	0.002791	3	-3	<Null>	R130
14	Polyline	14	16	15	11	2773.944443	14	10	66	2773.944443	0.001802	7	2	<Null>	R140
15	Polyline	15	17	16	14	463.284271	15	13	67	463.284271	0	3	3	<Null>	R150
16	Polyline	16	18	18	14	1265.391052	16	13	68	1265.391052	0.00079	4	3	<Null>	R160
17	Polyline	17	21	19	18	113.63961	17	16	71	113.63961	0.017599	6	4	<Null>	R170
18	Polyline	18	13	20	10	2785.060967	18	9	63	2785.060967	0.002154	3	-3	<Null>	R180
19	Polyline	19	7	21	5	5001.665222	19	3	57	5001.665222	-0.0004	1	3	<Null>	R190
20	Polyline	20	20	22	18	1261.543289	20	16	70	1261.543289	0.001585	6	4	<Null>	R200
21	Polyline	21	19	17	23	2808.91919	21	23	69	2808.91919	0.004628	26	13	<Null>	R210
22	Polyline	22	24	24	22	1132.253967	22	20	74	1132.253967	0.004416	11	6	<Null>	R220
23	Polyline	23	26	23	24	551.421356	23	22	76	551.421356	0.003627	13	11	<Null>	R230
24	Polyline	24	23	26	21	1028.284271	24	19	73	1028.284271	0.001945	3	1	<Null>	R240
25	Polyline	25	28	25	23	4849.812768	25	23	78	4849.812768	0.004536	35	13	<Null>	R250
26	Polyline	26	27	27	24	1091.751442	26	22	77	1091.751442	0.005496	17	11	<Null>	R260
27	Polyline	27	30	28	26	1908.944443	27	24	80	1908.944443	0.001048	5	3	<Null>	R270
28	Polyline	28	22	29	21	2751.492783	28	19	72	2751.492783	0.001454	5	1	<Null>	R280
29	Polyline	29	31	30	28	358.994949	29	27	81	358.994949	0.002786	6	5	<Null>	R290
30	Polyline	30	36	31	28	1674.680374	30	27	86	1674.680374	0.002986	10	5	<Null>	R300
31	Polyline	31	32	32	29	606.482323	31	28	82	606.482323	0.006595	9	5	<Null>	R310
32	Polyline	32	37	33	31	2343.883476	32	30	87	2343.883476	0.003413	18	10	<Null>	R320
33	Polyline	33	38	34	31	1109.827561	33	30	88	1109.827561	0.003604	14	10	<Null>	R330
34	Polyline	34	29	35	26	2764.716088	34	24	79	2764.716088	0.002894	11	3	<Null>	R340
35	Polyline	35	39	36	34	484.705627	35	33	89	484.705627	0.002063	15	14	<Null>	R350
36	Polyline	36	25	38	22	9005.519113	36	20	75	9005.519113	0.003998	42	6	<Null>	R360
37	Polyline	37	41	37	39	929.203102	37	38	91	929.203102	0.002152	15	13	<Null>	R370
38	Polyline	38	33	39	29	3338.477631	38	28	83	3338.477631	0.002396	13	5	Lag	R380
39	Polyline	39	42	40	39	14.142136	39	38	92	14.142136	0	13	13	<Null>	R390
40	Polyline	40	40	41	34	5348.868684	40	33	90	5348.868684	0.003739	34	14	<Null>	R400
41	Polyline	41	43	42	40	511.335137	41	39	93	511.335137	0.001956	14	13	<Null>	R410
42	Polyline	42	44	43	40	521.837662	42	39	94	521.837662	0.001916	14	13	<Null>	R420
43	Polyline	43	34	44	30	3927.975106	43	29	84	3927.975106	0.004073	22	6	<Null>	R430
44	Polyline	44	45	46	43	1630.868325	44	42	95	1630.868325	0.004292	21	14	<Null>	R440
45	Polyline	45	35	47	30	4619.604615	45	29	85	4619.604615	0.003247	21	6	<Null>	R450
46	Polyline	46	46	48	43	1043.050865	46	42	96	1043.050865	0.003835	18	14	<Null>	R460
47	Polyline	47	47	45	49	869.974747	47	48	97	869.974747	0.004598	26	22	<Null>	R470
48	Polyline	48	49	49	47	440.416306	48	45	99	440.416306	0.002271	22	21	<Null>	R480
49	Polyline	49	50	50	49	324.705627	49	48	100	324.705627	0.006159	24	22	<Null>	R490
50	Polyline	50	48	51	47	452.340187	50	45	98	452.340187	0.004421	23	21	<Null>	R500

4.3.8. Develop HMS Inputs

SI units were used in the process of **Map to HMS Units** for HMS unit conversion. The HMS schematic with the regular legend symbols, that was generated in the process of **HMS Schematic**, shown in the Figure 4.22. And finally, available data for model exporting was prepared. The data for the model export tool assembles the required HMS data for export to ASCII format.

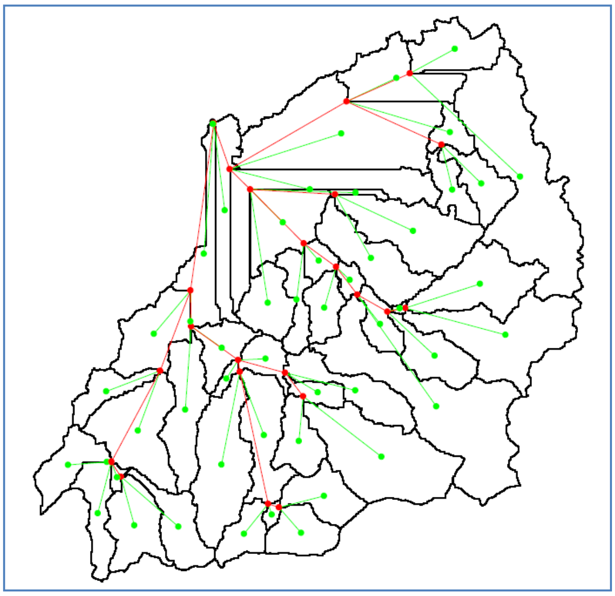


Figure 4. 22 HMS Schematic

4.4. Hydrologic Modeling System

The HEC-HMS project was created then background map files, river and sub-basin shape files, and basin file were copied to project folder. U.S. Customary unit system was chosen for default unit system. HEC-HMS project after adding basin file is shown in the Figure 4.23 and HEC-HMS basin model map is shown in the Figure 4.24.

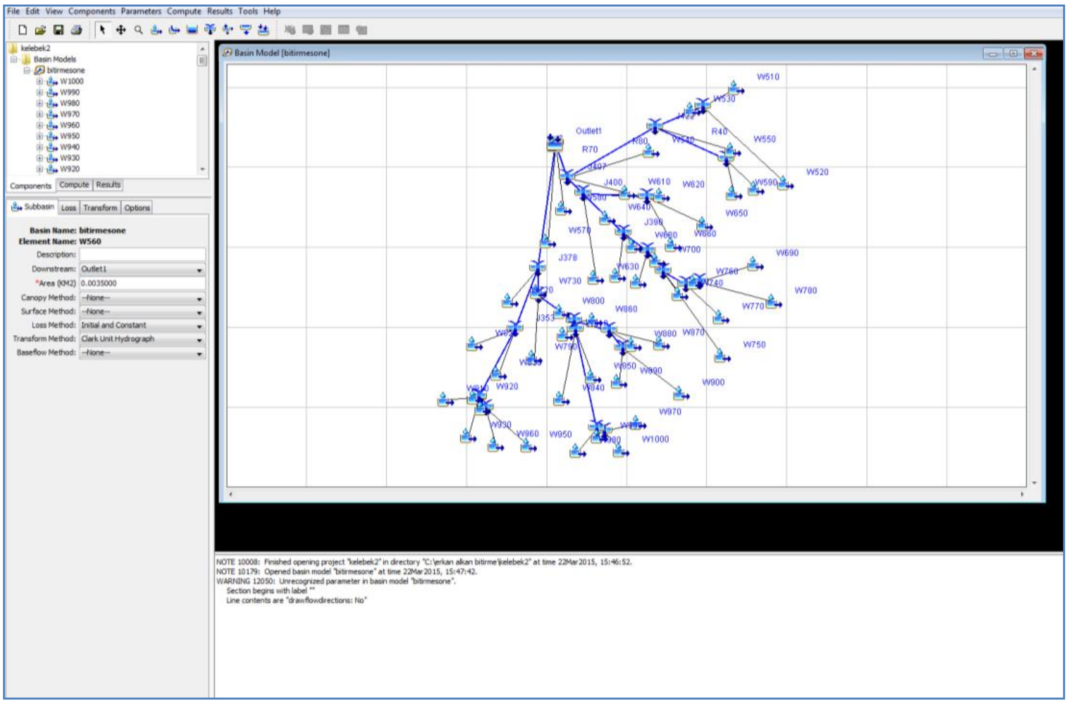


Figure 4. 23 HEC-HMS project after adding basin file

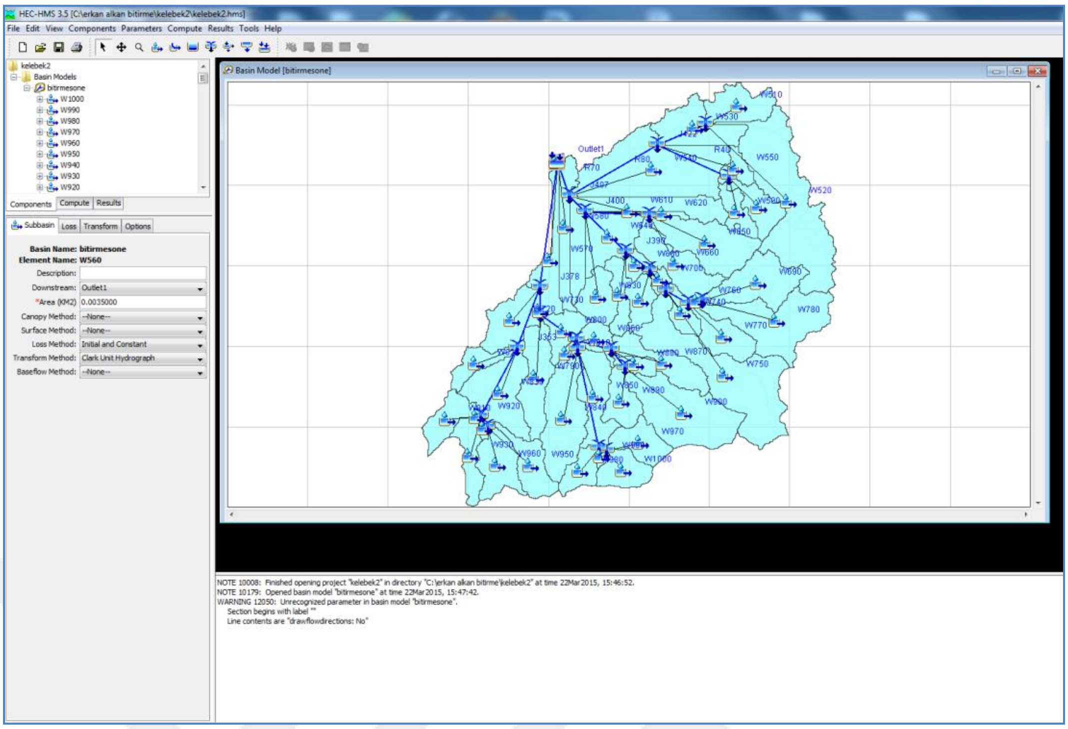


Figure 4. 24 HEC-HMS basin model map

CHAPTER 5
FINDINGS AND RESULTS

HMS project of Dakar was generated by using HecgeoHMS software. Number of hydrologic elements used in HMS project is shown in Table 5.1. In the study, daily precipitation data of 2012, these are given in the Table 5.2, were used to get flood hydrographs and results. Daily precipitation data of August 2012 was added to the time series data manager and daily rainfall graph was obtained (Figure 5.1). As can be seen from this graph, in the 26th of August a non-normal rainfall was observed.

Initial+Constant Method (for Loss Method), Clark Method (for transform method), None (for base flow method), and Lag Method (for route method) were used as sub-basin parameters (Figure 5.2). In this process permeability rate of study area was assumed to be 22%. Used junction parameters are given in Figure 5.3.

Graph of sub-basin 'W1000', sink 'Outlet1', junction 'J310' and reach 'R20' are respectively given as examples of the study results in Figures 5.4, 5.5, 5.6, 5.7. Summary result for sub-basin 'W1000', sink 'Outlet1', junction 'J310'and reach 'R20' are respectively given in Figures 5.8, 5.9, 5.10, 5.11. According summary results of Outlet1, peak flow was observed as 208.9 (m^3/s) and total depth of outflow was observed as 192.20 mm. The date of peak flow was 00:00/27 August 2012. Summary results of the HMS run project are given in Figure 5.12 (mm) and Figure 5.13 (m^3).

Table 5. 1 Number of hydrologic elements in HMS project

Hydrologic Element	Total Number (Name)
Sub-basin 	There are 50 sub-basins in project area (W510, W520, W530, W540, W550, …, W1000).
Reach 	There are 24 reach in project area (R20, R30, R40, R50, R60, …, R480).
Junction 	There are 24 junction in project area (J310, J313, J320, J325, J330, J335, …, J249)
Reservoir 	There is 1 reservoir in project area (Outlet1)

Table 5. 2 Daily precipitation data of 2009 and 2012

YEAR	MONTH	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
2009	**1**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	tr	0	0	0	0	0	0
2009	**2**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
2009	**3**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2009	**4**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2009	**5**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2009	**6**	0	0	tr	0	0	0	0	tr	tr	0	0	0	0	0	tr	0	0	0,1	0	0	0	0	0	0,5	0,1	0	0	0,1	0	0	
2009	**7**	8,2	0	0	0	1	0	0	0	0	0	0	8,7	0	11	1	0	0	0	0	6	0,1	0	0	0	0	tr	3,3	32	0	0	0
2009	**8**	0	0	15	2	0	0	5	14	tr	tr	29	17	0	0	4	0	0	0	2	0	7,9	0	27	54	0,5	0	25	29	tr	0	51
2009	**9**	4,7	1,8	0,2	0	4	20	tr	1,7	30	26	8,3	0,3	6,7	1	0	22	0	0,1	0	0	0	0	0	tr	25	13,4	0	0	0	0	
2009	**10**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	26	7,3	0	0	0	0	0	0	tr	tr	0	0	0	0	0
2009	**11**	0	0	tr	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
2009	**12**	0	tr	tr	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	**1**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	**2**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
2012	**3**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2,1	1,7	0	0	0
2012	**4**	tr	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
2012	**5**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	tr	tr	0	0	0	0	0	0	0	0	0	0	0	0
2012	**6**	0	0	tr	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
2012	**7**	0	tr	0	0	0	22	0,5	0,2	0	0	0	37	0	tr	0	0	0	0	0	0	2,8	1	0,2	tr	0	0	6,3	0	0	0	tr
2012	**8**	29	0,7	0,1	6	1	0	0,5	2,7	13	0	18	2,7	72	0	0	0	0,4	24	2	0	22	8	0	3	4,4	161	13	4,1	2	0	0
2012	**9**	15	42	2,8	0	tr	0	44	0	0	0,2	0,5	0,2	0	0	tr	0	0	0	0	0	0	17	0,5	20	3,3	0	42	4	1	1	
2012	**10**	0	0	tr	0	0	0	0	0	0	tr	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	**11**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0,1	0	0	tr	
2012	**12**	tr	0	0	tr	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

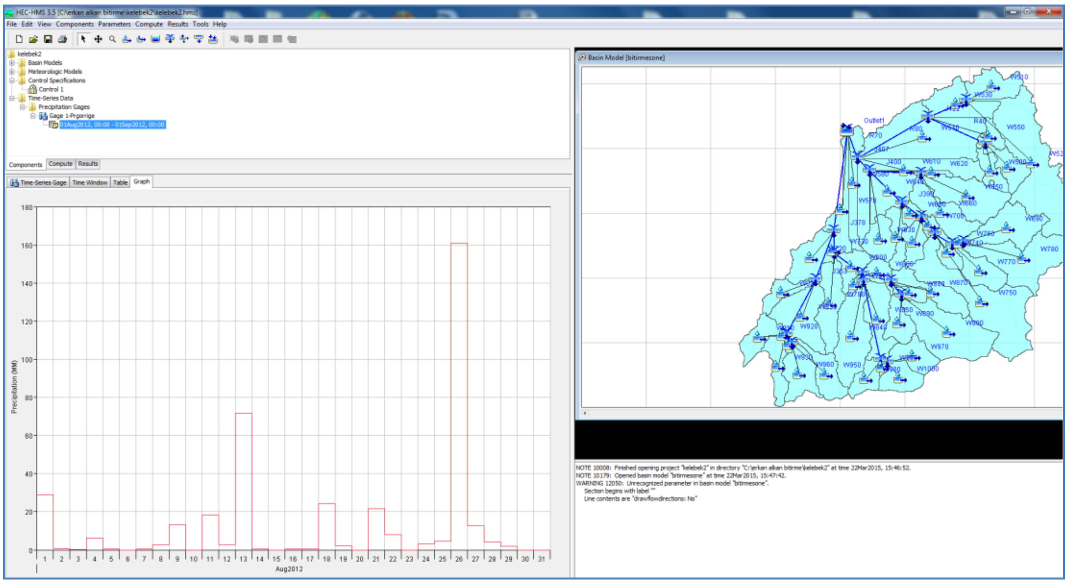


Figure 5. 1 Precipitation graph on HMS Project

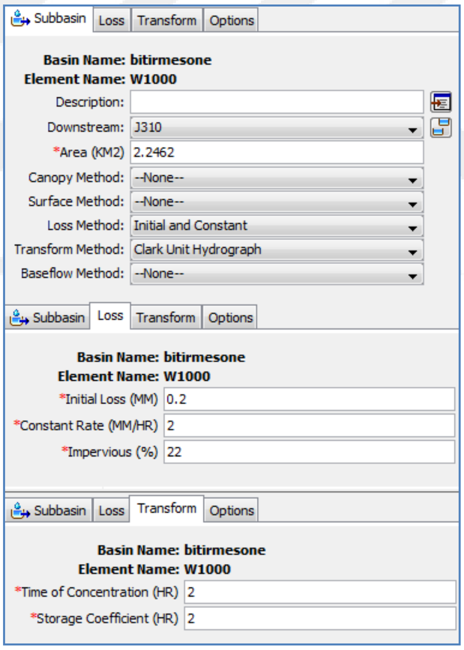


Figure 5. 2 Sub-basin parameters used in the study

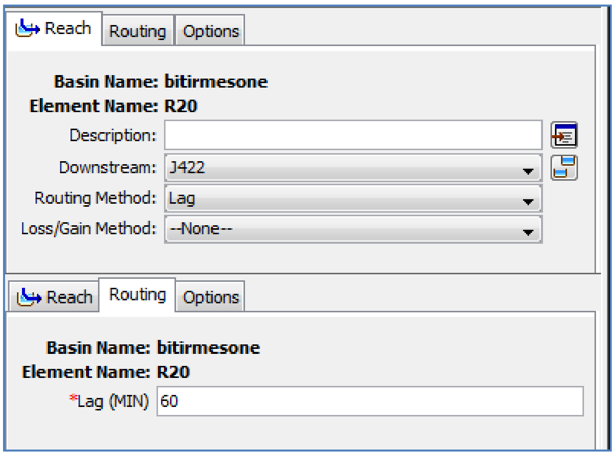


Figure 5. 3 Junction parameters used in the study

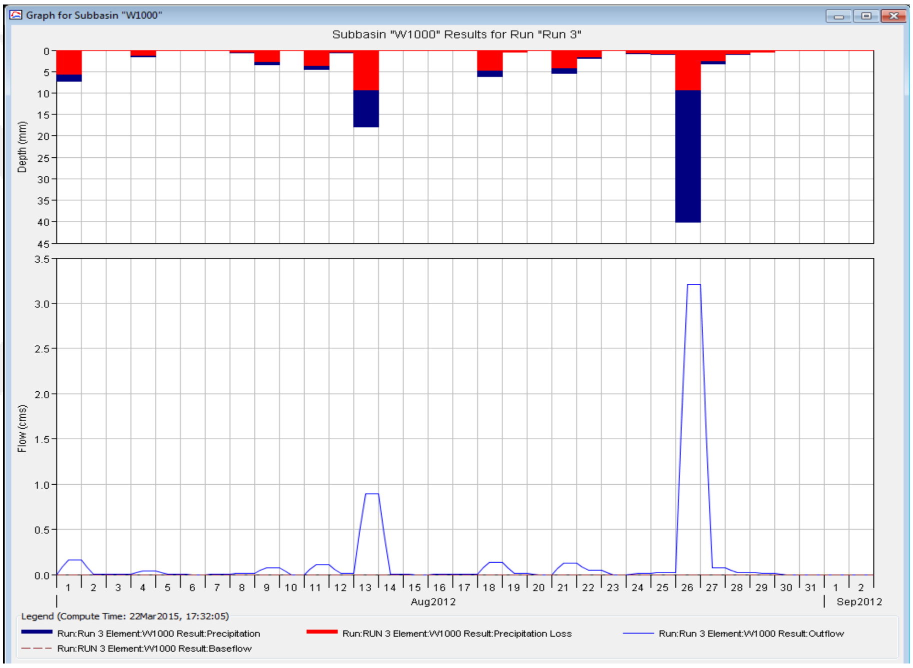


Figure 5. 4 Graph of sub-basin ‘W1000’

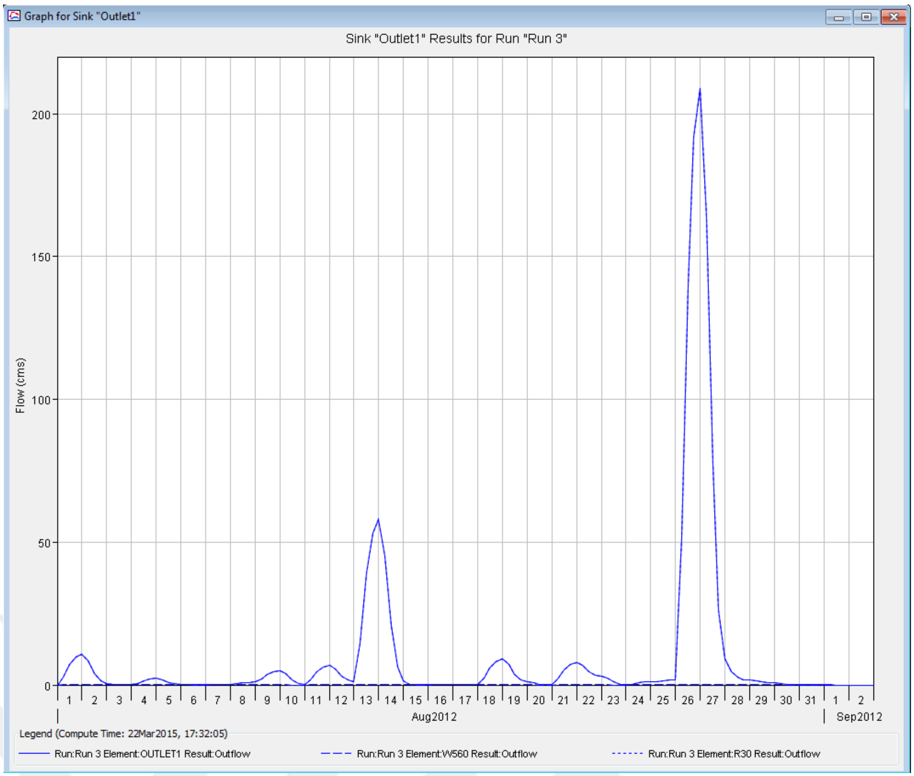


Figure 5. 5 Graph of sink 'Outlet1'

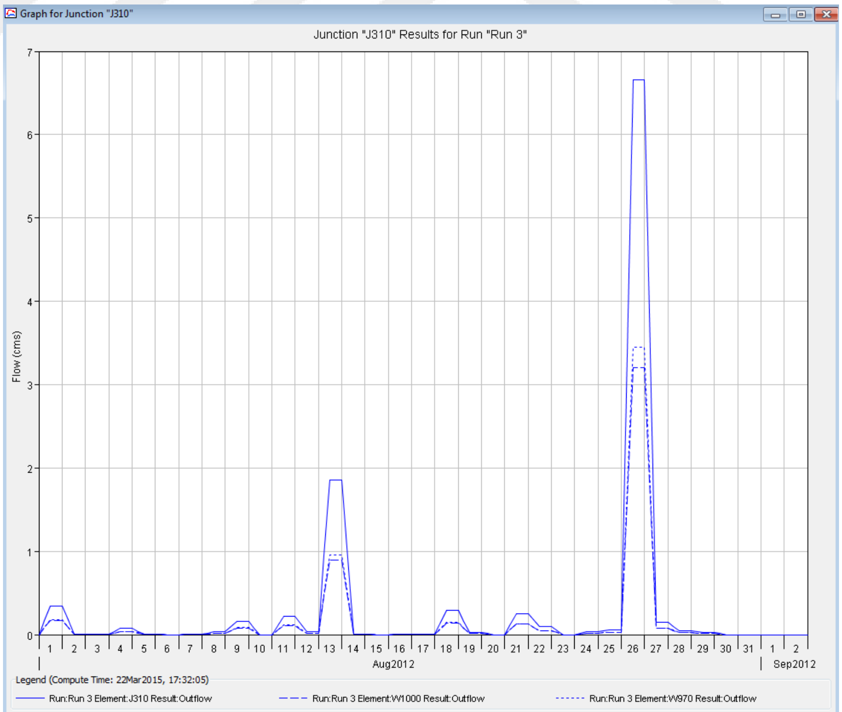


Figure 5. 6 Graph of junction 'J310'

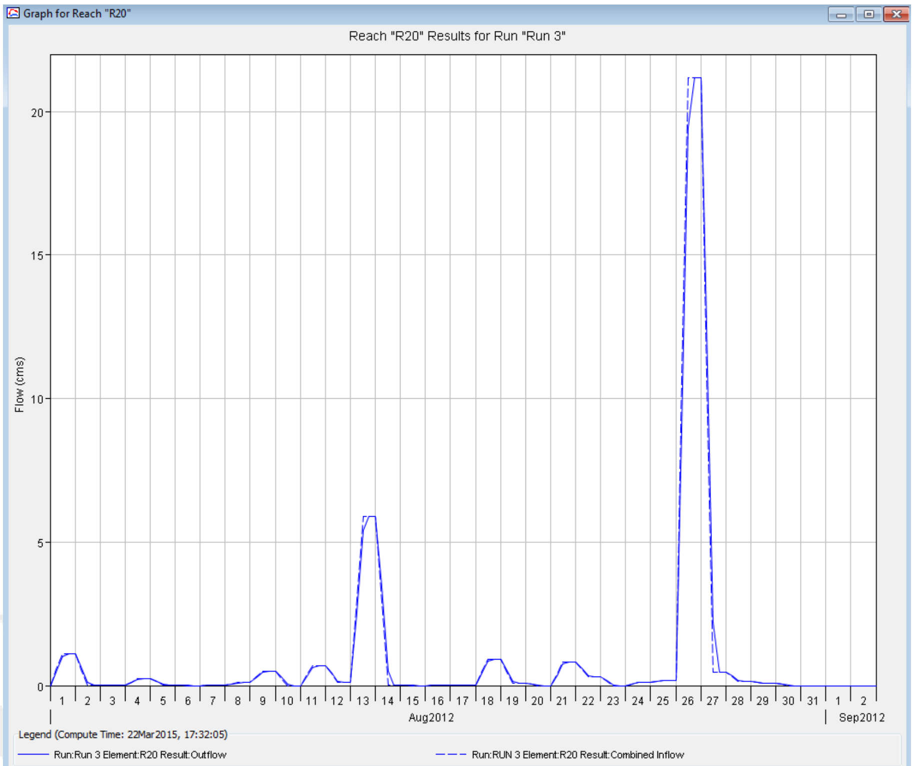


Figure 5. 7 Graph of reach ‘R20’

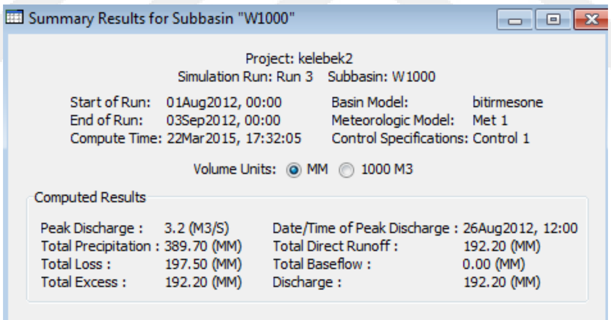


Figure 5. 8 Summary result for subbasin ‘W1000’

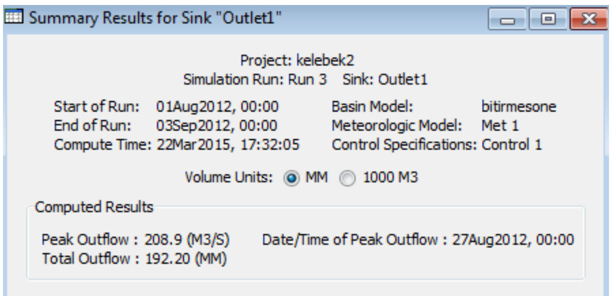


Figure 5. 9 Summary result for sink ‘Outlet1’

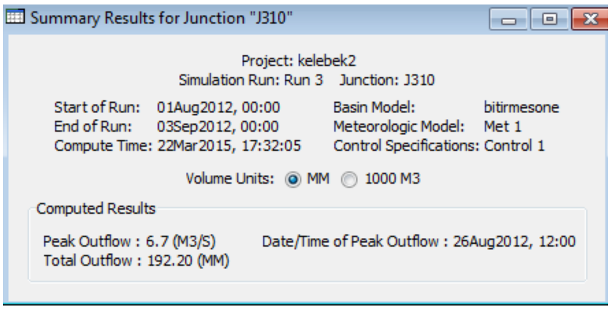


Figure 5. 10 Summary results for junction ‘J10’.

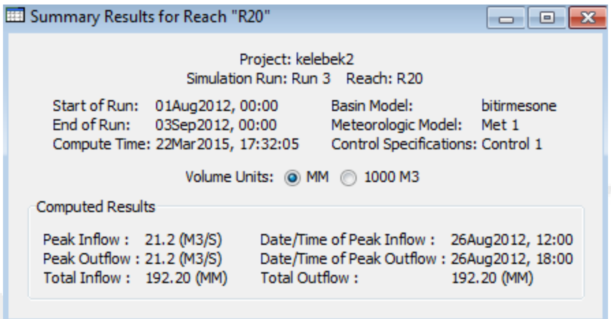
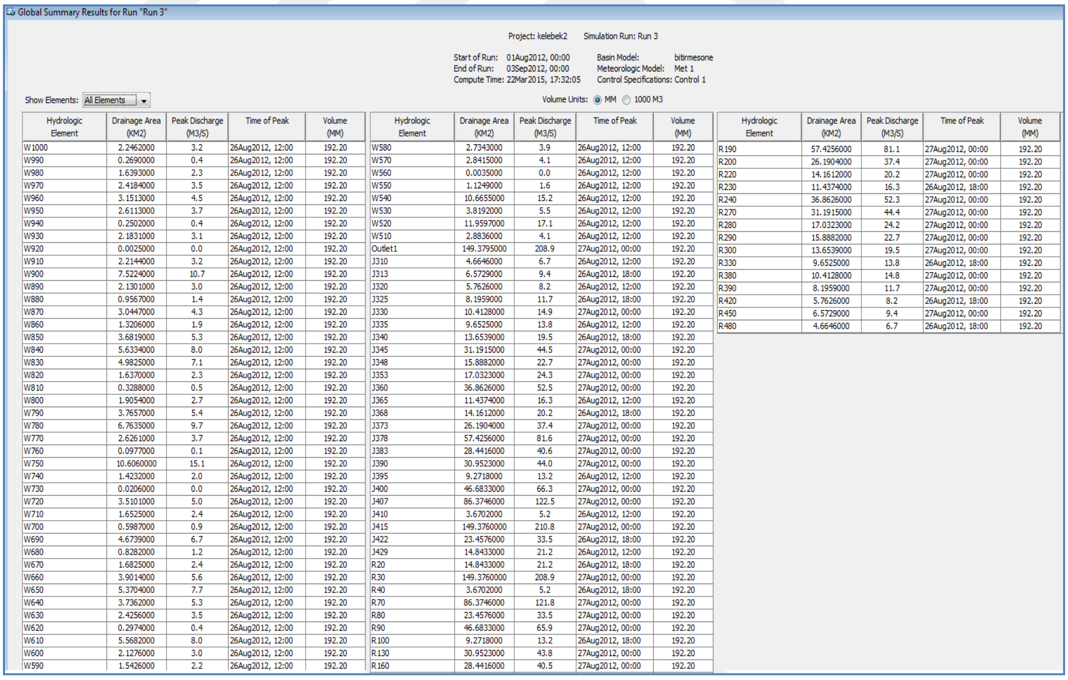


Figure 5. 11 Summary results for reach ‘R20’.



Global Summary Results for Run "Run 3"

Project: kelebek2 Simulation Run: Run 3

Start of Run: 01Aug2012, 00:00 Basin Model: bitirmesone
End of Run: 03Sep2012, 00:00 Meteorologic Model: Met 1
Compute Time: 22Mar2015, 17:32:05 Control Specifications: Control 1

Show Elements: All Elements

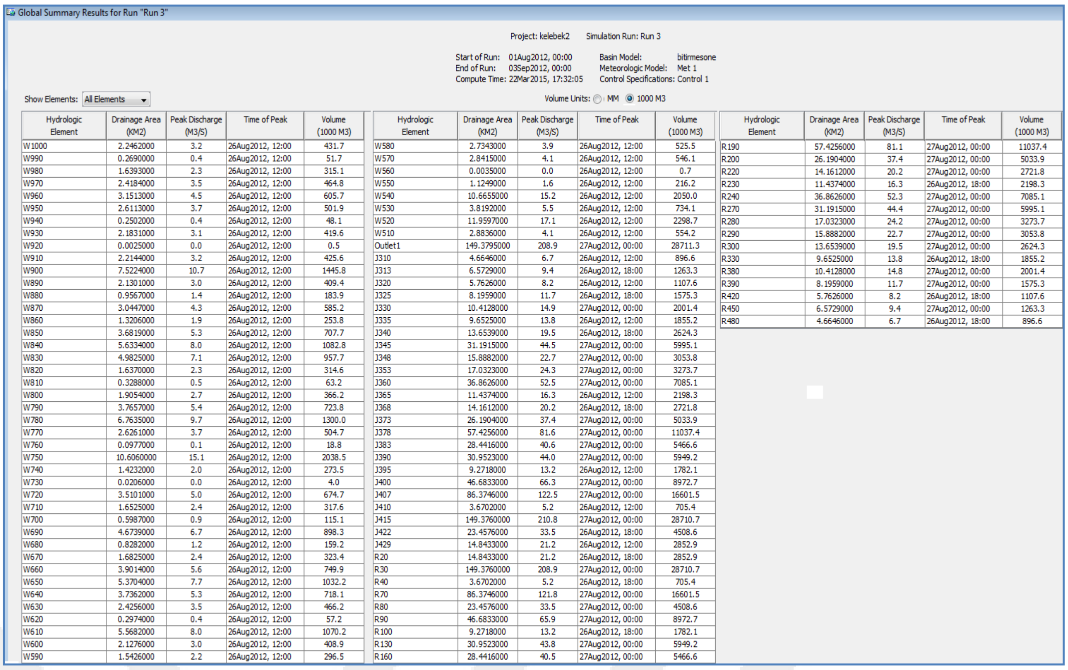
Volume Units: MM 1000 M3

Hydrologic Element	Drainage Area (KM2)	Peak Discharge (M3/S)	Time of Peak	Volume (MM)
W1000	2.2462000	3.2	26Aug2012, 12:00	192.20
W990	0.2690000	0.4	26Aug2012, 12:00	192.20
W980	1.6393000	2.3	26Aug2012, 12:00	192.20
W970	2.4184000	3.5	26Aug2012, 12:00	192.20
W960	3.1513000	4.5	26Aug2012, 12:00	192.20
W950	2.6113000	3.7	26Aug2012, 12:00	192.20
W940	0.2502000	0.4	26Aug2012, 12:00	192.20
W930	2.1831000	3.1	26Aug2012, 12:00	192.20
W920	0.0025000	0.0	26Aug2012, 12:00	192.20
W910	2.2144000	3.2	26Aug2012, 12:00	192.20
W900	7.5224000	10.7	26Aug2012, 12:00	192.20
W890	2.1301000	3.0	26Aug2012, 12:00	192.20
W880	0.9567000	1.4	26Aug2012, 12:00	192.20
W870	3.0447000	4.3	26Aug2012, 12:00	192.20
W860	1.3206000	1.9	26Aug2012, 12:00	192.20
W850	3.6819000	5.3	26Aug2012, 12:00	192.20
W840	5.6334000	8.0	26Aug2012, 12:00	192.20
W830	4.9825000	7.1	26Aug2012, 12:00	192.20
W820	1.6370000	2.3	26Aug2012, 12:00	192.20
W810	0.3288000	0.5	26Aug2012, 12:00	192.20
W800	1.9054000	2.7	26Aug2012, 12:00	192.20
W790	3.7657000	5.4	26Aug2012, 12:00	192.20
W780	6.7635000	9.7	26Aug2012, 12:00	192.20
W770	2.6261000	3.7	26Aug2012, 12:00	192.20
W760	0.0977000	0.1	26Aug2012, 12:00	192.20
W750	10.6060000	15.1	26Aug2012, 12:00	192.20
W740	1.4232000	2.0	26Aug2012, 12:00	192.20
W730	0.0206000	0.0	26Aug2012, 12:00	192.20
W720	3.5101000	5.0	26Aug2012, 12:00	192.20
W710	1.6525000	2.4	26Aug2012, 12:00	192.20
W700	0.5987000	0.9	26Aug2012, 12:00	192.20
W690	4.6739000	6.7	26Aug2012, 12:00	192.20
W680	0.8282000	1.2	26Aug2012, 12:00	192.20
W670	1.6825000	2.4	26Aug2012, 12:00	192.20
W660	3.9014000	5.6	26Aug2012, 12:00	192.20
W650	5.3704000	7.7	26Aug2012, 12:00	192.20
W640	3.7362000	5.3	26Aug2012, 12:00	192.20
W630	2.4256000	3.5	26Aug2012, 12:00	192.20
W620	0.2974000	0.4	26Aug2012, 12:00	192.20
W610	5.5682000	8.0	26Aug2012, 12:00	192.20
W600	2.1276000	3.0	26Aug2012, 12:00	192.20
W590	1.5426000	2.2	26Aug2012, 12:00	192.20

Hydrologic Element	Drainage Area (KM2)	Peak Discharge (M3/S)	Time of Peak	Volume (MM)
W580	2.7343000	3.9	26Aug2012, 12:00	192.20
W570	2.8415000	4.1	26Aug2012, 12:00	192.20
W560	0.0035000	0.0	26Aug2012, 12:00	192.20
W550	1.1249000	1.6	26Aug2012, 12:00	192.20
W540	10.6655000	15.2	26Aug2012, 12:00	192.20
W530	3.8192000	5.5	26Aug2012, 12:00	192.20
W520	11.9597000	17.1	26Aug2012, 12:00	192.20
W510	2.8836000	4.1	26Aug2012, 12:00	192.20
Outlet1	149.3795000	208.9	27Aug2012, 00:00	192.20
J310	4.6646000	6.7	26Aug2012, 12:00	192.20
J313	6.5729000	9.4	26Aug2012, 18:00	192.20
J320	5.7626000	8.2	26Aug2012, 12:00	192.20
J325	8.1959000	11.7	26Aug2012, 18:00	192.20
J330	10.4128000	14.9	27Aug2012, 00:00	192.20
J335	9.6525000	13.8	26Aug2012, 12:00	192.20
J340	13.6539000	19.5	26Aug2012, 18:00	192.20
J345	31.1915000	44.5	27Aug2012, 00:00	192.20
J348	15.8882000	22.7	27Aug2012, 00:00	192.20
J353	17.0323000	24.3	27Aug2012, 00:00	192.20
J360	36.8626000	52.5	27Aug2012, 00:00	192.20
J365	11.4374000	16.3	26Aug2012, 12:00	192.20
J368	14.1612000	20.2	26Aug2012, 18:00	192.20
J373	26.1904000	37.4	27Aug2012, 00:00	192.20
J378	57.4256000	81.6	27Aug2012, 00:00	192.20
J383	28.4416000	40.6	27Aug2012, 00:00	192.20
J390	30.9523000	44.0	27Aug2012, 00:00	192.20
J395	9.2718000	13.2	26Aug2012, 12:00	192.20
J400	46.6833000	66.3	27Aug2012, 00:00	192.20
J407	86.3746000	122.5	27Aug2012, 00:00	192.20
J410	3.6702000	5.2	26Aug2012, 12:00	192.20
J415	149.3760000	210.8	27Aug2012, 00:00	192.20
J422	23.4576000	33.5	26Aug2012, 18:00	192.20
J429	14.8433000	21.2	26Aug2012, 12:00	192.20
R20	14.8433000	21.2	26Aug2012, 18:00	192.20
R30	149.3760000	208.9	27Aug2012, 00:00	192.20
R40	3.6702000	5.2	26Aug2012, 18:00	192.20
R70	86.3746000	121.8	27Aug2012, 00:00	192.20
R80	23.4576000	33.5	27Aug2012, 00:00	192.20
R90	46.6833000	65.9	27Aug2012, 00:00	192.20
R100	9.2718000	13.2	26Aug2012, 18:00	192.20
R130	30.9523000	43.8	27Aug2012, 00:00	192.20
R160	28.4416000	40.5	27Aug2012, 00:00	192.20

Hydrologic Element	Drainage Area (KM2)	Peak Discharge (M3/S)	Time of Peak	Volume (MM)
R190	57.4256000	81.1	27Aug2012, 00:00	192.20
R200	26.1904000	37.4	27Aug2012, 00:00	192.20
R220	14.1612000	20.2	27Aug2012, 00:00	192.20
R230	11.4374000	16.3	26Aug2012, 18:00	192.20
R240	36.8626000	52.3	27Aug2012, 00:00	192.20
R270	31.1915000	44.4	27Aug2012, 00:00	192.20
R280	17.0323000	24.2	27Aug2012, 00:00	192.20
R290	15.8882000	22.7	27Aug2012, 00:00	192.20
R300	13.6539000	19.5	27Aug2012, 00:00	192.20
R330	9.6525000	13.8	26Aug2012, 18:00	192.20
R380	10.4128000	14.8	27Aug2012, 00:00	192.20
R390	8.1959000	11.7	27Aug2012, 00:00	192.20
R420	5.7626000	8.2	26Aug2012, 18:00	192.20
R450	6.5729000	9.4	27Aug2012, 00:00	192.20
R480	4.6646000	6.7	26Aug2012, 18:00	192.20

Figure 5. 12 Summary results for HEC-HMS project run (in mm)



Global Summary Results for Run "Run 3"

Project: kelebek2 Simulation Run: Run 3

Start of Run: 01Aug2012, 00:00 Basin Model: bitirmesone
End of Run: 03Sep2012, 00:00 Meteorologic Model: Met 1
Compute Time: 22Mar2015, 17:32:05 Control Specifications: Control 1

Show Elements: All Elements Volume Units: MM 1000 M3

Hydrologic Element	Drainage Area (KM2)	Peak Discharge (M3/S)	Time of Peak	Volume (1000 M3)
W1000	2.2462000	3.2	26Aug2012, 12:00	431.7
W990	0.2690000	0.4	26Aug2012, 12:00	51.7
W980	1.6393000	2.3	26Aug2012, 12:00	315.1
W970	2.4184000	3.5	26Aug2012, 12:00	464.8
W960	3.1513000	4.5	26Aug2012, 12:00	605.7
W950	2.6113000	3.7	26Aug2012, 12:00	501.9
W940	0.2502000	0.4	26Aug2012, 12:00	48.1
W930	2.1831000	3.1	26Aug2012, 12:00	419.6
W920	0.0025000	0.0	26Aug2012, 12:00	0.5
W910	2.2144000	3.2	26Aug2012, 12:00	425.6
W900	7.5224000	10.7	26Aug2012, 12:00	1445.8
W890	2.1301000	3.0	26Aug2012, 12:00	409.4
W880	0.9567000	1.4	26Aug2012, 12:00	183.9
W870	3.0447000	4.3	26Aug2012, 12:00	585.2
W860	1.3206000	1.9	26Aug2012, 12:00	253.8
W850	3.6819000	5.3	26Aug2012, 12:00	707.7
W840	5.6334000	8.0	26Aug2012, 12:00	1082.8
W830	4.9825000	7.1	26Aug2012, 12:00	957.7
W820	1.6370000	2.3	26Aug2012, 12:00	314.6
W810	0.3288000	0.5	26Aug2012, 12:00	63.2
W800	1.9054000	2.7	26Aug2012, 12:00	366.2
W790	3.7657000	5.4	26Aug2012, 12:00	723.8
W780	6.7635000	9.7	26Aug2012, 12:00	1300.0
W770	2.6261000	3.7	26Aug2012, 12:00	504.7
W760	0.0977000	0.1	26Aug2012, 12:00	18.8
W750	10.6060000	15.1	26Aug2012, 12:00	2038.5
W740	1.4232000	2.0	26Aug2012, 12:00	273.5
W730	0.0206000	0.0	26Aug2012, 12:00	4.0
W720	3.5101000	5.0	26Aug2012, 12:00	674.7
W710	1.6525000	2.4	26Aug2012, 12:00	317.6
W700	0.5987000	0.9	26Aug2012, 12:00	115.1
W690	4.6739000	6.7	26Aug2012, 12:00	898.3
W680	0.8282000	1.2	26Aug2012, 12:00	159.2
W670	1.6825000	2.4	26Aug2012, 12:00	323.4
W660	3.9014000	5.6	26Aug2012, 12:00	749.9
W650	5.3704000	7.7	26Aug2012, 12:00	1032.2
W640	3.7362000	5.3	26Aug2012, 12:00	718.1
W630	2.4256000	3.5	26Aug2012, 12:00	466.2
W620	0.2974000	0.4	26Aug2012, 12:00	57.2
W610	5.5682000	8.0	26Aug2012, 12:00	1070.2
W600	2.1276000	3.0	26Aug2012, 12:00	408.9
W590	1.5426000	2.2	26Aug2012, 12:00	296.5

Hydrologic Element	Drainage Area (KM2)	Peak Discharge (M3/S)	Time of Peak	Volume (1000 M3)
W580	2.7343000	3.9	26Aug2012, 12:00	525.5
W570	2.8415000	4.1	26Aug2012, 12:00	546.1
W560	0.0035000	0.0	26Aug2012, 12:00	0.7
W550	1.1249000	1.6	26Aug2012, 12:00	216.2
W540	10.6655000	15.2	26Aug2012, 12:00	2050.0
W530	3.8192000	5.5	26Aug2012, 12:00	734.1
W520	11.9597000	17.1	26Aug2012, 12:00	2298.7
W510	2.8836000	4.1	26Aug2012, 12:00	554.2
Outlet1	149.3795000	208.9	27Aug2012, 00:00	28711.3
J310	4.6646000	6.7	26Aug2012, 12:00	896.6
J313	6.5729000	9.4	26Aug2012, 18:00	1263.3
J320	5.7626000	8.2	26Aug2012, 12:00	1107.6
J325	8.1959000	11.7	26Aug2012, 18:00	1575.3
J330	10.4128000	14.9	27Aug2012, 00:00	2001.4
J335	9.6525000	13.8	26Aug2012, 12:00	1855.2
J340	13.6539000	19.5	26Aug2012, 18:00	2624.3
J345	31.1915000	44.5	27Aug2012, 00:00	5995.1
J348	15.8882000	22.7	27Aug2012, 00:00	3053.8
J353	17.0323000	24.3	27Aug2012, 00:00	3273.7
J360	36.8626000	52.5	27Aug2012, 00:00	7085.1
J365	11.4374000	16.3	26Aug2012, 12:00	2198.3
J368	14.1612000	20.2	26Aug2012, 18:00	2721.8
J373	26.1904000	37.4	27Aug2012, 00:00	5033.9
J378	57.4256000	81.6	27Aug2012, 00:00	11037.4
J383	28.4416000	40.6	27Aug2012, 00:00	5466.6
J390	30.9523000	44.0	27Aug2012, 00:00	5949.2
J395	9.2718000	13.2	26Aug2012, 12:00	1782.1
J400	46.6833000	66.3	27Aug2012, 00:00	8972.7
J407	86.3746000	122.5	27Aug2012, 00:00	16601.5
J410	3.6702000	5.2	26Aug2012, 12:00	705.4
J415	149.3760000	210.8	27Aug2012, 00:00	28710.7
J422	23.4576000	33.5	26Aug2012, 18:00	4508.6
J429	14.8433000	21.2	26Aug2012, 12:00	2852.9
R20	14.8433000	21.2	26Aug2012, 18:00	2852.9
R30	149.3760000	208.9	27Aug2012, 00:00	28710.7
R40	3.6702000	5.2	26Aug2012, 18:00	705.4
R70	86.3746000	121.8	27Aug2012, 00:00	16601.5
R80	23.4576000	33.5	27Aug2012, 00:00	4508.6
R90	46.6833000	65.9	27Aug2012, 00:00	8972.7
R100	9.2718000	13.2	26Aug2012, 18:00	1782.1
R130	30.9523000	43.8	27Aug2012, 00:00	5949.2
R160	28.4416000	40.5	27Aug2012, 00:00	5466.6

Hydrologic Element	Drainage Area (KM2)	Peak Discharge (M3/S)	Time of Peak	Volume (1000 M3)
R190	57.4256000	81.1	27Aug2012, 00:00	11037.4
R200	26.1904000	37.4	27Aug2012, 00:00	5033.9
R220	14.1612000	20.2	27Aug2012, 00:00	2721.8
R230	11.4374000	16.3	26Aug2012, 18:00	2198.3
R240	36.8626000	52.3	27Aug2012, 00:00	7085.1
R270	31.1915000	44.4	27Aug2012, 00:00	5995.1
R280	17.0323000	24.2	27Aug2012, 00:00	3273.7
R290	15.8882000	22.7	27Aug2012, 00:00	3053.8
R300	13.6539000	19.5	27Aug2012, 00:00	2624.3
R330	9.6525000	13.8	26Aug2012, 18:00	1855.2
R380	10.4128000	14.8	27Aug2012, 00:00	2001.4
R390	8.1959000	11.7	27Aug2012, 00:00	1575.3
R420	5.7626000	8.2	26Aug2012, 18:00	1107.6
R450	6.5729000	9.4	27Aug2012, 00:00	1263.3
R480	4.6646000	6.7	26Aug2012, 18:00	896.6

Figure 5. 13 Summary results for HEC-HMS project run (in m^3)

CHAPTER 6
DISCUSSION OF THE RESULTS AND CONCLUSION

Sudden rainfall is observed in Dakar between July and October and the rainfalls leads to flooding because of landscape formation and the irregular settlements in floodplain. Floods cause loss of life and properties. To avoid disasters caused by flooding, conservation and mitigation studies and activities should be performed in natural floodplains.

In the study, hydrological model studies were tried to apply to the Dakar Basin. For determination of watershed boundaries and drainage lines, HEC-GeoHMS software and for hydrologic modeling studies, HEC-HMS software were used. Daily rainfall data obtained from Floods and Disaster Ministry of Senegal were used for HMS project, and simulation has been started (scenario of simulation were began). Results of study were presented in Chapter 5.

Daily precipitation data of August, 2012 were used in simulation to estimate the maximum discharge where is reaching the reservoir. Area of watershed has 149,3795 km^2 area and it is represented by Outlet 1 reservoir which is located at the junction of see. The studied subbasin covers the project area. Maximum discharge of 208,9 m^3/s flow reached to the Outlet 1 reservoir as a result of this simulation. At the end of 31 days total volume of flow was estimated as 28711 m^3. The hydrograph of reservoir from simulation result are given in Figure 5.5.

For this study daily precipitation data are not enough to get satisfactory result. Outlet hydrograph obtained from daily precipitation, hides the some information between the two consequent precipitations. Instead of daily precipitation data, using minimum hourly precipitation data is necessary to obtain more sensitive results (outlet hydrographs).

If the flood hydrograph obtained by using at least hourly rainfall data, first stage of flood problem will be solved by using HMS software and more sensitive rainfall-runoff relationship will be obtained. The next stage of the study will include flood control measures. There are three group of measures should be thought for flood control; curative, protective and administrative measures. Structural, technical and engineering measures are expensive activities to control flood, bur at the beginning of flood occurrence hydraulic structures stop or mitigate the flood damages. These are temporary solutions of flood damages. Permanent solution of flood should be curative and reclamative of nature. Nature should be bringing to its original characteristic form. In the time passes, nature is reclaimed by natural measures such as to improve vegetative cover of surface to protect the land and soil. Once the balance of water changed and destroyed, it will take long time to recover the nature and bring it back to its original conditions.

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