ESTIMATION OF RUNOFF FOR SMALL WATERSHED USING WATERSHED MODELING SYSTEM (WMS) AND GIS

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JUNE - 2008

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A PROJECT REPORT SUBMITTED IN PARTIAL FULFILLMENT OF REQUIREMENTS FOR THE DEGREE OF

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ABSTRACT

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For many hydrological studies on an ungaged watershed, a methodology has to be select for the determination of runoff at its outlet. The Watershed Modeling System is a comprehensive hydrologic modeling environment. WMS provides tools for all phases of watershed modeling including automated watershed and sub-basin delineation, geometric parameter computation, hydrologic parameter computation (CN, time of concentration, rainfall depth, etc.) and result visualization. At the same time, the possibility of rapidly combining data of different types in a Geographical Information System (GIS) has led to significant increase in its use in hydrological application.

Watershed Modeling System (WMS) is to be used with GIS in this study to estimate the surface runoff from Wadi Hasca Watershed located Beit Kahil Area in the Hebron District of the West Bank. The morphological parameters for the same Wadi will be determined. The geographical area of Wadi Hasca is 7.324 square kilometer, and the average annual rainfall is around 500 mm. The rainfall data for ten years will be used for the analysis and estimation of the direct runoff for the study area.

The results of this Wadi show that the average annual runoff depth for the study area (Wadi Hasca) is 95 mm, and the average volume of surface runoff from the same watershed is 693500 cubic meter per year. The amount of runoff represents 19% of the total rainfall.

CERTIFICATION

Palestine Polytechnic University

PPU

Hebron-Palestine

The Senior Project Entitled:

ESTIMATION OF RUNOFF FOR SMALL WATERSHED USING WATERSHED MODELLING SYSTEM (WMS) AND GIS

Prepared By:

ALIA' AL ZEER **FADIA AL ATAWNA**

HIBA SHAHEEN

In accordance with the recommendations of the project supervisors, and the acceptance of all examining committee members, this project has been submitted to the Department of Civil and Architectural Engineering in the College of Engineering and Technology in partial fulfillment of the requirements of Department for the degree of Bachelor of Science in Engineering.

Project Supervisors **Department Chairman**

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CHAPTER

1 *INTRODUCTION*

1.1 General

1.2 Problem Definition

1.3 Objectives of the Project

1.4 Previous Studies

1.5 Study Area

1.6 Project Methodology

1.7 Project Task Plan

1.8 Structure of the Report

PREVIEW

The main concepts of the project are introduced in this chapter. The problem identification, the study area, objectives, and the methodology to solve the problem are presented in this chapter.

CHAPTER ONE
INTRODUCTION

1.1 General

Watershed is the area covering all the land that contributes runoff water to a common point. In Palestine, the availability of accurate information on runoff is scarcely available in most sites. However, quickening of watershed management programmed for conservation and development of natural resources management has necessitated the runoff information. Advances in computational power and the growing availability of spatial data have made it possible to accurately predict the runoff. The possibility of rapidly combining data of different types in a Geographical Information system (GIS) has led to significant increase in its use in hydrological applications.

Many methods are used to estimate the runoff from a watershed. The Curve Number and Rational Methods are versatile and widely used procedure for runoff estimation. These method includes several important properties of the watershed namely soils permeability, land use and antecedent soil water conditions which are taken into consideration. In the present study, the runoff from Wadi Hasca watershed in Beit Kahal area will be estimated using Rational Method and Watershed Modeling System (WMS) with the help of Geographical Information System (GIS).

1.2 Problem Definition

The problem most often encountered in hydrological studies is the need for estimating runoff from a watershed for which there is records of precipitation and no records of runoff. An approach to solution of this problem is to compare runoff characteristics with those of watershed characteristics. Watershed characteristics which may be mostly readily compared to estimating the volume of runoff that will result from a given amount of rainfall are soil type and cover, which includes land use. Many such methods are available ranging from simple empirical equations relating catchment characteristics to the runoff, to complicated physical models that flow the movement of water from the farthest point of the catchments.

Technologies like Geographic Information Systems (GIS), have gained significant importance over the last decade in their applications pertaining to distributed hydrologic modeling. Nowadays GIS is widely used for resources planning in watershed and can be used for the computation of these morphological characteristics of the watershed. Using the presently available GIS one has to go through tedious steps for generating these characteristics. Moreover the user must be fully acquainted with both the type of GIS being used for the generation of the morphologic characteristics as well as the morphologic characteristics of interest. Thus a suitable model should be developed with the help of GIS to generate these watershed morphologic characteristics.

In this study an attempts is made to estimate the amount of runoff that will result from a given amount of precipitation for Wadi Hasca watershed, Beit Kahil village in the Hebron area using rational method and with the help of Geographical Information System (GIS) also to compute geomorphological characteristics, generation of various thematic data base in GIS format, find out soil information, and generation of alternate land use plan for it .

1.3 Objectives of the Project

The main objective of this study is to estimate direct runoff for the study area watershed and provide geomorphologic database for the surface of Wadi Hasca drainage basin to specify the hydrology of the Wadi and. Within the framework of this study, the following data and parameters should be obtained and determined:

1) The boundary of catchment, sub-catchment, and stream network of the watershed under study, which located at Wadi Hasca, Beit Kahil City and GIS.
2) The climate data include values of precipitation, temperature, relative humidity, and wind information.
3) The geographical characteristics and land use of the study watershed.

4) The morphological characteristics like stream order, drainage density, aerial extent, watershed length and width, channel length, channel slope and relief aspects

All the data obtained were used to calculate the direct runoff of the study watershed and were demonstrated in GIS.

1.4 Previous Studies

In our country, the hydrological studies are limited some investigators have studies the hydrology of different wadis and watersheds in the West Bank and Gaza strip in order to develop additional usable water resources to help in solving future hydrological problems.

Applied Research Institute of Jerusalem (ARIJ) published six articles on environmental profiles of West Bank cities. The Hebron district environmental profile shows in such area, most land is sloppy (2%-20%) and the infiltration rate is low. Consequently, low cost water harvesting could be introduced in this area. This method depends on collecting runoff water using construction such as soil dam or concrete dam.

The geomorphological study of Wadi Al Arroub carried out by Qannam (2000) in his master thesis shows that the topography has more effect on the drainage pattern than the structure. The main effect of topography is in the W-E direction, while that of structure is mainly in the NNW-SSE direction and to some extent in the N-S direction. The relatively high relief ratio of Wadi Al Aroub drainage basin and high elongation ratio (0.78) indicate that the study area is among the sub-basins that contribute strongly to the flooding in the Dead Sea-Jordan River Basin.

Lange, J. et al (2000) have studies the runoff on a steep 180 m^2 Mediterranean Karts environment. To provide quantitative information, measurements are under taking on experimental hill slope plot applying artificial rainfall of predefined intensities. The results show that on a dry plot about 16 mm of rainfall was needed before terrain

Lange, J. et al (2000) have studies the runoff on a steep 180 m^2 Mediterranean Karts environment. To provide quantitative information, measurements are under taking on experimental hill slope plot applying artificial rainfall of predefined intensities. The results show that on a dry plot about 16 mm of rainfall was needed before terrain other bar rock generated runoff. Overall 16% of rainfall turn into runoff, while in the following day 73% of the applied rainfall arrived at the outlet of the wet plot.

In the study of Mohammadin, A. et al (2003), the mount of runoff for east Bani Naim watershed in the Hebron area using soil conservation service method were calculated and estimated to be about 417,913 cubic meters per year.

Al-Namor, A.. et al (2006) study the hydrology of Wadi Su'd in Dura Area using GIS and GPS techniques. The results of the study show that the average annual runoff depth for the study area (Wadi Hasca watershed) is 95 mm, and the average volume of runoff from the same watershed is 693,500 cubic meter per year. The amount of runoff represents 19% of the total annual rainfall.

1.5 Study Area

The study area, named Wadi Hasca, is located in Beit Kahil city of the Hebron area which will known later as Wadi Hasca watershed. The watershed having a geographical area of 1.2 square kilometer, Figure (1.1) shows the study area and its location. Physiographically, the watershed is divided into hills, pediments. Elevation in the watershed ranges from 450 to 1000 m above mean sea level. The average annual precipitation at Beit Kahil city for the last five years is approximately 500 mm. About 90% of this rainfall is received from November to April, and the major land use/land cover categories in the watershed are: pasture, agricultural area, and stony waste land.

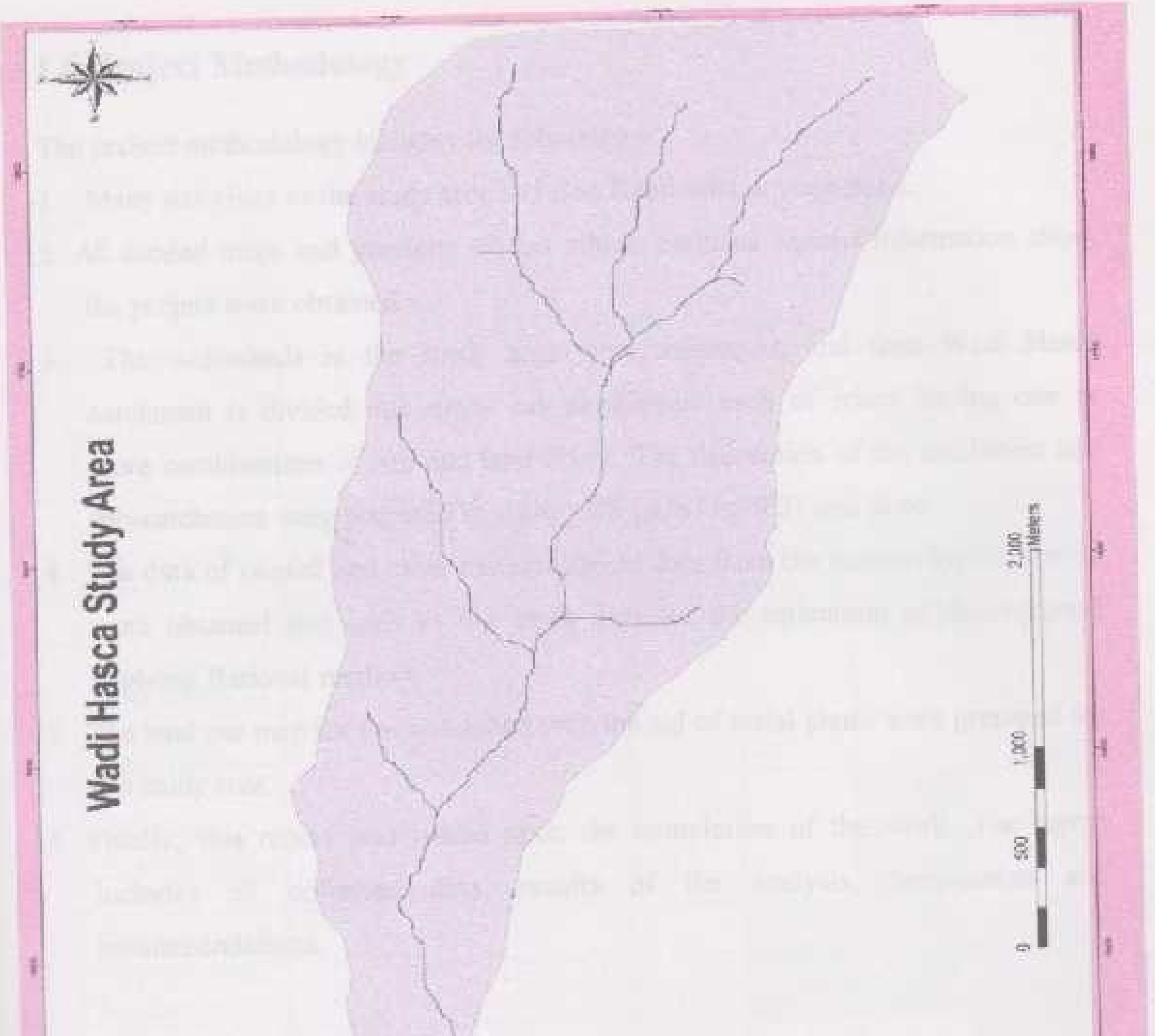

Figure (1.1): Location of the Study Area (Wadi Hasca Watershed)

1.6 Project Methodology

The project methodology includes the following:-

1. Many site visits to the study area and Beit Kahil village were done.
2. All needed maps and previous studies which, contains various information about the project were obtained.
3. The watersheds in the study area were delineated, and then Wadi Hasca catchment is divided into many sub catchments each of which having one or more combinations of soil and land cover. The delineation of the catchment and sub-catchment were prepared by using GIS (Arc Gis. 9.2) was done.
4. The data of rainfall and other meteorological data from the meteorological station were obtained and used as the input data for the estimating of direct runoff applying Rational method.
5. The land use map for the watershed with the aid of aerial photo were prepared for the study area.
6. Finally, this report was issued upon the completion of the work. The report includes all collected data, results of the analysis, conclusions and recommendations.

1.7 Project Task–Plan

The following matrix explains the tasks have been under taken and the duration of each task.

Table (1.1): Project Task–Plan

Phase No.	Task	Duration(monthly)							
		2007			2008				
		10	11	12	1	2	3	4	5
1	Review of literature and other lab work	■	■	■	■	■	■	■	
2	Delineation of the Watersheds		■						
3	Preparation land use map						■		
4	Preparation of Morphometric Parameters					■	■	■	■
5	Analysis and results							■	■
6	Writing the report							■	■

1.8 Structure of the Report

The subject matter of the project is presented in four chapters. The first chapter entitled "Introduction" outlines the problem, project objectives, literature review, study area, methodology, and structure of the report. The second chapter entitled "Hydrologic Principles and Models" explains the morphometric parameters, rational method, hydrological models in GIS, geographic information system and watershed modeling system. The third chapter entitled" Hydrological Analysis in ARC GIS "deals with water flow analysis, flow direction grids, watershed and stream delineation, and watersheds. The fourth chapter entitled' Materials and Methods' deals with watershed boundary and land use, Watershed Modeling System (WMS), and watersheds. Chapter five on "Analysis and Discussion of Results" presented land use and land cover, morphometric Analysis and estimation of the surface runoff. The overall conclusions and recommendations are given in chapter six.

CHAPTER

2 *HYDROLOGIC PRINCIPLES AND MODELS*

2.1 General

2.2 Morphometric Parameters

2.3 Rational Method

2.4 Hydrological Models In GIS

2.5Geographic Information System

2.6 Watershed Modeling System

PREVIEW

The main concept of this chapter is the hydrological models. It explains the rational method, hydrological models in GIS, geographic information system and watershed modeling system.

CHAPTER TWO
HYDROLOGIC PRINCIPLES AND MODELS

2.1 General

Hydrology is the science that deals with the origin, distribution and properties of water on the earth including that in the atmosphere in the form of water vapor, on the surface as water, snow or ice, and beneath the surface as ground water.

The hydrology study is useful for the design and operation of engineering projects for the control and use of water. The purpose of this chapter is to present fundamental hydrologic principles and models for estimating surface runoff from the watershed.

The knowledge and understanding that the researcher and scientist have about the world is often represented in the form of models. The aim of the models is to simplify and explain the complexity and confusion of the world. The applied scientist and technologist then use the models of science to predict and control the world.

2.2 Morphometric Parameters

Morphological characteristics like stream order, drainage density, aerial extent, watershed length and width, channel length, channel slope and relief aspects coupled with land use and soil information of watershed are important in understanding the hydrology of the watershed. Runoff response of the watershed is different for different slopes, shapes, lengths, widths and areas of watershed. Response is also affected by the factors like drainage density, length of overland flow, stream frequency, relative relief and relief ratios. Computation of watershed morphological characteristics is prerequisite to further detailed hydrological analysis of the watershed. Presently these characteristics are determined manually from the topographic and stream network map of the watershed. Manual computation in order to generate these characteristics is not only tedious and error prone but also time consuming. Computers can be used to compute these characteristics with greater efficiency and accuracy.

Various important morphometric parameters used in this study for analysis are described below.

1) **Stream order:** The most commonly used method for stream ordering (u) as suggested by strahler (1964) was used for this study. The rules for stream ordering using this method are:
   - Streams that originate at a source are defined to be first order steams.
   - When two streams of order u join, a stream of order u+1 is created.
   - When two streams of different orders join, the channel segment immediately down streams has the higher of the order of the two joining streams.
   - The order of a basin is the order of the highest streams.

2) **Stream number (Nu):** is the number of stream segments of various orders. It is inversely proportional to the stream order.

3) **Total stream length total (Lu):** is the length of all the streams having order u. The total stream length divided by the number of stream segments of that order gives the mean stream length for that order.

4) **Main stream length (Lms):** is the length of the stream having maximum stream length. This is the length along the stream. The time of concentration along the stream will be maximum.

5) **Watershed perimeter (Lp):** is the length of the watershed boundary.

6) **Maximum length of watershed (Lb):** is the distance between watershed outlet and the farthest point in the watershed.

7) **Length ratio (Rt):** is defined as the ratio of the average stream length **(Lu)** of order u, to average stream length (Lu-1) of the next lower order u-1:

$$Rt = \frac{Lu}{Lu-1} \quad \text{.......(2.1)}$$

8) **Form factor** **(Rf)**: is the ratio of the basin area (A) to the square of the maximum length (**Lb**).

$$Rf = \frac{A}{Lb^2} \quad \text{....... (2.2)}$$

9) **Drainage density** **(Dd)**: is defined as the total length of the streams of all the orders of a basin to the area of the basin. The drainage density gives an idea of the physical properties of the underlying rocks. Low drainage density occurs in regions of highly resistant and permeable subsoil materials with dense vegetation and low relief; whereas high drainage density is prevalent in regions of weak, impermeable sub surface materials which are sparsely vegetated and have high relief (strahler, 1964).

10) **Drainage frequency** **(Df)**: is the number of streams per unit area of the basin. It mainly depends upon the litho logy of the basin and reflects the texture of the drainage network.

$$Dd = \frac{L}{A} \quad \text{....... (2.3)}$$

11) **Constant of channel maintenance** **(Cm)**: is the ratio of the area of the drainage basin and total length of all the streams of all the orders. Hence, it is the reciprocal of the drainage density.

$$Cm = \frac{1}{Dd} \quad \text{....... (2.4)}$$

12) **Elongation ratio** **(Re)**: is defined as the ratio between the diameters of a circle with the same area as that of the basin, and is computed as:

$$Re = \frac{2}{Lb}\sqrt{\frac{A}{\pi}} \quad \text{....... (2.5)}$$

The elongation ratio ranges from 0.6 to 1.0, over a wide variety of climatic and geological environments. Values nearing 1.0 are typical of regions of very low relief, whereas, values in the range of 0.6 to 0.8 are generally associated with strong relief and steep ground slopes. Elongated basins with high bifurcation ratios yield a low but extended peak flow.

13) Circular ratio (**Rc**): is computed as:

$$Rc = \frac{2}{Lp}\sqrt{A \times \pi} \quad \text{......(2.6)}$$

Circular basins with low bifurcation ratios produce a sharp peak.

14) Maximum watershed relief (**H**): is the maximum vertical distance between the lowest and the highest points of a watershed. It is also known as total relief.

15) Relief ratio (**Rh**): is the total relief of watershed divided by the maximum length of the watershed. It is an indicator of the potential energy of the system to drain off.

16) Ruggedness number (**RN**): is defined as the product of the maximum watershed Relief and its drainage density. It provides an idea of overall roughness of a watershed, and is computed as:

$$R_N = h \cdot Dd \quad \text{......(2.7)}$$

17) Relative relief (**Rr**): is the ratio of the maximum watershed relief to the perimeter of the watershed.

For morphometric analysis, perimeter, maximum length, drainage map, stream length of each order, number of streams of each order and watershed relief values is required. These inputs were derived by using GIS software. Once these inputs were obtained, then by making use of the mathematical formulas as discussed above, all the necessary parameters for morphometric analysis were calculated.

18) Time of concentration (tc): is the time require to move the surface runoff from remotest point of the watershed to outlet, is known as time of concentration.

$$tc = 0.00032 * L^{0.77} * S^{-0.385} \qquad (2.8)$$

Where:

tc = time of concentration (h)

L = maximum length of travel of water

S = slope equal to H/L, where H is the difference in elevation between the remotest point on the basin and the outlet (m)

For morphometric analysis, perimeter, maximum length, drainage map, stream length of each order, number of streams of each order and watershed relief values is required. These inputs were derived by using GIS software.

Once these inputs were obtained, then by making use of the mathematical formulas as discussed above, all the necessary parameters for morphometric analysis were calculated

2.3 Rational Method

In this method, the runoff is correlated with the rainfall. Attempts have been made to estimate the maximum flood discharges by having a series of formulae to correlate the many variable factors. The most noteworthy of them is by Richards. His theory of flood estimation rest on the principle "that the average intensity of rainfall is an average function of both the catchment area and of the duration of the storm"the assumptions are then made that the storm fully covers the catchment and that its duration is equal to the period of concentration of flood. The rainfall is assumed uniform and constant over the catchment. The slope of the catchment is assumed uniform. All these conditions are difficult to be met with and this method cannot be used for large basins.

In this method the basic formula $Q = \frac{C * i * A}{360}$ ....(2.9) is used, where:

Q = flood flow in cubic meter.

C = runoff coefficient, ratio between runoff and rainfall.

i = Rainfall in mm per hour

A = drainage area contributing to runoff in hectar.

In this method, the drainage area is divided into a number of sub areas and with known time of concentration of different sub areas, runoff contribution from each area is calculated. The values of C for use in rational formula as given by M Bernard (1938) are given in the Table (2.1).

Table (2.1): The Values of (C) for Use in Rational Formula (Bernard, 1938)

Soil Type	Value of C for Watershed Cover		
	Cultivated	Pasture	Wood land
With above average infiltration rates, usually sandy or gravely	0.20	0.15	0.15
With average infiltration rates, no clay pans; loams and similar soils.	0.40	0.35	0.30
With below average infiltration rates; heavy clay soils or soils with a clay pan near the surface.	0.50	0.45	0.40

2.4 Hydrological Models in GIS

An important method of the studying of hydrology is hydrological modeling as shown in Figure (2.2); which is an approximation of the actual hydrologic system.

Linking hydrology and GIS are very necessary due to ability of GIS to capture and manage a vast amount of data. In this project, the watershed delineation will mad by ArcGis 9.2 with a set of script and menus that automates the geographic data processing for in input files to the HEC-HMS model and other hydrology model.

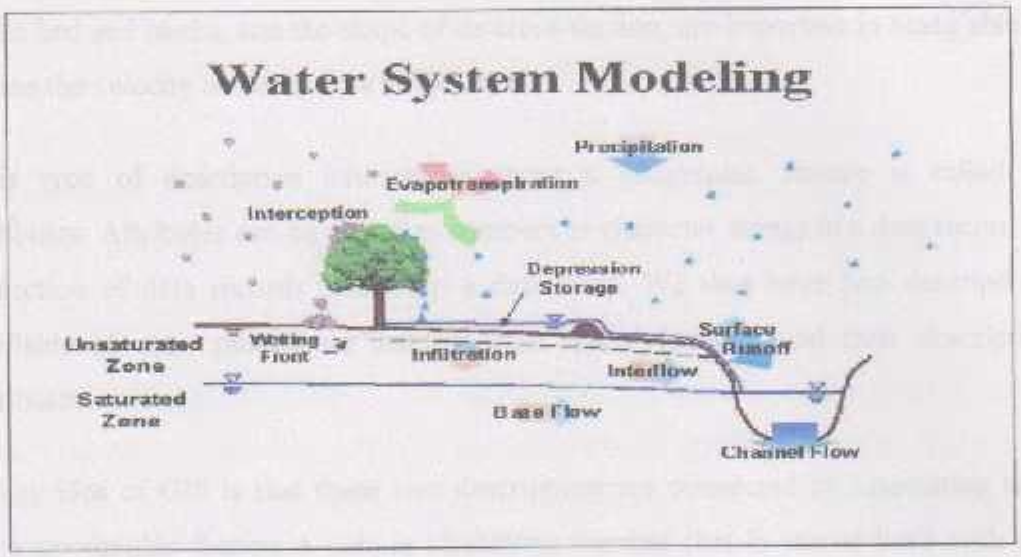

Figure (2.1): Hydrological Model Shows the Behavior of Water.

2.5 Geographic Information System

Geographic Information System (GIS) is defined by ESRI (Environmental System Research Institute) as an organized collection of computer hardware, software, geographic data, and personal designed to efficiently capture, store, update, manipulate, analysis, and display all forms a geographically referenced information.

Many GIS databases consist of sets of information called layers. Each layer represents a particular type of geographic data. For example, one layer may include information on the streets in an area. Another layer may contain information on the soil in that area, while another records elevation.

The GIS can combine these layers into one image, showing how the streets, soil, and elevation relate to one another. Engineers might use this image to determine whether a particular part of a street is more likely to crumble.

When looking at a map to know more about the features represented in it, than simply where they are. For example, when looking at a map of rivers and streams, it is helpful to know their names, and hydrologists want to know a good deal more about a river than its name. Such information as the slope of the river, the roughness of its bed and banks, and the shape of its cross-section, are important in being able to define the velocity of water flow in the river.

This type of descriptive information about a geographic feature is called its attributes. Attributes can be stored as numbers or character strings in a data record. A collection of data records makes up a data table. We thus have two descriptions available of each geographic feature: their spatial location and their descriptive attributes.

A key idea of GIS is that these two descriptions are connected by associating with each geographic feature a unique identifying number that is stored both with the spatial description and with the attribute description.

A GIS is designed to accept geographic data from a variety of sources, including maps, satellite photographs, and printed text and statistics. GIS sensors can scan some of this data directly—for example, a computer operator may feed a map or photograph into the scanner, and the computer "reads" the information it contains. The GIS converts all geographical data into a digital code, which it arranges in its database. Operators program the GIS to process the information and produce the images or information they need.

The applications of a GIS are vast and continue to grow. By using a GIS, scientists can research changes in the environment; engineers can design road systems; electrical companies can manage their complex networks of power lines; governments can track the uses of land; and fire and police departments can plan emergency routes. Many private businesses have begun to use a GIS to plan and improve their services. GIS technology attempts to precisely describe the spatial environment, while hydrology attempts to describe how water and pollutant move through environment, then the synthesis of GIS and hydrology is spatial hydrology.

The purpose of spatial hydrology is to use spatial data and functions of GIS to help in solving the problems in water management. The spatial technology currently used in spatial hydrology is ArcGis.9.2 software and ArcGis.9.2 spatial Analysis Extension. ArcView GIS is readily available to the greatest number of users, although Arc/ Info software can be employed to solve spatial hydrology problems just as effectively. (Maidment, 2002)

The substance of current spatial hydrology is devoted to spatial data development for hydrology because GIS does not have explicit provisions for time-series data and much of hydrology is concerned with time-series measurement systems.

The ArcGis.9 Spatial Analysis has several built-in functions that enable simple watershed delineation using a Digital Elevation Model (DEM). These functions have been further developed by other organization, including the Center for Research in Water Resources (CRWR).

2.6 Watershed Modeling System

In the past several years the availability of hydrologic modeling data sets, including digital elevations, stream reach, basin boundaries, land use, and soils, in GIS format has become common place. The Watershed Modeling System (WMS) was designed to use these and other data sets to set up hydrologic simulations for HEC-1, TR-20, NFF, Rational Method, and other lumped parameter models. The WMS-Hydro extension for ArcView 3.x helps to prepare and transfer these GIS data from ArcView to the WMS. It is intended for use with vector data sets and does not require the Spatial Analyst extension for ArcView, but if you do have Spatial Analyst it will help to manage import and export of grid data sets for use with WMS.

WMS-Hydro works within the ArcView GIS to perform the following primary tasks:

1) Prepare shape files of stream networks and basin boundaries for export to WMS to set up hydrologic models.

2) Start WMS and pass hydrologic modeling data layers directly from WMSHydro.

3) Create a topologic representation of streams and basins where the topology is not inherently defined so that these data can be used to run hydrologic models in WMS.

4) Computing composite curve numbers (CN) from GIS data for use in the various hydrologic models supported by WMS.

5) Manage export and import data for use in WMS. Basin boundaries, stream networks, soil and land use layers, digital elevation, and accompanying hydrologic models can all be exported, while results from WMS, the shape file format, can be imported.

WMS requires three primary data layers in order to build a hydrologic modeling schematic (sometimes referred to as a "tree") from GIS data. These three data layers include a basin boundary layer, a stream network layer, and an outlet or basin confluence layer.

In order to be able to create a hydrologic model from these three GIS vector data layers, topologic relationships between stream reaches, basin boundaries, and outlet points must be explicitly defined. Depending on the origin of the GIS data set, some or all of the following may need to be done to prepare the data so that a correct hydrologic model can be derived directly when exported to WMS.

1) Consistent intersections must exist between basin boundary, stream network, and outlet layers at sub-basin boundary confluences. In other words, the basin boundary and stream network layers should share an arc node at the confluence, and this node should also exist as an outlet point in the outlet layer. In addition, nodes or vertices should exist along the basin boundary and stream network layers at each outlet location.

2) In order to define the appropriate connectivity between stream reaches and basins, stream arcs should be consistently ordered from downstream to upstream. In other words, arc "from" nodes should be at the downstream end and arc "to" nodes at the upstream.

3) If the basin, stream, or outlet layers already contain attributes useful for hydrologic modeling, they can be imported directly to WMS providing the item names match specified keywords used by WMS.

Because GIS data is often created without the purpose of hydrologic modeling in mind, it is often the case that you will need to perform these various steps before transferring the data to WMS.

CHAPTER

3 *GIS AND SPATIAL HYDROLOGY*

3.1 General

3.2 Water Flow Analysis

3.3 Flow Direction Grids

3.4 Watershed and Stream Network

3.5 Watershed

3.6 Case Study: Wadi Hasca Watershed-Beit Kahil Area

PREVIEW

Since it is important in the project to make synthesis of GIS and the hydrology, this chapter will discuss the spatially hydrology, and how the models make the delineation of watersheds.

CHAPTER THREE
GIS AND SPATIAL HYDROLOGY

3.1 General

The study of the hydrology begins in describing the scientific principles governing hydrologic phenomena, studying the hydrologic system operation and predicts it's output, and applying the knowledge into water resources and environmental engineering project. As mentioned earlier, geographical information system (GIS) has lead to significant increase in its use in hydrological application. This chapter explains how to generate watershed and water stream for the project area using (GIS)

3.2 Water Flow Analysis

The model which used here follows the water from the farthest point until arriving the outlet, and analyses the movement of the point according to the elevations as describes below.

3.2.1 Triangulated irregular network

Triangulated Irregular Networks data (TIN) sets can be used to display and analyze surfaces. They contain irregularly spaced points that have x, y coordinates describing their location and a z-value that describes the surface at that point. The surface could represent elevation, precipitation, or temperature. A series of edges join the points to form triangles. The resulting triangular mosaic forms a continuous faceted surface, where each triangle face has a specific slope and aspect (Library of ArcGIS 9.2).

3.2.2 Digital elevation model

A Digital Elevation Model (DEM) is a digital earth surface terrain elevations in xyz coordinates which built by converting the contour map of study area to Triangulated Irregular Network (TIN).

The terrain elevations for ground positions are sampled at regularly spaced horizontal intervals. In other countries DEMs are produced by some national institute, e.g. in the USA DEMs are produced by U.S Geological Survey (USGS) as apart of its national mapping program. Cell sizes for United States are available at (30m), (100m), (500m), and for the world at (1 km) cell size. (Maidment, 2002)

A Digital Elevation Model (DEM) consisting of a rectangular mesh of elevation points located over the landscape. Rectangular mesh has a number of cells represents the elevation of the center of the cell as the following Figure (3.1).

67	56	55	40	50
49	44	37	38	48
65	55	23	32	24
57	47	21	17	20
53	34	30	11	13

Figure (3.1): Surface Terrain Represented by a Mesh of Cells

The highest resolution DEM data is being produced by local mapping efforts with cell sizes of 10 m or smaller.

The USGS produces five different digital elevation products. Although all are identical in the manner the data are structured, each varies in sampling interval, geographic reference system, areas of coverage, and accuracy; with the primary differing characteristic being the spacing, or sampling interval, of the data.

3.2.3 The eight direction pour point model

The eight direction pour point model is the basis for cell-based drainage analysis using a DEM. Pour point is a location where the water flows out the cells. From Figure (3.2) each grid cell surrounding by eight cells (four on the principal axes and four on the diagonals) (Library of ArcGis.9).

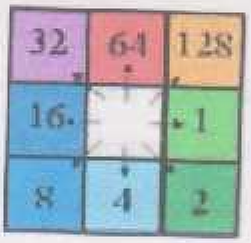

Figure (3.2): Pour Point Model

Water can flow in the cell to one and only one of its neighboring cells, in the direction of the steepest descent. The slope between the adjacent cells is defined as the ratio of the elevation difference to horizontal distance of the two cells centers. For example, Figure (3.3) illustrates a DEM grid with a cell size equal to one unit. (Maidment, 2002)

Figure (3.3): Direction of Steepest Descent

The distance between the cell centers is 1 on the principal axes and $\sqrt{2}$ = 1.414 along the diagonals. The water flow from cell 67 to:

The slope between cell 67 to cell 56: (67-56)/1 = 11

The slope between cell 67 to cell 53: (67-53)/1 = 14

The slope between cell 67 to cell 50: (67-50)/1.414 = 12

The flow direction of cell 67 to the steepest descent is from cell 67 to cell 53. The eight direction pour point models is a simplification of the true path of water flow in any direction, not just one of the eight prescribed directions.

3.3 Flow Direction Grids

Flow direction grids are the flow directions from cell center to cell center. When the DEM is filled the flow direction grid derived directly. It stores the flow direction number for each cell, which corresponding to the direction of steepest descent as determined by the eight direction pour point model. These directions can be represented schematically using arrows, as shown below in Figures (3.4), (3.5) and (3.6). (Maidment, 2002).

67	56	52	44	50
49	44	37	38	48
65	55	23	32	24
57	47	21	17	20
53	34	30	11	13

Figure (3.4): DEM Grid

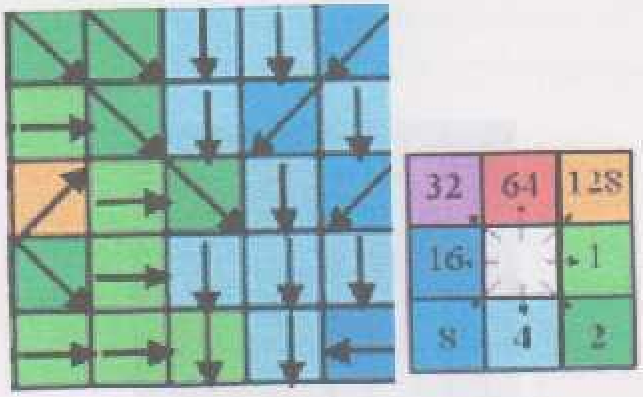

Figure (3.5): Flow directions and the Eight Directions

Pour Point Model

2	2	4	4	8
1	2	4	8	4
128	1	2	4	8
2	1	4	4	4
1	1	1	2	16

Figure (3.6): Flow Direction Grid

3.3.1 Grid networks

Flow network is a network of elementary flow paths that connected each cell in the grid, cell by cell downstream, to the eventual outlet point of the terrain surface. This network called network grid (defined with a grid).

DEMs useful in the hydrology if it can be able to describe a flow with a one-dimensional network over a two-dimensional surface. Because modeling two-dimensional flows is more complex, grid networks transform the problem of describing a two-dimensional flow over a surface into a problem of defining a one-dimensional flow through a network, (see Figure (3.7)).

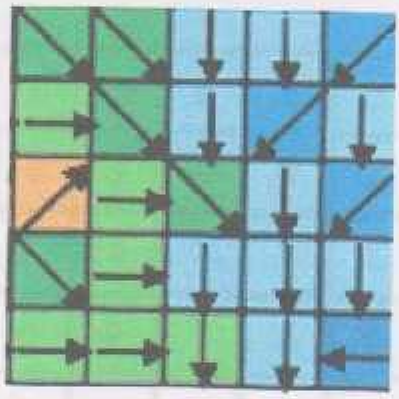

Figure (3.7): Flow Direction for Each Cell

3.3.2 Flow accumulation grids

Is one of the most important grids in hydrologic analysis, count the number of cells upstream from each individual cell? To illustrate how derived flow accumulation grid from a grid network look at the following Figures (3.8.a) and (3.8.b).

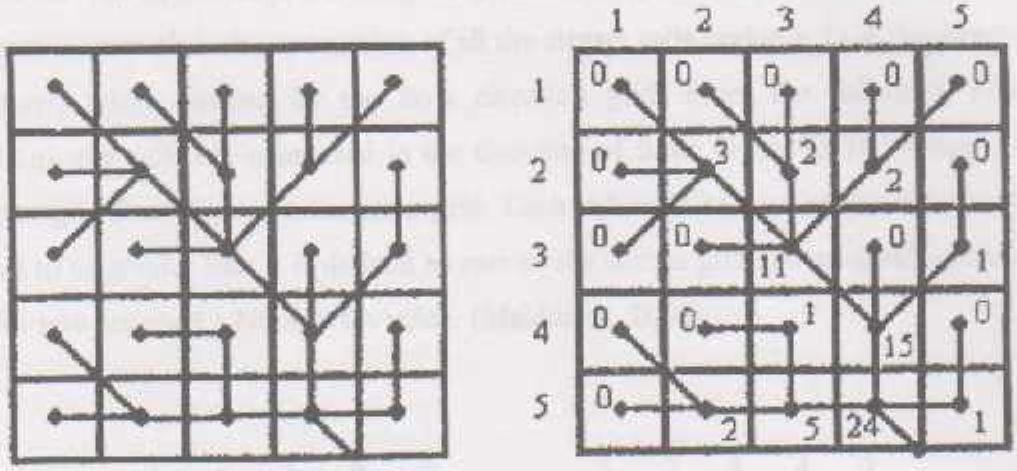

Figure (3.8): a) Grid Network **b) Flow Accmulation Grid**

(Mohammadin, 2003)

The entire cell in the first column and first row gave zero upstream cells, which are coded with a flow accumulation of 0. Cell (2, 2) has 3 cells upstream. Cell (2, 3) has two cells upstream ...etc. To determined the flow accumulation grid by similarly computing the values for all other cells as indicated in the Figure (3.9).

0	0	0	0	0
0	3	2	2	0
0	0	11	0	1
0	0	1	15	0
0	2	5	24	1

Figure (3.9): Flow Accumulation Grid (Mohammadin, 2003)

3.4 Watershed and Stream Network

Stream Network and its watersheds is a fundamental to studying the movement of water through the landscape. Watershed and stream networks are defined using DEM. A stream cell is any cell with a flow accumulation value larger than the cell threshold. All stream cells are assigned a value of 1; all others are NO DATA cells. A stream network is the connection of all the stream cells (value = 1) in the direction of flow, which defined by the flow direction grid. From the following Figure (3.10.a), the cells are connected in the direction of flow. Figure (3.10.b) shows the stream grid from flow accumulation grid. Each cell with its flow accumulation value equal to or greater than 5 is defined as part of the stream grid and assigned a value of 1. All arte assigned a NO DATA value. (Maidment, 2002)

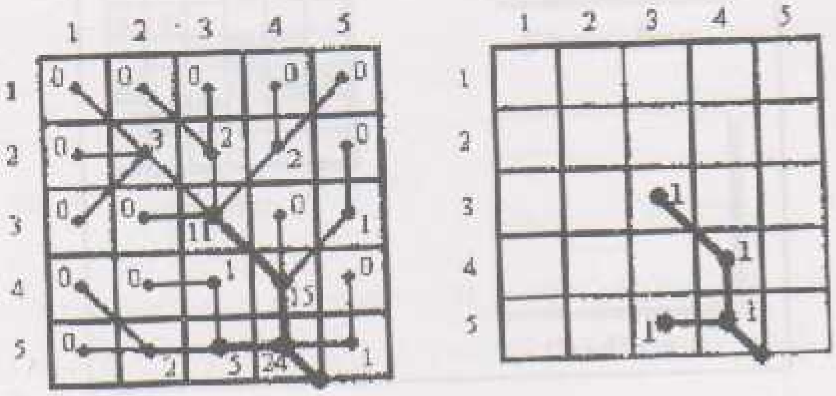

Figure (3.10): a) Flow Accumulation Grid **b) Stream Grid**

(Mohammadin, 2003)

Water flows downstream cell by cell. Flow accumulation grids count the number of cells upstream from any given cell. When the amount of water flow into the cell accumulation to a certain point, the cell considered part of the stream network.

3.4.1 Steam links

The Stream Link function allows you to assign unique values to each of the links in a raster linear network, as shown in Figure (3.11). This is most useful as input to the watershed function to quickly create watersheds based on stream junctions. It can also be useful for attaching related attribute information to individual segments of a stream.

A raster linear network can be accurately converted to features representing the linear network using the stream to feature function. The vectorization algorithm is designed primarily for vectorization of raster stream networks, or any other raster representing a raster linear network for which directionality is known. In the output feature dataset, all arcs will point downstream.

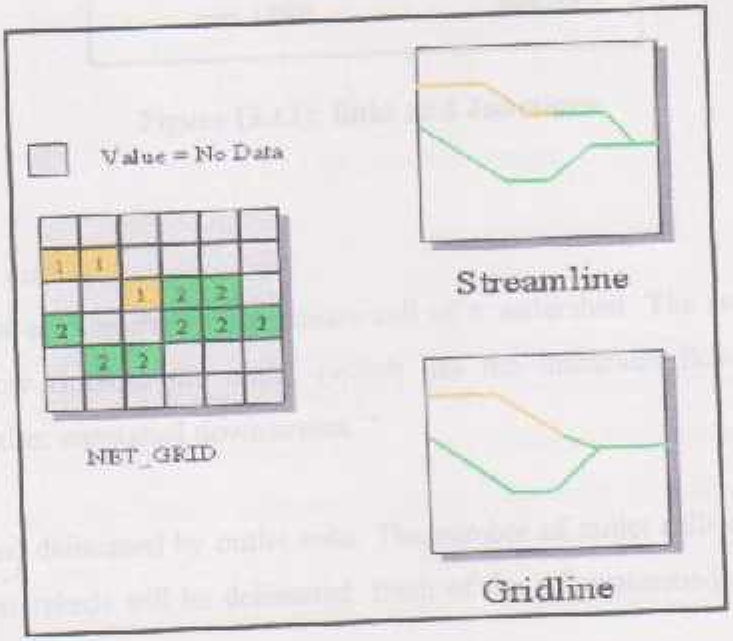

Figure (3.11): Stream Links

The stream to feature algorithm is optimized to use a direction raster to aid in vectorizing intersecting and adjacent cells. With stream to feature it is possible for two adjacent linear features of the same value to be vectorized as two parallel lines instead of being lumped into a single line as they would when using other vectorization methods.

Links are the sections of a stream channel connecting two successive junctions, a junction and the outlet, or a junction and the drainage divide, (Figure (3.12)).

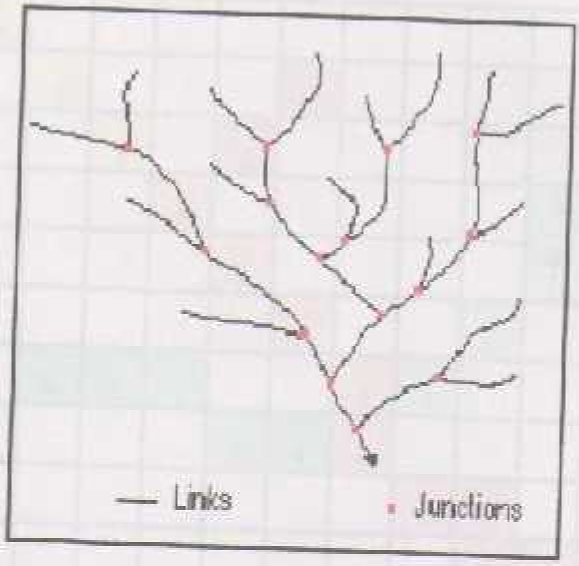

Figure (3.12): links and Junctions

3.4.2 Stream outlets

Stream outlets are the most downstream cell of a watershed. The water within the watershed flow through the outlet (which has the maximum flow accumulation value) to another watershed downstream.

The watershed delineated by outlet cells. The number of outlet cells determines how many sub-watersheds will be delineated. Each of the sub-watersheds is the drainage area to its outlet.

To determined the drainage area for a certain location (as a stream gauging station or water right location), should be define those locations as the outlet cells by converting the point theme of those locations to a grid theme, then delineate the watershed or drainage area from those locations (see Figure (3.13)). It is important that the location points fall exactly on the streams; otherwise the delineation will not be accurate.

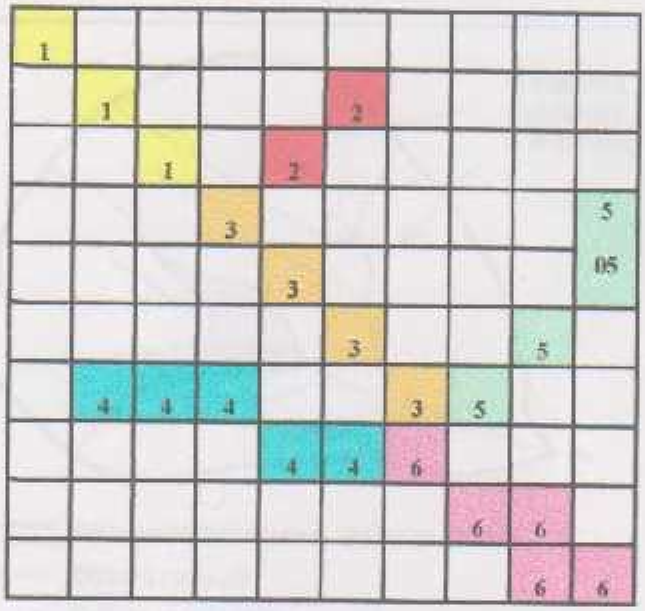

Figure (3.13): Stream Outlet

3.5 Watershed

A watershed is an area that drains water and other substances to a common outlet as concentrated drainage. Other common terms for a watershed are basin, catchment, or contributing area. This area is normally defined as the total area flowing to a given outlet, or pour point. These areas are the output of the watershed function. The boundary between two watersheds is referred to as a watershed boundary or drainage divide .

An outlet, or pour point, is the point at which water flows out of an area. This is the lowest point along the boundary of the watershed. The cells in the source raster are used as pour points above which the contributing area is determined. Source cells may be features such as dams or stream gauges, for which you want to determine characteristics of the contributing area, (Figure (3.14)).

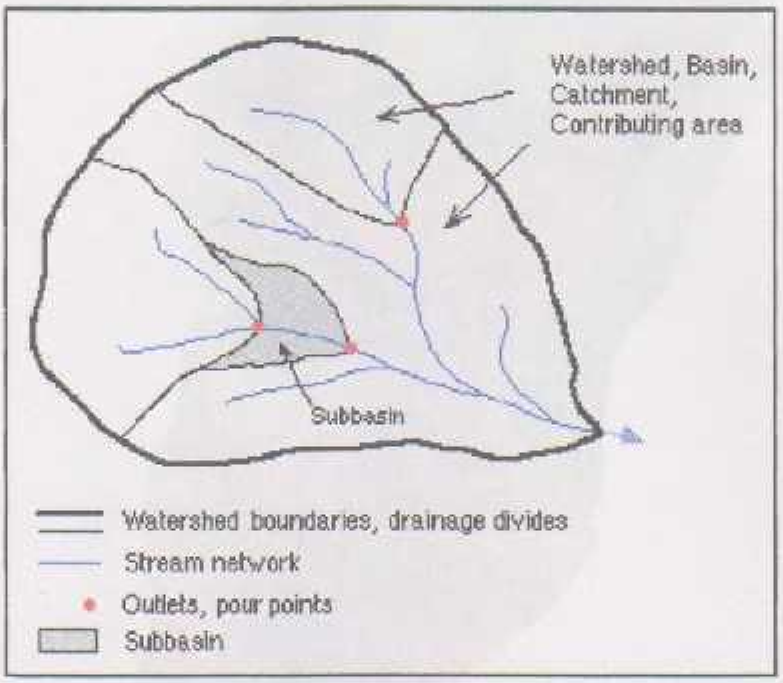

Figure (3.14): Watershed and Sub Watershed Boundaries

In the ArcGis.9 Spatial Analysis Extension watershed built as a function. The input grids for the watershed function are a flow direction grid and an outlet grid. The output grid is a watershed grid.

3.6 Case Study: Wadi Hasca Watershed-Beit Kahil Area

An ArcGis.9 was used to process the DEM and generate the hydrologic parameters required to develop the spatially distributed travel time distribution and direct runoff hydrographs by routing the runoff down to the outlets. The original procedure was created the DEM in ArcGIS.9.2 project; to identify and fill sinks; to generate flow direction, flow accumulation, and stream network. The procedures are as follow:

1- Triangulated Irregular Networks (TIN) was fined as appear in Figure (3.15).
2- The Digital Elevation Model (DEM) derived from (TIN) as shown Figure (3.16).
3- The Flow Direction was computed as shown in Figure (3.17).
4- The Flow Accumulation derived from flow direction as shown in Figure (3.18).
5- The Stream Network was constructed as shown in Figure (3.19).

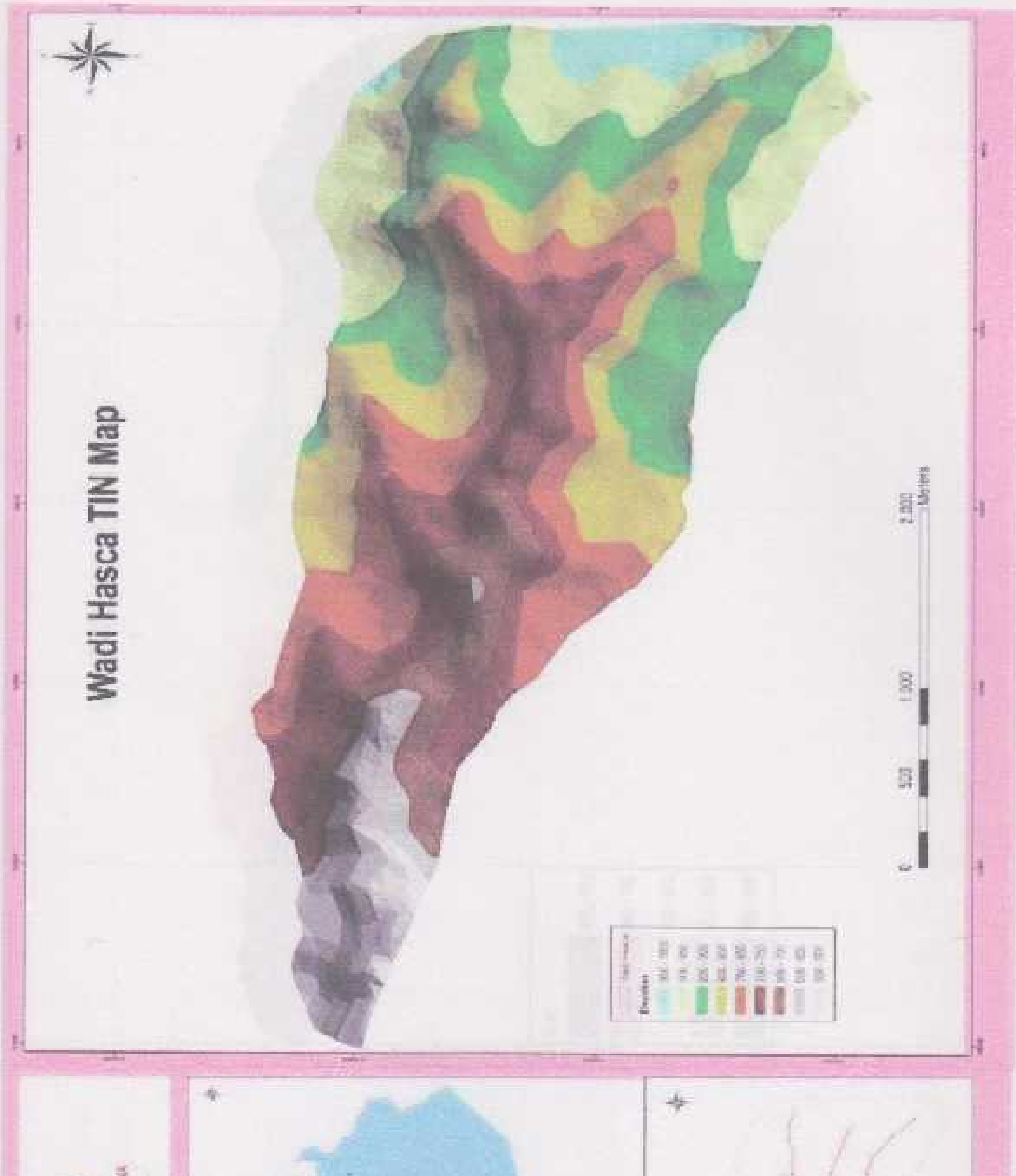

Figure (3.15): Triangulated Irregular Networks (TIN)

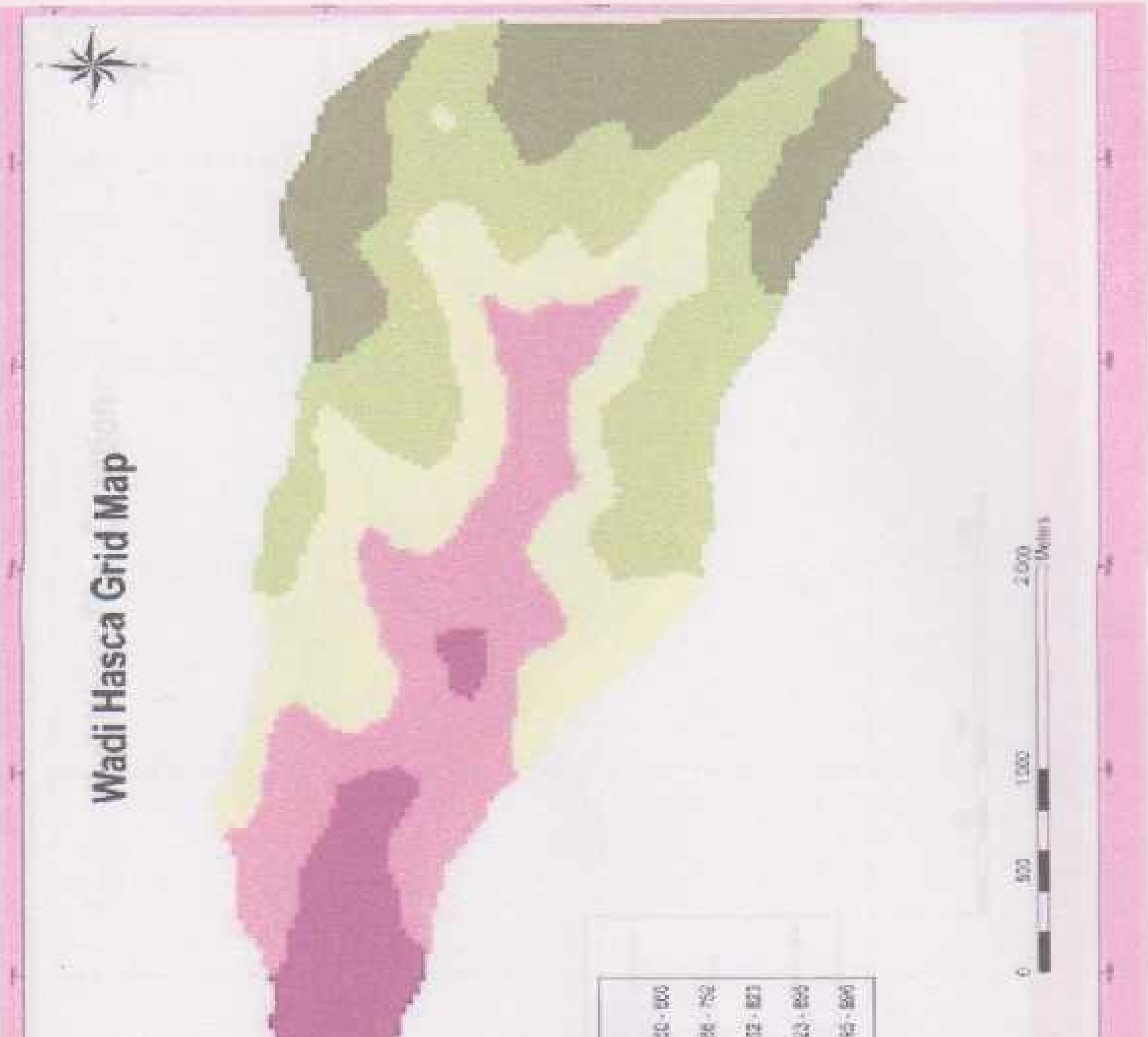

Figure (3.16): The Digital Elevation Model (DEM)

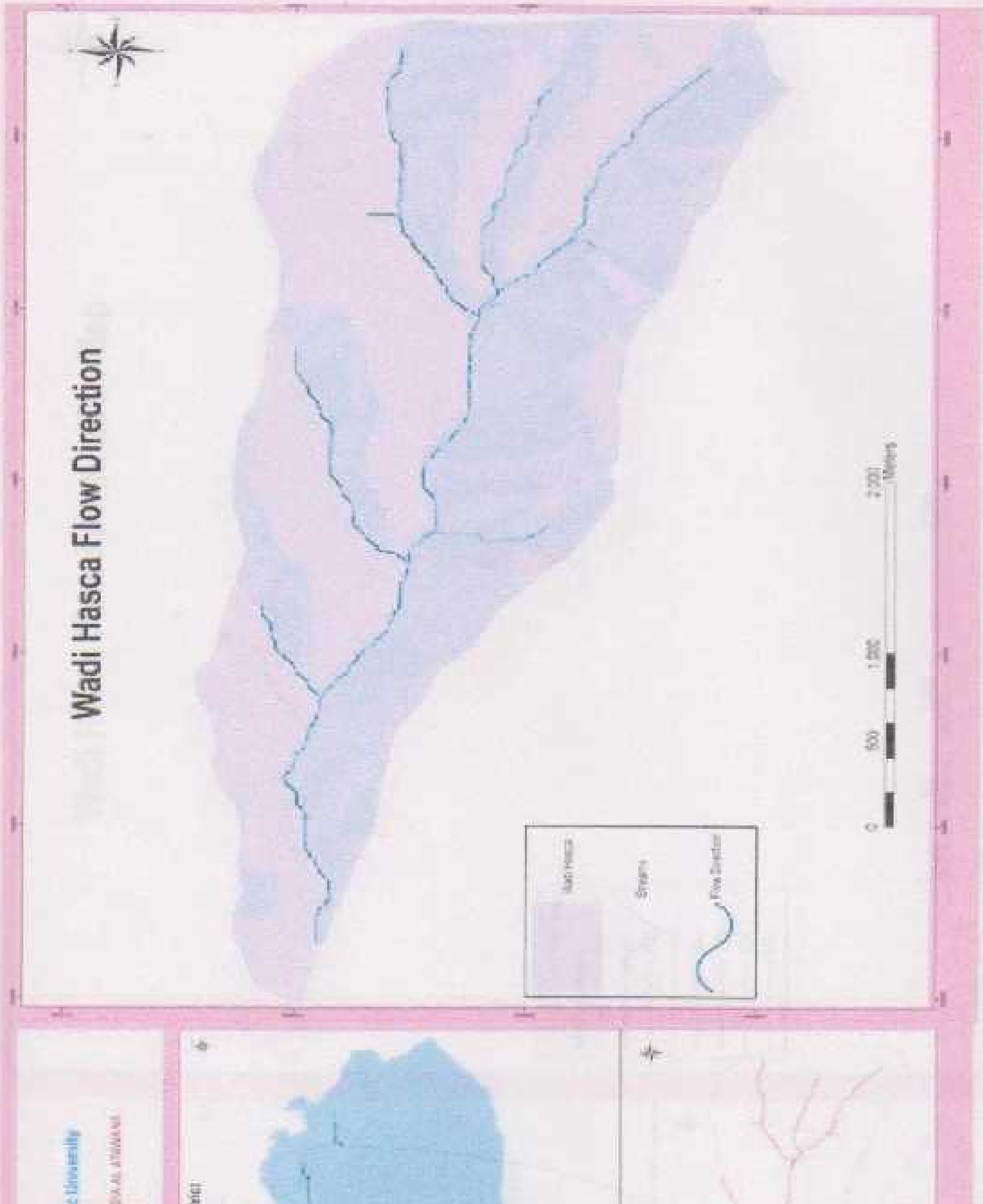

Figure (3.17): The Flow Direction

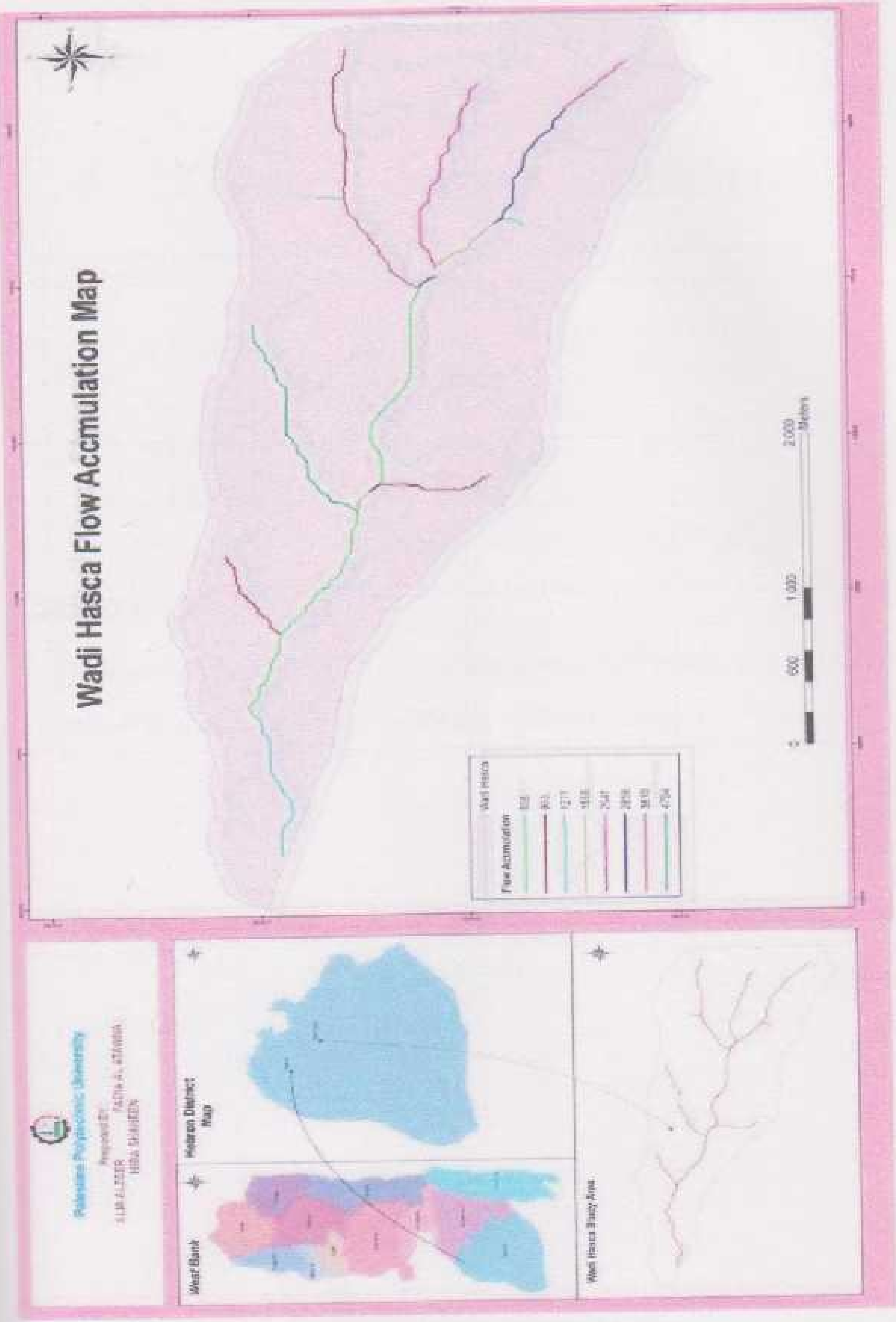

Figure (3.18): The Flow Accumulation

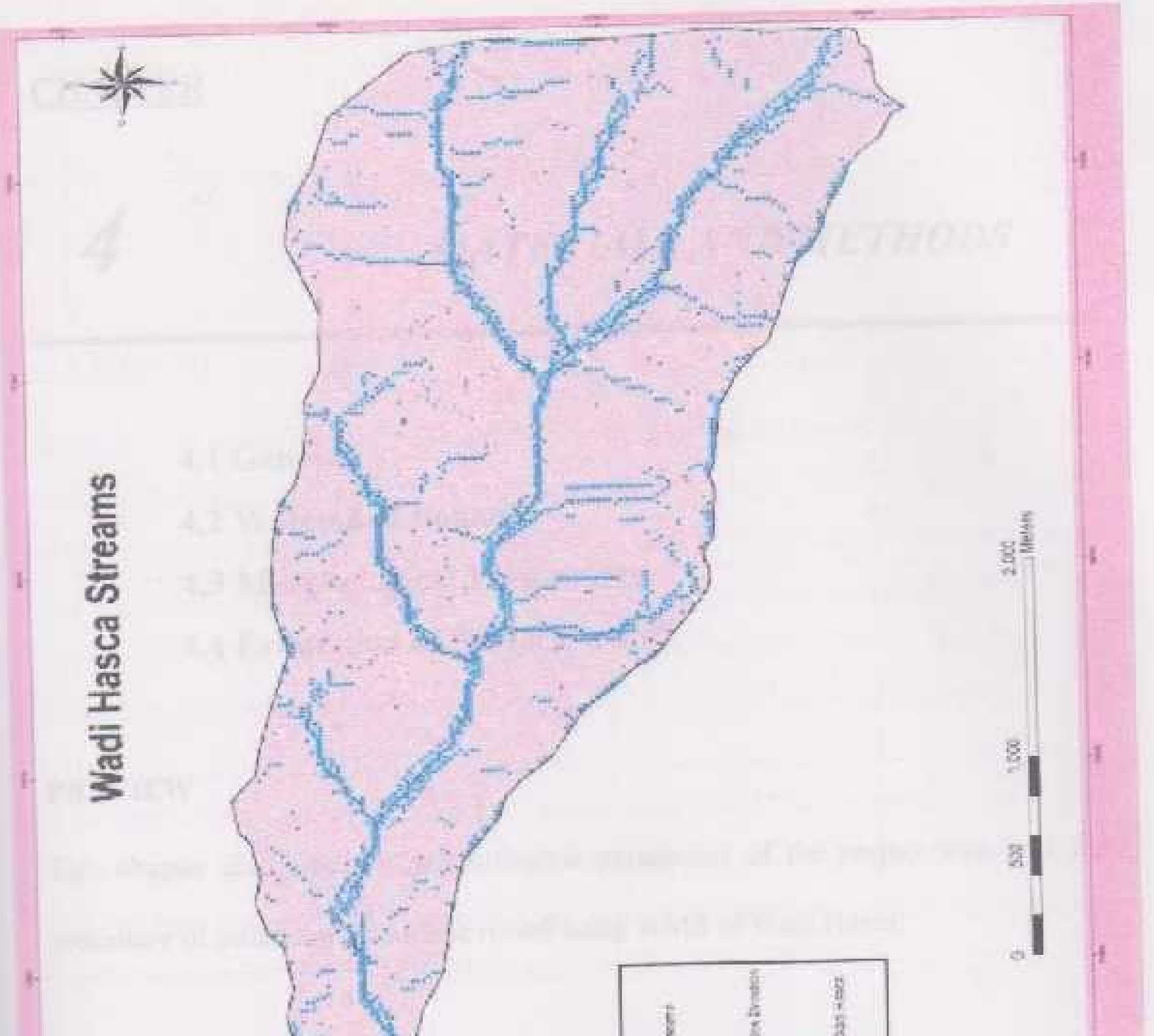

Figure (3.19): The Stream Network

CHAPTER

4 *MATERIALS AND METHODS*

4.1 General

4.2 Watershed Boundary

4.3 Morphological Parameters

4.4 Estimation of Surface runoff.

PREVIEW

This chapter discussed the morphological parameters of the project area, and the procedure of estimation of surface runoff using WMS of Wadi Hasca

CHAPTER FOUR

MATERILS AND METHODS

4.1 General

Response of a watershed (catchment) to specified rainfall input is shaped by the catchment characteristics such as land use and land cover (LULC), morphological parameters, soil classification, infiltration rate.. The data of land use and land cover and morphological characteristics of Wadi Hasca watershed located in Beit Kahil village of the Hebron district is used to estimate the amount of direct runoff for the given precipitation using Rational Method and Watershed Modeling System.

This chapter deals with the procedures which were carried out in order to determine the boundary of the project area and morphological parameters, and prepare the land use and land cover map. The results were used to estimate the surface direct runoff for the watershed that is studies in the next chapter.

4.2 Watershed Boundary

4.2.1 Boundary of the catchments

The watershed boundary was restricted by digitizing the project area on the aerial photograph with the help of Geographical Information System (GIS) software. The boundary of the watershed is appeared in Figure (4.1).

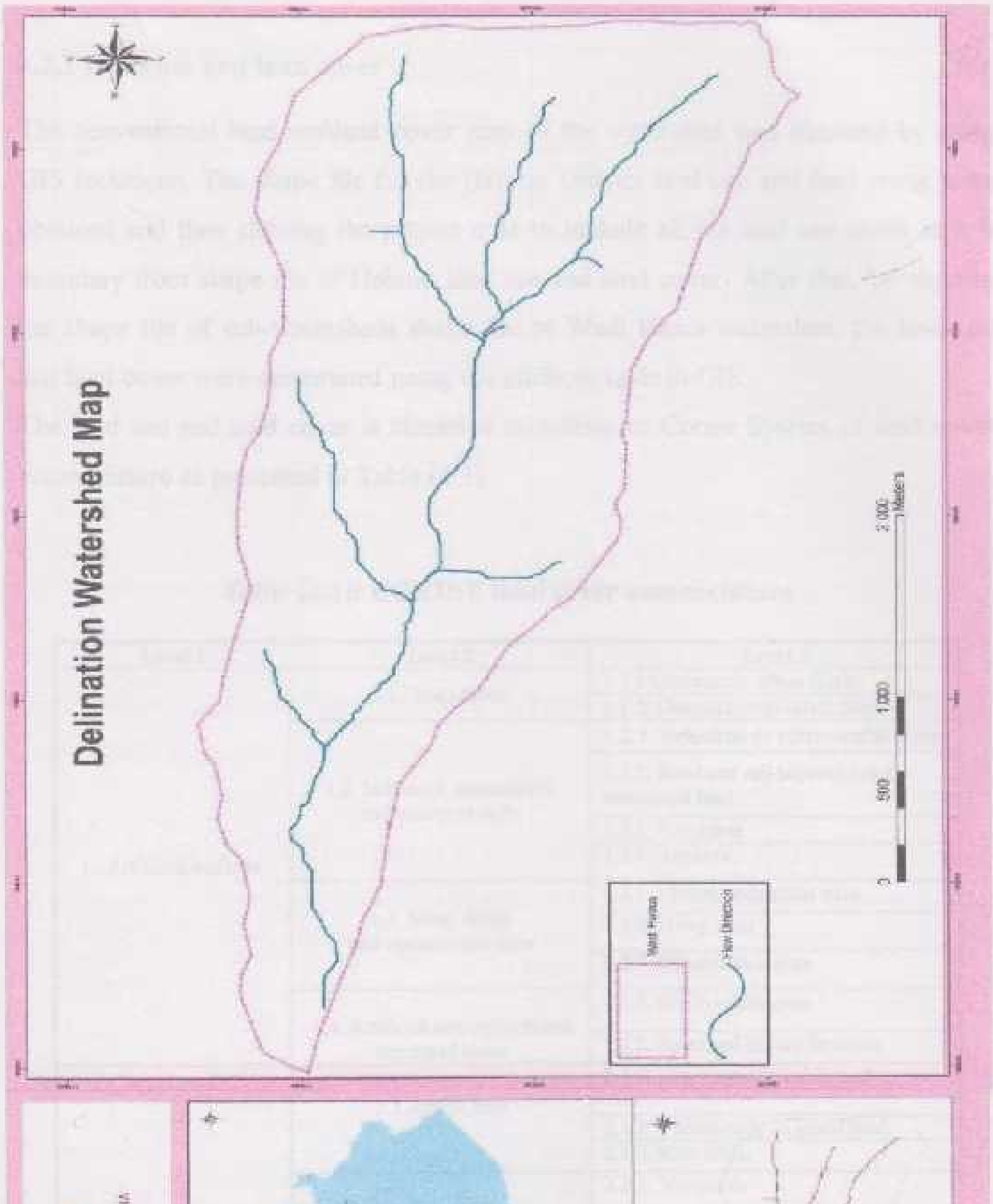

Figure (4.1): Boundary of Wadi Hasca Watershed

4.2.2 Land use and land cover

The conventional land use\land cover map of the watershed was obtained by using GIS technique. The shape file for the Hebron District land use and land cover were obtained and then clipping the project area to include all the land use levels in it is boundary from shape file of Hebron land use and land cover. After that, by clipping the shape file of sub-watersheds shape file of Wadi Hasca watershed, the land use and land cover were determined using the attribute table in GIS.

The land use and land cover is classified according to Corine System of land cover nomenclature as presented in Table (4.1).

Table (4.1): CORINE land cover nomenclature

Level 1	Level 2	Level 3
1. Artificial surfaces	1.1 Urban fabric	1.1.1 Continuous urban fabric
		1.1.2. Discontinuous urban fabric
	1.2. Industrial, commercial and transport units	1.2.1. Industrial or commercial units
		1.2.2. Road and rail networks and associated land
		1.2.3. Port areas
		1.2.4. Airports
	1.3. Mine, dump and construction sites	1.3.1. Mineral extraction sites
		1.3.2. Dump sites
		1.3.3. Construction sites
	1.4. Artificial non-agricultural vegetated areas	1.4.1. Green urban areas
		1.4.2. Sport and leisure facilities
2. Agricultural areas	2.1.Arable land	2.1.1. Non-irrigated arable land
		2.1.2. Permanently irrigated land
		2.1.3. Rice fields
	2.2. Permanent crops	2.2.1. Vineyards
		2.2.2. Fruit trees and berry plantations
		2.2.3. Olive groves
	2.3. Pastures	2.3.1. Pastures
	2.4. Heterogeneous agricultural areas	2.4.1. Annual crops associated with permanent crops
		2.4.2. Complex cultivation
		2.4.3. Land principally occupied by agriculture, with significant areas of natural vegetation
		2.4.4. Agro-forestry areas

Level 1	Level 2	Level 3
3. Forests and semi-natural areas	3.1. Forests	3.1.1. Broad-leaved forest
		3.1.2. Coniferous forest
		3.1.3. Mixed forest
	3.2. Shrub and/or herbaceous vegetation association	3.2.1. Natural grassland
		3.2.2. Moors and heath land
		3.2.3. Sclerophyllous vegetation
		3.2.4. Transitional woodland shrub
	3.3. Open spaces with little or no vegetation	3.3.1. Beaches, dunes, and sand plains
		3.3.2. Bare rock
		3.3.3. Sparsely vegetated areas
		3.3.4. Burnt areas
		3.3.5. Glaciers and perpetual snow
4. Wetlands	4.1. inland wetlands	4.1.1. Inland marshes
		4.1.2.Peatbogs
	4.2. Coastal wetlands	4.2.1. Salt marshes
		4.2.2. Salines
		4.2.3. Intertidal flats

The level three is considered for the project area, where the land used and cover is classified into nine categories as shown in Table (4.2). The values of coefficient of permeability (C) is also given in the table.

Table (4.2). The values of coefficient of permeability (C)

Land Use	C	Land Use	C
Industrial: Light areas	0.6	Open spaces with no vegetation	0.15
Forest	0.05	Permanent crops	0.2
Commercial	0.6	Plastic house	0.6
Urban fabric	0.3	Arable	0.2
Hydrogenous agriculture	0.15		

4.3 Morphological Parameters

As mentioned earlier, the study of the characteristics of the project area (Wadi Hasca Watershed) were carried out by using Watershed Modeling System (WSM). The morphological parameters were determined as the following steps:-

1. Delineating the watershed by importing a DEM.

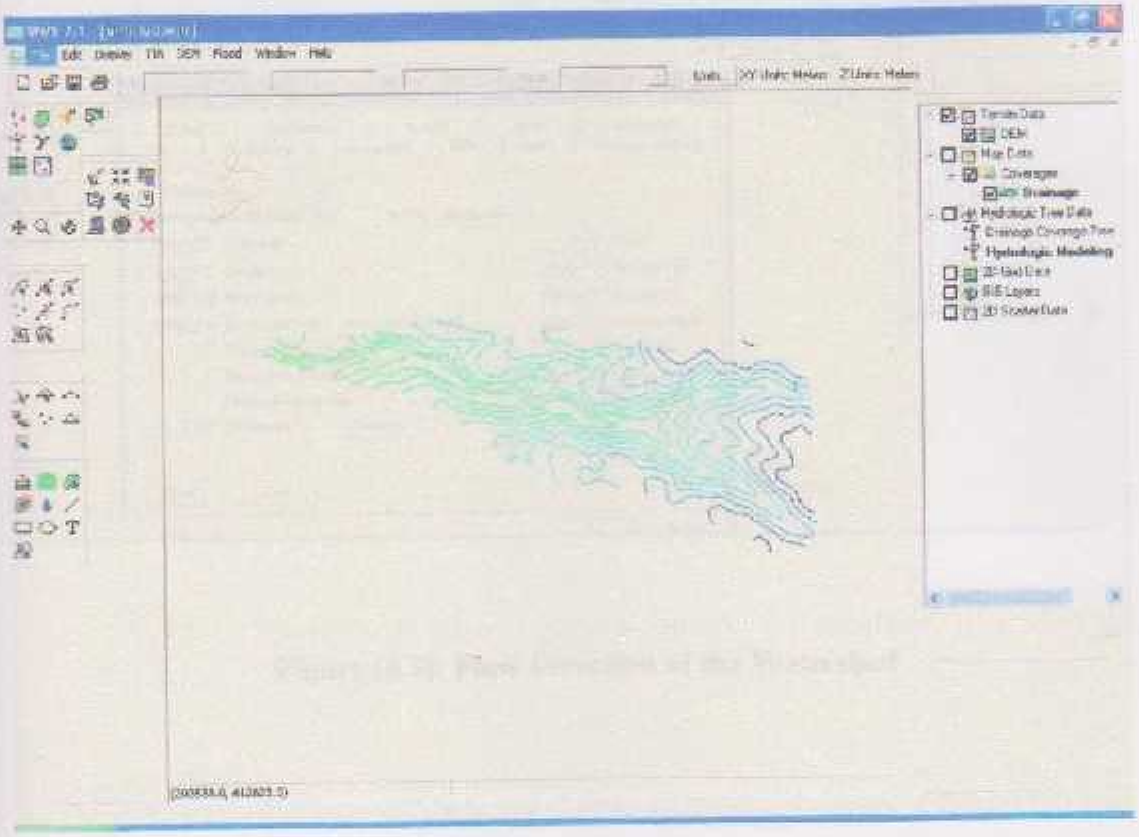

Figure (4.2): Delineating The Watershed

2. Using TOPAZ to compute flow direction and accumulations.

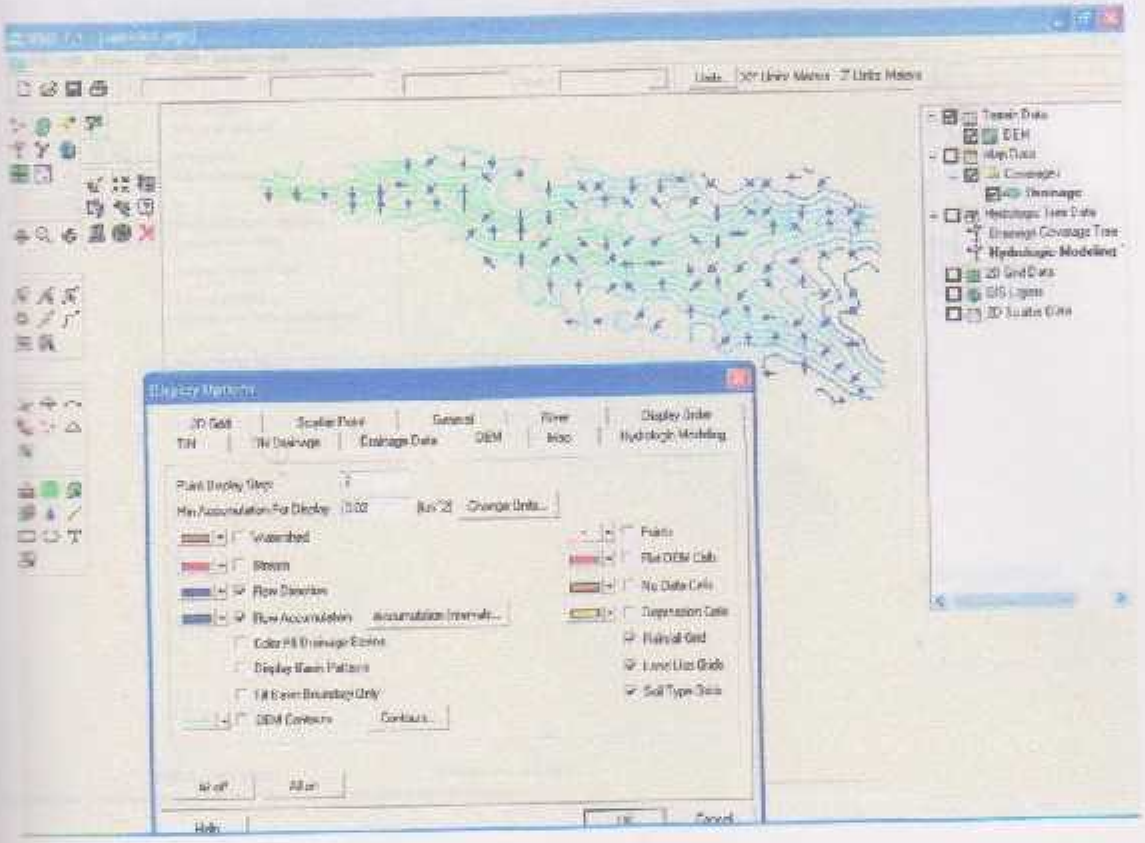

Figure (4.3): Flow Direction of the Watershed

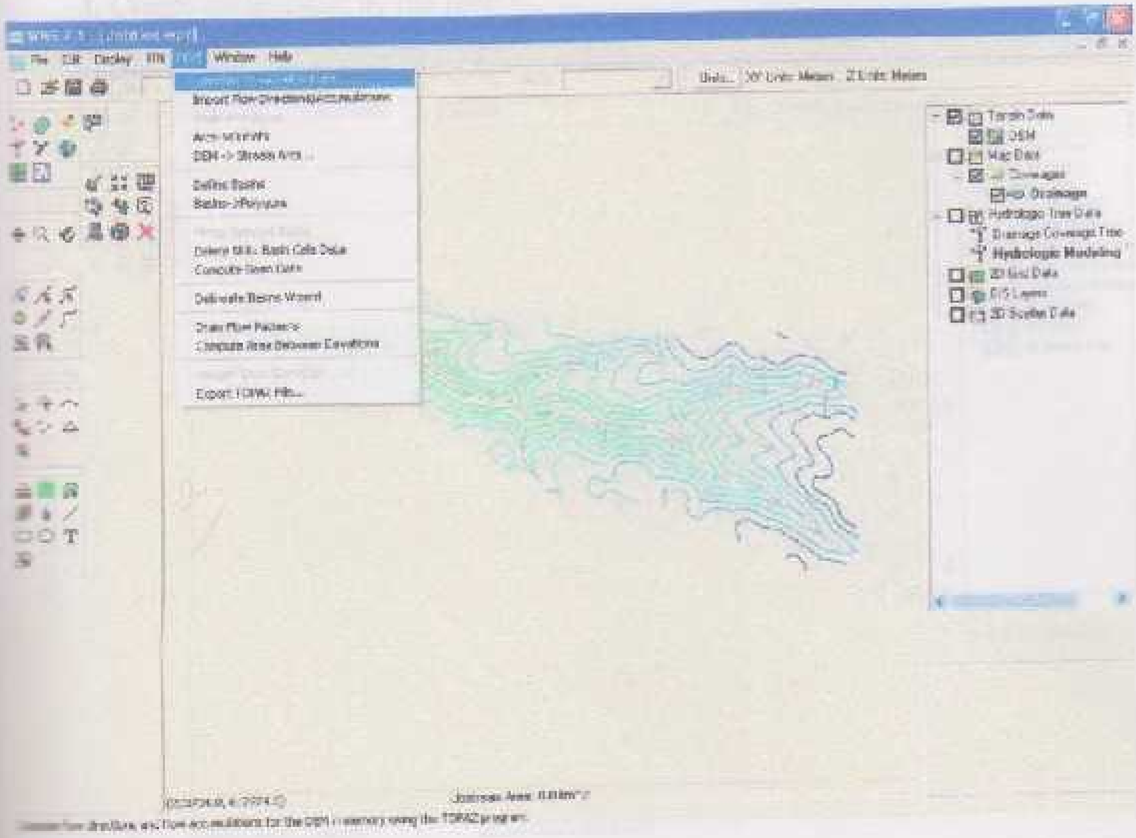

Figure (4.4): Flow Accumulation of the Watershed

3. Create outlet point by the tool .

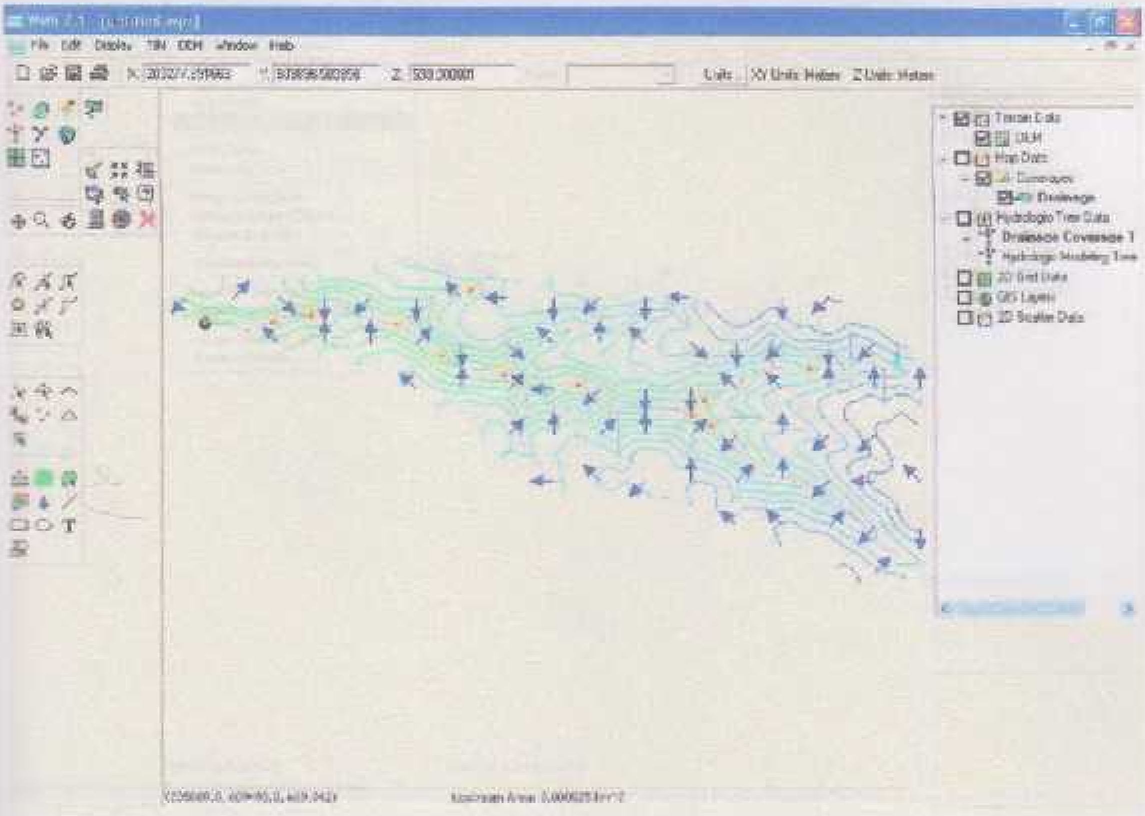

Figure (4.5): Outlets of the Watershed

4. Create stream arcs.

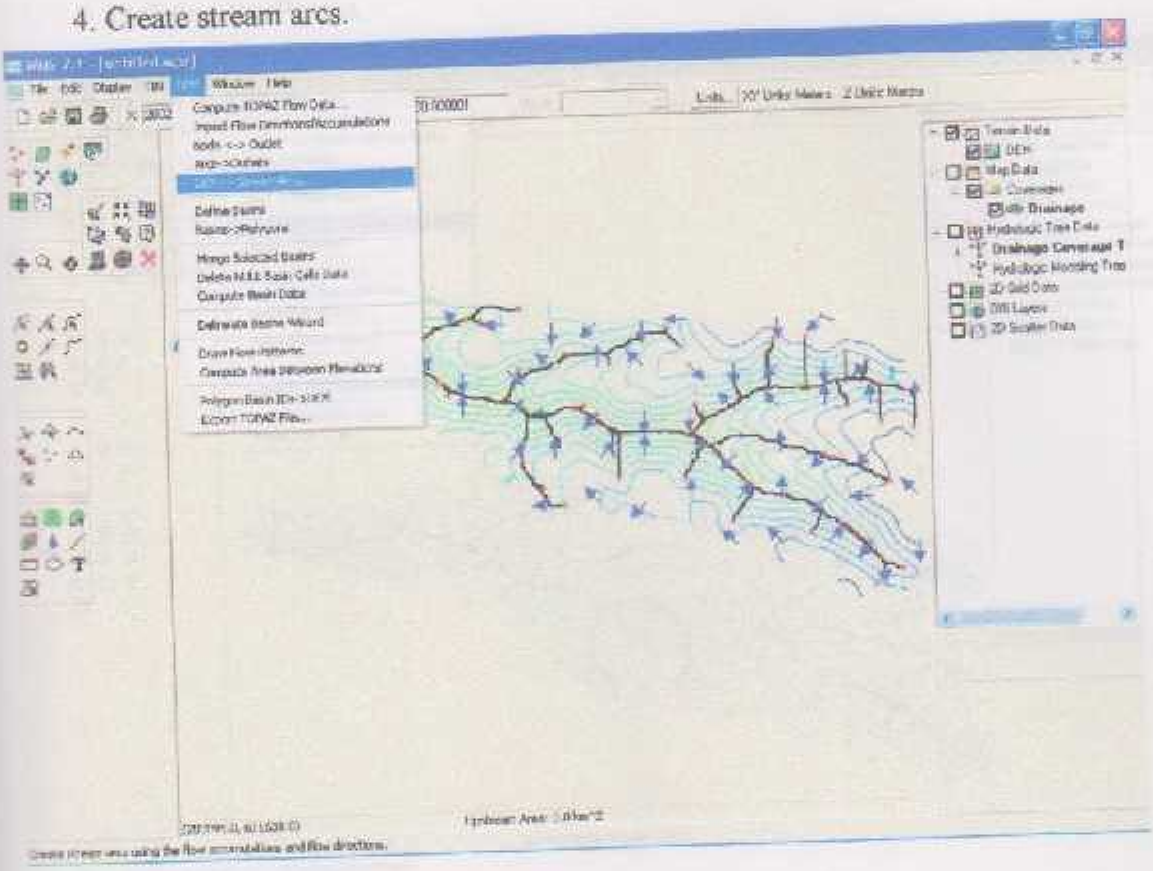

Figure (4.6): Streams of the Watershed

5. Defining the Basins

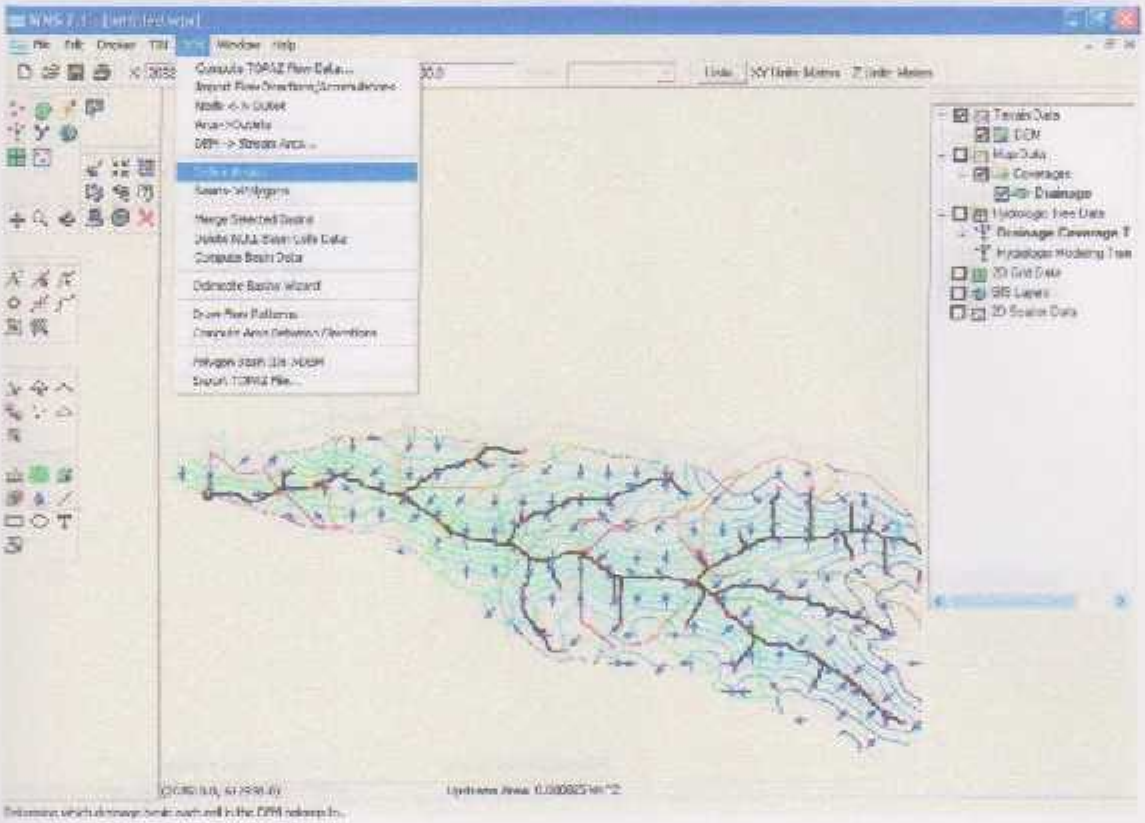

Figure (4.7): Sub-Basins of the Watershed

6. Create basins polygons.

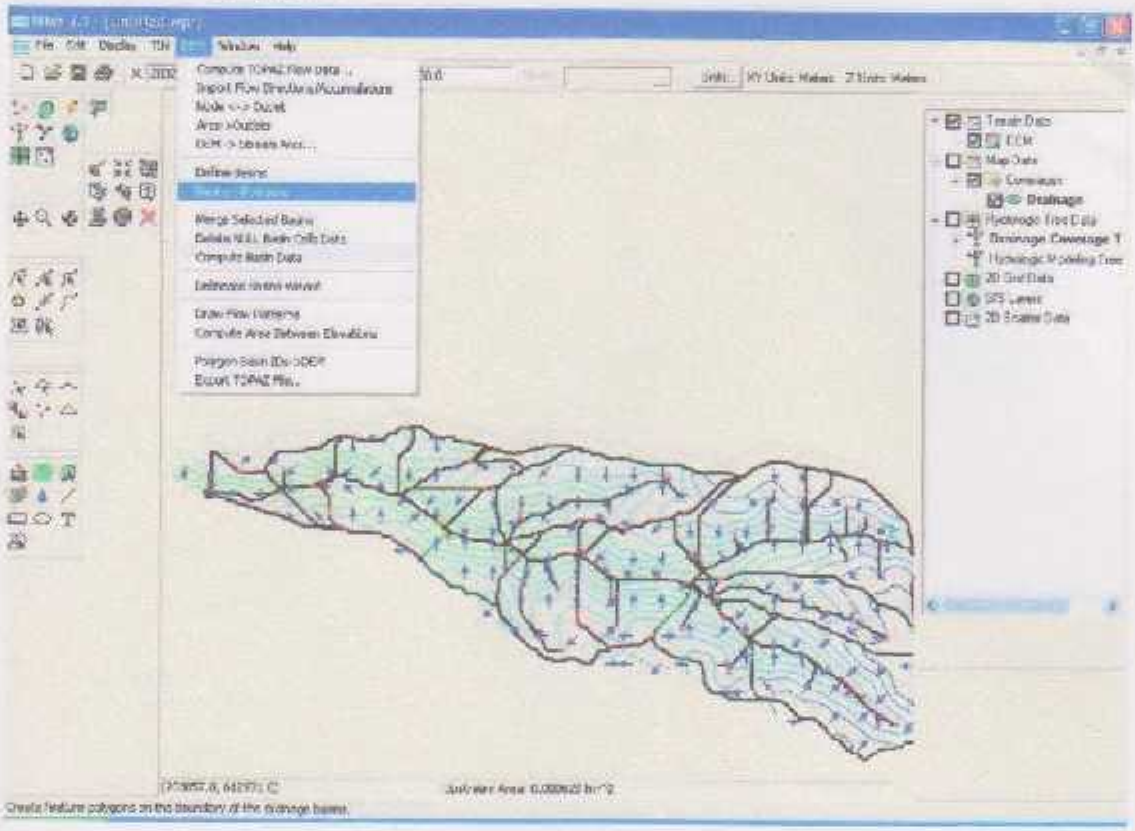

Figure (4.8): Sub-Watershed of the Project Area.

7. Compute basin data.

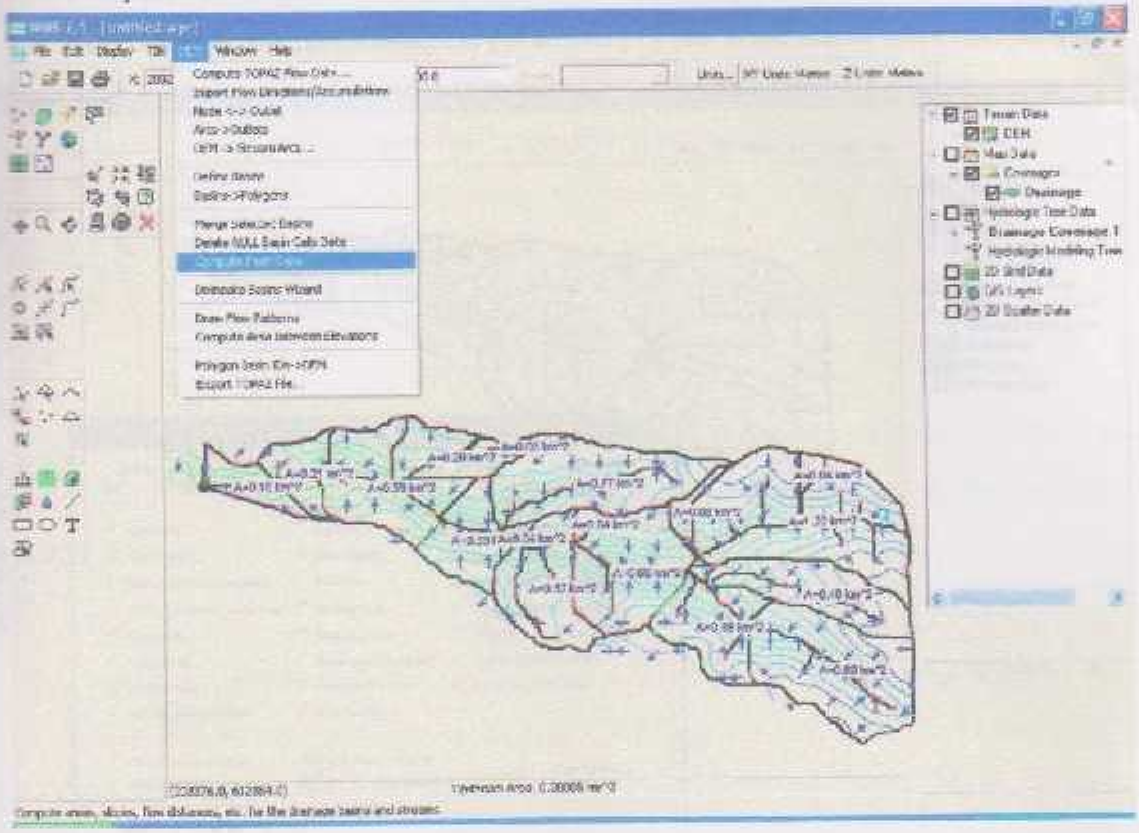

Figure (4.9): The Basic Data of Sub-Basins

After determined the boundary of the catchments, sub catchments, a flow direction and accumulation, the morphological parameters of the Wadi Hasca were computed.

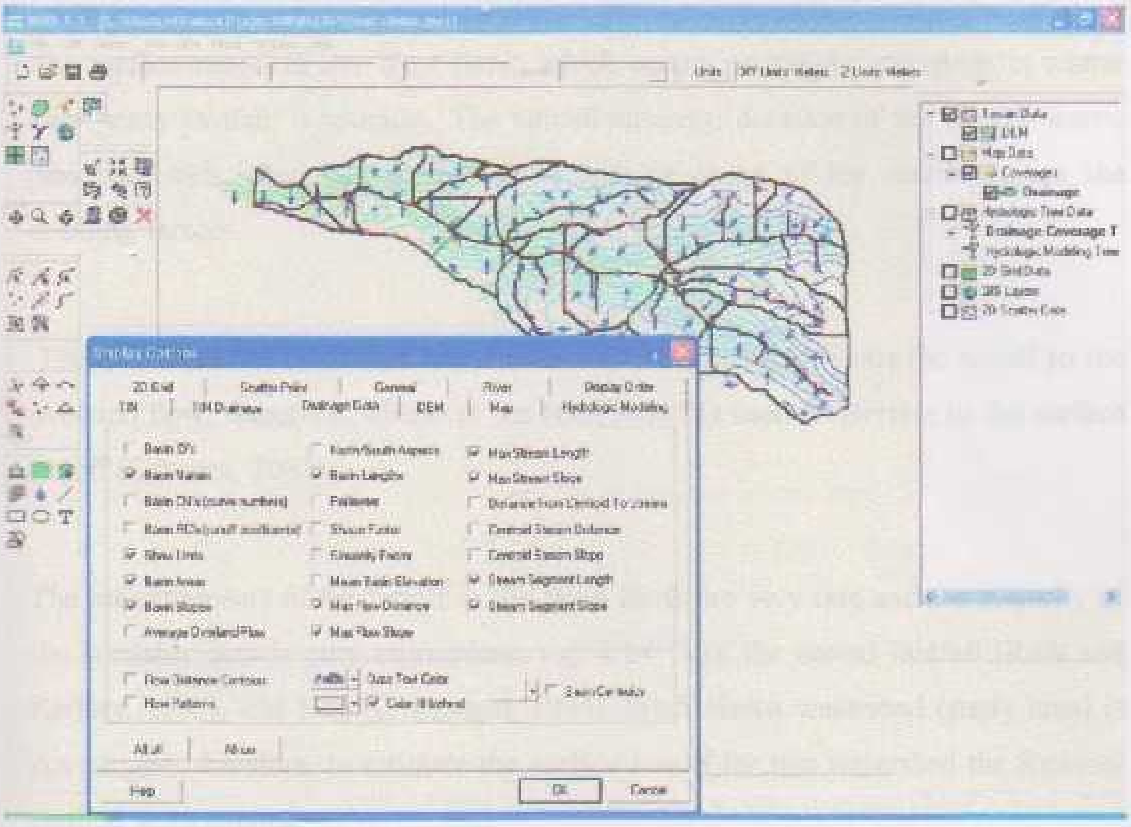

Figure (4.10): Morphological Characteristics of the Watershed.

4.4 Estimation of Surface runoff.

4.4.1 Introduction

The surface runoff in the West Bank, which occurs on the dry riverbeds in winter after heavy rainfall, is sporadic. The rainfall intensity, duration of the rainfall storm, land use, soils; elevation, surface slope and the shape of the catchment are the deciding factors.

The non existence of surface water bodies in the study area limits the runoff to the overland flow, therefore, whenever the term runoff is used it referrers to the surface runoff (Qannam, 2003).

The measurements of the runoff in the West Bank are very rare and the majority of the available data is only estimations, e.g. 7-14 % of the annual rainfall (Rofe and Raffety, 1963), and 5 % (Gvirtzman, 1994). Wadi Hasca watershed (study area) is not gauged; therefore, to estimate the surface runoff for this watershed the Rational method were applied.

In rational method the basic parameters to be calculated is the runoff coefficient (C) and rainfall intensity (i). The value of C depends mainly on the permeability of the soil and land use and land cover, while the value of (i) depends on the time of concentration. The results of these parameters for Wadi Hasca watershed are described below; and the values of runoff coefficients and rainfall intensity are calculated and used for estimating the runoff depth and volume for the study area.

4.4.2 Rainfall data

Although the average annual rainfall recorded at Hebron Meteorological Station for the period 2000 – 2007 is 500 mm, there are considerable variations in the quantity of the annual rainfall from year to year. The maximum recorded annual rainfall was 645.3 mm in 2002/2003 season, while the minimum was 287.8 mm in 2006/2007 season as shown in Figure (4.11).

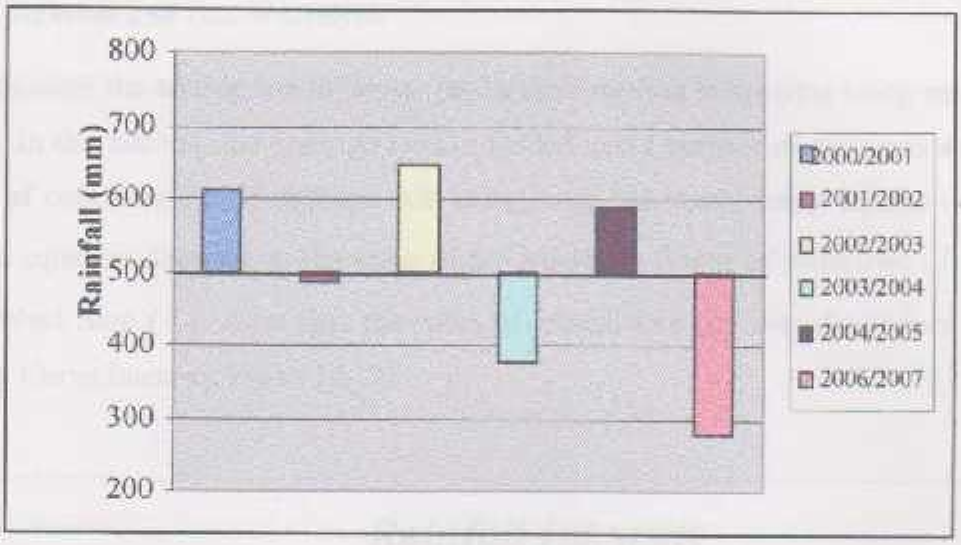

Figure (4.11): The Annual Rainfall Variation at the Hebron District Meteorological Station during the Period (2000 – 2006)

Generally, the wet season in the area of Wadi Hasca stretch over eight months (October to May). But most of the rain falls during the period (November to April). About two thirds of the rainfall amount falls between December and February as shown in Figure (4.12).

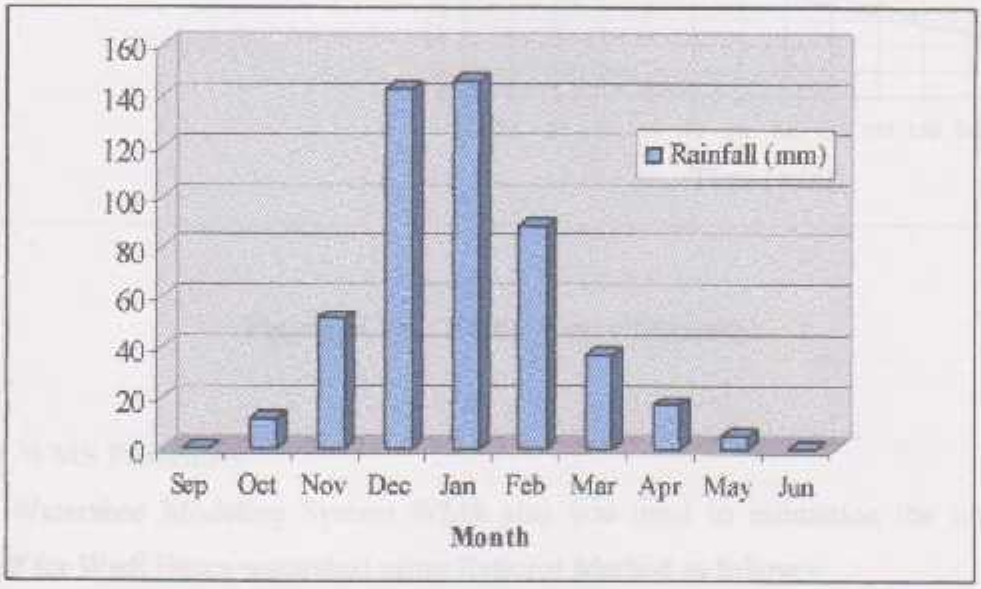

Figure (4.12): The Average Monthly Rainfall Recorded at the Hebron District Meteorological Station during the Period (2000 – 2006).

4.4.3 Rainfall and runoff analysis

To calculate the surface runoff depth, the rational method is applying using equation (2.9). In this method, the drainage area is divided into a number of sub areas and the time of concentration of different sub areas, were calculated using equation (2.8). These equation depends on the value of the maximum length of watershed (L) and watershed Slop (S). After that the value of rainfall intensity was determined from Multy Curve Intensity Figure (4.13).

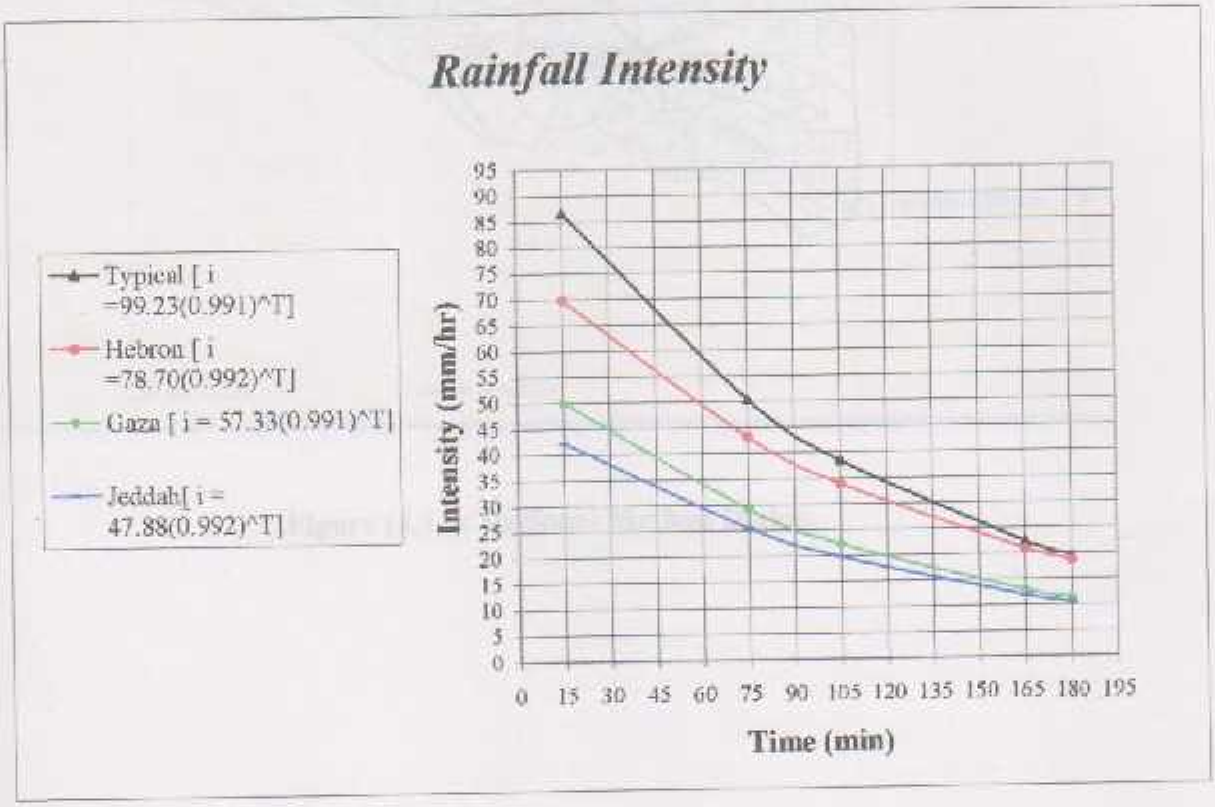

Figure (4.13): Multy Curve Intensity

4.4.4 WMS Procedure

The Watershed Modeling System WMS also was used to estimation the surface runoff for Wadi Hasca watershed using Rational Method as follow:-

1- Running a Rational Method simulation.

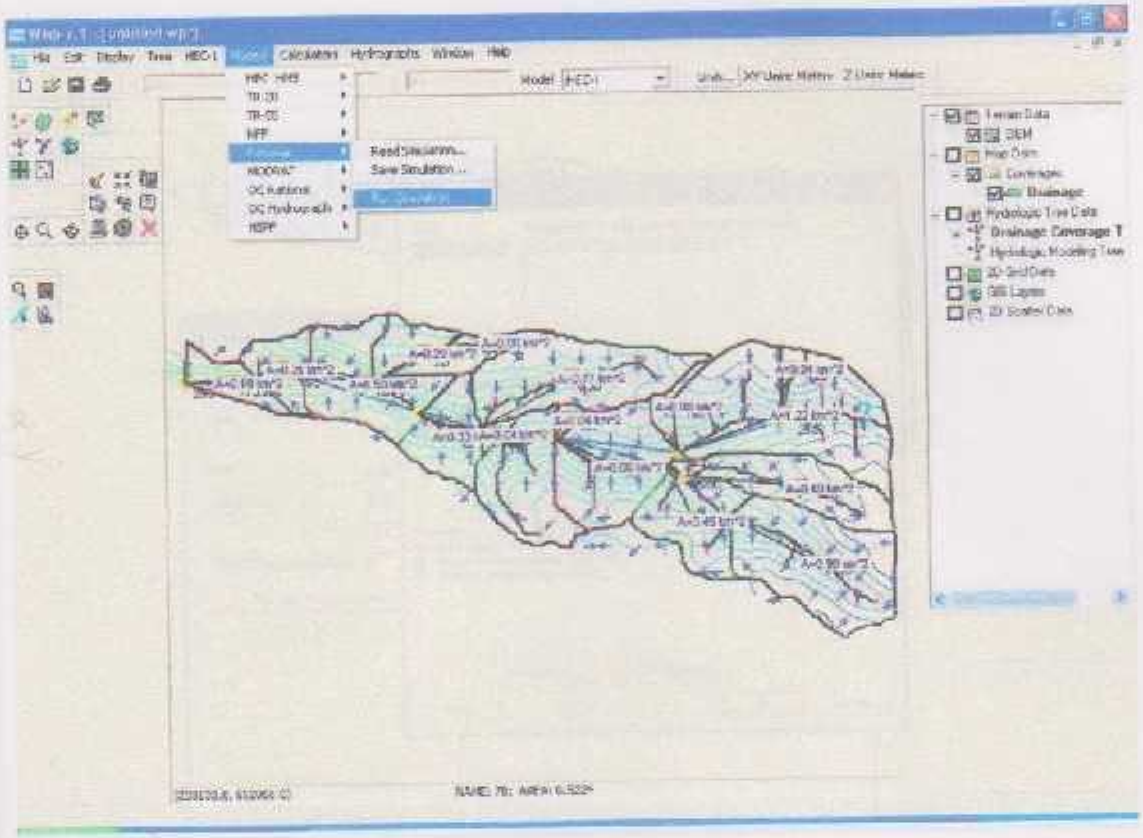

Figure (4.14): Rational Method Dialog.

2- Defining the runoff coefficient and time of concentration.

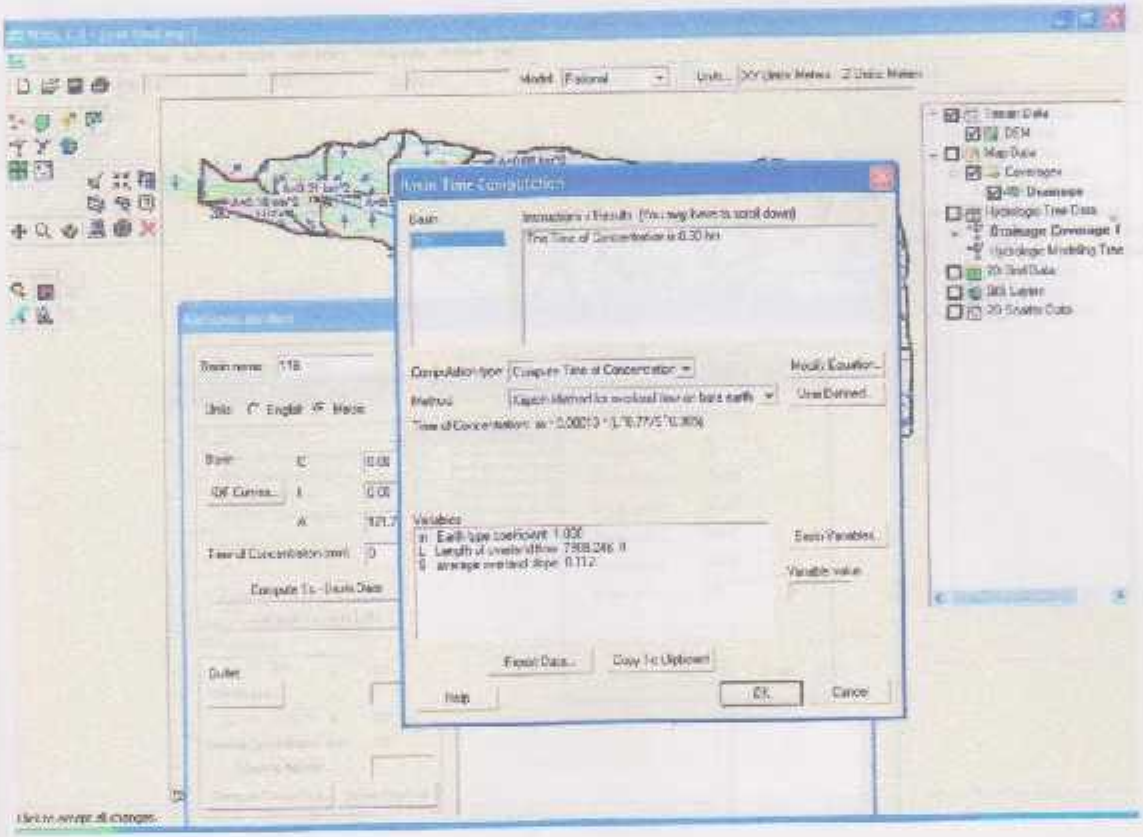

Figure (4.15): Estimation of Time of Concentration

3- Defining the Intensity Duration Frequency curves (IDF).

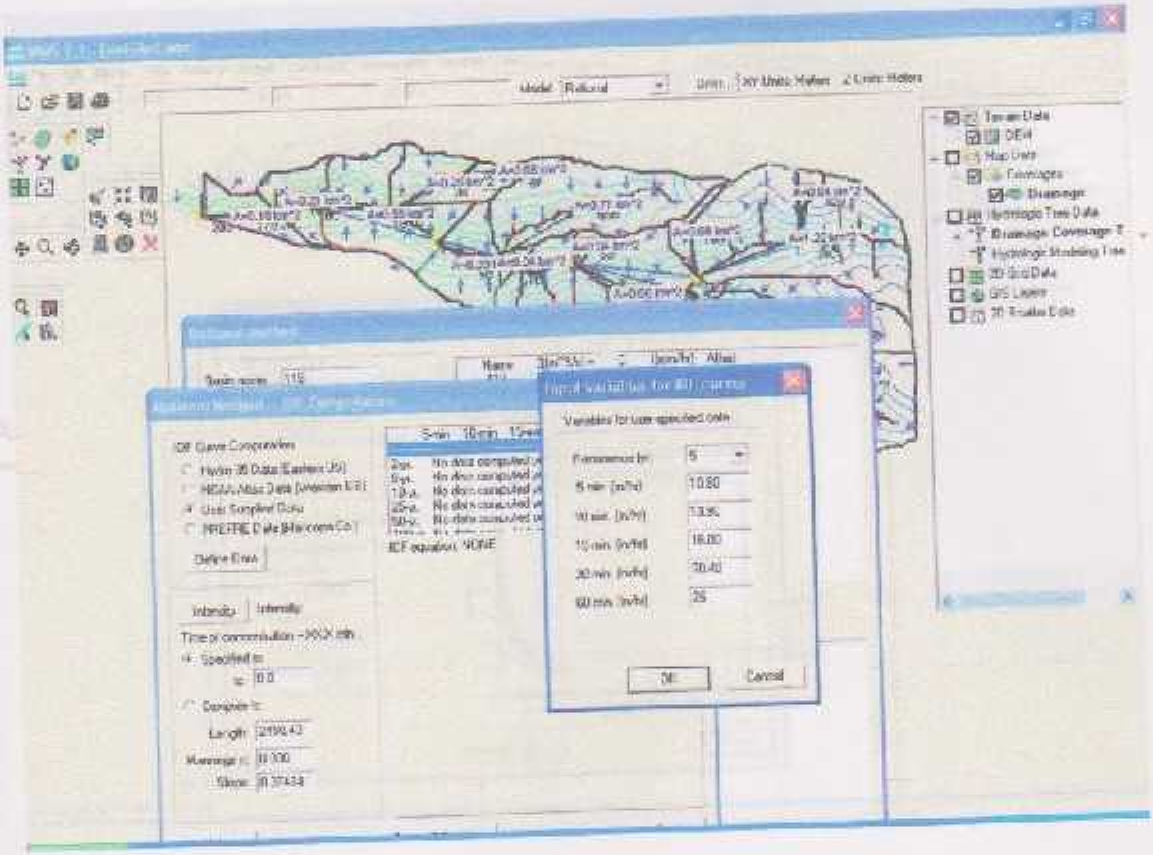

Figure (4.16): The Average Rainfall Data for the Last Five Years

4- Defining the rainfall intensity.

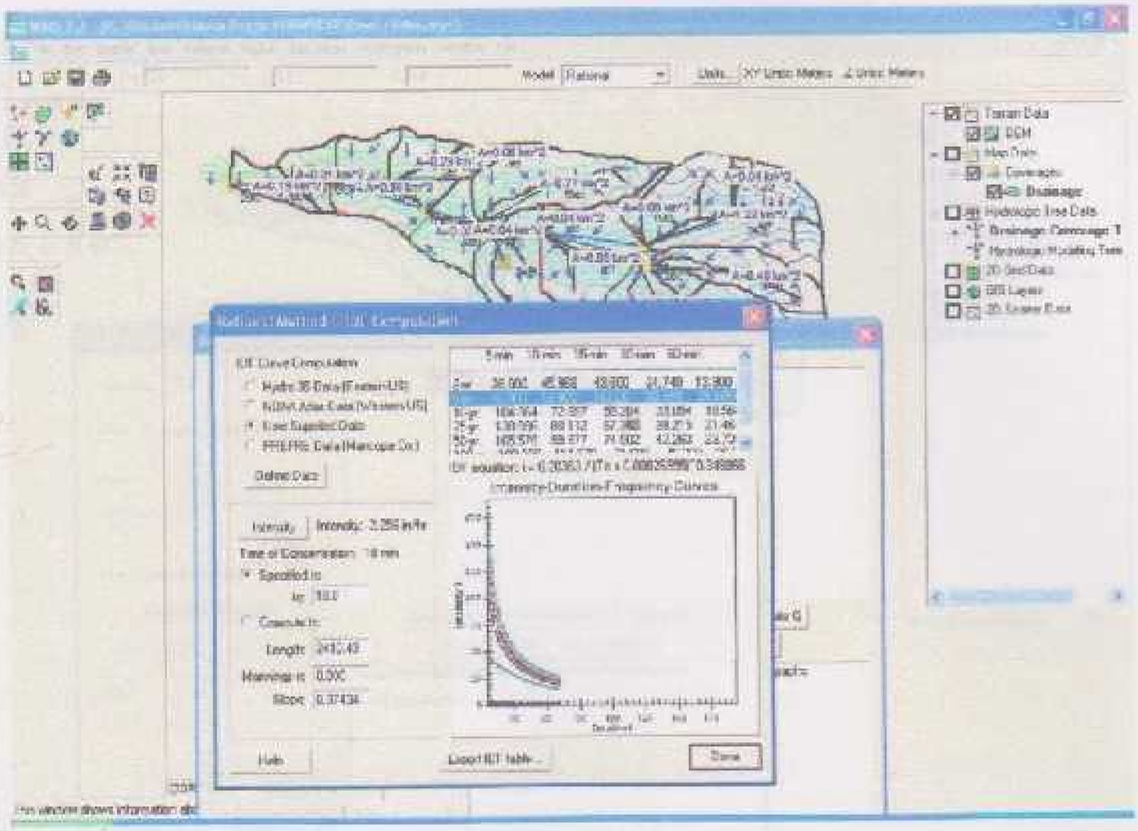

Figure (4.17): Intensity- Duration- Frequency Curve

5- Computed the surface runoff (Q).

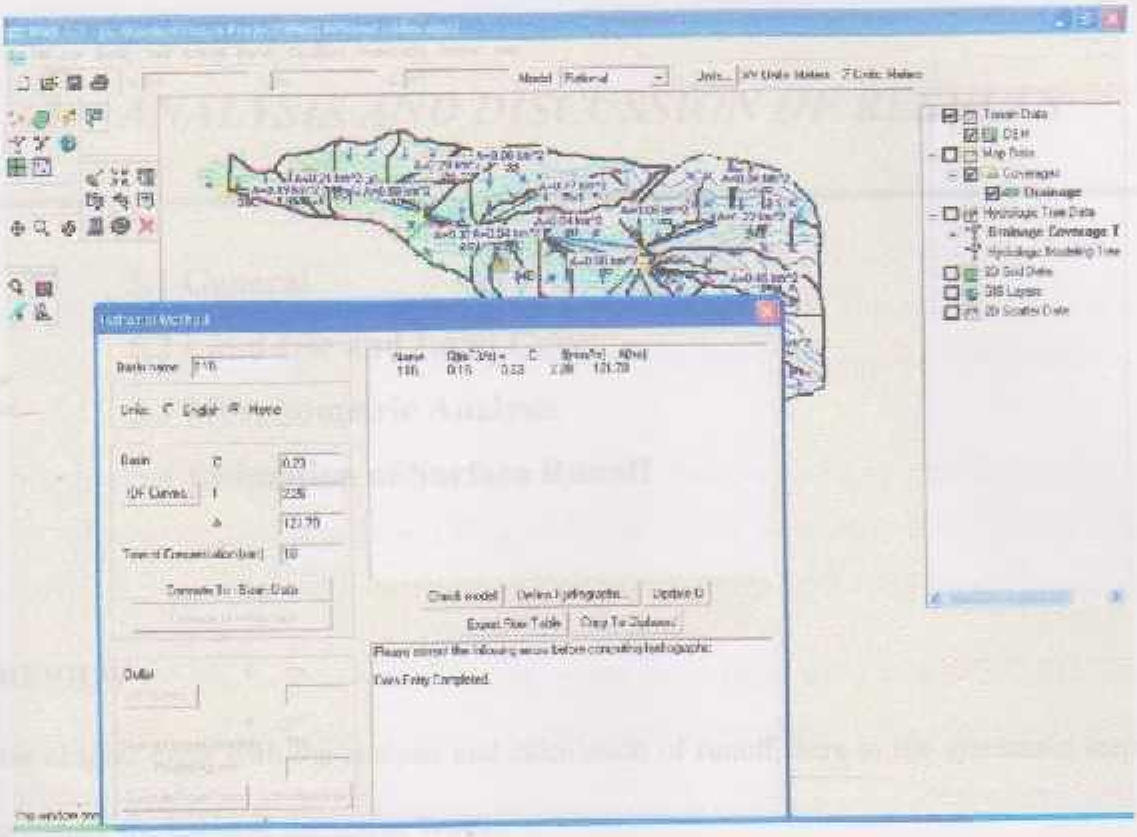

Figure (4.18): Estimated Value of the Surface Runoff

CHAPTER

5 ANALYSIS AND DISCUSSION OF RESULTS

5.1 General

5.2 Land Use and Land Cover

5.3 Morphometric Analysis

5.4 Estimation of Surface Runoff

PREVIEW

This chapter deals with the analysis and calculation of runoff, here in the systematic steps to implement the Rational method in WMS.

CHAPTER FIVE
ANALYSIS AND DISCUSSION OF RESULTS

5.1 General

After preparing all the necessary maps for the project area, the morphometric parameters and annual runoff were calculated for the Wadi Hasca watershed. The calculation was done through the map calculator using ArcGis.9.2 Spatial Analyst Extension and WMS software.

WMS requires three primary data layers in order to build a hydrologic modeling schematic (sometimes referred to as a "tree") from GIS data. These three data layers include a basin boundary layer, a stream network layer, and an outlet or basin confluence layer.

In order to be able to create a hydrologic model from these three GIS vector data layers, topologic relationships between stream reaches, basin boundaries, and outlet points must be explicitly defined.

In this chapter, the analysis and results obtained for the project area including land use and land cover, morphological parameters , and the quantity of runoff are presented..

5.2 Land Use and Land Cover

As mentioned earlier, the conventional land use\land cover map of the watershed was obtained from Hebron land use and land cover shape file, and by digitizing the rectified aerial photograph of the project area of Wadi Hasca watershed. Boundaries of different land use class were digitized in the (ArcGis.9), and the attribute where linked to them. Three land use\land cover classes were categorized in the watershed (see Table (5.1) and Figure (5.1). The land use and land cover map for Wadi Hasca watershed is shown in Figure (5.2).

Table (5.1): Classes of Land Use/Cover of the Study Area

Land Use	Area (m^2)	Percentage of Area %
Agricultural	4347322.95	59.4 %
Artificial Surface	192372.15	2.6 %
Forest & Semi-nature area	2784924.68	38 %
SUM	**7324619.8**	**100**

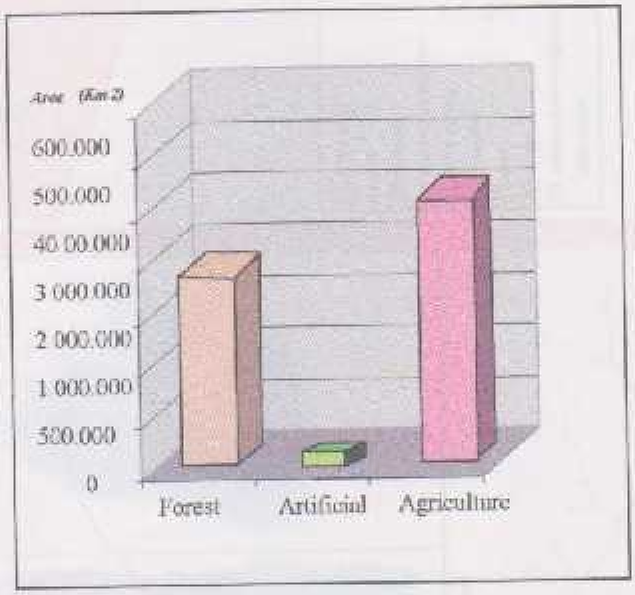

Figure (5.1): Classes of Land Use/Cover of the Study Area

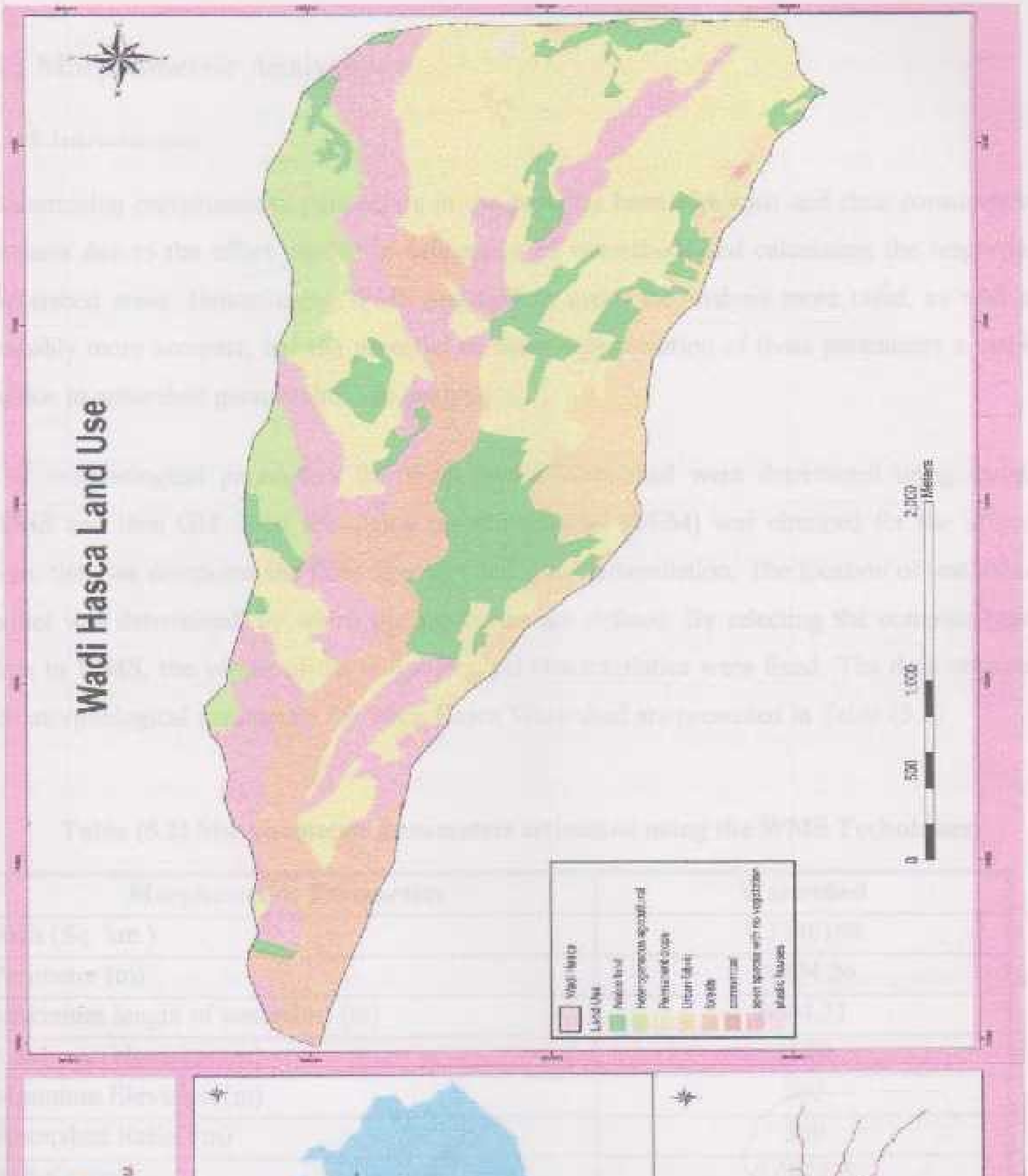

Figure (5.2): Land Use and Land Cover Map for Wadi Hasca Watershed

5.3 Morphometric Analysis

5.3.1 Introduction

Determining morphometric parameters in the past has been a tedious and time consumptive process due to the effort needed in delineation of watersheds and calculating the respective watershed areas. Hence, using WMS and GIS to make the analysis more rapid, as well as possibly more accurate, has the potential to make determination of these parameters a viable option in watershed geomorphologic analysis.

The morphological parameters for Wadi Hasca Watershed were determined using mainly WMS and then GIS. First the digital elevation model (DEM) was obtained for the project area, then we computed the flow direction and flow accumulation. The location of watershed outlet was determined, by which the sub-basins are defined. By selecting the compute basin data in WMS, the values of the morphological characteristics were fixed. The data obtained for morphological parameters for Wadi Hasca Watershed are presented in Table (5.2)

Table (5.2) Morphometric Parameters estimated using the WMS Techniques

Morphometric Parameters	Watershed
Area (Sq. km.)	7.3246198
Perimeter (m)	19404.26
Maximum length of watershed (m)	6044.31
Maximum elevation (m)	1000
Minimum Elevation (m)	500
Watershed Relief (m)	500
Relief ratio	0.082722
Elongation Ratio	0.088756632
Average Slope (m/m)	0.5121
Drainage density (km/km^2)	49.888
Form factor	0.200489
Circulatory Ratio	0.278949
Drainage frequency (No/km^2)	571
Ruggedness Number	24.94
Total Length of streams of all orders (km)	365.413
Time of concentration (min)	48
Constant of channel maintenance (km)	0.020045

The total stream length of the different order reveals that the total stream length in the study area is 365.413 km where the total number of streams of different order is 3563. The total number of streams and stream length is very high because the pixel size is very small (2.5 m). The pixel size is taken equal to half of contour interval for accuracy. The maximum length of the watershed is 6044.3 m, and the difference between the maximum and minimum elevation (total Relief) is 500 m which mean that the watershed is very steep (average slope= 51%).

5.3.2 Geomorphologic Parameters of Sub-Watershed

Morphometric parameters of the sub-watersheds were calculated using WMS and GIS environment and are presented in Table (5.3) and Table (5.4). After analysis of the drainage map, it was found that sub-watershed is 14 watersheds and drainage pattern is dendrite.

It can be seen that the Relief ratio (R_h) values ranges from 0.0572 (minimum) for sub-watershed 3 to 0.2041 (maximum) for sub-watershed 12. High value of R_h indicates quick depletion of water, which results in large peaked and steep limbed hydrograph.. The relative relief values ranges from 0.0423 for sub-watershed number 13 to 0.6772 for sub-watershed 10. The sub-watershed, with high (Rr) and (Rh) are considered critical from erosion point of view and should be provide with suitable soil and water conservation measure.

The ruggedness number (Rn) ranges from 2.3724 to 14.874 for different sub-watershed. The sub-watershed 11 has an over all high roughness or unevenness.

In general, the shape of a basin affects stream flow hydrographs and peak flows. The important parameters that describe the shape of the basin viz. are elongation ratio, circulatory ratio and form factor. The values of these parameters were computed for all the 14 sub watersheds and given in Table (5.4). High value of (Rc) indicator mature to old stage topography. It is also indicator of low drainage from the watershed. According to elongation ratio (Re), sub-watershed 7,sub-watersheds 6 and 12 have an oval shape, sub-watersheds 2,8, and 10 have a less elongated shape, and sub-watersheds 1,3,4,5,9,11,13 and 14 have an elongated shape. More the value of form factor (Rf), more elongated is the basin. In this case, elongated basin with low (Rf) indicates that the basin will have a flatter peak of flow for longer duration. Flood flows of such elongated basins are easier to mange than from the circular basin.

Table (5.3) Sub-watershed Wise Morphometric Parameters of Study Area

Sub-watershed no.	Area (km^2)	Perimeter (m)	Max. Length (m)	Mean Elevation (m)	Maximum Elevation (m)	Minimum Elevation (m)	Total Relief (m)	Number of Stream	Total Stream Length (km)
1	1.51	9549	2670.4	749.885	849.83	649.94	199.89	704	79.23943
2	0.2	2550.4	672.25	749.8895	799.859	699.92	99.939	89	9.49205
3	0.13	2609.6	874.14	774.859	799.859	749.859	50	92	6.16831
4	0.11	1966.4	580.78	899.8	949.77	849.83	99.94	63	5.734407
5	0.19	3002.9	818.73	749.8895	799.859	699.92	99.939	135	9.87178
6	0.5	3678.6	916.53	774.875	849.83	699.92	149.91	289	27.97091
7	0.57	4411.7	922.84	824.84	899.8	749.88	149.92	244	30.41241
8	1.35	6609	1667.3	874.8125	999.745	749.88	249.865	659	65.9766
9	0.4	4630.6	1533.9	849.825	949.77	749.88	199.89	258	24.78939
10	0.1	1476.2	467.39	974.7575	999.745	949.77	49.975	72	4.95772
11	1.07	6541.7	1747.5	874.8125	999.745	749.88	249.865	515	63.69341
12	0.13	1966.7	489.72	849.83	899.8	799.86	99.94	67	5.51955
13	0.14	2011.3	627.87	824.915	849.83	800	49.83	113	7.50612
14	0.48	4712.4	1280.6	649.945	699.92	599.97	99.95	263	24.08087

Table (5.4) Sub-watershed Computed Morphometric Parameters of Study Area

Sub-watershed No.	R_h	R_r	R_N	R_e	R_c	R_F	D_f (No/km²)	D_d (km/km²)	C_m (km)	t_c min	S %
1	0.0749	0.3332	10.490	0.5191	0.4563	0.211	466.2	52.47644	0.01905	26	34.46
2	0.1487	0.1697	4.7431	0.7505	0.6217	0.443	445.0	47.46025	0.02107	5	28.34
3	0.0572	0.3065	2.3724	0.4653	0.4898	0.170	707.7	47.44854	0.02107	8	15.23
4	0.1721	0.4829	5.2100	0.6442	0.5980	0.326	572.7	52.13097	0.01918	6	26.25
5	0.1221	0.2663	5.1925	0.6006	0.5147	0.283	710.5	51.95674	0.01924	7	32.23
6	0.1636	0.2310	8.3862	0.8703	0.6815	0.595	578.0	55.94182	0.01787	10	38.05
7	0.1625	0.2040	7.9990	0.9230	0.6068	0.669	428.1	53.35511	0.01874	10	36.22
8	0.1499	0.1513	12.211	0.7862	0.6233	0.486	488.1	48.87156	0.02046	17	35.97
9	0.1303	0.2051	12.388	0.4652	0.4842	0.170	645.0	61.97348	0.01613	12	24.80
10	0.1069	0.6772	2.4776	0.7633	0.7595	0.458	720.0	49.5772	0.02017	4	18.36
11	0.1430	0.1528	14.874	0.6677	0.5606	0.350	481.3	59.52655	0.01679	16	34.27
12	0.2041	0.4575	4.2433	0.8306	0.6500	0.542	515.4	42.45808	0.02355	5	27.61
13	0.0794	0.0423	2.6716	0.6723	0.6596	0.355	807.1	53.61514	0.01865	8	11.66
14	0.0780	0.1485	5.0143	0.6103	0.5213	0.293	547.9	50.16848	0.01993	12	34.57

Sub-watersheds having circular to oval shape allow quick runoff, and result in a high peaked and narrow hydrograph, while elongated shape of sub-watersheds allows slow disposal of water, and result in a broad and low peaked hydrograph.

Drainage density (D_d) and Derange frequency (D_f) are computed for all the sub-watersheds and are given in Table (5.4). The drainage frequency ranges between 445.0 for sub-watershed 2 to 807.1 for sub-watershed 13. The drainage density ranges from 42.46 (minimum) for sub-watershed 12 to 61.97 (maximum) for sub-watershed 9.

It was observed that the sub-watersheds having large area under dense forest have low drainage frequency (D_f) and the area having more agricultural land have high (D_f). High value of (D_f) in the sub watershed 13 produces more runoff compared to others.

In general, it has been observed over a wide range of geologic and climatic types, that low (D_d) is more likely to occur in regions of highly permeable subsoil material under dense vegetative cover, and where relief is low. In contrast, high (D_d) is favored in regions of weak or impermeable subsurface materials, sparse vegetation and mountainous relief.

In the present study, and in order to find out the correlation of (D_d) with Land use/cover, and soil, spatial distribution of land use/cover and soil was studied. The major land use category found in the study area is agriculture; it is also observed that row crops are cultivated on a poor contoured land. Low (D_d) value for sub-watershed 12 indicates that it has highly resistant, impermeable subsoil material with dens vegetated cover and low relief, whereas high drainage density value for sub-watershed 9 indicates a situation conducive for quick disposal of runoff, a region of weak subsurface materials, high relief and sparse vegetation.

The data of Table (5.4) show that the values of concentration time (t_c) are range between 4 and 26 minutes depend on the value of maximum length of the watershed and the slope. If the value of (t_c) is high, it means that the value of rainfall intensity is less, and consequently, the surface runoff is low and viz versa.

Wadi Hasca watershed is very steep, hence, the values of the slope of all sub-watershed are high and ranges between 12% to 38%, which allow more runoff.

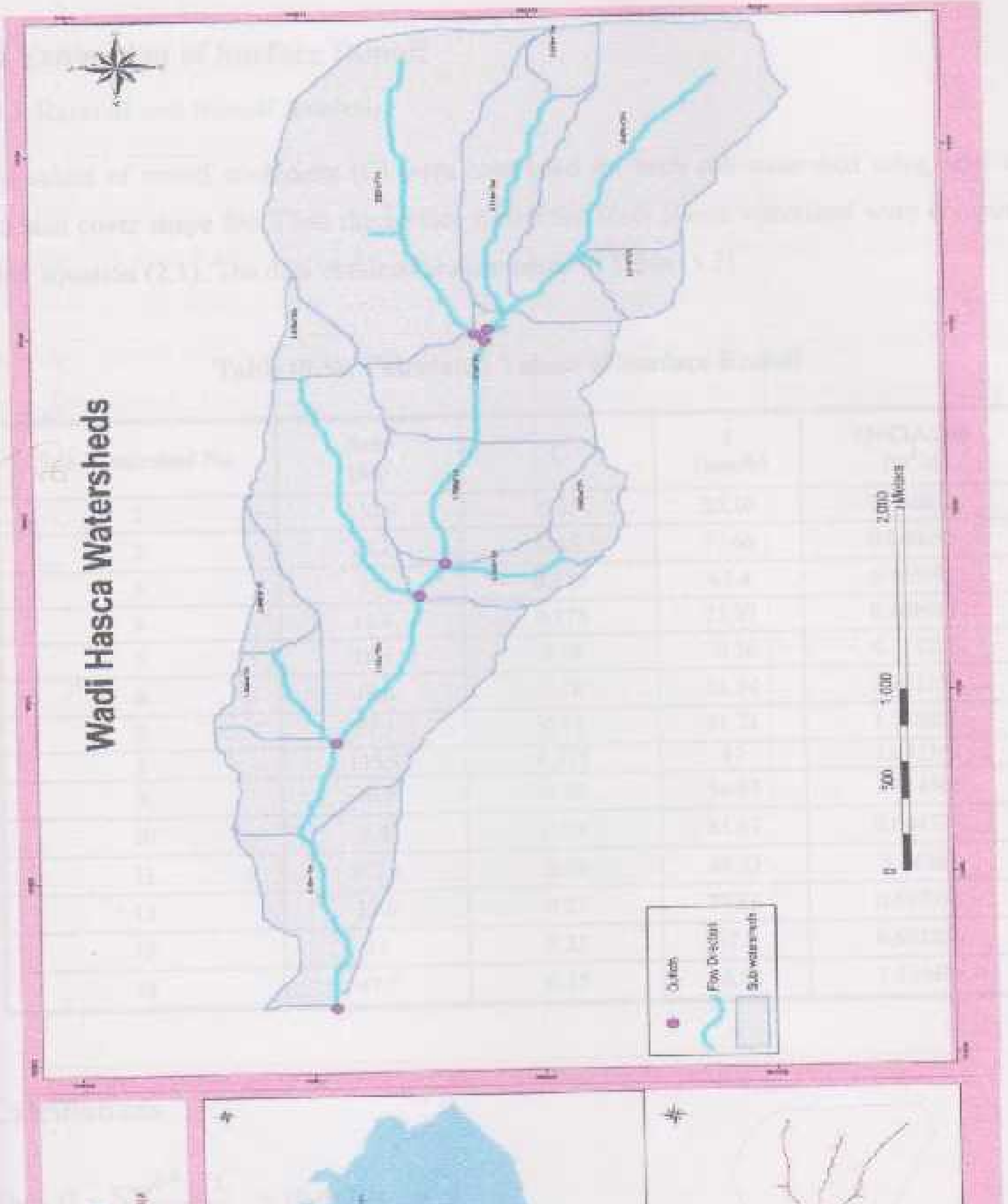

Figure (5.3): Sub-watersheds Map for Wadi Hasca and its Stream Network.

5.4 Estimation of Surface Runoff

5.4.1 Rainfall and Runoff Analysis

The values of runoff coefficient (C) were calculated for each sub-watershed using land use and land cover shape file. Then the surface runoff for Wadi Hasca watershed were computed using equation (2.1). The data obtained are presented in Table (5.5).

Table (5.5): Calculated Values of Surface Runoff

Sub-Watershed No.	Area (ha)	C	i (mm/h)	Q=CiA/360 (m^3/s)
1	150.9	0.15	35.10	2.206913
2	19.8	0.15	77.66	0.640695
3	13	0.175	67.4	0.425931
4	11.4	0.175	73.97	0.409917
5	19.1	0.19	70.56	0.711284
6	49.6	0.18	61.74	1.531152
7	57.3	0.18	61.74	1.768851
8	135.4	0.175	47	3.093514
9	30.9	0.29	56.83	1.414593
10	9.8	0.29	81.67	0.644739
11	107.4	0.23	48.73	3.34369
12	12.8	0.25	77.66	0.690311
13	14	0.23	67.4	0.602856
14	47.7	0.15	56.83	1.129496

Calculations

Then $Q = \sum \frac{A*i*C}{360} = 18.61394 \ m^3/s$

At c = 1 , $Q = \sum \frac{A*i*C}{360} = 98.06576 \ m^3/s$

The presents of the flood flow in these watershed is = $\frac{18.61394}{98.06576} * 100 = 0.19\%$

$Q = \frac{19*500}{100} = 95 \text{ mm}$

$$Q = \frac{95 * 7.32 * 10^{\wedge}6}{1000} = 693500 \ m^3/year$$

5.4.2 Water balance in Wadi Hasca watershed

The final result in this study determine the water balance parameters of Wadi Hasca watershed in Beit Kahil village whereas the precipitation (500 mm/year) is the main input parameter in the water balance and the measured average Permeability is (105 mm/year), estimated runoff (95 mm/year) and calculated evaporation (300 mm/year) are the major output parameters. The results of water budget in the study area are shown in Figure (6.10).

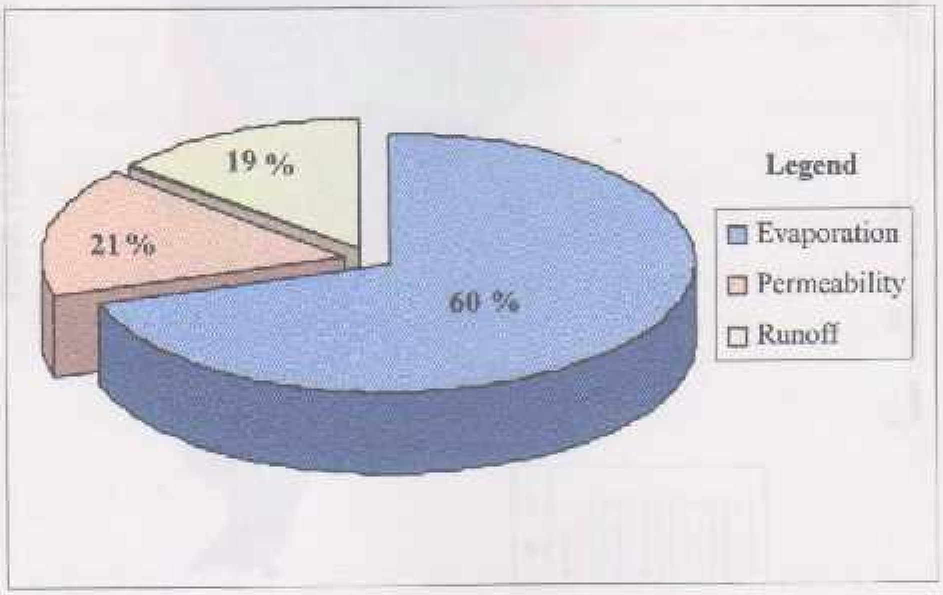

Figure (5.4): Water Balance of Wadi Hasca Watershed

Figure (5.5): Surface Runoff of Wadi Hasca Watershed

<u>**CHAPTER**</u>

6 *CONCLUSIONS*

PREVIEW

In the previous chapters, were discussed the problem of the project, hydrological models and spatial hydrology, materials, land use and methods, the conclusions will presents according to the results which we obtained until this moment.

CHAPTER SIX
CONCLUSIONS

In this project an attempt is made to estimate the amount of surface runoff from Wadi Hasca Watershed in the Hebron area of the West Bank using Watershed Modeling System (WMS) and Geographical Information System (GIS). The land use and land cover along with morphological features of the watershed were first determined, and then, the surface runoff were estimated using Rational Method and with the help of WMS. The main conclusions drawn from the present study are:

1) Since there were no runoff observations available from Wadi Hasca watershed, the results could not be compared with the measured values.

2) Nine land use/land cover classes were categorized in project area watershed, namely; industrial, open spaces with no vegetation, forest, permanent crops, commercial, plastic houses, urban fabric, arable land, heterogonous agriculture.

3) The calculations and results, based on the Rational method, shows that the average annual runoff depth for the last five years in Wadi Hasca watershed is equal to 95 mm, and if the total area of the watershed is 7.32469 km^2, the total volume of water that can be collected is around 693500 cubic meter, which represents 19 % of the total annual rainfall.

4) The results determined the water balance parameters for Wadi Hasca watershed as, precipitation 500 mm (100%), evaporation 300 mm (60%), infiltration 105 mm (21%) and surface runoff 95 mm (19%).

5) In the present project, the methodology for determination of runoff for Wadi Hasca watershed using WMS and rational method was described. This approach could be applied in other Palestinian watersheds for planning of various conservations measures.

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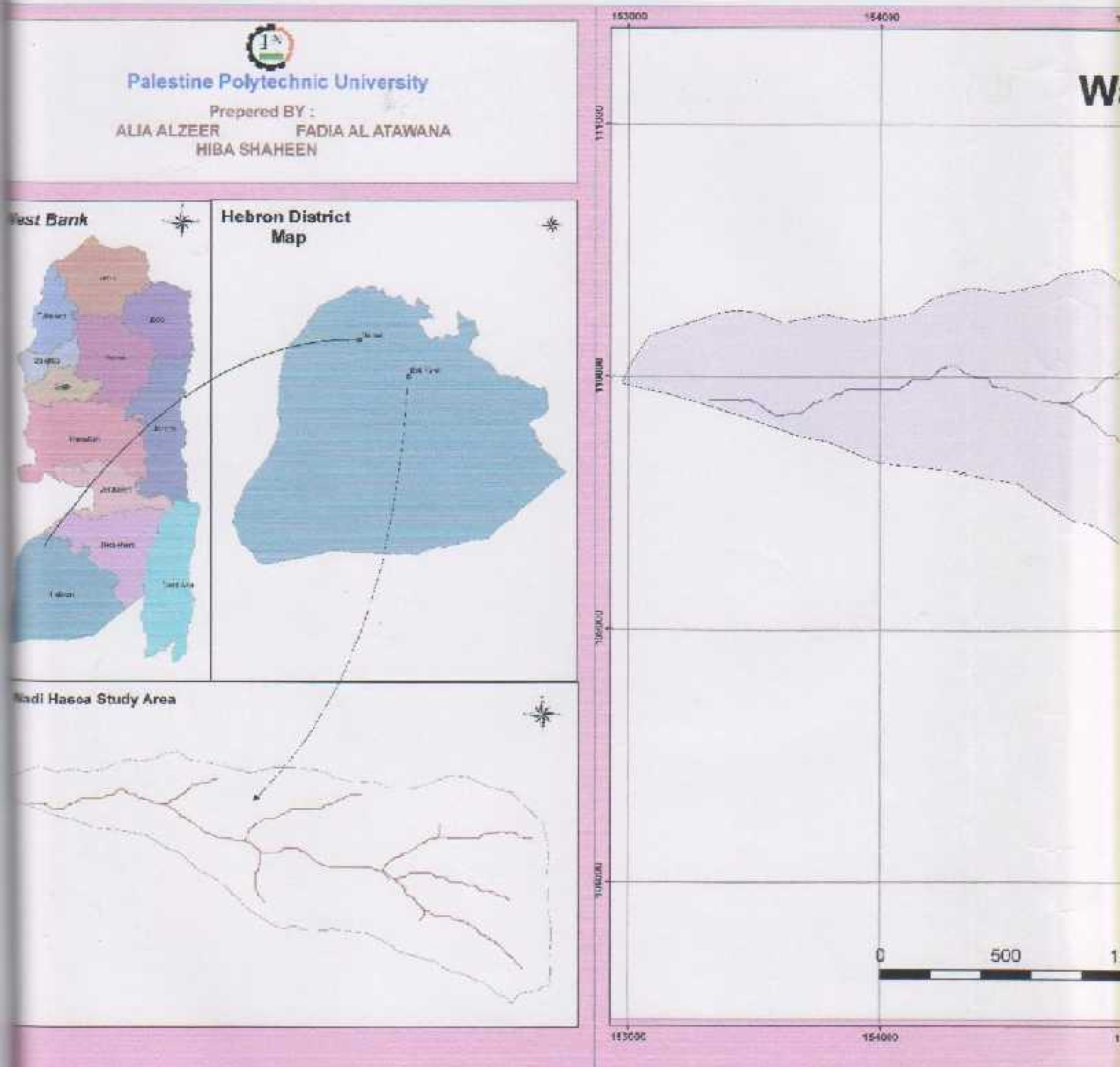
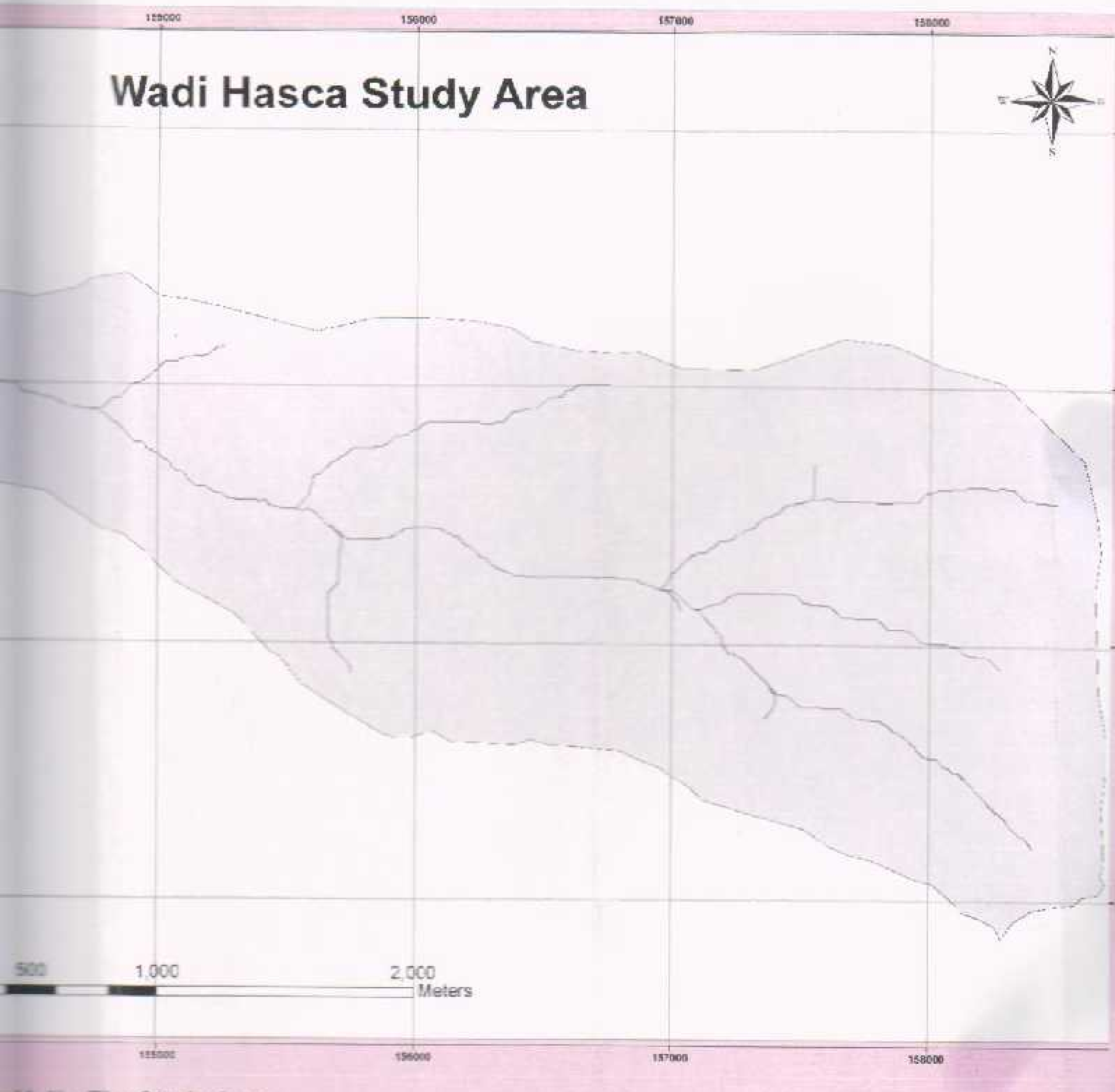
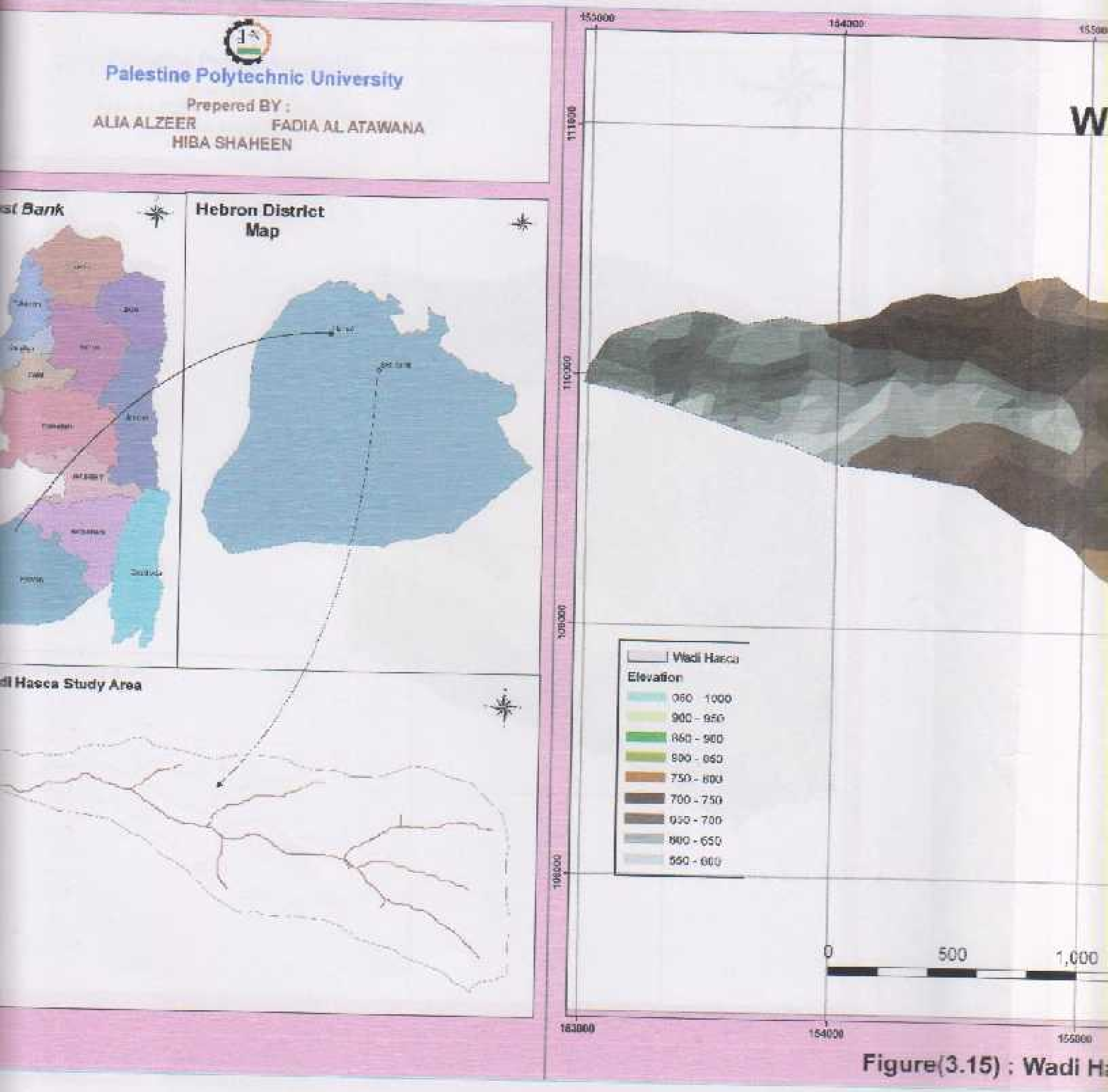
APPENDIX



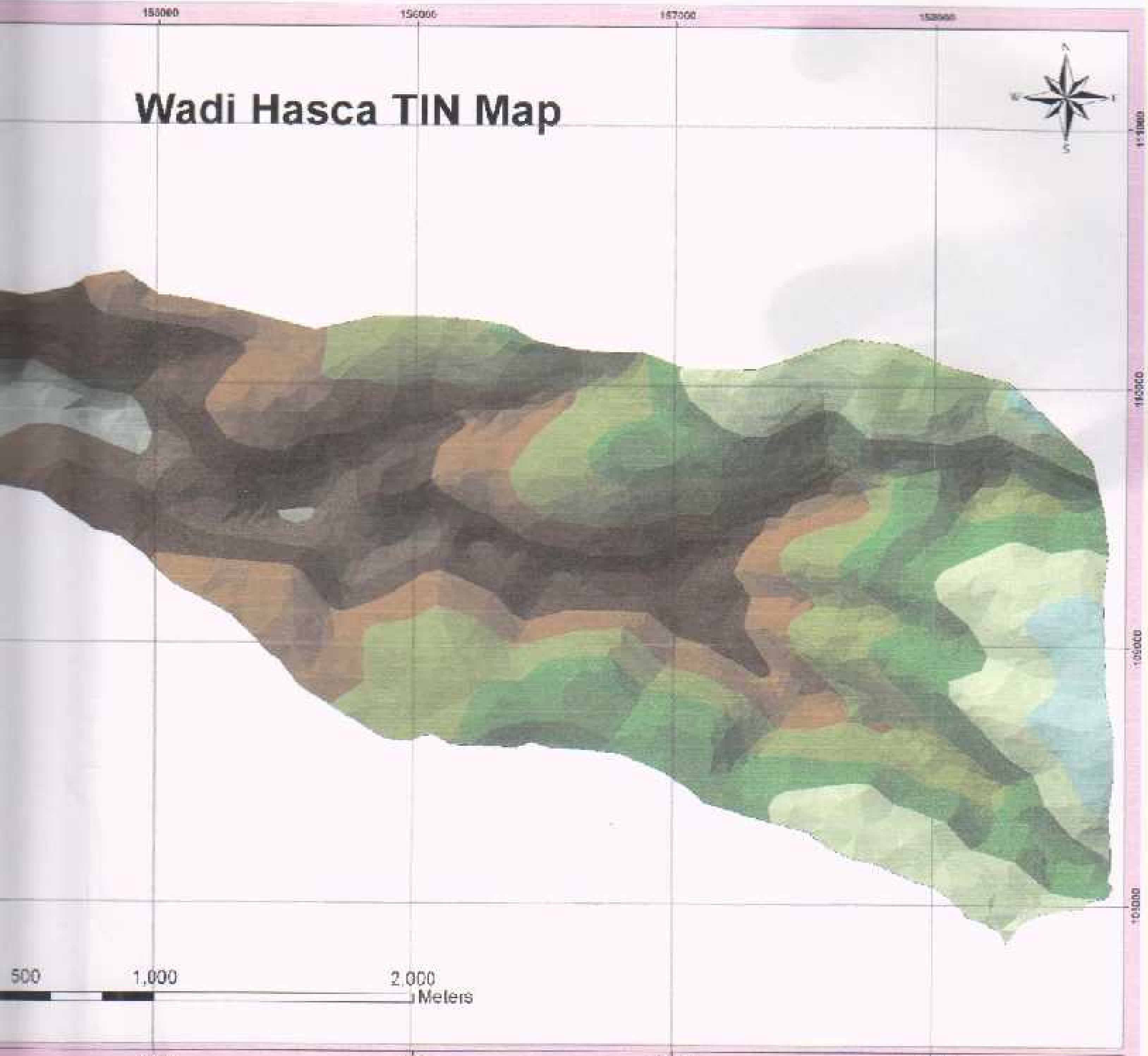
Figure(1.1) : The S



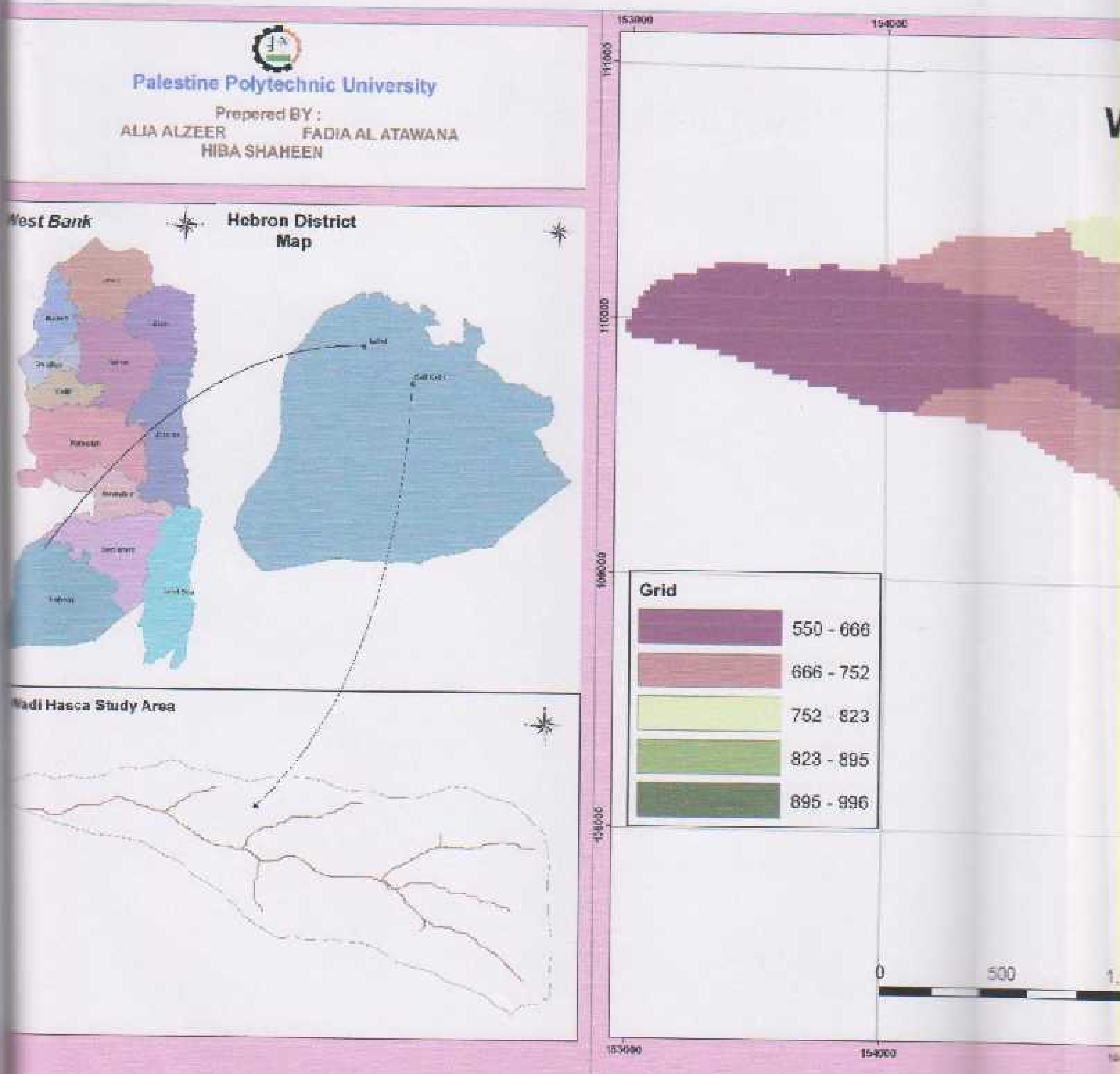
e(1.1) : The Study Area



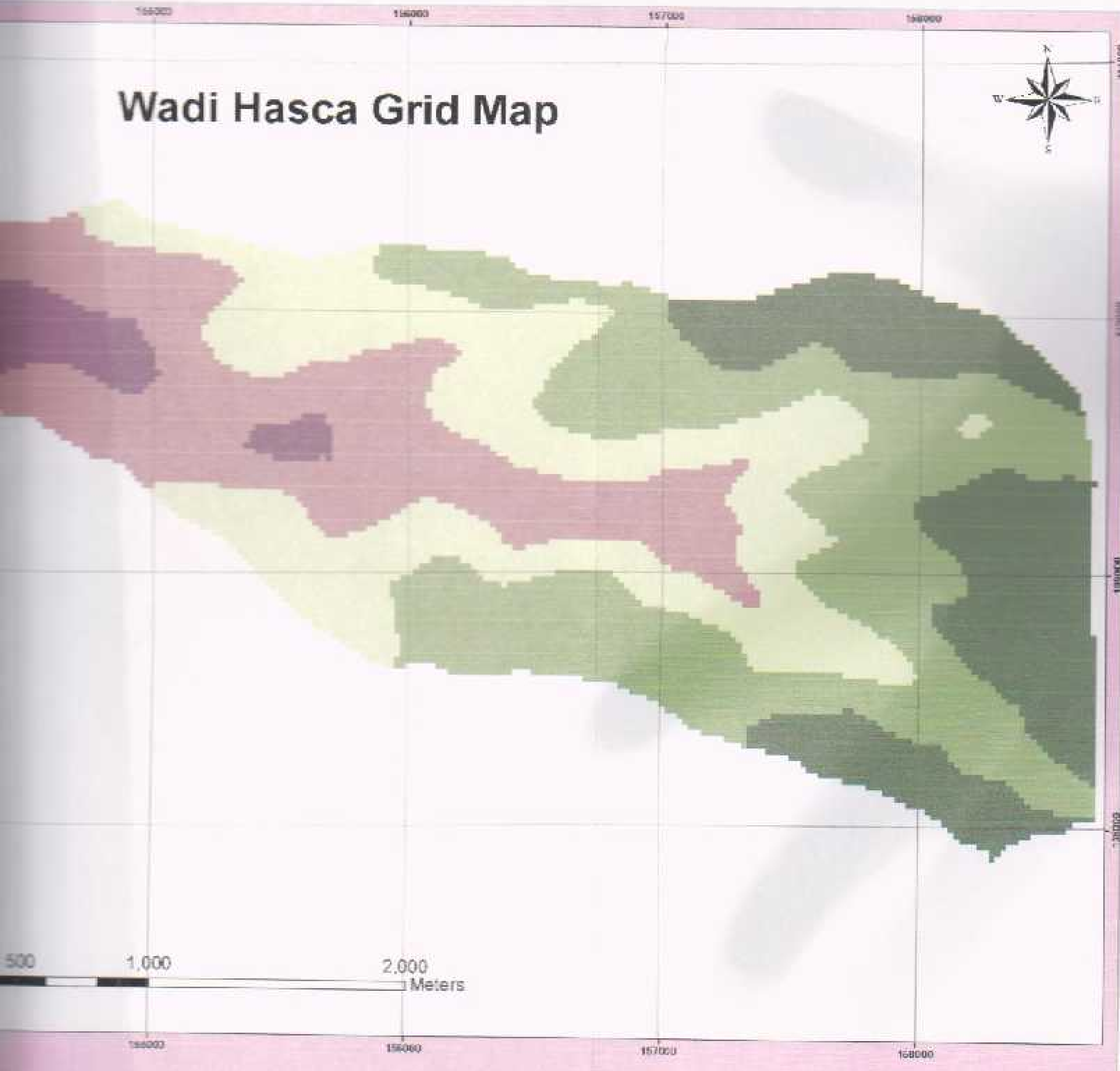
Figure(3.15) : Wadi H



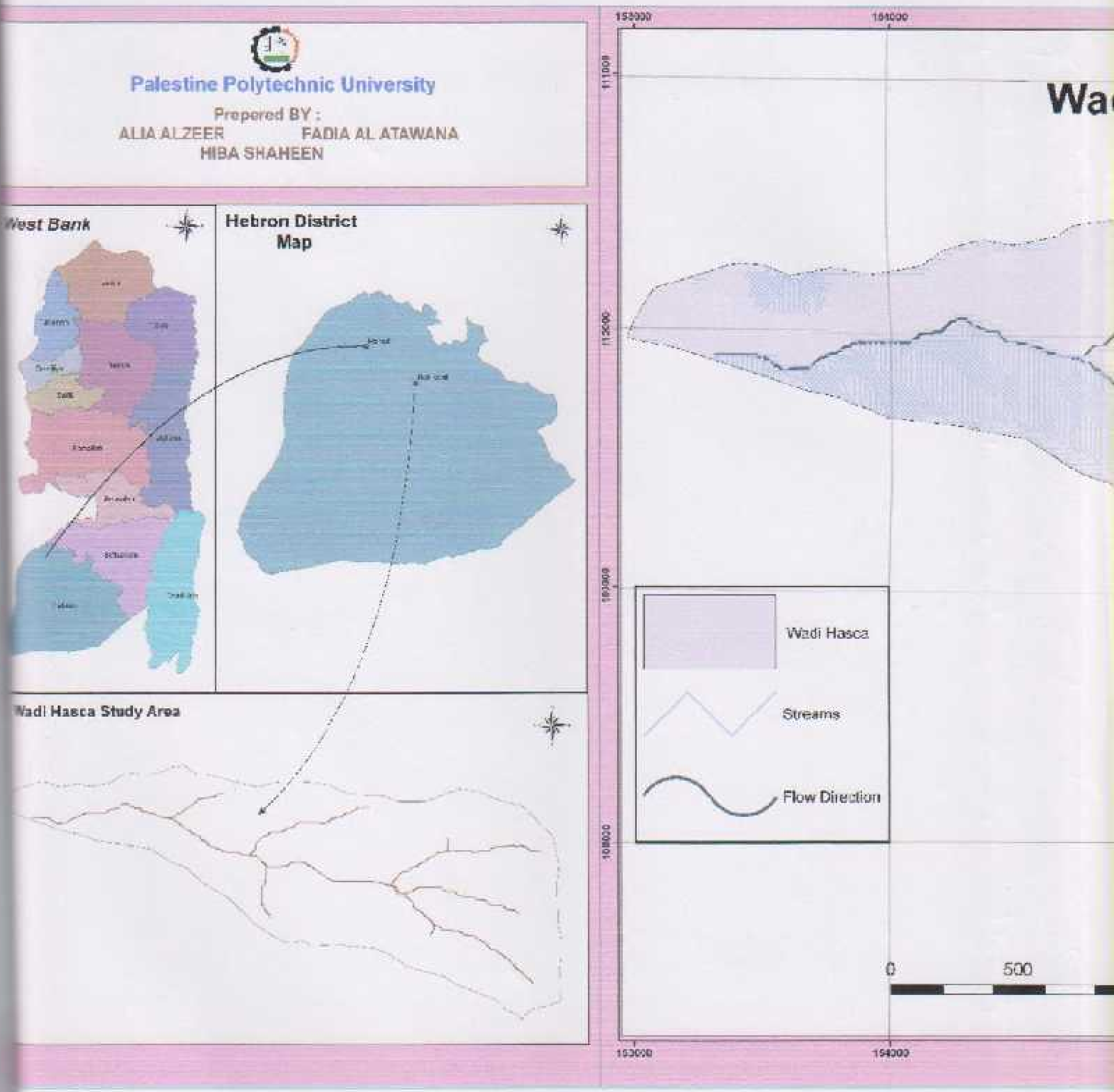
e(3.15) : Wadi Hasca TIN

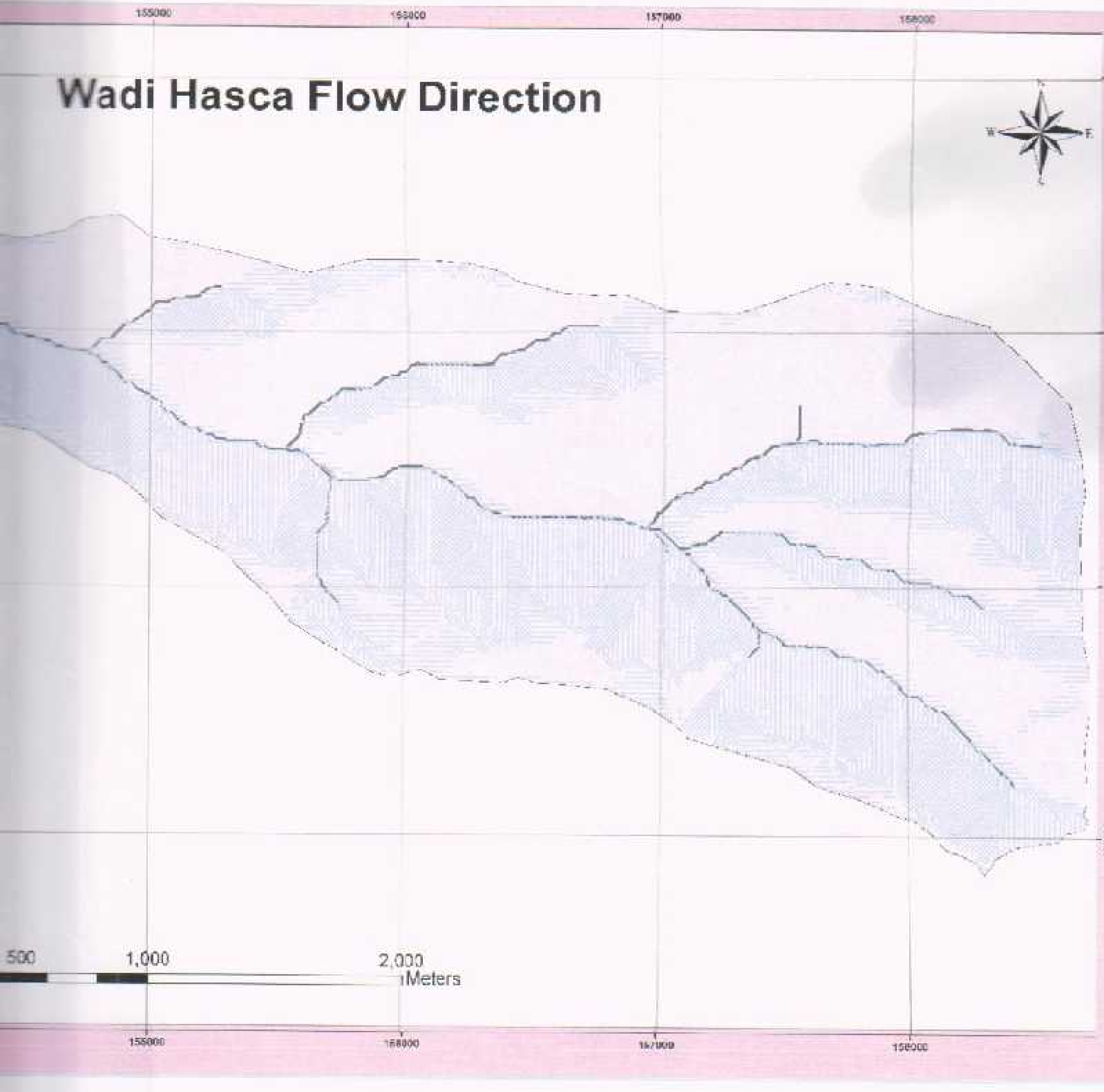


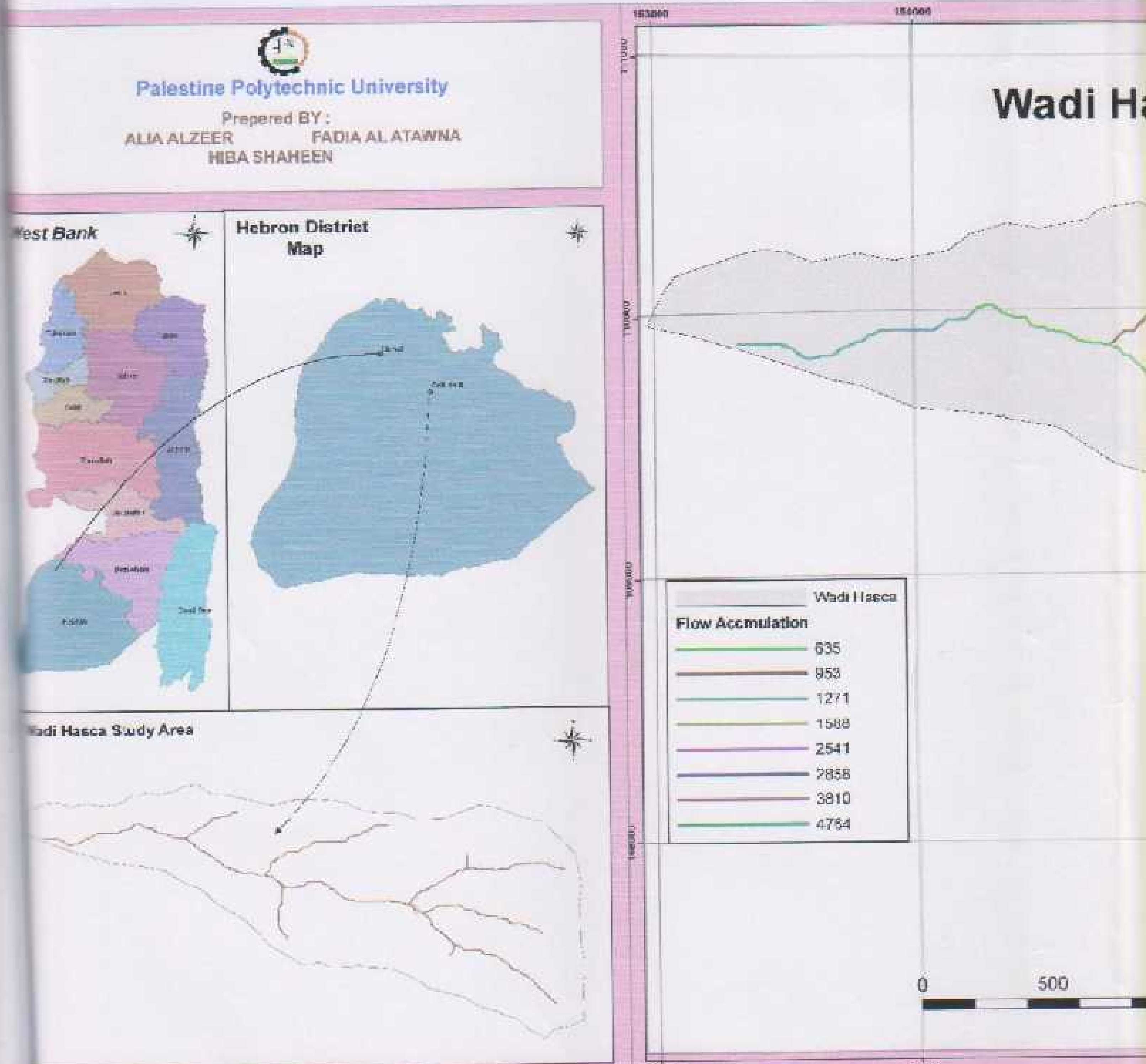
Figure(3.16) : The Digital El



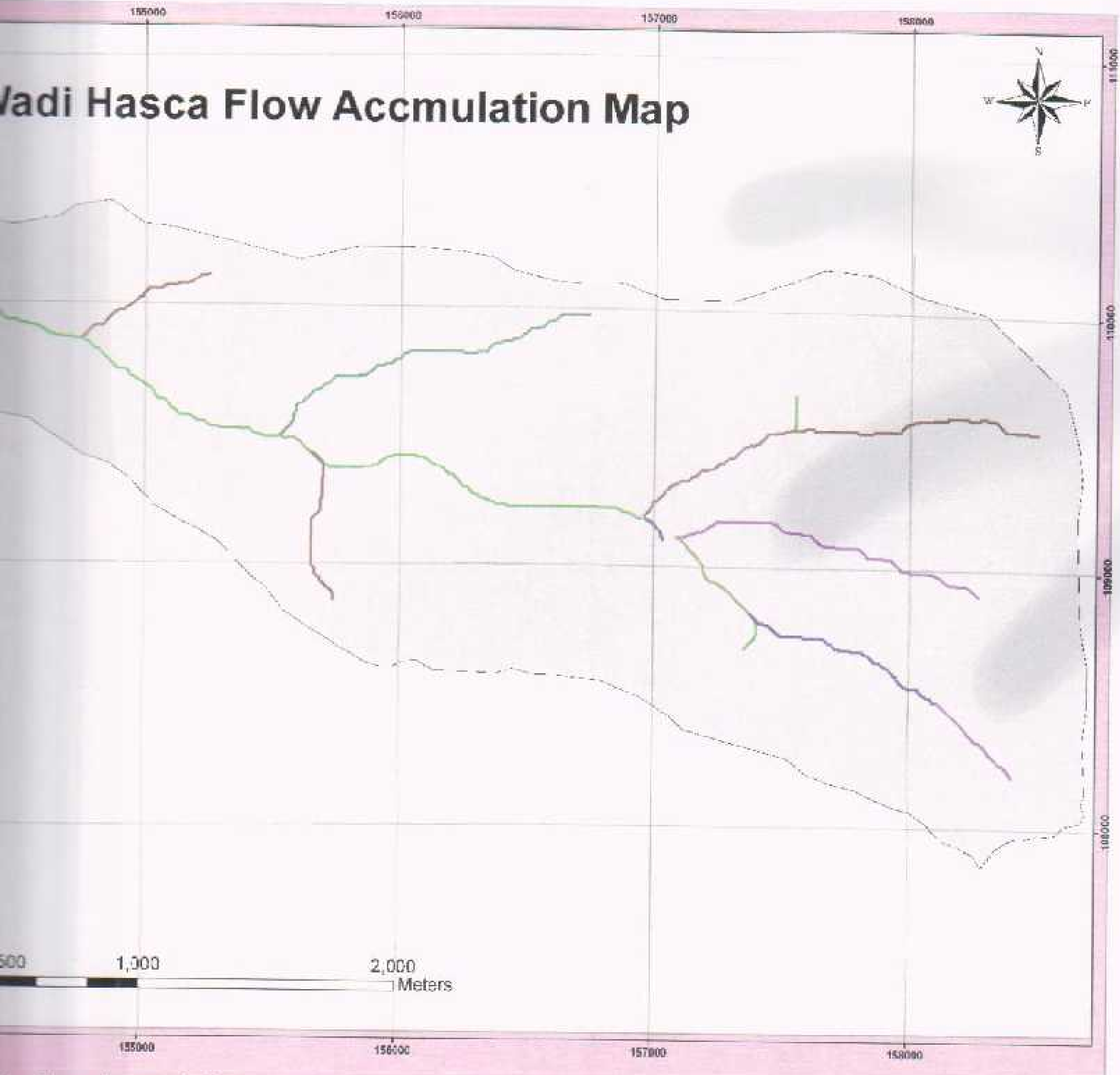
e Digital Elevation Model (DEM)


Palestine Polytechnic University
Prepered BY :
ALIA ALZEER
FADIA AL ATAWANA
HIBA SHAHEEN
West Bank
Hebron District Map
Wadi Hasca Study Area
Wa
Wadi Hasca
Streams
Flow Direction
0
500
153000
154000

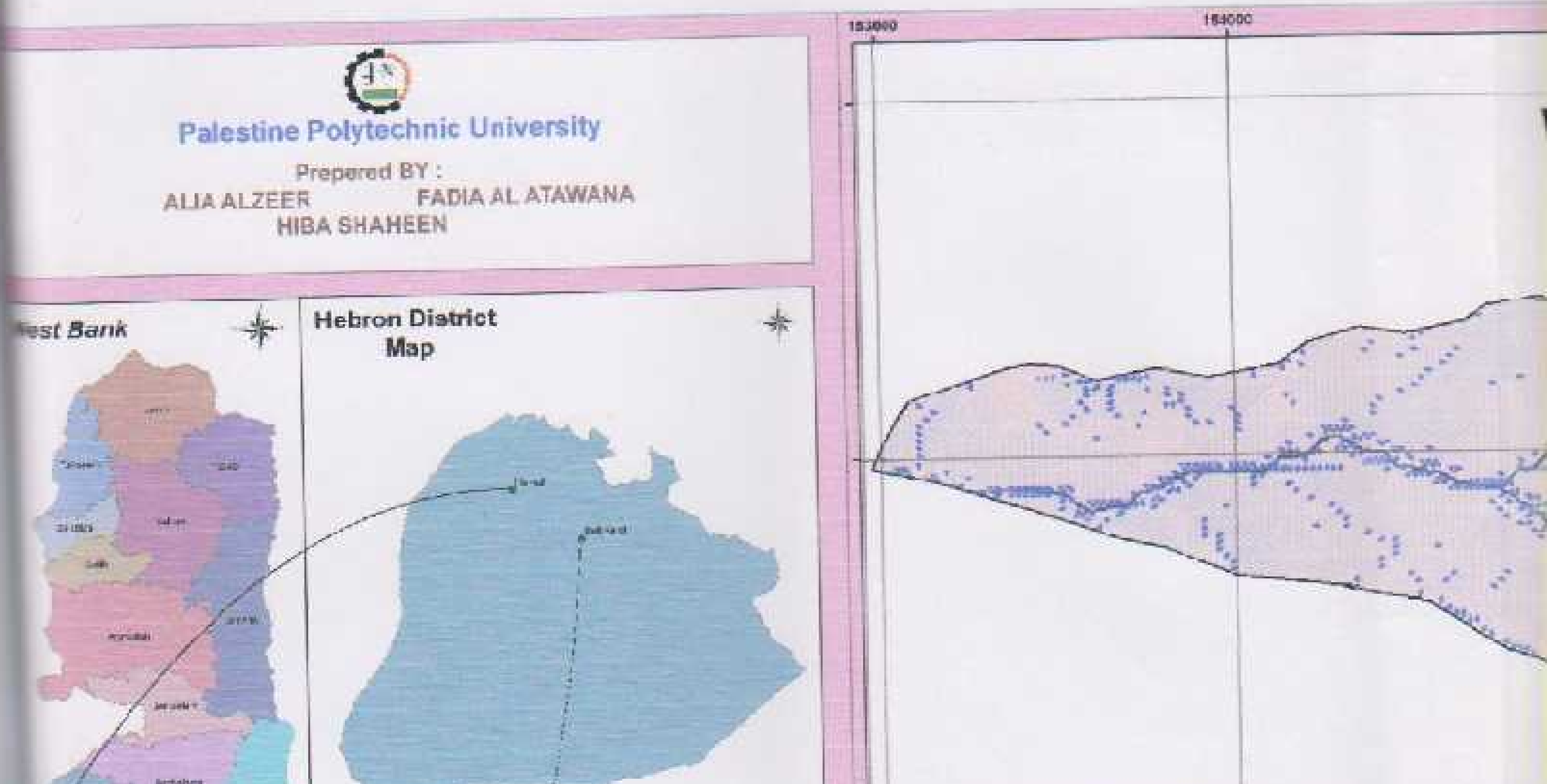

Wadi Hasca Flow Direction
W
E
500
1,000
2,000
Meters



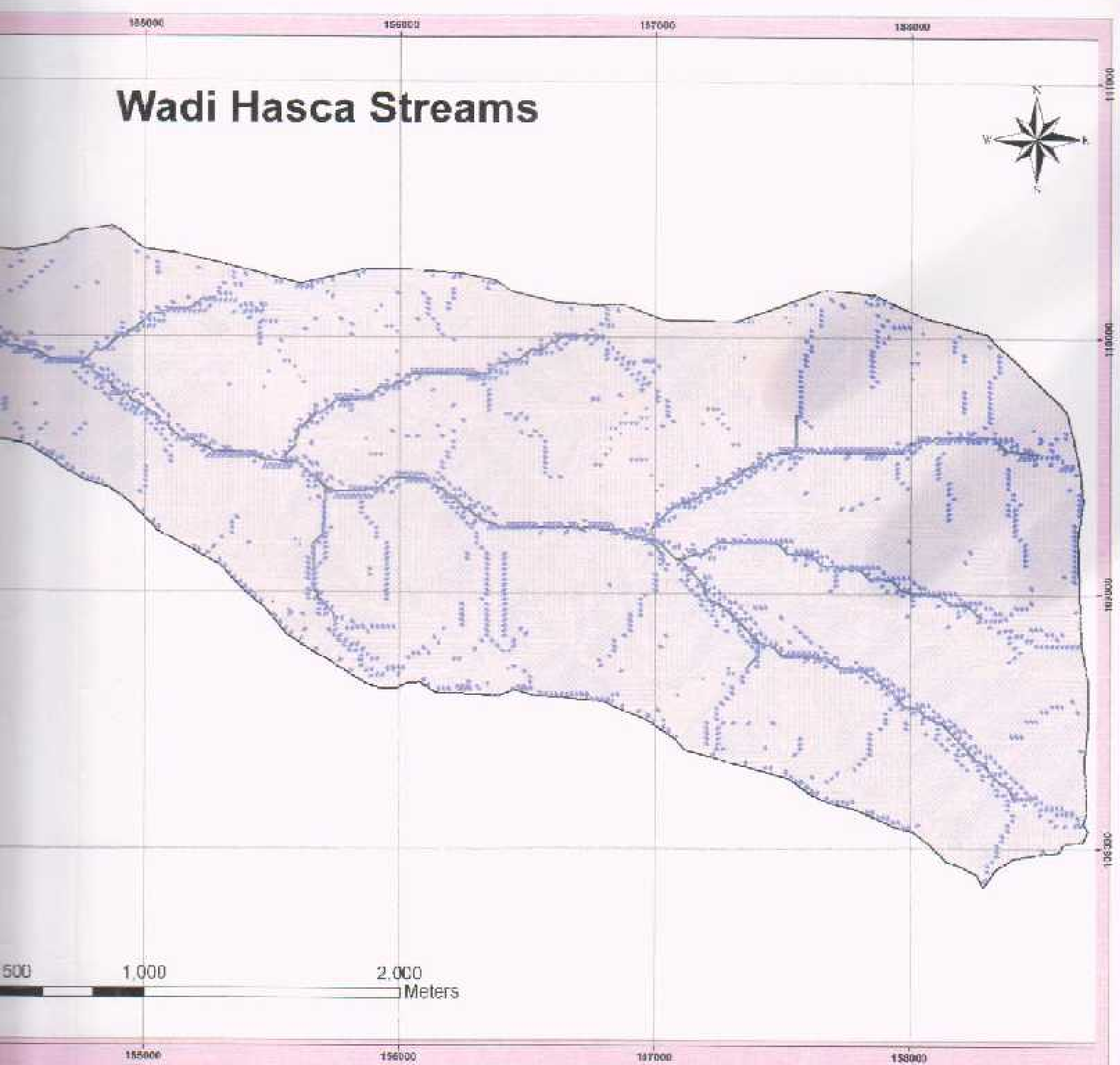
Figure(3.18) : Flow



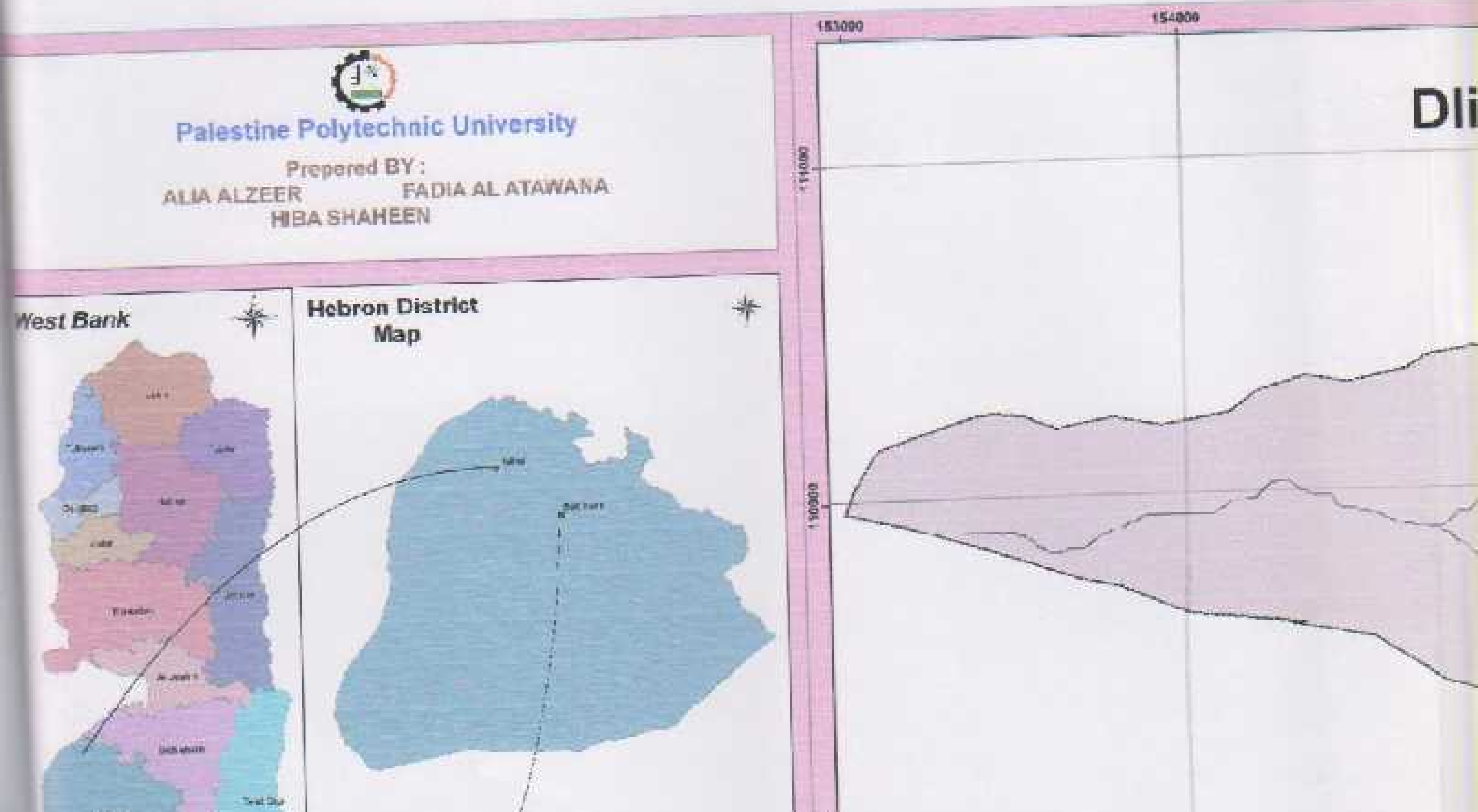
) : Flow Accmulation



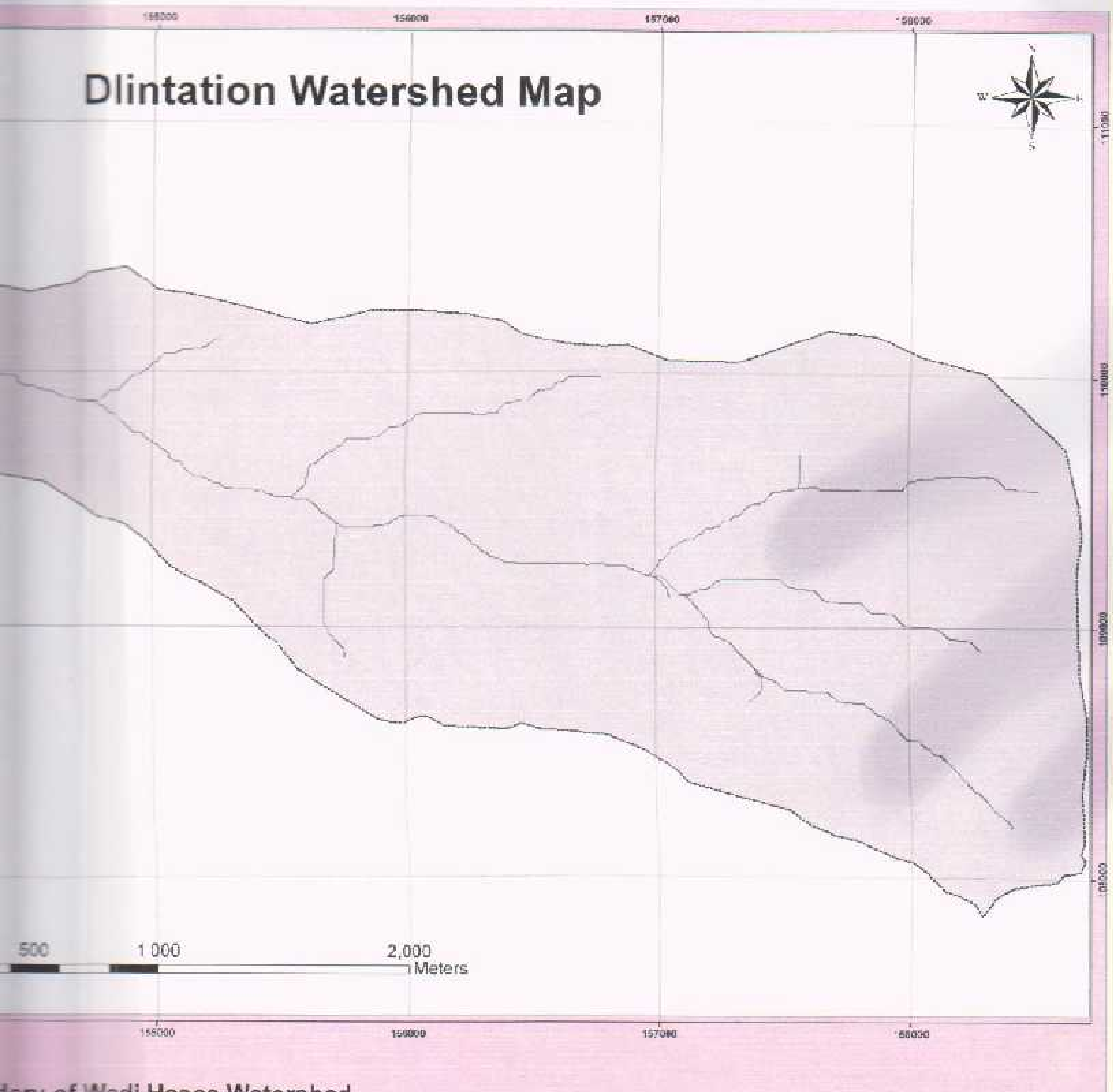
Figure(3.19) : Th



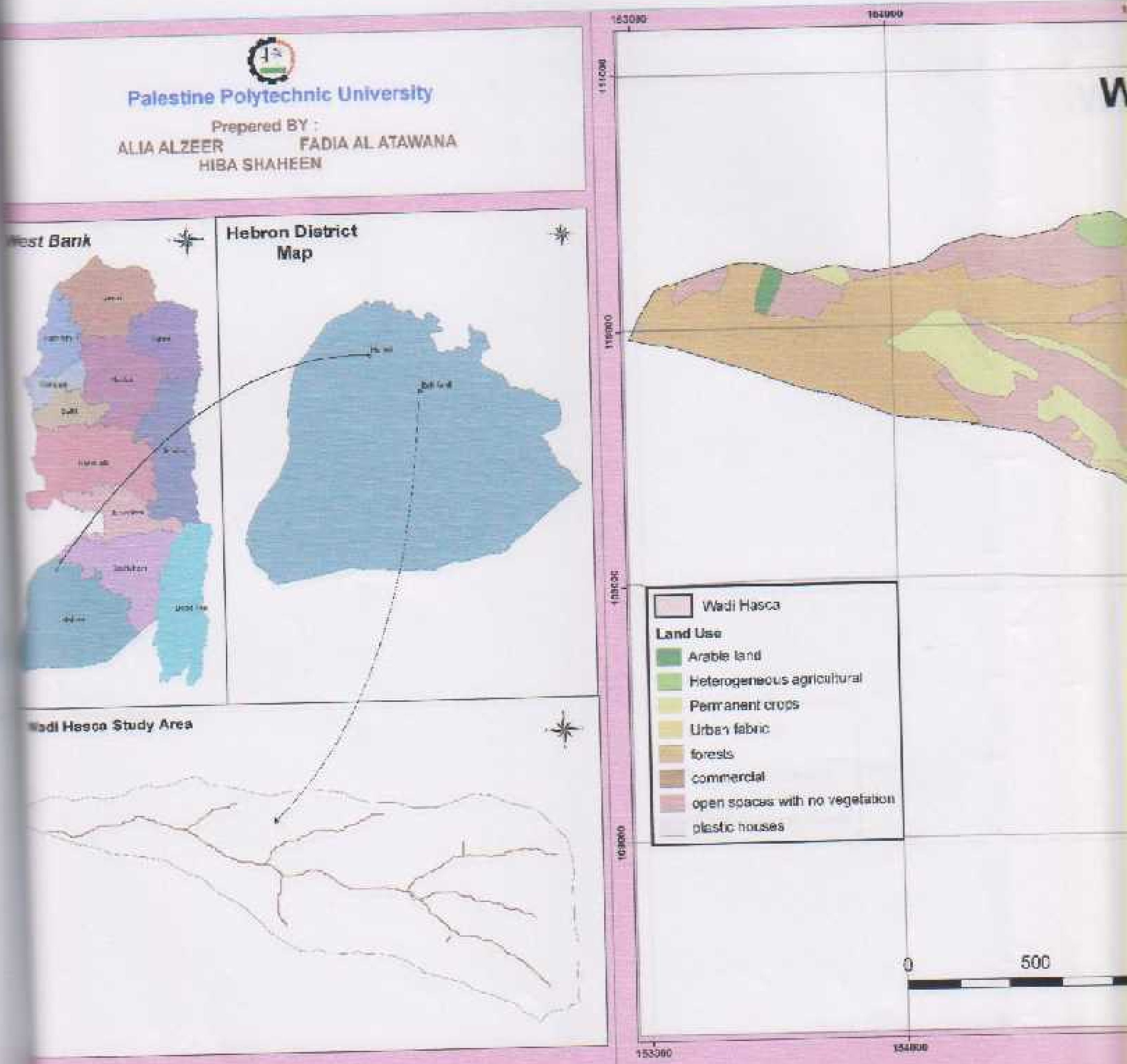
.19) : The Stream Network



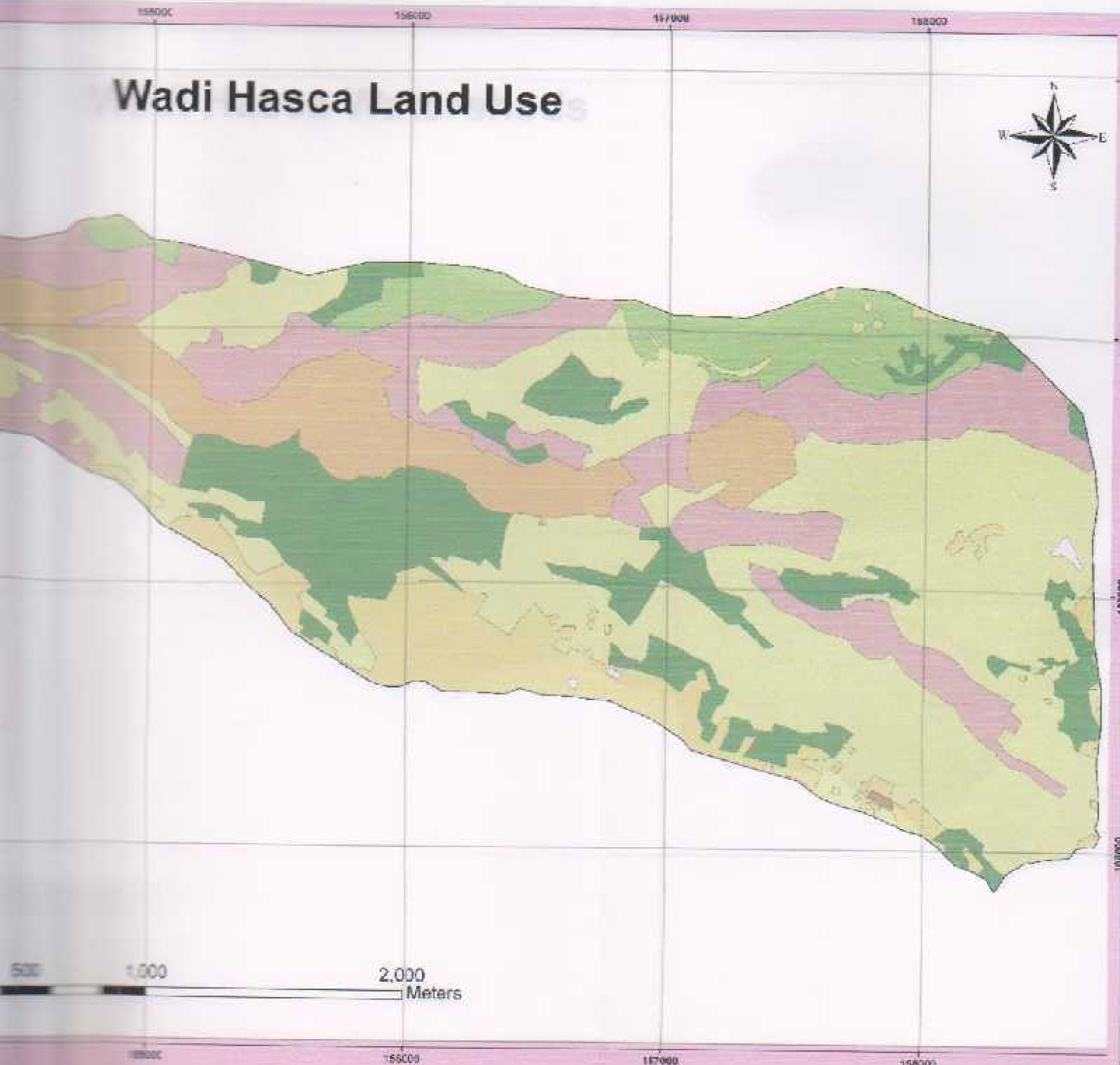
Figure(4.1) : Bundary of W



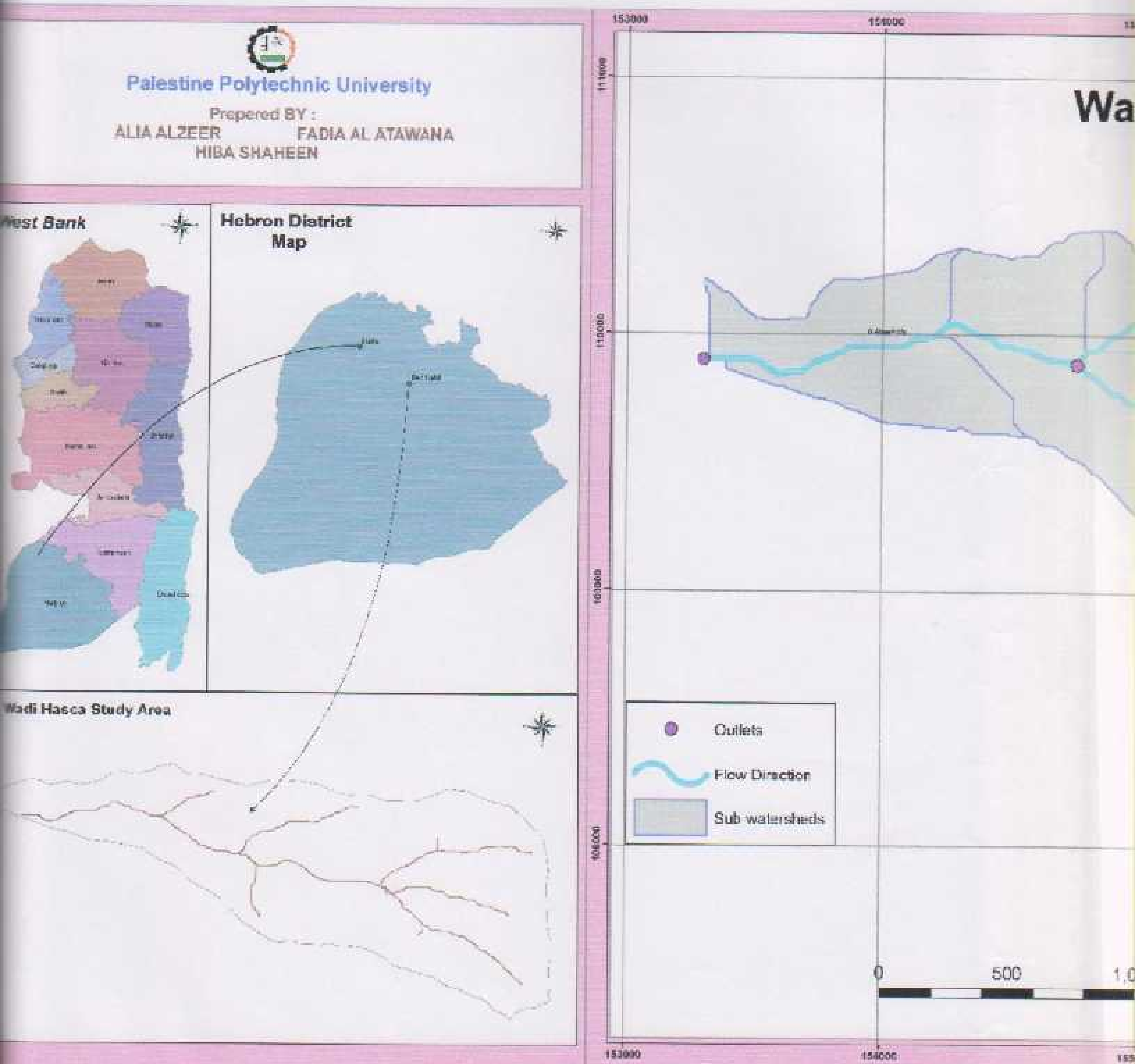
dary of Wadi Hasca Watershed



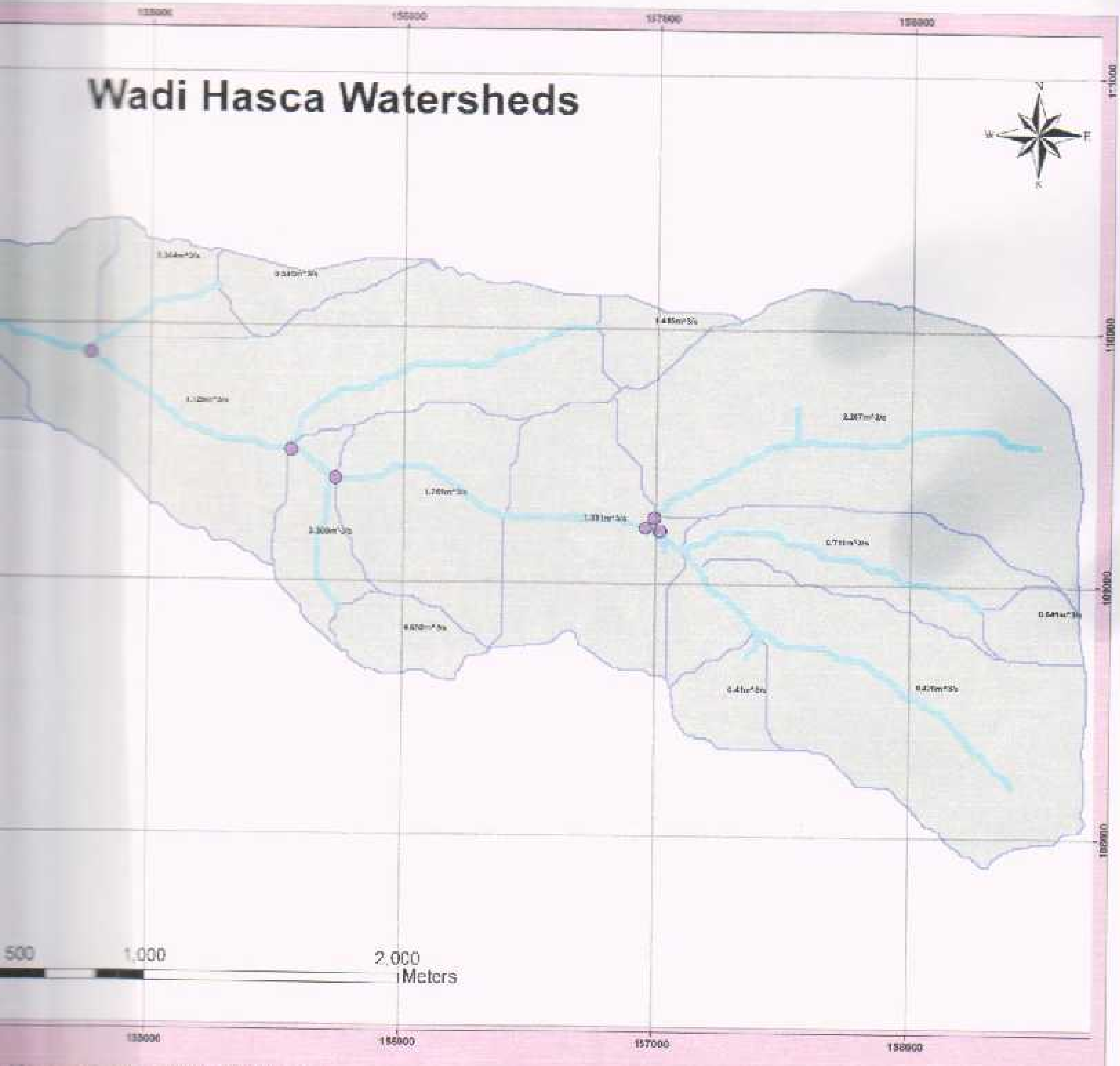
Figure(5.2) : Land Us



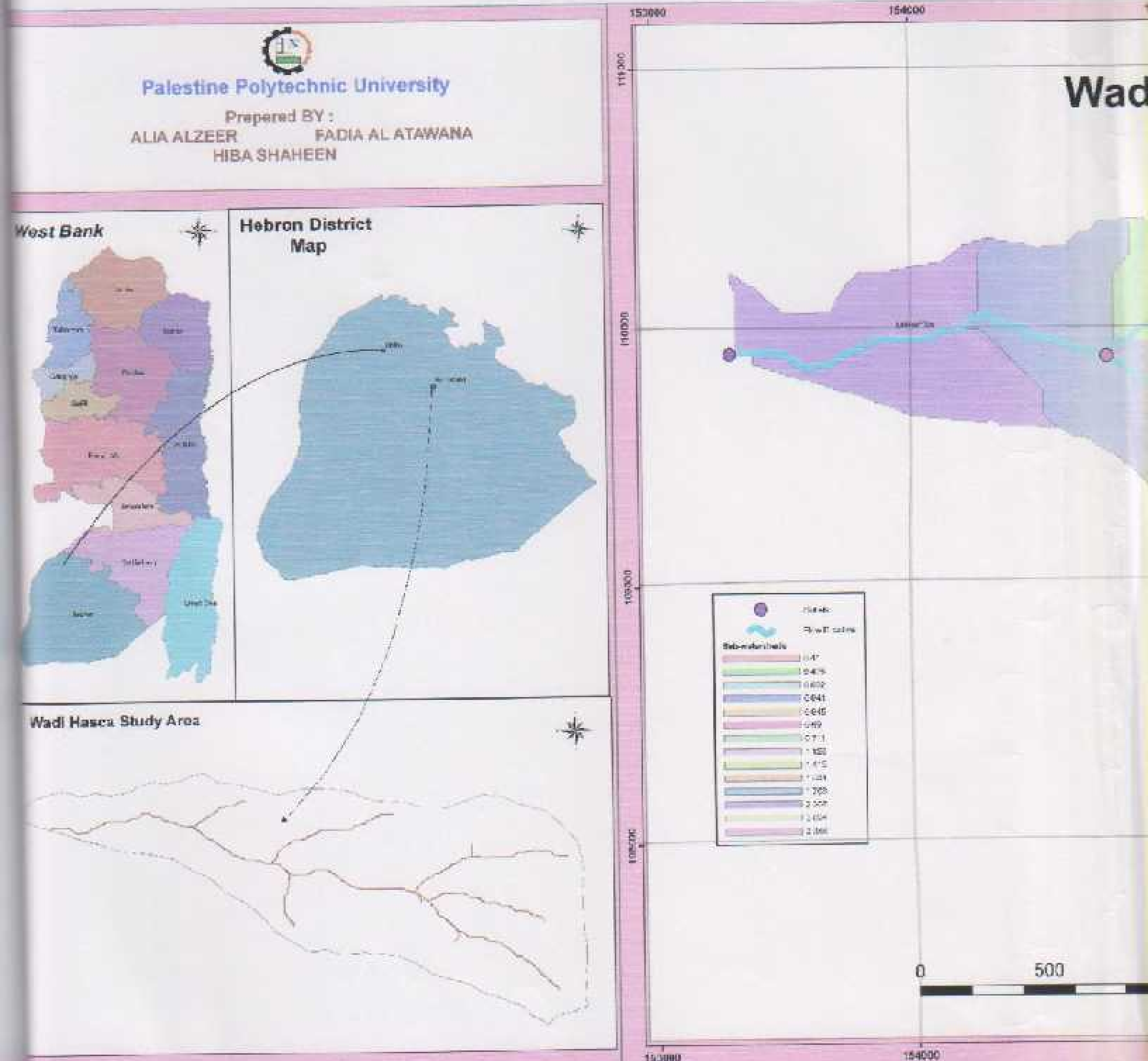
: Land Use and Land Cover



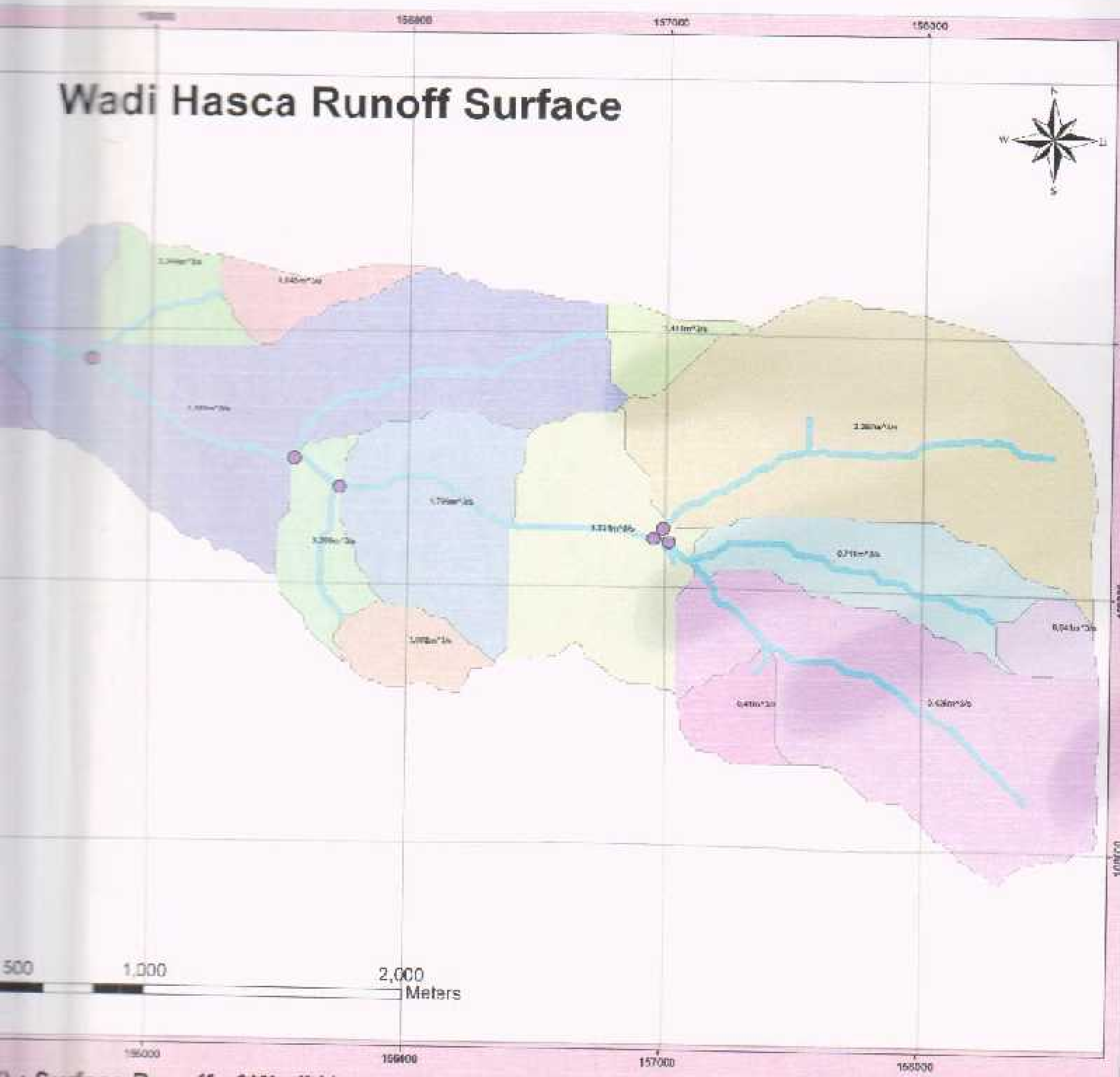
Figure(5.3) : Sub-Watersheds



-Watersheds of Wadi Hasca



Figure(5.5) : Surfac



) : Surface Runoff of Wadi Hasca