MORPHOMETRIC ANALYSIS OF THE BASINS BETWEEN ATSHAN AND AL-MISHRAQ IN NINEVEH (IRAQ)

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Thesis Advisor
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TABLE OF CONTENTS

I certify that in my opinion the thesis submitted by Abdullah Khalid ABDULLAH AL-HAYANI titled “MORPHOMETRIC ANALYSIS OF THE BASINS BETWEEN ATSHAN AND AL-MISHRAQ IN NINEVEH (IRAQ)” is fully adequate in scope and in quality as a thesis for the degree of Master’s Degree.

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DOĞRULUK BEYANI

Yüksek lisans/Doktora tezi olarak sunduğum bu çalışmayı bilimsel ahlak ve geleneklere aykırı herhangi bir yola tevessül etmeden yazdığımı, araştırmamı yaparken hangi tür alıntıların intihal kusuru sayılacağını bildiğimi, intihal kusuru sayılabilecek herhangi bir bölüme araştırmamda yer vermediğimi, yararlandığım eserlerin kaynakçada gösterilenlerden oluştuğunu ve bu eserlere metin içerisinde uygun şekilde atıf yapıldığını beyan ederim.

Enstitü tarafından belli bir zamana bağlı olmaksızın, tezimle ilgili yaptığım bu beyana aykırı bir durumun saptanması durumunda, ortaya çıkacak ahlaki ve hukuki tüm sonuçlara katlanmayı kabul ederim.

Adı Soyadı: Abdullah Khalid ABDULLAH AL-HAYANI

İmza:

FOREWORD

First, I thank GOD for my success, also I would like to thank my supervisor, Dr. Öznur YAZICI, whose expertise was invaluable in formulating and applying the research questions and methodology. Her insightful feedback pushed me to sharpen my thinking and brought my work to a higher level. I also thank Dr. Isbahiya YOUNIS AL-MOUHSEN, Dr. SALAH and Dr. Mücahit COŞKUN who supported and guided me to get the research thesis better.

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ABSTRACT

The study area is located in the northwestern part of Iraq and within the borders of the Nineveh Governorate. It lies Valley Al-Hulaila basin to the north-northwest of the study area, the Eatashanuh and Kleiaan low plateaus of Nokite (Nouquit) to the west, and the Al-Mishraq low plateaus to the south-southwest. The Tigris River forms a natural border in the northeast and the east. Research area, which has an area of 459.36 km^2 and is selected with the river basin boundaries determined by the water section lines, coordinate values 36° 00' 00" - 36° 23' 33" north latitudes and 42° 58' 30" - 43° 19' 30" is located between the eastern longitudes. It is located in the semi-mountainous region of northwestern Iraq in the range of low folds.

In the research, it is aimed to make the morphometric analysis of the river basins between Atshan and Al-Mishraq. For this purpose, first of all, the physical conditions affecting the geomorphology were examined. It has been observed that the study area has risen to the sea surface since the Tertiary (Cenozoic) Miocene period, and geological formations belonging to the Miocene and Pliocene periods are located in the region. In addition to the Sarkanki Formation, which began to emerge in the Middle Miocene, the region is also represented by fluvial deposits belonging to the present Quaternary Period. In terms of tectonics, the tectonics of the study area are affected by the tectonic history of Iraq.

The lands of the study area varied in the degree of slope in the study area between severe and few. Despite the multiplicity of slope directions in the region, most of them take the direction of the northeast, while the direction of the decline in other basins in the direction of the East and southeast and northwest direction. It is concluded that the directions of slopes correspond to the nature of the terrains and the direction of the valleys.

The climate of the region is characterized by moderately cold winters with fluctuations in precipitation and hot, dry summers. And also, the climate is influenced by the Mediterranean climate. Where the average of the minimum temperatures is 13.6°C, the average of the maximum temperatures is 27.4°C, and the average temperature range was 13.7°C. The year average of rain in the years of observation is 22.2 mm.

There are many types of trees or shrubs covering the study area, including grasses, buffalo plants, carob, sedge, and thorny plants. Many of these plants do not have a significant area of use.

It has been seen that the two types of soils are flooded soil and dry gypsum soil in the study area.

When the hydrographic structure of the study area is examined, it is seen that almost all of the streams pouring into the Tigris do not carry water except in rainy periods. The study area was characterized by a tree drainage model called dendritic drainage. This type of drainage is common in almost all basins and must have emerged as a result of homogeneous rock structure. 11 noteworthy basins were identified in the study area. These basins are ordered from northwest to southeast as follows: Okab, Hajar, Tammuz, Al-Dir, Al-Ain, Al-Areej, Al-Dabbas, Marei, Munira, Ramadan Salih, Gahanem stream basins. The largest of the basins studied in the field is the Al-Ain Stream basin (127.36 km^2) and the smallest is the Marei Stream basin (7.30 km^2). It has been seen that the most common drainage type in the study area was dendritic drainage.

In addition, the effect of the human factor in the study area is also briefly discussed.

The altitude of the region is between 185-440 meters. Also in the study, the north-south and west-directed profiles were drawn and the elevation groups in the field were compared. The existence of various geomorphological units, which were evaluated by both map analysis and field studies, were determined in the field. These are primary and secondary landforms such as low plateaus, convex and concave hills, erosional surfaces, flat areas, gully erosion areas, river terraces, V-shaped valleys, sand point bars, cut banks, karstic topography landforms. The characteristics of these landforms are explained and finally, the geomorphological development is revealed.

Morphometric analyzes were applied to explain the geomorphological characteristics of the study area. For this purpose, indicate formulas applied by various researchers were used and numerical values were obtained. Afterward, these were analyzed, and the characteristics of the basins were tried to be explained. It has been seen that the highest hypsometric integral value was in the Marei Stream basin and the lowest value was in the Tammuz Stream basin in the study area. According to the results, the Marei Stream basin is the only one still in its youth stage in the region. And the Tammuz Stream basin is the oldest basin in the area, and the sedimentation process is dominant in its basin. The Gahanem Stream basin has just left its youth period behind. And also, the Ramadan Salih Stream basin is at the stage of maturation very close to the youth. In these basins, the erosion process is still very effective. In contrast, the Munira and the Okab stream basins have completed their maturity stage a short time ago and entered the old age stage. The other basins (Al-Areej, Hajar, Al-Dir, Al-Ain, Al-Dabbas, and Ramadan Salih) were determined to be in the maturation stage.

As a result, the basins in the study area are listed as follows from the longer ones (low flood sensitivity) to the more circular ones (high flood sensitivity): Al-Dir Stream, Marei Stream, Gahanem Stream, Okab Stream, Al-Areej Stream, Tammuz Stream, Munira Stream , Hajar Stream, Al-Dabbas Stream, Al-Ain Stream, Ramadan Salih Stream.

This study supports that GIS-based analysis of various morphometric parameters of river basins is of great importance for the effective and efficient evaluation and protection of natural resources in the environment.

ÖZET

Çalışma alanı Irak’ın kuzeybatı kesiminde ve Ninova Valiliği sınırları içerisinde yer almaktadır. Çalışma alanının kuzey-kuzeybatısında Valley Al-Hulaila havzası, batısında Nokite’nin (Nouquit) Eatashanuh ve Kleiaan alçak platoları ve güney-güneybatısında Al-Mishraq alçak platoları yer alır. Kuzeydoğu ve doğuda Dicle Nehri doğal bir sınır oluşturmaktadır. 459.36 km^2’lik bir alan kaplayan ve su bölümü çizgileriyle tanımlanan alan, koordinat değerleri 36° 00' 00" - 36° 23' 33" kuzey enlemleri ve 42° 58' 30" - 43° 19' 30" doğu boylamları arasında uzanmakta ve Irak’ın kuzeybatısındaki yarı dağlık bölgenin uzantısı olan alçak platolarla temsil edilmektedir.

Araştırmada Atshan ve Al-Mishraq arasında kalan akarsu havzalarının morfometrik analizinin yapılması amaçlanmıştır. Bu amaçla; öncelikle jeomorfolojiyi etkileyen fiziki şartlar incelenmiştir. Çalışma alanında Tersiyer’in (Senozoik) Miosen döneminden itibaren deniz yüzeyine yükselmenin gerçekleştiği, Miosen ve Pliosen dönemlerine ait jeolojik formasyonların yer aldığı görülmüştür. Orta Miosen’de ortaya çıkmaya başlayan Sarkanki Formasyonu’nun yanı sıra bölge, mevcut Kuaterner Dönemi’ne ait akarsu çökelleri ile temsil edilmektedir. Tektonik açıdan, inceleme alanının tektoniği Irak’ın tektonik tarihinden etkilendiği düşünülmektedir.

Çalışma alanındaki araziler, eğim derecesi bakımından şiddetli ile az arasında değişmektedir. Bölgedeki eğim yönlerinin çokluğuna rağmen, çoğu kuzeydoğu yönünü alırken, diğer havzalarda düşüş yönü Doğu ve Güneydoğu ve kuzeybatı yönündedir. Yamaçların yönlerinin arazilerin doğasına ve vadilerin yönüne karşılık geldiği sonucuna varılmıştır.

Bölgenin iklimi; yağışlarda dalgalanmalar, sıcak-kuru yazlar ve orta derecede soğuk kışlar ile karakterizedir. Ayrıca, iklim Akdeniz ikliminden etkilenir. Minimum sıcaklıkların ortalaması 13.6°C, maksimum sıcaklıkların ortalaması 27.4°C ve yıllık ortalama sıcaklık değeri 13.7°C’dir. Verilerin sağlandığı istasyonun uzun dönemli gözlemlerine göre yıllık yağış ortalaması 22.2 mm olarak belirlenmiştir.

Çalışma alanını kaplayan ot, bufalo bitkileri, keçiboynuzu, saz ve dikenli bitkiler gibi birçok ağaç veya çalı türü bulunur. Ancak, bu bitkilerin birçoğunun önemli bir kullanım alanı bulunmamaktadır.

Çalışma alanında taşkın toprakları ve kuru jipsli topraklar olmak üzere iki tür toprak olduğu görülmüştür.

Hidrografik yapıya bakıldığında, Fırat Nehri'ne dökülen akarsuların hemen hepsinin, yağışlı dönemler dışında çoğunlukla su taşımadığı görülmektedir. Çalışma alanı, dendritik drenaj adı verilen bir ağaç drenaj modeli ile karakterize edilmiştir. Bu drenaj tipi hemen hemen bütün havzalarda yaygındır ve homojen kayaç yapısının bir sonucu olarak ortaya çıkmış olmalıdır. Çalışma alanında dikkate değer 11 akarsu havzası belirlenmiştir. Bu havzalar kuzeybatıdan güneydoğuya doğru şu şekilde sıralanır: Okab, Hajar, Tammuz, Al-Dir, Al-Ain, Al-Areej, Al-Dabbas, Marei, Munira, Ramadan Salih, Gahanem dere havzalarıdır. Sahada çalışılan havzalardan en büyüğü Al-Ain Deresi Havzası (127.36 km^2) ve en küçüğü ise Marei Deresi Havzası'dır (7.30 km^2). Çalışma alanında yaygın olarak görülen drenaj tipi dentritik drenajdır.

Ayrıca çalışma alanında insan faktörünün etkisi de kısaca ele alınmıştır.

Çalışma alanında yükselti değerleri 185-440 metreler arasında değişmektedir. Kuzey-güney ve batı-doğu doğrultulu profiller çıkarılarak, sahadaki yükselti grupları karşılaştırılmıştır. Sahada gerek harita analizleri ile gerekse arazi çalışmaları yoluyla değerlendirilen çeşitli jeomorfolojik birimlerin varlığı belirlenmiştir. Bölgede; geniş alçak platolar, tepeler, aşınım yüzeyleri, taban düzlükleri, yarıntı erozyonu alanları, akarsu sekileri, V şekilli vadiler, yığınaklar, menderes çarpak alanları, karstik çözünme şekilleri gibi birincil ve ikincil yerşekilleri bunlardandır. Bu yerşekillerinin özellikleri açıklanmış ve sonunda jeomorfolojik gelişim ortaya konulmaya çalışılmıştır.

Çalışma alanının jeomorfolojik özelliklerini açıklamak üzere morfometrik analizler uygulanmıştır. Bu amaçla, çeşitli araştırmacıların uyguladığı indis formülleri kullanılmış ve sayısal değerler elde edilmiştir. Sonrasında bunlar analiz edilerek, havzaların özellikleri açıklanmaya çalışılmıştır. Çalışma alanında en yüksek hipsometrik integral değerinin Marei Deresi havzasında, en düşük değerin ise Tammuz Deresi havzasında olduğu görülmüştür. Elde edilen sonuçlara göre, Marei Deresi havzası bölgede henüz gençlik aşamasında olan tek havzadır. Tammuz Deresi havzası bölgedeki en eski havzadır ve havzasında sedimantasyon süreci hakimdir. Gahanem Deresi havzası gençlik dönemini geride bırakmıştır. Ayrıca Ramadan Salih Deresi havzası da gençliğe çok yakın olgunlaşma aşamasındadır. Bu havzalarda erozyon süreci hala çok etkilidir. Buna karşılık Munira ve Okab dere havzaları ise kısa bir süre önce olgunluk evresini tamamlamış ve yaşlılık evresine girmiştir. Diğer havzaların (Al-Areej, Hajar, Al-Dir, Al-Ain, Al-Dabbas) olgunlaşma aşamasında olduğu belirlenmiştir.

Sonuç olarak çalışma alanındaki havzalar daha uzunlamasına olanlardan (düşük taşkın duyarlılığı) daha dairesel olanlara (yüksek taşkın duyarlılığı) doğru şu şekilde sıralanmıştır: Al-Dir Deresi, Marei Deresi, Gahanem Deresi, Okab Deresi, Al-Areej Deresi, Tammuz Deresi, Munira Deresi, Hajar Deresi, El-Dabbas Deresi, Al-Ain Deresi, Ramadan Salih Deresi.

Bu çalışma, akarsu havzalarının çeşitli morfometrik parametrelerinin CBS tabanlı analiz edilmesinin, çevredeki doğal kaynakların etkin ve verimli şekilde değerlendirilebilmesi ve korunabilmesi açısından büyük önem taşıdığını desteklemektedir.

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Tezin Yazarı	Abdullah KALID ALHAYANI
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ABBREVIATIONS

DEM - Digital Elevation Model

GIS - Geographical Information Systems

$CaSO_4$. H_2O - Gypsum

$CaSO_4$ - Anhydrite

$CaCO_3$ - Limestone

$CaCO_4$. H_2O Calcium sulfate dihydrate

H_2O - Water

H_2CO_3 - Dilute Carbonic Acid

° - Degree

C – Celsius

km - Kilometer

m – Meter

mm - Milimeter

INTRODUCTION

Öztürk (2020) defined the basin as an ecosystem in which organic and inorganic natural resources interact within the water division line. The study of valleys and water basins is one of the modern trends that have received significant interest by researchers and specialists in geomorphology and hydrology alike because it has an important impact in determining the amount of water discharge and the volume of sediments, as well as its contribution to the emergence of some land and sedimentary forms due to the effect of the flow system in them clearly in the basin in terms of shape, area, and topographical characteristics. Also, human activities are usually centered around valleys, river basins, and drainage areas. The environment and the form of the land may control these activities. Still, the human factor, in turn, affects practically a large degree by adapting them and harnessing them to serve him. In the light of that, he could plan agricultural projects within those basins and what can it needs water. Dams and reservoirs were built to benefit from the water reservoirs stored in agriculture and its various activities to achieve sustainable development in them.

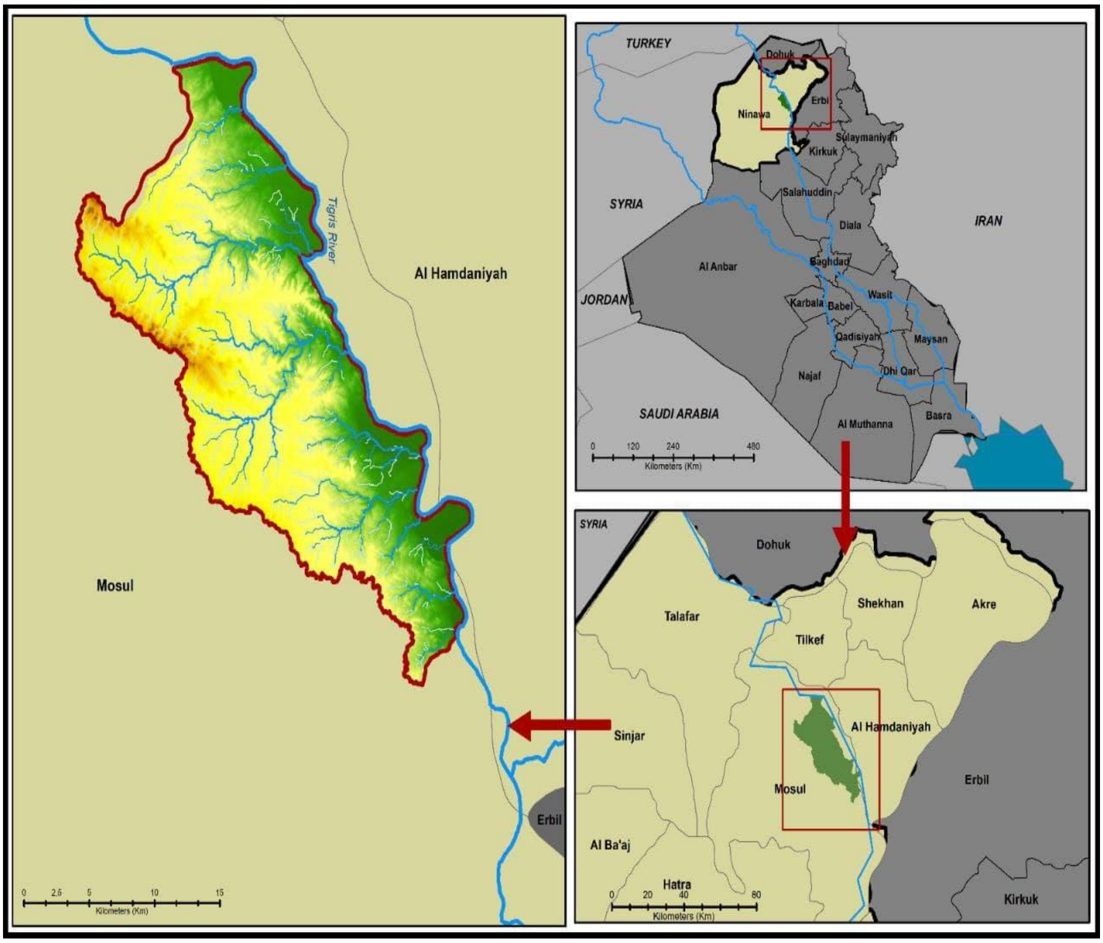
Studying and analyzing the morphometric characteristics of the network of the main valleys, water basins, and their drainage systems within the study area takes a large part of the interests of the geomorphological researcher because of these basins of hydrological indications terms of the characteristics of water drainage and sediment formation. It identifies some of the hydrological and morphological characteristics of the study area, such as types of rocks, soil quality, and the nature of water drainage. Topographical maps were also used to integrate them with aerial photographs and space data in the study and analysis of the engineering characteristics of the drainage patterns within the study area. As it includes a large number of valleys, and due to the large area of the study area and a large number of its valleys and its ramifications, the research was devoted to the study of the main valleys in it, which amounted to 11 valleys. These are Okab, Hajar, Tammuz, Al-Dir, Al-Ain, Al-Areej, Al-Dabbas, Marei, Munira, Ramadan Salih, Gahanem, relying on satellite visuals and the Digital Elevation Model (DEM) to extract all morphometric characteristics and Geographic Information Systems (GIS) techniques and hydrology related to those valleys. As the applied geomorphological studies at present have diversified greatly and have close links with other branches of science, as they are frequently used in evaluating and evaluating natural resources and the extent to which they are benefited, studying obstacles and natural problems, and finding appropriate solutions to them, primarily since the study area constitutes a significant field if prepared for it. Proper studies to identify its natural resources and wealth and the possibility of investing in the natural environment so it is necessary to achieve long-term sustainable development that meets human needs and various activities.

LOCATION OF THE STUDY AREA

The study area is located in the northwestern part of Iraq, within the Nineveh Governorate. The region is bordered by the Valley Al-Hulaila basin to the north and northwest, the Eatashanuh and Kleiaan low plateaus of Nokite (Nouquit) to the west, and the Tigris River to the northeast and east.

The study area was chosen as a mathematically generated natural area of 459.36 km^2. 36° 00' 00" - 36° 23' 33" North latitudes and 42° 58' 30" - 43° 19' 30" East longitudes are taken as coordinate points. As seen in Map 1, it is located in the semi-mountainous region of the low mountain ranges of Northwest Iraq.

The city of Mosul is the seat of the Nineveh Governorate in northern Iraq and is Iraq's second largest governorate in terms of population. This section is at the junction of many roads connecting east to west, where the Tigris River passes through the city and divides the city into two.



MAP 1. Location Map of the Study Area

RESEARCH PROBLEMS

To put forward the problem of the study represents the first steps of geographical scientific research and can be formulated as a primary question.

Problem statement:

"What are the morphometric features of the basins in the study area?"

This question represents the focal point of the study topic, and the next step revolves around secondary questions (sub-problems) to be answered as presented below:

- What is the nature of the dominant natural and human factors that impact the formation of the area's relief?
- What types of geomorphologic processes led to the drawing of the relief features?

- To highlight the general characteristics of the area as a ground feature with advanced and changing parts, and what are the implications of these characteristics in the applied aspects?
- What is morphometric analysis? What are the natural factors affecting the characteristics of morphometric basins?
- How do the morphometric analysis results relate to flood, overflow events, or drought in the problematic parts of the study area?
- How valid are the digital data using modern techniques and GIS programs in morphometric analysis of the study area?
- What is the impact of natural resources in the study area on the concentration of population?
- Do morphometric features affect soil and land use in the study area?

THE STUDY HYPOTHESIS

This thesis used scientific methods for the main problem and sub-problems that sought answers. The hypothesis will be put forward to establish a relationship between various events and determine the causes and consequences, and its validity will be tested in the study.

The hypothesis set for this research is expressed as follows:

The natural and human characteristics are drawn according to morphometric and geomorphological features.

Depending on the morphodynamic effect of water, it is possible to benefit from stream basins, especially in rainy seasons.

The presence, distribution, and quantitative and qualitative characteristics of groundwater resources (especially karst springs) clearly affect population density.

OBJECTIVES OF STUDY

The work aims to achieve the following:

The morphometric features of the river basins between Atshan and Mishraq in the vicinity of Mosul, on the banks of the Tigris River in Iraq, will be analyzed. For this purpose, first of all, the effects of natural geographical conditions such as structure, lithology, tectonics, geology, climate, vegetation, soil cover and hydrography on geomorphological features were determined. The possible flood risk was tried to be evaluated by calculating the quantitative data and morphometric indices of the stream basins in the region.

The basis of hydrological studies is to determine the extent of the contribution of the precipitations, which form one of the basin components, to surface flow and groundwater recharge due to infiltration.

Reliable development planning for the future can be done by preparing geographical databases according to the morphometric characteristics of the study area basins, which is considered one of the dry basins, explaining the correct steps, using remote sensing that provides precise accuracy in the outputs.

As the morphometric and hydrological characteristics of watersheds provide important indicators, analyzes can be made to help determine their effects.

An opportunity to invest in the basin's water resources can be provided by researching, evaluating, and classifying hydrogeomorphology.

SIGNIFICANCE AND LIMITATIONS OF STUDY

As a Geographic Information Systems unit, measurements and mathematical calculations are made for the morphometric characteristics of river basins by using modern technologies and remote sensing images, including automatic modeling.

This study is designed as an applied basis for researchers based on applying morphometric features to any field.

By using the results of this study, it is expected to serve for the resettlement of the people living in the region before the war and for the use of natural resources, especially human beings. On the other hand, it is hoped to be an effective direct communication tool to deliver a significant amount of accurate information to readers with less effort and less time.

There are no flow stations in the study area to record the flow amounts, water levels, flood, and slant characteristics of the streams. For this reason, reliable data on the hydrometric properties of the basins in the study area could not be accessed.

The work area has been under the influence of war for many years. Unfortunately, the region still faces significant security problems. For this reason, field studies were carried out under great difficulties during the thesis study. It was impossible to examine the basins' problematic parts and take a few photographs was under extremely limited opportunities.

STUDY METHODOLOGY

The morphometric study is based on statistical - quantitative foundations, employing its results in preparing maps and graphs using cartographic methods. It is not possible to stop at the limits of the results, which calls for work with Excel and other statistical programs. A descriptive approach based on an analytical-synthetic basis provides the opportunity for the researcher to dismantle the geomorphological complex into its primary spatial elements and then re-compose it by studying the overlapping spatial relationships according to an integrative view, the way to do this is to explain the totality of the factors and processes responsible for giving it its current formal characteristics and analysis. It also uses the regional approach to define the personality of the basin and study it as a specific and well-defined geomorphological unit, similar to the concept of the region.

Relying on the applications of Geographic Information Systems (GIS) and using the ArcMap 10.8 programs to derive the basin, mapping, derive the water network, analyze the data and use the Global Mapper program, as well as make use of the Google Earth program to determine some aspects in the study area, as well as the reliance on visual images (DEM) and visual images, were used at a distance of 15 * 15 m. There were no images closer to the study area, and information systems are a set of programs used to archive, manage and organize data and process it with specific procedures established according to the workflow mechanism in the organization to obtain the final outputs. It is noted that information systems are entirely different from information technology, as information systems use information technology techniques was created to serve their business.

The study relied on several approaches to give an integrated analysis interconnected with ideas. The inductive and analytical method was counted on as basic methods in the study. In order to reach more accurate and precise results, it is necessary to use quantitative mathematical methods and a series of statistical analyzes. The analysis and extraction of data and mathematical equations were relied on in the section of the morphometric analysis that was addressed in the third chapter of the research based on the equations of [Gravelius (1914), Horton (1945), Smith (1950), Strahler (1952, 1958, and 1964), Schumn (1956), Hadley and Schumn (1961), Schumn (1963)]. As shown in the table, Strahler's method has been applied to determine bifurcation data in this research. According to Strahler Method, bifurcation stages are minor channels formed in the source part of the basin. According to this method, two 1st directories merge and form the 2nd directory. The 3rd directory is created by the merging of two 2nd strings. This sequence progresses to the main branch and is completed into a system. In the climate part of the study, Thornthwaite's climate classification formulas were used. On the other hand, the mainstream creates the last row and the most significant numbered string.

Study method:

In order to complete the research in line with its applied nature, the study relied on the following stages:

1. Literature review stage: Data and information are collected through

A. Studies and scientific research (Arabic and foreign) are represented by sources and references, library documents and letters, and university theses.

B. Data, information, and statistics (published and unpublished) issued by relevant official departments.

C. The International Information Network (Internet)

D. Maps, satellite visuals, and techniques of the study area.

2. Fieldwork stage

3. Writing stage

This is the last stage after the above steps, in which data, information, and maps were collected, and then the thesis was written.

RESEARCH STRUCTURE

The research was prepared based on its division into four chapter, in addition to the introduction, findings, conclusions, and recommendations, as follows:

Chapter One is about the natural and human factors affecting the region's characteristics. This chapter is divided into two sections. The first topic included the natural factors that affect the study area, which was divided into several sections:

1. Geology of the study area
2. Climate of the study area
3. Native plant communities (vegetation) in the study area
4. Hydrography in the study area

As for the second topic, it also included several sections:

1. Mining in the study area

2. Agriculture and grazing in the study area
3. Human settlement in the study area

Chapter Two discusses the basic geomorphological units, secondary landforms, and particular topographic forms such as karst in the study area are discussed in detail.

Chapter Three analysis of the morphometric characteristics of the study area, which is divided into several sections:
1. Linear morphometric characteristics of the basins
2. Areal morphometric characteristics of the basins
3. Relief morphometric characteristics of the basins

Chapter Four is related to the results of this thesis. This study’s findings were discussed compared to previous studies, and conclusions and recommendations were given.

PREVIOUS STUDIES

The geomorphological studies that dealt with the morphometric characteristics of the river basins varied, which included the trend of using modern technologies and software such as digital elevation models, remote sensing, and geographic information systems. Some previous studies on the subject are summarized below:

1- The Study of Kazem Musa MUHAMMAD (1981):

The Great Zab Basin in Iraq dealt with a hydrological study, where the hydrological characteristics of the river were studied by studying the natural factors affecting the flow of the Great Zab River and reviewing the hydrographic description of the river its tributaries. Another, which requires the establishment of several dams in the appropriate sites on the river and its tributaries, the factors that determine the locations of dams and reservoirs have also been studied.

2- The Study of Ibtisam Ahmed JASSIM (2006):

‘The hydrogeomorphology of the Altun Bridge Basin in the Kirkuk Governorate’ concluded that the basins reached the highest rank, reaching the seventh rank, as in the Golek Basin. According to him the basin is undergoing senescence.

3- The Study of İsa CÜREBAL and Ahmet Evren ERGİNAL (2007):

In the article (Analysis of Geomorphological Features of Mıhlı Creek Basin Using Geomorphic Indices) prepared by Cürebal and Erginal (2007), morphometric analyzes of the Mıhlı Stream basin on the Kazdağlar Massif were made. Regarding the basin, which was evaluated with a wide variety of parameters, researchers observed that it continued to develop under the neotectonic effect.

4- The Study of Beyhan ÖZTÜRK and Ahmet Evren ERGİNAL (2008):

In the article [Morphometric Analysis of Neighbor River Basins: A Key Study on Sarıköy and Kocakıran Streams (Gönen Basin, South of Marmara)] written by Öztürk and Erginal (2008), morphometric analyzes were used to examine the conditions affecting the development of the Bayramdere basin, which forms a part of the Marmara Sea basin. High angle normal faults were observed in the study area. With the results obtained, it has been revealed that the region is under a significant influence of tectonics and the role of faults in drainage.

5- The Study of Emre ÖZŞAHİN (2010):

Özşahin (2010), in his article titled 'Morphometric Analysis of Neighbor River Basins: A Key Study on Sarıköy and Kocakıran Streams (Gönen Basin, South of Marmara)', conducted a comparative morphometry study to determine the geomorphological features of Sarıköy and Kocakıran streams basins. Using various indices, Özşahin revealed that river erosion and deposition activities are the dominant forces in the determination of geomorphological features.

6- The Study of Engin KESMEN (2013):

Engin Kesmen (2013) focused on the morphometry of Turkey's drainage basins in his master's thesis titled 'Drainage Basins of the Border in Turkey and Determination of their Morphometric Characteristics'. The projected area of all the basins in Turkey is 779911.19 km^2, and the average elevation is 1140.79 m. The smallest basin is Küçük Menderes, the largest basin is the Euphrates Basin. In terms of age, the Meriç-Ergene Basin is the oldest and closest to the equilibrium profile, while the Çoruh Basin is the youngest and the furthest from the equilibrium profile. For the same reason, while the slope values are low in the Meriç-Ergene basin, the slope values are high in the Çoruh basin. This thesis study of Keskin is of great importance in terms of evaluating the water availability in Turkey, solving the problems in the basins, and ensuring sustainability.

7- The Study of Murat UZUN (2014):

Murat Uzun (2014) conducted a study titled 'Investigation of the Geomorphological Features of the Lale Creek (Yalova) Basin with Geomorphometric Analysis.' In the study, the features affecting the geomorphology of the basin were analyzed with morphometric indices using GIS techniques. As a result, it was seen that the basin was in the maturity stage and tectonism was influential in the region. The main geomorphological elements marked by the researcher in the study area are mountains, plateaus, plains, valleys, slopes, terraces, and delta areas.

8- The Study of Zainab Ibrahim Hussein AL-MOTWANI (2015):

Al-Motwani's study named 'The Spatial Variance of Dangerous Geomorphological Phenomena in the Erbil Governorate' is of geomorphological significance. It has been revealed that the lithology of the region dates back to the Mesozoic and Tertiary. In the study, natural data represented by geological and climatic features, water resources, soil, natural vegetation, topographic, morphometric and structural features were determined, and finally, the main geomorphological risks that the Erbil Governorate is exposed to were discussed.

9- The Study of Vedat AVCI and Halil GÜNEK (2015):

In the article (The Use of Morphometric Analysis in Determining Geomorphological Features of the Uludere Basin) written by Avcı and Günek (2015), the geomorphology of the Uludere basin was revealed by using morphometric analyzes. It has been observed that the region is tectonically active, and Uludere Stream is a flowing stream suitable for the structure. As a result of the evaluation of the parameters, it was seen that the basin showed an asymmetrical feature, and the geomorphological development was in the youth period.

10- The Study of Marwa Ali TAHER (2015):

He dealt with the ‘Morphometric Ccharacteristics of the Valley Afi Sirka Basin in the Governorate of Dohuk’. The study aimed to highlight the most important natural features of the region and the extent of their impact on the geomorphological manifestations and processes to detect the shapes that formed in the valley and know their importance, and aimed to study the morphometric properties to see On the development of geomorphological phenomena resulting from the spatial relations between the factors and processes that form the land appearance. The study showed that the ratio of rotation and elongation indicates a ratio that mediates between 0-1. Still, it is closer to the circuit and indicated that the basin is going through the stage of youth, which shows increased erosion and terrain formation Little due to the large area of the basin.

11- The Study of Burç ERDEDE and Derya ÖZTÜRK (2016):

Erdede and Öztürk (2016) evaluated the morphometric and hydrological features of the Kızılırmak Basin in their study named ‘Evaluation of Flood Potential of Kızılırmak Basin Using Linear, Areal and Relief Morphometric Indices’. They completed all the analyzes in GIS environment and benefited from the Strahler Method. It has been determined that there are 8 different grades of drainage networks in the basin, and the flood risk is low. On the other hand, the researchers concluded that the bifurcation rate of the 7th sequences was below the basin average and the flood risk in these sections should be examined in more detail.

12- The Study of Suzan ALTIPARMAK ve Necla TÜRKOĞLU (2018):

Altıparmak ve Türkoğlu (2018), in their study named ‘The Morphometric Analysis of Yakacık Stream Basin (Hatay)’, made morphometric analyzes for Yakacık Stream Basin using GIS. Thus, many morphometric features could be determined easily and quickly with the GIS method.

13- The Study of Yıldız GÜNEY (2018):

Güney (2018), in his research article ‘Evaluation of Morphotectonic of Çalıdere Basin (Armutlu Peninsula, Yalova) Using Geomorphometric Analysis’, made geomorphological and tectonic inferences by using geomorphometric indices. As a result of the evaluation of the obtained parameters, it has been observed that the effect of tectonism is great due to the faults located in the lower parts of the Çalıdere Stream Basin. In the research, it was understood that the age of the basin is young.

14- The Study of Cem KÜÇÜK (2018):

In his master’s study named ‘Evaluation of Morphometric Properties of the Lakes Region and its Surrounding Major Lakes’ prepared by Küçük (2018), Beyşehir Lake, Eğirdir Lake, Burdur Lake, Acıgöl, Eber Lake, Çavuşçu (Ilgın) Lake, Akşehir Lake, Kovada Lake, Salda Lake and Yarışlı Lake were investigated. Most of these lakes, whose morphometric features are discussed, are of tectonic and/or karstic origin. At the end of the thesis, the obtained parameters were compared with each other, and comments were made on the geomorphological and tectonic development.

15- The Study of Nureddin POLAT (2019):

Nureddin Polat (2019), in his master’s thesis titled ‘Applied Hydrography of the Araç Stream Basin’ evaluated the hydrographic, hydrometric and morphometric features of the basin. Sub-basins were determined in the study area and comparisons were made between them. Furthermore, in the research, opportunities, threats, strong and weak features (SWOT Analysis) of the basin were also emphasized. As a result, suggestions were made on river basin management, planning, and protection from flood and overflow risk.

16- The Study of Gül YURUN MAVİGİL (2019):

Yurun Mavigil (2019), in her master’s thesis named ‘Morphometry of Yanarsu (Garzan) Stream and its Basin’, examined the Yanarsu (Garzan) Stream basin, which is one of the three main catchments of the Tigris River. Geographic Information Systems were used in the study and morphometric analyzes were performed. At the end of the study, in which a wide variety of linear, areal, and relief parameters was evaluated, the general framework of geomorphological and tectonic features was drawn.

17- The Study of Ali İMAMOĞLU (2020):

İmamoğlu (2020) in his study ‘Relation of Erosion Status with Morphometric Measurement in Alaca Stream Basin’ aimed to reveal the relationship between morphometric features and erosion. This study was carried out in the Alaca watershed basin, which is located in the water collection basin of Yeşilırmak. In the study, the perimeter of the basin, basin area, basin length, bifurcation ratio, hypsometric curve, drainage density, stream frequency, texture ratio, basin relief, ruggedness number, basin shape, Gravelius index, stream length ratio was examined. The results were also confirmed by fieldwork. While erosive activities increase in high and inclined places, the amount of erosion is low in places where it decreases. The basin is round in shape and the flood risk was found to be high as the water level rises rapidly after heavy rains.

18- The study of Ahmet ÖZTÜRK (2020):

Öztürk (2020), in his thesis (Evaluation of the Applicability of the Holistic Watershed Management Approach in the Example of the Ermenek Stream Basin), made morphometric analyzes to propose a useful method in the management studies of the Ermenek River Basin. Linear, area and relief morphometry of the basin was calculated over 23 parameters. In the study, the envisaged holistic management of the Ermenek Basin was evaluated by taking into account the field studies, interviews with the relevant people, and the physical-human structure of the national and international protocols of the basin. In addition, 'river basin regions' and 'transboundary basins’, which are problematic in watershed management practices, are also explained.

19- The study of Şaziye ARSLANTAŞ DİK (2021)

Arslantaş Dik (2021), who prepared her master’s thesis titled ‘Applied Hydrography of the Ulus Stream Basin’, examined one of the sub-basins of the Bartın Stream basin. In the study, the existing water potential was emphasized and the conditions affecting the hydrography were explained. In the study, morphometric analyzes of various parameters of the Ulus basin were also carried out. Finally, evaluations were made through SWOT analyzes and suggestions were made.

20- The study of Alemsha BOGALE (2021):

Alemsha Bogale (2021) discussed the linear and spatial morphometric aspects of the Gilgel Abay Basin, which empties into Lake Tana, the source of the Blue Nile. ‘Morphometric Analysis of a Drainage Basin Using Geographical Information System in Gilgel Abay Watershed, Lake Tana Basin, Upper Blue Nile Basin, Ethiopia’ focuses on the evolution of various morphometric parameters. Gilgel Abay has a total of 662 stream orders, including 511 first, 111 second, 30 third, 9 fourth, 1 fifth. The drainage density of the region, which is permeable and has rich vegetation, is low. It has been determined that the upper part of the basin is sensitive to soil erosion, and the accumulation and groundwater potential is high in the lower part. According to the results of the research, GIS and Remote Sensing technique facilitate planning such as effective soil conservation, water conservation and natural resource management.

21- The study of Safiye Yüksel ÖZTEKİNCİ (2021):

Safiye Yüksel ÖZTEKİNCİ (2021), in her master’s thesis (Vegetation and Hydrography of Devrek River Basin), discussed the factors controlling the environmental ecology in Devrek Stream Basin. Each of these factors is important in terms of protecting the structure of the environment. Environmental problems such as improper land use and vegetation destruction due to human influence have become today’s disasters. By using morphometric analysis methods, the researcher made inferences and suggestions for preserving the ecological order in the study area and the surrounding geography.

CHAPTER ONE

1. AFFECTING PHYSICAL FACTORS ON MORPHOMETRIC PROPERTIES

The study of the natural characteristics of the water basin, such as the geologic infrastructure, composition, slope, and landforms, in terms of their characteristics and distribution, is an important matter. As these characteristics affect the morphology of the water basins and the processes prevailing in them, knowing the geological formation of the area, types of rocks, the nature of the climate and water resources, It helps in understanding geomorphological processes and in interpreting the morphometric properties of the water network, And contribute to the development of forms of land, This chapter deals with the general natural characteristics of the basins of the study area, where the region’s geology, climate, natural plant, soil vegetation, Hydrography in the study area.

1.1. THE GEOLOGY OF THE STUDY AREA

The region of northern Iraq was in a state of geological instability during Tertiary period, sometimes rising from sea level. This situation continues for several million years, during which the erosion and erosion of ancient rocks occur, then sometimes it descends to the seafloor, receiving sediments and remnants of living organisms for millions of years, and so on. The situation continued in the same manner in several stages. This reflects us in the study area represented by a backwater with geological formations of rocks containing gypsum and lime structures and sand and gravel geological formations. Up to the present time, it is in a state of continuous geological activity (Elomary and Sadek, 1977: 71). At the end of the Pliocene period, the Bakhtiari formations were subjected to a slight torsional movement, which resulted in the emergence of the region of the undulating hills.

“These torsions were followed by a long period of carving during the Pleistocene period, during which the formations of the upper member aperture and some formations of the lower member aperture were exposed along the tops of some of the torsion. It paved the way for wide curvatures that formed many plains in the region, followed by general sedimentation, and the background valleys and plains were filled with sedimentation until they overflowed and covered many sides. These movements were the last stage of the geological development of the region" (Kasbak, 1973: 14).

1.1.1. Geological History of the Study Area

The geological and tectonic history of the study area is part of Iraq's geological and tectonic history. The geological development of Iraq begins from the oldest geological times and extends to the most recent. The land of Iraq represents a transition zone between two different formations, one of which is relatively recent and dates back to the Tertiary period. It is represented by the Taurus Mountains - Zagros in its east and north-east and represented by the plateau of Arabia in its west and southwest that both are part of continent Gondwana Land.

The formations of Iraq are distributed largely and uniformly, from the oldest to the most recent. Under its surface, there are ancient igneous rocks believed to be part of the Archean continent. As for the deposits on the surface, they are newly formed (Al-Sammak, 1985: 19).

The land of Iraq, including the study area, was affected by land movements and geological events that They occurred in different geological times, and the following is a result of the critical geological events:

1. Early Precambrian period 1400 million years ago:

The rocks of this period are among the oldest rocks as they are the basis of the other rocks. They are widely spread globally, but they do not appear in Iraq. Nevertheless, they appear in Saudi Arabia and Yemen. About 4/5 of the rocks of this time it is hidden under older sediments, and one of the most important types of it is gneiss metamorphosed from granite due to pressure and heat (Al-Mael, 1996: 17). "The information about the rocks of this period is not available from Iraq. Therefore, it relies on the little information scattered in neighboring Saudi Arabia, Iran, Syria, Turkey, which indicates the presence of sedimentation basins formed by the sedimentation of deposits marine clastics deposited as a result of the Kibaran Mountain building movement more than 1 million years ago. A year later, a mountain-building movement in the Hijaz led to the emergence of sitting areas in the region Iraq" (Al-Sayyab, 1982: 146). The period of deposition ended with the movement of mountain building in Najd more than 600 million years ago which caused the formation of cracks in a northwest-southeast direction (Al-Jumaily, 1990: 21).

2. Paleozoic Era 375 million years ago:

The Paleozoic era includes the Cambrian, Ordovician, Silurian, Devonian, Carboniferous, Permian periods. During this period, important tectonic movements occurred, such as Caledonian and Hercynian (Al-Mael, 1996: 17). The development of the geography of Iraq is characterized by this period is very complicated due to the lack of information about the sediments of the Cambrian-Permian rocks.

According to the information available in the neighboring countries of Saudi Arabia and Syria, the source of the crumbs and rocks In the Iraqi basin is of a crumbly type. Some of them are watery, riverine, and some are marine. These areas aggregate rocks of terrestrial origin at the end of the Cambrian and up to Silurian due to an uplift in the region. During this period, there were many movements of progress and receding of the sea, and at the end of the Devonian, A new marine progress occurred, which led to a rapid settlement in the basin. Many sedimentary gaps have characterized the Carboniferous period due to the Hercynian movement (Al-Sayyab, 1982: 146 - 149). In the Late Permian, the Tethys Sea covered most of the land of Iraq. Because of the presence of an island, the Arabs, which were part of the Gondwanaland continent, affected the earth's movements in the less solid parts as for the solid parts near the Arabian Peninsula. They were not affected by these movements (Al-Sammak, 1985: 19).

3. Mesozoic (Triassic - Jurassic – Cretaceous) Era 160 million years ago:

"This era witnessed important geological and tectonic events that affected Iraq in general and the Western Plateau in particular, as it witnessed a wide opening to the sea due to the movement of the Iranian Plate and Turkey to the north away from the Arabian Plate. It collided with the blocks of the northern continent and that on the impact of the Early and Late Cambrian movement, and this resulted in a tectonic effect on large parts of the Iraq" (Al-Shu'aa, 1986: 26). By the end of the cycle, the basin became less active, which stimulated a gathering earth crumb, and the sea moved ahead again. In the Middle Jurassic, a sudden change occurred as the sea continued to advance with the advent of sediments with shallow environments that replaced tidal and lagoon environments and overlapped these calcareous environments sandy environments. This period ended with a comprehensive marine retreat (Al-Sayyab, 1982: 152-154).

The Cretaceous period witnessed the formation of the first Alpine geosynclinal basin in Iraq. The Cretaceous limestone formations, which form the Iraq basin's upper outer edges, are considered the oldest sedimentary formations and sit on other formations. During that period, the sea moved ahead again towards the north and included large areas of the Middle East, including Iraq, and the sea began to recede gradually at the end of this cycle (Sharif, 1962: 8-9). Al Hartha formations were deposited during that period.

4. Tertiary Era Paleogene - Neogene 35 million years ago:

"It is one of the most important and influential geological periods in the study area. During this period, the first phase of the Alpine movement occurred, which affected the stable sidewalk. In the Paleocene era, the sea moved ahead, and sedimentation continued without interruption despite the occurrence of introverted movement in parts of the eugiosyncline at the beginning of the Eocene" (Al-Sayyab, 1982: 166). In the middle Eocene, the sea advanced, which led to the deposition of limestone formations over the Cretaceous formations. In the Oligocene, the land conditions prevailed, and the erosion factors were more active than the sedimentation factors. Thus, the areas of the western parts remained high during that period (Fayyad, 2008: 6). In the Lower and Middle Miocene, the sea advanced and submerged the land of Iraq, which led to the formation of shallow and wide sedimentary basins, where the formation of the cavernous sedimentation and the formation of limestone were deposited (Fayyad, 2008: 6).

"In the middle Miocene, the conditions of the dry land prevailed, and gypsum, anhydrite, salt, limestone and sandstone formations were deposited in the backward swamps" (Sharif, 1962: 9). In the Upper Miocene and Pliocene, the second phase of the Alpine movement occurred, which had a significant influence in the Middle East. They caused the opening of the Red Sea and the Gulf of Aden, and the collision of the two plates (Turkish and Iranian components of the Taurus and Zagros mountains). As a result, the tectonic layers could not resist the intensity and pressure, so they cracked and fractured. There is the subsidence of a section of the earth's crust (Mail, 1999: 18).

5. Quaternary Period

The Quaternary period includes the last 2-3 million years passed on earth within. It is the era of modern life and the previous era in geological time units. The Quaternary period begins with the first glacial periods that followed the triple time on earth, so the stratigraphic limit can be set bottom at sediments that contain evidence of a significant decrease in the temperature of climates the world is called the Pleistocene era. During this period, the processes of water erosion were extraordinarily active. This caused the incision of a large number of valleys and depressions that appeared in the study area. Of great importance in hydrological studies, it is filled with coarse-grained river sediments composed of a mixture of river pebbles, sand grains, silt and clay, lime, flint, and dolomite transported by floods over great distances—water and wind sedimentation factors, which significantly contributed to drawing the picture of Iraq. The final geomorphology, the upper stratigraphic limit, begins with the end of the last glacial period and an increase in earth temperatures and extends to our days and is called the Holocene era (Shaker, 1989: 228-232).

1.1.2. Tectonic

The tectonics of the study area is affected by the tectonic history of Iraq. Many researchers developed numerous tectonic studies and divisions, which resulted in the division of Iraq into different tectonic zones in their characteristics. It is sandwiched between the two directions mentioned above so that the direction of the layers, in general, is affected by a northwestern, southeastern direction, which is as follows (Al-Obaidi, 2012: 25):

1. The Arab Nubian Plate, which is divided into stable and unstable plates.
2. Alpine regional basin is divided into regional volcanic concavity and unvolcanic regional concavity.

1.1.3. Geological Formations and Sediments

The geologic formations in the study area are characterized by similar characteristics in terms of the conditions of their features. Qualities date back to different geologic ages between the Miocene-Holocene (from the Tertiary to the deposits of the Quaternary). According to the oldest to the most recent (Abualainain, 1995: 160).

1.1.3.1. Theban-Sircachin Formation (Lower Miocene)

This formation is revealed in a narrow area that constitutes an area of 14.11 km^2 in the study area, which is 459.36 km^2. The rocks of this formation spread in scattered parts within the study area, and it consists of thick layers of gypsum intertwined with thin layers of limestone and clay, with a thickness ranging from 40-100 meters" (Elomary and Sadek, 1977: 117).

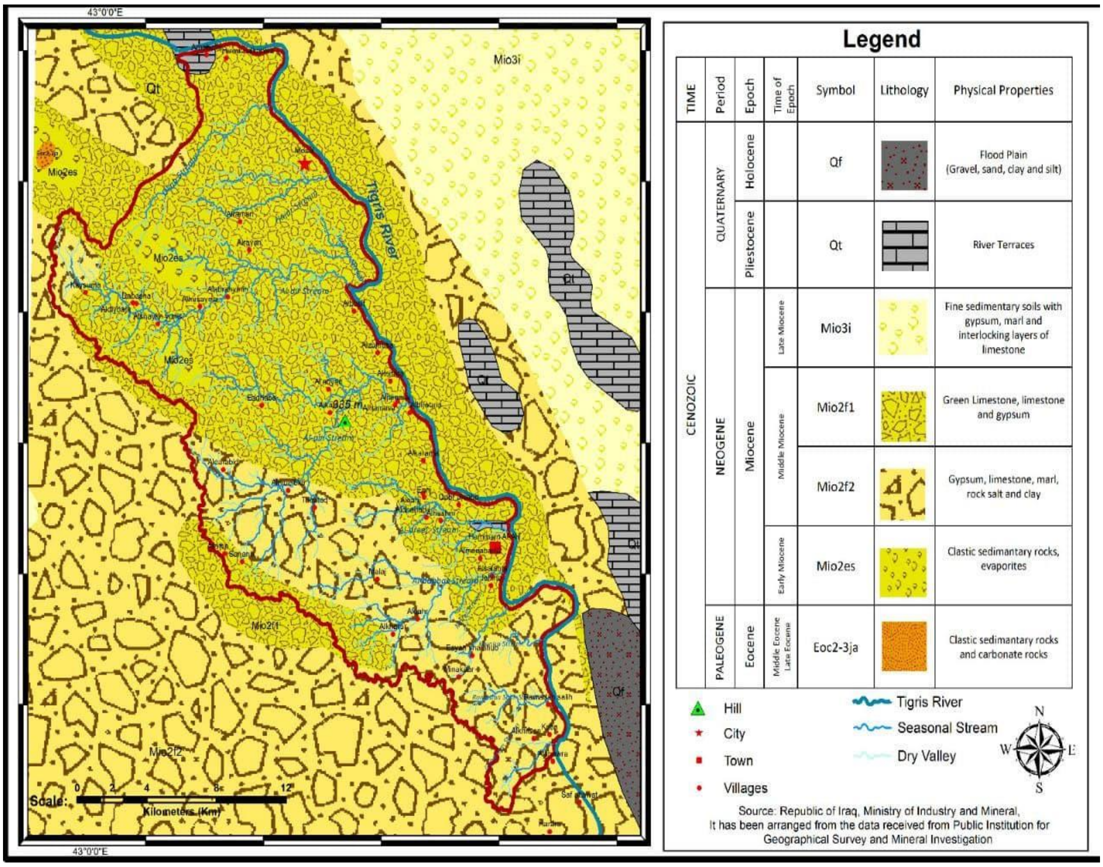
The Theban Formation is the formation of a water passage towards the subsurface formations due to many dissolution channels in the gypsum formations, which reduces the number of water deposits above its surface. The Sirkanki Formation unfolds in a narrow range within the study area, and its thickness is 300 meters (Almaadedee, 2017: 18). The rocks are composed of a stratigraphic succession of limestone, which is solid and helps form water flows on its surface.

1.1.3.2. Orifice Formation (Middle Miocene)

This part occupies approximately 166.13 km^2 of the area and consists of a periodic succession of hydrated gypsum rocks ($CaSO_4$. H_2O). Hydrated gypsum ($CaSO_4.H_2O$) and limestone ($CaCO_3$), marl, rock salt, and clays within successive sedimentation cycles (Elomary and Bahho, 2000: 4). This formation covers the Al-Mishraq Fold, the convex Hammam Al-Alil Fold, and the concave Hammam Al-Alil Fold. It occupies an area of 308.95 km^2 and makes a boundary between the lower and the upper members of two formations in the study area. This formation is characterized by its rapid response to geomorphological processes in all their manifestations and forms, especially chemical weathering, which helped form various manifestations such as caves and karst pits. It had a clear impact on forming the characteristics of the terrestrial appearance in the study area (Alomary, 1993: 377).

1.1.3.3. River Deposits

"These deposits which cover 14.51 km^2 of the area of the study area date back to the Pleistocene and Holocene periods of the Quaternary era" (Alani, 2018: 19). Other sediments that appear in the study area, such as river terraces' deposits, consist of a mixture of gravel of varying morphological and quantitative characteristics with particles of sand, clay, and silt. These sediments are located in the north of the area under study, as shown in Map 2.



MAP 2. Geology Map of the Study Area

1.2. CLIMATE

The distribution and duration of external factors and processes operating on Earth are under the control of climate (Türkeş, 2010: 4). "Climate is one of the most influential factors in hydrological and geomorphological studies. The relationship between climatology and hydrology is close. If hydrology is developing as an independent science, its attachment to climatology is inseparable. Land water is the visible and tangible form on the earth's surface. Atmospheric water is the source of terrestrial water" (Musa, 1982: 73).

The effect of climate on the histomorphometric characteristics of the water basins is a direct reflection of it. Its indirect effect appears through its control over vegetation in terms of quality, density, distribution, soil, and the extent of its response to geomorphological processes (Altameme, 2016: 30).

The impact of climate is also highlighted through its influence on the determination of the groundwater presence, amount, and levels in time and space. An increase in the amount of rain mainly and a decrease in the amount of evaporation leads to an increase in the amount of groundwater and a rise in its levels. In contrast, an increase in temperature, evaporation, solar radiation, and lack of rain leads to a decrease in underground storage. The climatic elements of the Mosul Station were studied according to the years of observation, which is the closest station that has data available about the study area, and the results are as follows:

1.2.1. Temperature

It is the primary source of energy. It is the engine linking other climate elements such as evaporation, precipitation, moisture, and wind movement, through its influence as a geomorphological factor on the course of geomorphological processes such as physical and chemical weathering (Sanawi, 1979: 589). Mosul Meteorology Station records were taken as a basis for the climate data in the study area. According to 38 years of records between 1980 and 2018, the following information was obtained.

The following results have been achieved by analyzing the climatic data for maximum and minimum temperatures. The month of July recorded the highest maximum average temperature at 42.9°C, and in January also recorded the lowest maximum average temperature at 12°C as shown in Table 1 and Figure 1, as well as in Map 3.

Table 1. Mosul Station Monthly Maximum Temperature Averages (°C) (1980-2018)

Winter				Spring			Summer			Autumn			
Months	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Annual rate**
Mean max. temp	13.8	12	14.2	19.3	25.9	32.6	39.2	42.9	42.3	37.6	29.7	20	27.4
Total	40			77.8			124.4			87.3			83.3
The average	13.3			25.9			41.4			29.1			27.4

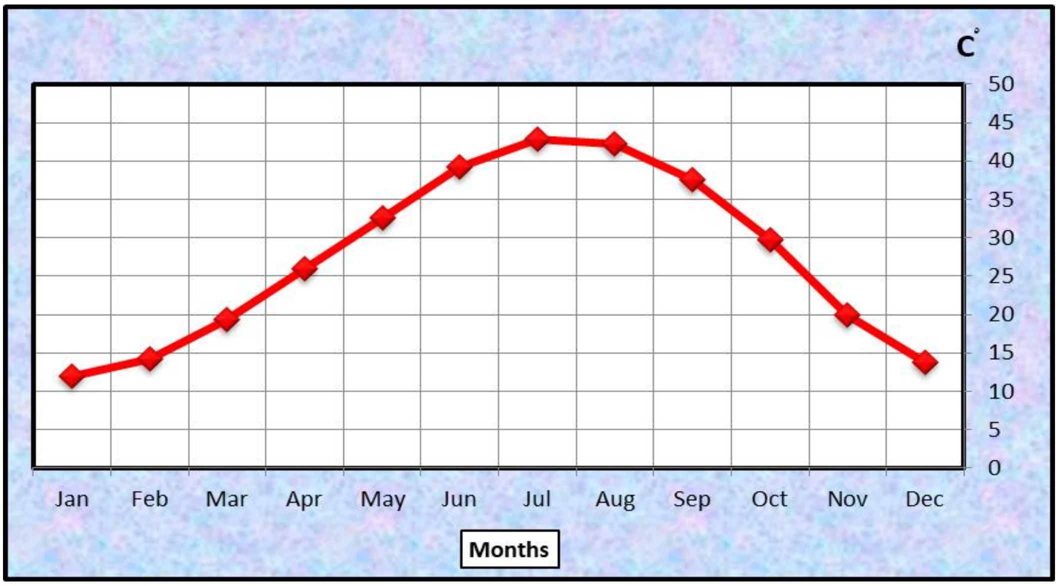


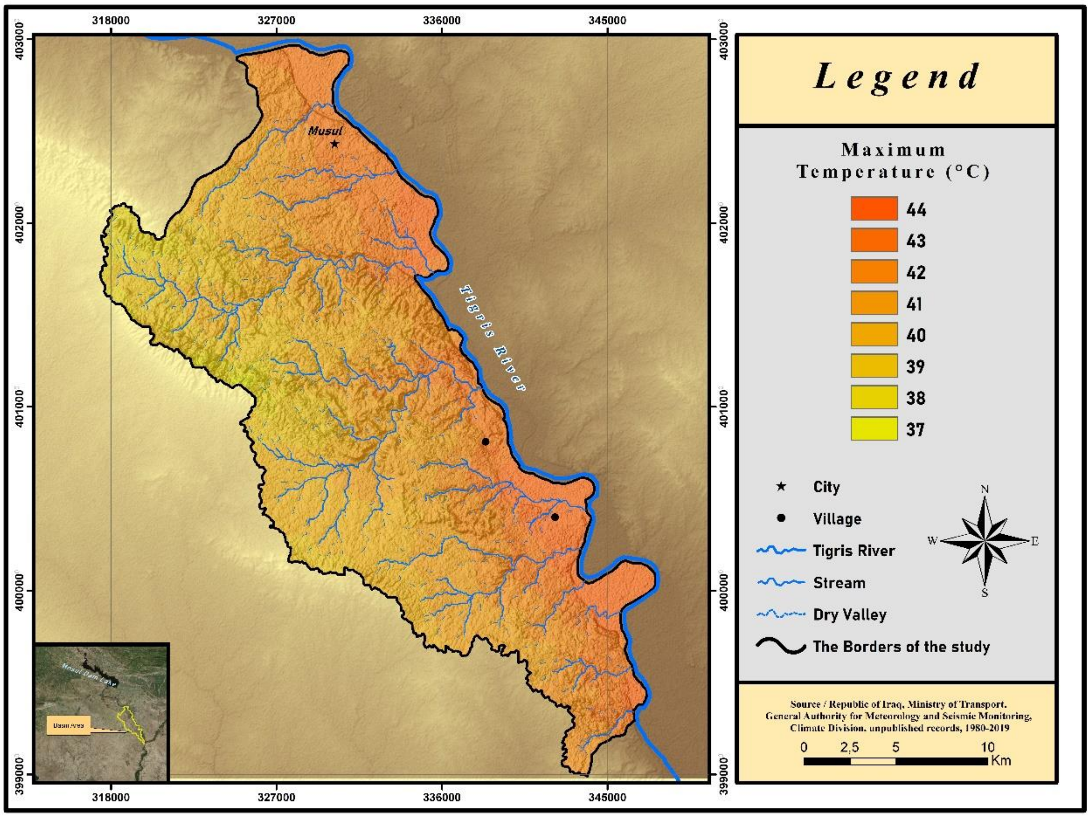
Figure 1. Monthly Averages of Maximum Temperatures (°C) for the Mosul Station for the Years of Observation (1980-2018)

Table 2. Mosul Station Monthly Minimum Temperature Averages (°C) (1980-2018)

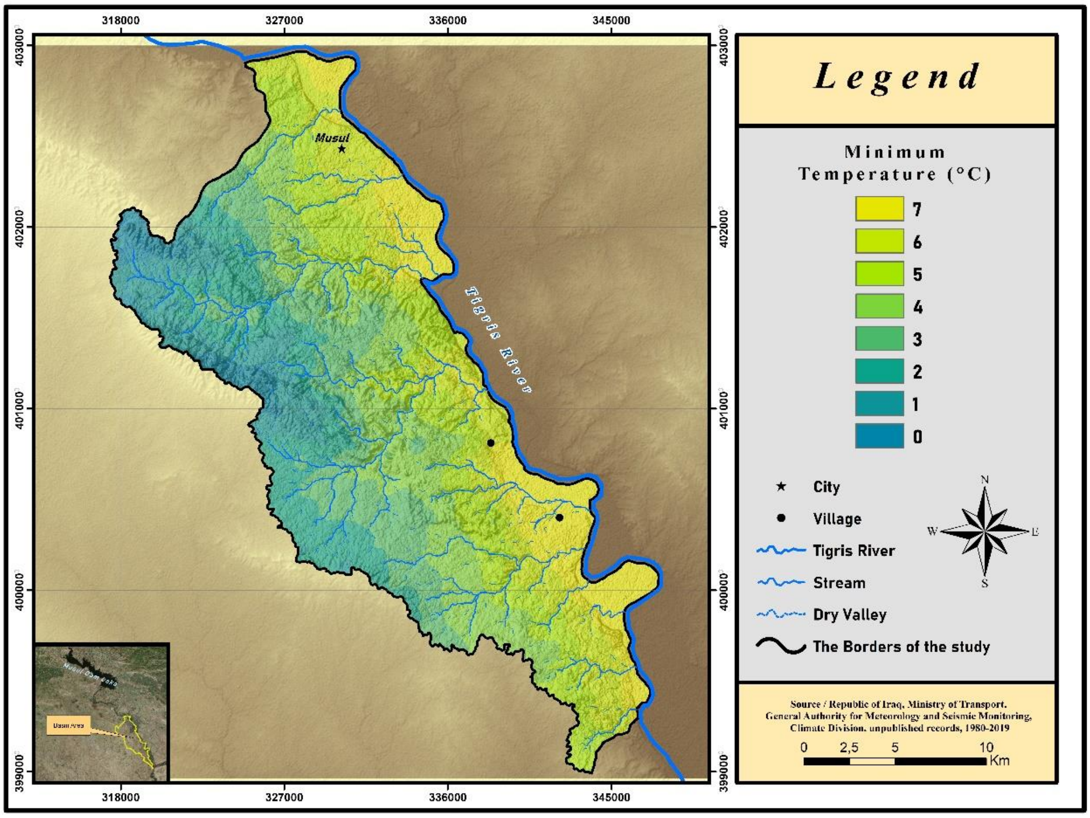
	Winter			Spring			Summer			Autumn			
Months	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Annual rate**
Mean min. temp (°C)	3.5	1.5	2.4	6	11.3	17	22.5	26.5	26.4	22.2	16.3	8.5	13.6
Total	7.4			34.3			75.4			47			41
The average	2.4			11.4			25.1			15.6			13.6

As for the minimum average temperature, the highest minimum average temperature was recorded as 26.5°C in July. The lowest minimum average temperature was recorded as 1.5°C in January, as shown in Table 2 and Figure 2 as in Map 4.

Figure 2. Monthly Averages of Minimum Temperatures (°C) for the Mosul Station for the Years of Observation (1980-2018)



MAP 3. Maximum Temperature Map of the Study Area



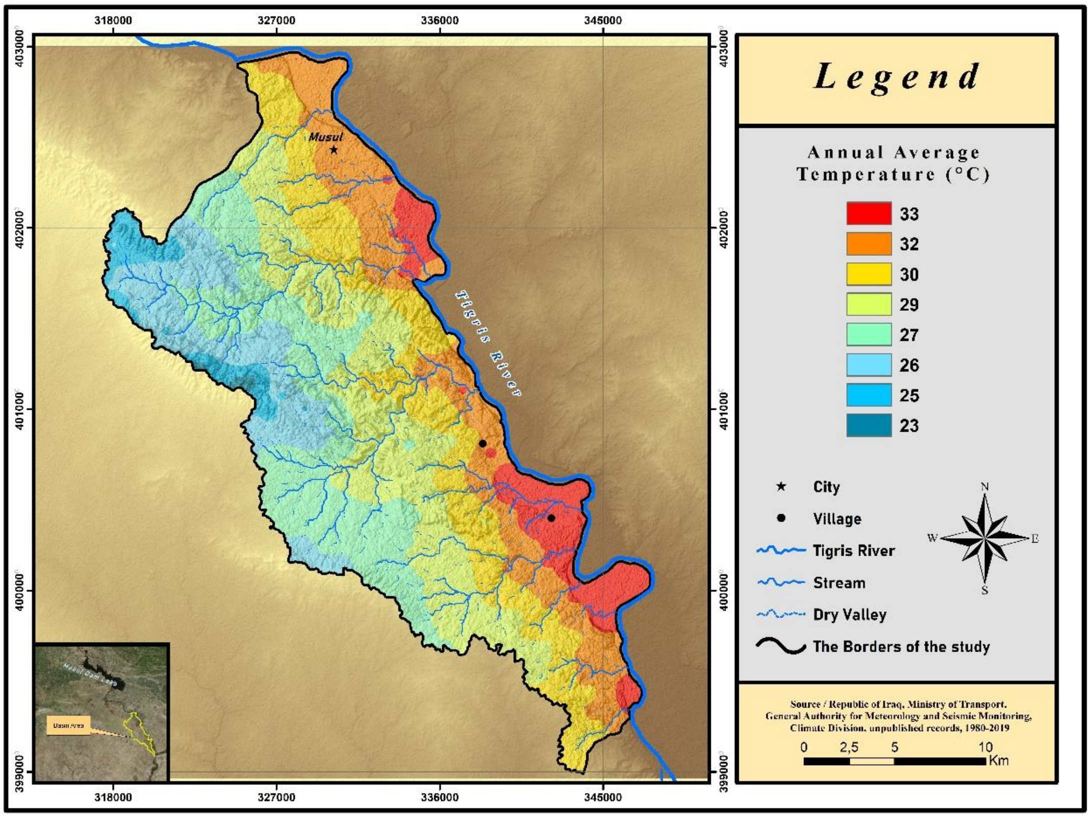
MAP 4. Minimum Temperature Map of the Study Area

The monthly average temperature value is high in the region. The highest monthly average temperature is 16.7°C in June, and the lowest monthly average temperature is 10.3°C in December, as shown in Table 3, Figure 3, Map 5. This difference in temperatures leads to a significant variation of the impact in activating the physical weathering processes of the rocks. Cover varies in their mineral and natural properties; the consequent changes in the rocks and the soil become a sedimentary load for surface water later.

Table 3. Mosul Station Monthly Temperature Range Averages (°C) (1980-2018)

Winter				**Spring**			**Summer**			**Autumn**			
Months	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Annual rate**
Mean temp. (°C)	10.3	10.5	11.8	13.3	14.6	15.6	16.7	16.4	15.9	15.4	13.4	11.5	13.7
Total	32.6			43.5			49			40.3			41.3
The average	10.8			14.5			16.3			13.4			13.7

Figure 3. The Monthly Averages of the Temperature Range (°C) for the Mosul Station According to the Years of Observation (1980-2018)



MAP 5. Annual Average Temperature Map of the Study Area

1.2.2. Relative Humidity

"It is defined as the percentage between the amount of water vapor present in the air under a certain temperature and the maximum that the air can absorb water vapor at the same temperature. The relationship between temperature and humidity is inverse, as it rises with a decrease in temperature and decreases with height (provided the pressure remains constant)" (Krbill and Weli, 1978: 111). The role of humidity is highlighted by its effect on the activity of the processes of weathering and erosion, and it also affects the climatic balance in water basins. High humidity is a positive factor in the availability of surface water because condensation depends mainly on the amount of relative humidity, and it also affects water loss by evaporation.

From the analysis of the climate data related to humidity in Table 4 and Figure 4, it is seen that the highest monthly relative humidity is recorded in January in winter with 64.7%. Meanwhile, it was concluded that high relative humidity with the cold season reduces evaporation to the lowest levels and increases the chances of providing surface water runoff to seasonal streams and improving hydrological characteristics. Relative humidity, which decreases due to the increase in evaporation rate and increases in temperatures in the dry summer season, is at its lowest level in July with 15.7%.

Table 4. Monthly Averages of Relative Humidity (%) for Mosul Station According to the Years of Monitoring (1980-2018)

Winter				**Spring**			**Summer**			**Autumn**			
Months	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Annual rate**
Relative humidity	62.9	64.7	60.9	54.7	47.2	35.7	19.7	15.7	16.3	18.6	32.2	51.5	40
Total	188.5			137.6			51.7			102.3			120
The average	62.8			45.8			17.2			34.1			40

Figure 4. Monthly Averages of Relative Humidity (%) for Mosul Station According to the Years of Monitoring (1981-2018)

1.2.3. Rain

"Climate is the most important factor affecting the water system of any region, especially arid and semi-arid regions, and is the main source of water in the study area. Its forms and characteristics change from one season to another. The amount of rain that falls in different seasons is a reflection of one of these characteristics" (Abualainain, 1996: 37). Fluctuations of rainfall are affected by the rock weakness areas, vegetation cover, evaporation, groundwater recharge, soil types, and rock quality.

Excessive precipitation and lack of evaporation raise the groundwater level due to infiltration, and the soil becomes saturated with water. Stream drainage is strengthened by the emergence of runoff (Salama, 1985: 34).

The study area is characterized by seasonal rainfall. The period of rain begins in November and extends until May. This is due to the fact that the region falls within the Mediterranean climate, where the humid rainy period is limited between autumn and spring, while dry periods appear in which there is no rain during the summer (Jressi, 2012: 41).

It is clear through the analysis of the climatic data of the Mosul Station for the period from 1980-2018 that the annual precipitation rate has reached 267.2 mm (Table 5**,** Figure 5 and Map 6). The most significant part of the annual precipitation falls in the winter months (December, January, February), determined as 114.2 mm. The second highest precipitation period is the 94.4 mm precipitation amount represented by the spring months March, April, and May. In the study area, the precipitation amount in autumn appears to be 52.3 mm, while almost no precipitation (only 6.3 mm) falls in the summer season. the month with the highest rainfall in the whole year is March of the autumn season, with a total value of 40.6 mm.

Table 5. Monthly Averages of Rainfall Amount (mm) for Mosul Station According to the Years of Monitoring (1980-2018)

Winter				**Spring**			**Summer**			**Autumn**			
Months	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Annual rate**
Rainfall (mm)	38.4	38.6	37.2	40.6	34.5	19.3	3.9	1.4	1	1.7	17.7	32.9	22.2
Total	114.2			94.4			6.3			52.3			66.8
	267.2												
The average	38			31.4			2.1			17.4			22.2

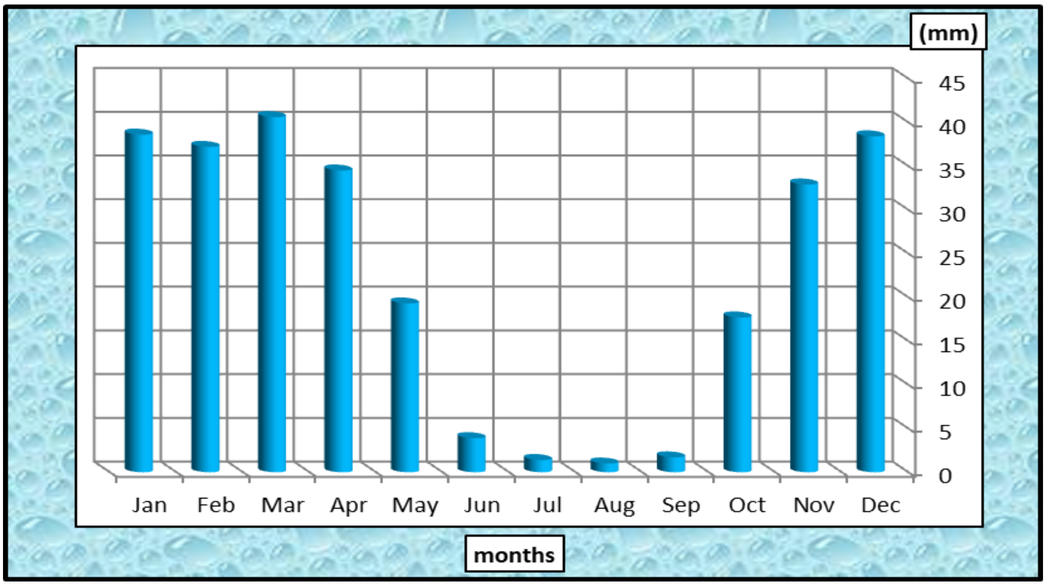
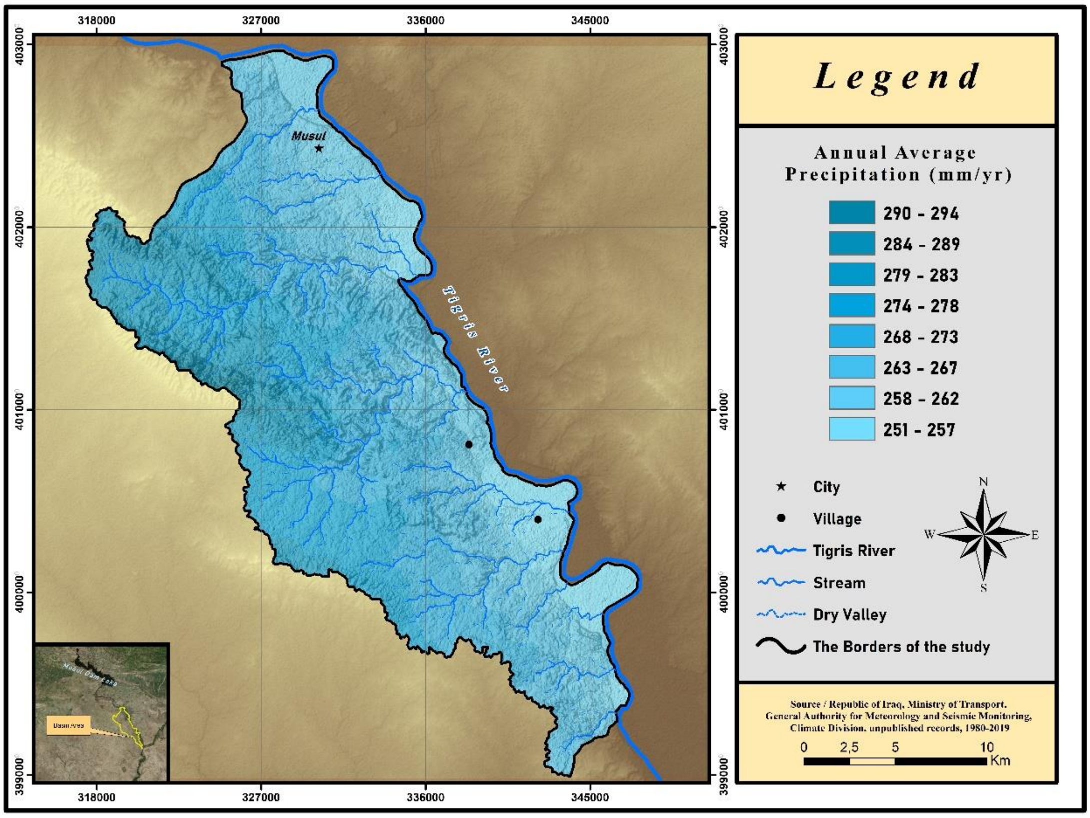


Figure 5. Monthly Averages of Rainfall Amount (mm) for Mosul Station According to The Years of Monitoring (1980-2018)



MAP 6. Annual Average Precipitation Map of the Study Area

This activates the geomorphological processes of physical and chemical weathering and water erosion from the rainy season, while the geomorphological action of winds is intense in the dry summer. The phenomenon of surface run-off directly impacts drawing the features of the watercourses. It causes new pathways which are constantly being created due to erosion processes in the weak areas represented by the cracks and breaks in the surfaces of the convex folds and some areas of the fragile rocky parts. And this situation results in a change in the properties of the ground view of the study area.

In order to find out the adequacy of the rainfall and the drought coefficient in the study area, the Thornthwaite equation was applied to adequate rain over the study area station. It was found that the climate of the study area is characterized by semi-arid. This is evident in the results of the equation 17.02 mm in Tables 6, 7, 8, and Figure 6.

Thornthwaite equation:

$$E_{121.65}(\frac{R}{T+12.2})^{\frac{10}{9}}$$

Table 6. Thornthwaite Equation Results

Total annually rain (mm)	Annual average temperature (°C)	Rain adequacy (mm)	Climate type
267.2	20.5	17.02	Semi dry

Table 7. Thornthwaite Water Balance Table of Anah Station

Thornthwaite Water Balance Table of Anah Station													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Monthly average temperature	10.5	11.8	13.3	14.6	15.6	16.7	16.4	15.9	15.4	13.4	11.5	10.3	13.78
Temperature indice	3.07	3.67	4.4	5.07	5.6	6.21	6.04	5.76	5.49	4.45	3.53	2.99	56.28
Uncorrected	37.75	44.33	52.27	59.43	65.11	71.51	69.75	66.84	63.96	52.81	42.79	36.77	
PET Correction coefficient	0.87	0.85	1.03	1.09	1.21	1.21	1.23	1.16	1.03	0.97	0.86	0.85	
Corrected PET	32.84	37.68	53.84	64.78	78.78	86.53	85.79	77.53	65.88	51.23	36.8	31.25	702.93
Monthly total precipitation	38.6	37.2	40.6	34.5	19.3	3.9	1.4	1	1.7	17.7	32.9	38.4	267.2
Water storage change	5.76	-0.48	-12.43	0	0	0	0	0	0	0	0	7.15	
Water storage	12.91	12.43	0	0	0	0	0	0	0	0	0	7.15	
Actual evapotranspiration	32.84	37.860	53.03	34.5	19.3	3.9	1.4	1	1.7	17.7	32.9	31.25	267.2
Water deficiency	0	0	0.81	30.28	59.48	82.63	84.39	76.53	64.18	33.53	3.9	0	435.73
Water surplus	0	0	0	0	0	0	0	0	0	0	0	0	0
Runoff	0	0	0	0	0	0	0	0	0	0	0	0	0
Humidity	0.18	-0.01	-0.25	-0.47	-0.76	-0.95	-0.98	-0.99	-0.97	-0.65	-0.11	0.23	

Table 8. Thornthwaite Climate Type Interpretation of the Anah Station

Thornthwaite Climate Type Interpretation of the Anah Station			
	Symbol	Explanation	Indices
Precipitation efficiency indice	D	Arid (Desert)	-37.19
Temperature efficiency indice	B"1	Megathermal (Climates with high temperatures)	702.93
Humidity & drought indice	D	Little or no water surplus	0
Ratio of PET three summer months	A"	Nautical effect	35.54

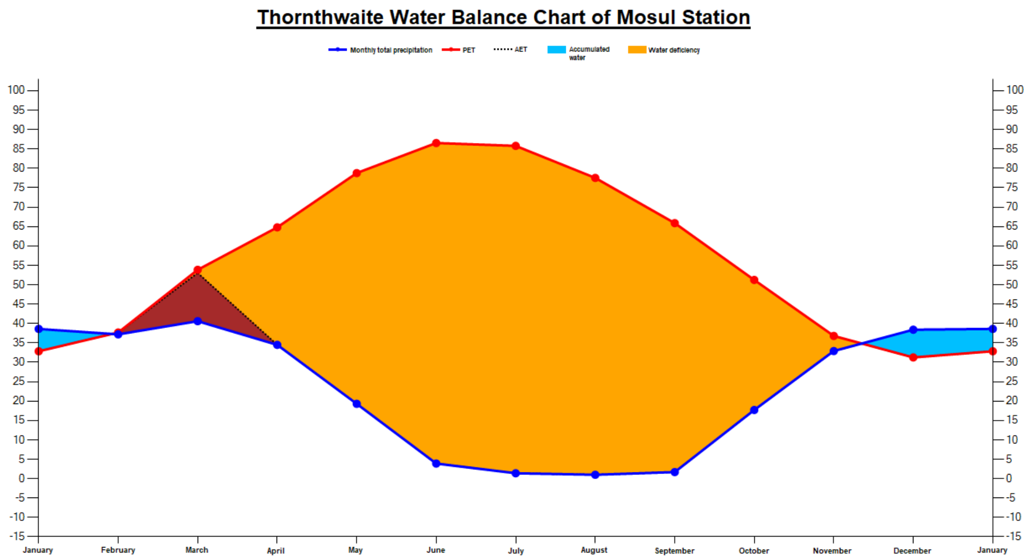


Figure 6. Thornthwaite Water Balance Chart of Mosul Station

1.2.4. Winds

"The importance of the wind element, which is known as the horizontal movement of air parallel to the surface of the earth, is highlighted" (Alrawi and Albayati, 1990: 125). Through its indirect effect on the surface runoff, the high-speed and descending winds are more capable of carrying water vapor, and at a certain temperature and wind speed, and when they reach the saturation stage, then the evaporation turns into the rain because it is unable to carry an additional amount. The effectiveness of aquatic erosion and sedimentation increases due to several factors (Alturaihi, 1985: 313). Winds directly affect the temperature distribution by transporting the air from one place to another (Yazıcı, 2019a: 152). Low general rates characterize the winds in the study area, and this is because the region is under the influence of high pressure in winter and low in summer. Climatic data indicate a discrepancy in the general distribution of wind speed in time and space, which is the result of the variation or seasonal thermal disparity and the surface of the study area.

It is evident from Table 9 that the average annual wind speed in the region was 2.8 m/s, as its speed drops in winter 2.4 m/s, while it rises in summer 3.3 m/s. The lowest rate of its speed was recorded in December at 2.4 m/s, while the average reached its maximum in June and July at 3.4 m/s.

The summer season increases evaporation energy and affects the surface layer of the soil by causing its dehydration and disintegration and accelerates to carry on surface materials. Wind speed decreases due to the low temperatures and the high atmospheric pressure in winter, especially in January (Aljayzani, 2010: 33).

According to this, it is seen that the wind geomorphological process is higher in summer and decreases in winter, as seen in Figure 7.

Table 9. Monthly Averages of Wind Speed m/s for Mosul Station According to the Years of Monitoring (1980-2018)

Winter				**Spring**			**Summer**			**Autumn**			
Months	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Annual rate**
Wind speed	2.4	2.5	2.5	2.6	2.7	3	3.4	3.4	3.3	3	2.8	2.5	2.8
Total	7.4			8.3			10.1			8.3			8.5
The average	2.4			2.7			3.3			2.7			2.7

Figure 7. Monthly Averages of Wind Speed (m/s) for the Mosul Station According to the Years of Monitoring (1980-2018)

1.2.5. Evaporation

"Evaporation is one of the basic elements of the water cycle and is affected by a range of climatic, terrestrial, and plant factors. It includes the first of them (solar radiation, heat, wind, and humidity), and the second (soil moisture, its ability to conduct water, its color and precipitation intensity)" (Alrawi and Alsamirrae, 1990: 114). Its direct effect on surface runoff highlights the impact of evaporation on hydroforming processes. As the amount of groundwater and surface running water is reduced, the relationship is inverse between them. The greater the evaporation, the less the amount of water discharge because of the increase in water losses and vice versa. The density of drainages increases, which is reflected in the development of the river network (Shahatha, 1988: 27).

"If evaporation is the process of converting water vapor from a liquid state to a gaseous state, evaporation is directly related to temperature, so the higher the temperature, the greater the value of evaporation" (Alkhalaf, 1980: 2). By reading the climatic data in Table 10 for the Mosul station from the year 1980-2018 and following them, it was found that the rate of evaporation increased in some months, especially the months characterized by high temperatures, while the rate of evaporation decreased in the months with low temperatures.

Table 10. Monthly Averages of Evaporation for Mosul Station According to the Years of Monitoring (1980-2018)

	Winter			**Spring**			**Summer**			**Autumn**			
Months	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Annual rate**
Evaporation	29.1	30.5	46.7	86.7	132.4	236.1	330.1	373.7	331.8	242.1	143.1	61.4	170.3
Total	106.3			455.2			1035.6			446.6			510.9
The average	35.4			151.7			345.2			148.8			170.3

The highest value of evaporation was recorded in July, which amounted to 373.7 mm, while the lowest value of evaporation was recorded in December, which amounted to 29.1 mm Figure 8.

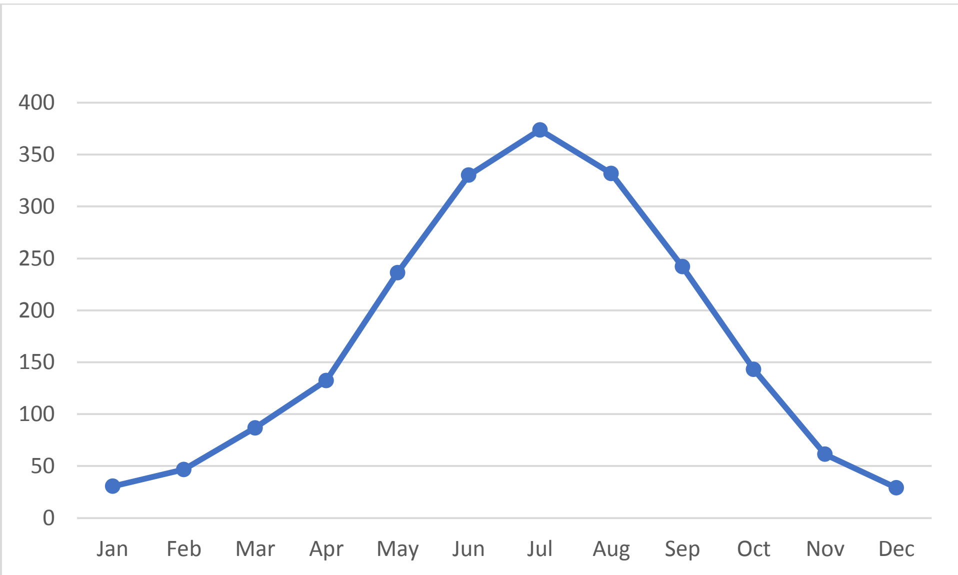


Figure 8. Monthly Rates of Evaporation for Mosul Station According to the Years of Monitoring (1980-2018)

1.3. NATIVE VEGETATION

"They are plants that grow with stimulation from the environment and climate without human intervention in their cultivation or irrigation. On the contrary, it is not considered a natural plant, but rather cultivated. In other words, the natural plant is formed in dry and semi-arid environments in direct response to a group of factors (climate - soil - terrain - time)" (Faid, 2020: 290). Despite the lack of vegetation cover, its spot, its spacing, and the low productivity of its organic matter, it compensates for this by the multiplicity of its types in different shapes, sizes, and construction, as it was able, through several physiological, behavioral and formal adaptations, to coexist with the dry and harsh conditions of the climate through the exploitation of the most elements of water scarcity, heavy rain, and dew The accumulated, no matter how small its quantity, is rare (Salama, 2010: 138).

The vegetation cover affects the hydro geomorphological processes directly and indirectly. When the raindrops fall, the vegetative group reduces the speed and intensity of their collision with the soil surface, protects it from disintegration, and regulates water flow by reducing its speed. The plant's roots depend on the cohesion of the soil and the cohesion of its granules, thus protecting it from the processes of water and wind erosion (Bahri, 1997: 95-96). The study area has many natural plants covering the area, primarily weeds, herbs, blink plants, weeds, and thorny plants such as carob and sedge, sometimes classified as trees and shrubs. These plants are graduating on the banks that are not exploited for agriculture (Alnish, 1999: 136).

There are also annual natural plants that are associated with the rainy season and have an influential role in reducing the amount of surface water runoff by impeding and slowing the flow rate to provide an opportunity and sufficient time for penetration into the soil. Examples include heels, chamomile, baker's, harem, and steppe grasses, and some of them are used in folk medical treatments, and a large part of these plants are used for grazing (Aljanabi and Galib, 1992: 155). There is a group of spiny plants that we referred to, which adapted themselves to dry climatic conditions (perennial) through deep roots and pointed leaves covered with a waxy layer, such as wormwood, akool, sidr, belladonna, and khila, a significant role in the development of karst, especially the melting spaces.

1.4. SOIL

"There are several definitions of the concept of soil, but it is collected as fragments of rocks covering the surface of the earth with varying depths, from centimeters to several meters, on which plants grow and on which humans and animals live together" (Albarazi, 1981: 7). And others known as a natural formation in constant evolution, nature made by physical and chemical processes of life and between the lithosphere and the gaseous atmosphere and the field of life of the plant, animal and knows the science that studied the science of soil (Sharif and Alshalash, 1985: 7). By checking the types of soils according to the classification of FAO, as in Map 7, it was found that the two types of soils are flood soils and dry gypsum soils.

1.4.1. Fluvisols

It forms one of the two soil types available in the study area. "Fluvisols typically are young soils in alluvial, deltaic, lacustrine, or marine deposits, and occur all over the world. These soils have fluvic soil material starting within 25 cm from the soil surface and continuing to a depth of at least 50 cm from the surface" (URL-1). These soils cover the parts of the study area of 184.3 km^2 close to the banks of the Tigris River and cover the lower parts of all 11 studied river basins. The Tigris River, which borders the study area from the northeast and east and forms the main river into which 11 streams flown, is one of the largest rivers in the world. Fluvisol soils are also common around major rivers.

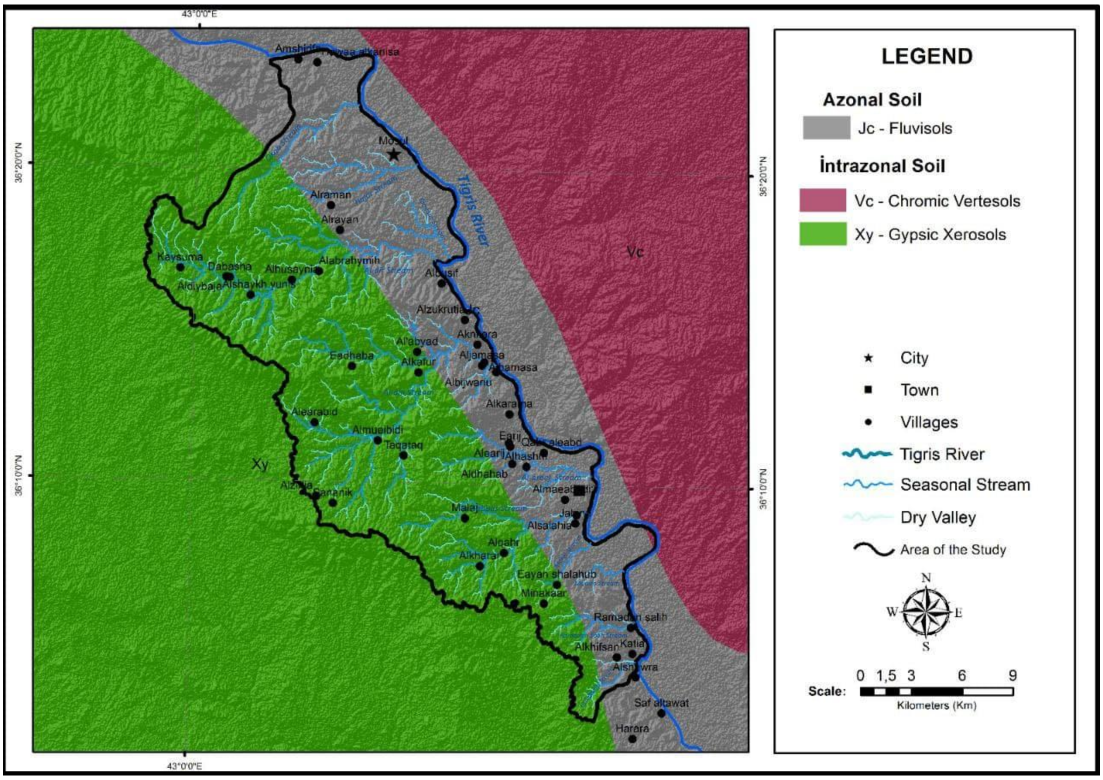
Fluvisols (fluvient) are an alluvial soil type. "Alluvial soils from the Azonal soils class, USDA new soil classification system, it is named as Flüvisol" (Akkurt Gümüş, 2020: 115). According to Mater (2004), a distinct diagnostic horizon and their profile morphology is not very developed. In addition, it is often saturated with water. It is observed that many materials are deposited in the immediate vicinity due to the floods seen in the rivers one after the other.

According to Gerrard (1993), homogenization in the fluvisol profile is expressed in a disturbance of the sedimentary layering under the influence of the biological activity of vegetation roots, animals, and microorganisms. These soils are genetically young soils. "The magnetic properties of fluvisols are conditioned first by the lithogenic contribution from the alluvial/delluvial deposits (the parent material) and, second, by the duration of the pedogenesis" (Jordanova, 2017: 327).

1.4.2. Xerosols

Xerolsols form a soil type seen in climates dominated by arid and semi-arid properties. These can become very fertile soils. However, it is very difficult to cultivate on these lands due to the lack of precipitation and lack of precipitation. With irrigation, xerosols can be classified among the best soils Contains the study area (274.6 km^2) (Bouwman, 1989). Soils of arid climates, known as aridisol in the American classification, are classified as xerosols in the FAO classification. These soils, like brown soils, contain little organic matter (1-2%). A calcic horizon is always present, forming a hard crust, usually as in reddish chestnut soils. This crust often contains gypsum along with carbonate (Duchaufour, 1982).

Xerosol soils are spread throughout the upper and middle basins of 11 river basins that make up the study area. In the region covered by these soils, the degree of slope generally does not show significant values, but they are highly fragmented by flood cut-offs. These soils, which constitute the largest group common in the study area and are very weak in terms of organic matter, are therefore covered with weak vegetation. However, there are deep cracks along the upper and middle basins on these soils.



MAP 7. Soil Map of the Study Area

(Source: Based on the FAO classification)

1.5. HYDROGRAPHY

Water in the study area varies depending on its characteristics. There are surface water and groundwater with meteoric origin in the study area.

1.5.1. Surface Water

The Tigris River represents the surface waters from the east. It forms the eastern borders of the area under study, with the presence of a group of networks of seasonal valleys flowing, the number of which is 11 basins and with different sloping directions, some of which descend from the northwest towards the southeast, and we will explain them in detail in the second chapter.

1.5.2. Groundwater

A source containing precise information about the groundwater in the study area could not be reached. However, some determinations were made based on field studies. It is found in the form of springs, the most prominent of which are the karst springs located within the Fatah formation, which emerge in the form of a rising drain, especially in the rainy season (winter-spring).

In addition, there are rift springs I represented by the Hammam Al-Alil sulfur spring represented by a group of springs (Ain Zahra one and Ain Zahra two) and (Ain Khasousa one - Ayn Khasusa two) In addition to the Mosul sulfur spring, which is located near the Republican Hospital on the right side of Mosul. These springs are characterized by higher metal content, which has been described as therapeutic and tourist areas within their presence.

2. HUMAN FACTORS IN THE STUDY AREA

The human influence has a significant role in the study area and investments in the ground appearance, which is represented in the diversity of its investments, as the area is located in parts and some neighborhoods on the right side represented (Aqab neighborhood - Al-Hajar neighborhood - Al-Tayaran neighborhood - Dandan neighborhood - Al-Ain neighborhood). And here it will be mentioned the largest of which is the village of Al-Areej as in Photograph 1 some of the houses in the village of Al-Areej.

Photograph 2 shows the agricultural, pastoral, and mining investments represented in the extraction of Mishraq sulfur located in the south of Mosul city (The northern side of the country).

PHOTOGRAPH 1. A View from Areej Village

PHOTOGRAPH 2. Sulfur Plant in Mishraq

With the oil fields and mining mines represented by the extraction of gravel, sand (building materials), and stones to feed the Hammam Al-Alil Cement Factory, which is also located in the south of the city of Mosul (in the north of the country), as shown in Photograph 3, which was established in 1977 and production began in 1979. The executing company was a French company.

PHOTOGRAPH 3. Hammam Al-Alil Cement Factory

CHAPTER TWO

2. THE PREVAILING GEOMORPHOLOGICAL PROCESSES AND THE RESULTING LANDFORMS

2.1. THE PREVAILING GEOMORPHOLOGICAL PROCESSES IN THE STUDY AREA

Geomorphological processes are the main factor affecting the appearance of the earth’s surface in the past and the present. These processes include the resulting changes, physical and chemical activities that have a role in developing the terrain, removing it, or re-forming it in different forms. For example; sedimentary rocks are a product and a result of the material cycle in the Earth’s crust (Erinç, 2012).

The processes prevalent in the study area are characterized by their diversity and interdependence to work singly, separately. It is the result of the combination of the factor, the process, and the time. It determines and clarifies the processes and manifestations resulting from them. These processes were classified in the basins of the study area into:

2.1.1. Morphological Processes

It means the processes that result from the impact of rocks on the elements of the climate, and it includes the processes of weathering of all kinds and erosion in its various forms, whether water or wind. These processes will be clarified as follows:

2.1.1.1. Weathering Process

It means the process of breaking and crushing rocks near the surface of the earth to achieve a kind of balance with the physical and chemical conditions that have arisen in the place (Mahsub, 2001: 49).

It is a simplified process of decomposition and disintegration of rocks in their original location without moving so that they are prepared for erosion and transportation. The rocks turn into small pieces, change their size and occur under appropriate humidity, temperature, and biological efficiency that prevails on the earth’s surface. The weathering process is an external process that is not related to the internal structure of the Earth’s interior (Alkashab, 1978: 66).

Weathering is divided into two types, physical and chemical weathering, which arose in the period of biological weathering by living organisms and plants, seen resulting from the action of roots and crushing of rocks. The physical and chemical weathering processes cannot be separated even though they do not work all the time. For example, when rocks are subjected to physical weathering, Cracks and joints occur, which helps in water penetration into the cracks and joints. Thus, the chemical weathering process and its activity occur.

2.1.1.1.1. Mechanical (Physical) Weathering

"It means the process of changing the properties of rocks without affecting the internal mineral composition. For the original rocks as they break down and turn into small rocky crumbs without any change for chemical composition, even if it is simple" (Karbel, 1986: 88).

This type is simple and does not contain interaction or the formation of new materials. Several factors lead to this type of weathering, such as freezing of water droplets inside the rocks, the effect of plants, and the extension of their roots or the effect of digging animals and thermal variation (expansion and contraction), rocks, and then the occurrence of weathering physics in many ways will lead to pressure on the rocks (Alkashab, 1978: 67), as shown in Photograph 4.

Although mechanical fragmentation occurs mainly in deserts, high parts of mountains, and Arctic regions where vegetation is very rare (Atalay, 2016: 159), it takes place, albeit to a lesser extent, almost everywhere except flatlands.

PHOTOGRAPH 4. Rocks Disintegration in the Athba Village due to Physical Weathering in Study Area

2.1.1.1.1.1. Thermal Variation (Expansion and Contraction)

This discrepancy occurs due to the difference in temperature and its decrease during the night and its rise during the day, which will expose the rocks to the processes of expansion and contraction. With the repetition of this process, the rocks are exposed to external exfoliation without a change in the internal properties. Because the rocks are poor conductors of heat, this variation will cause pressures on the rocks and lead to their breaking and separation in the form of rock crusts in thin sheets (Almusawe and Aburaheel, 2010: 160).

Since the study area is located within a desert climate and a high-temperature range, as it is devoid of vegetation cover, this will increase the occurrence of physical weathering. Cracks often arise, and the rock masses exfoliate in the form of fragments and rock chips extending parallel to the surface of the earth due to the expansion at the pressure was removed by the rock detectors that covered them and were subjected to the weathering process, as shown in the Photograph 5.

PHOTOGRAPH 5. Weathering by Thermal Contrast (Expansion and Contraction)

2.1.1.1.1.2. Freezing due to Frost

Freezing weathering is activated during the winter when temperatures drop below zero degrees Celsius, especially at night, which leads to the freezing of water inside the rocks in cracks and joints, which creates pressure on them that leads to the breaking of blocks as a result of an increase. Its volume is 9% of the original volume and generates a pressure equivalent to 125 kg/cm^2. This process is repeated successively, as the blocks will break down to a smaller size and separate from the original rock, facilitating the erosion process (Karbel, 1986: 64). As shown in Photograph 6, the occurrence of this process is small in the study area because it is characterized by a dry climate most of the time and does not occur on rainy days with high humidity and low temperatures. It is found in the upper parts of all the plateaus of the region Nokite (Nouquit), where they are found in limestone rocks due to outcrops and breaks.

PHOTOGRAPH 6. The Effect of Frost on the Rocks in the Upper Parts of the Nokite Plateau

2.1.1.1.2. Salt Weathering (Crystal Growth)

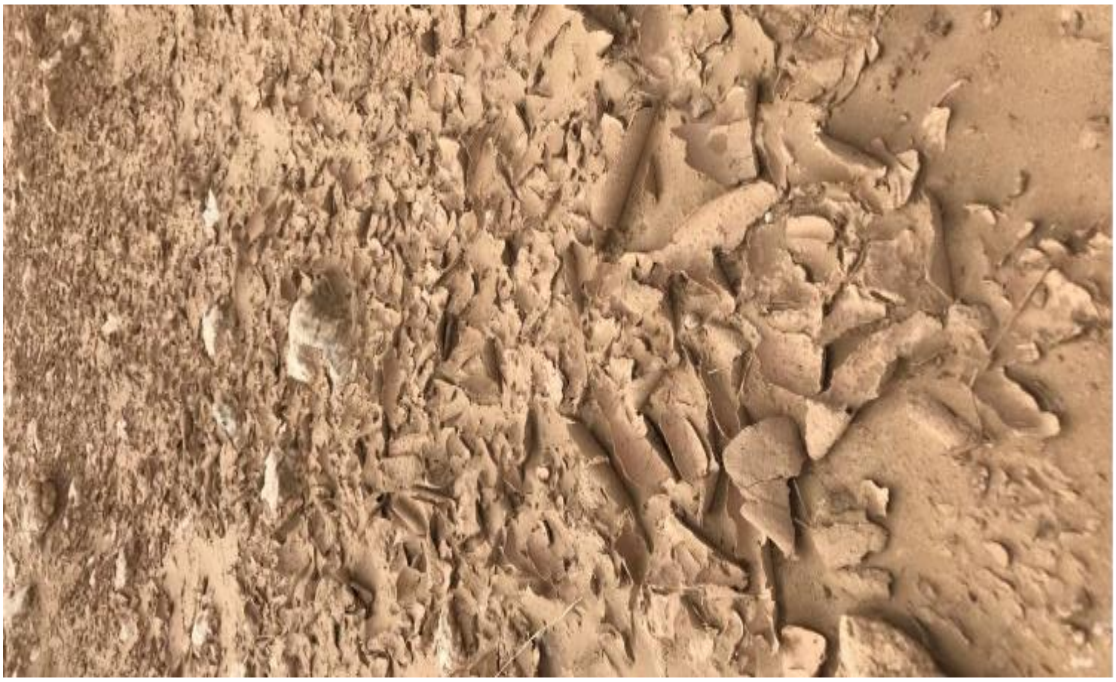
This species is active in dry and semi-arid areas in the area under study as a result of the growth of salt crystals as a result of the crystallization of dissolved salts in water when saline water is available, such as groundwater or irrigation water when it permeates the rocks, in addition to high temperatures and the presence of rocky materials or soil with high porosity. The lower rocky layers are saturated with alkaline water.

This leads to the activation of the capillary property and the rise of the water with its salts to the surface, and its exposure to evaporation and crystallization of the salts.

These crystals lead to the dissolution of rocks through the pressure they cause in the rock voids and pores, resulting in an increase in volume that exceeds what many minerals and rocks achieve when exposed to high temperatures such as limestone (Salama, 2004: 131).

2.1.1.1.2.1. Moisturizing and Drying

The desert land of the study area is a suitable environment for the occurrence of this type of weathering, as it is active through rainfall and the penetration of rainwater into the mud rocks and saturation with them, and the event of drought leads to swelling of the soil and then shrinking. The increase in salt in the clay leads to the convexity of the surface of the clay blocks located between these cracks. In contrast, the surface becomes concave with the increase in drying intensity. The cracks take an orthogonal pattern that varies in the degree of regularity (Salama, 2004: 133). This type is found in rocks and clay soils that belong to the formation of the opening and sediments of rivers shown in Photograph 7.



PHOTOGRAPH 7. Weathering by Wetting and Drying in the Okab Stream Basin

2.1.1.1.2.2 Biological Factors

"Biological factors are of less importance than the aforementioned factors in changing the land appearance of the study area, as living organisms sabotage the surface of the earth and their role is limited to demolition without building, wild animals dig their burrows, such as ants and rodents" (Amin, 2010: 52). The majority of the cultivation of the study area is characterized by the presence of wild herbs.

Lack of trees and plants are among the factors affecting soil decomposition. Plant roots have a weak effect in breaking up rock masses by widening cracks and joints. This leads to their expansion, which helps the movement of air and water downward and in a limited way Photograph 8.

PHOTOGRAPH 8. Physical Weathering by the Effect of Animals and Plants on the Soil in the Northeastern Parts of Al-Areej Village

2.1.1.1.3. Chemical Weathering

It arises from the interaction of atmospheric gases, oxygen, carbon dioxide, and water vapor with the rocks of the Earth’s surface and, as a result, leads to a change in their mineral compounds (Strahler, 1975). It is expressed as the total processes that bring about changes in the rocks as a result of chemical interactions with the elements of the atmosphere and the gaseous atmosphere through changes in the internal structures of minerals.

This weathering is more effective over the whole earth than physical weathering in breaking down rocks. This weathering appears to be utterly dominant in some areas where temperatures are high, and there is an amount of rain (Karbel, 1986: 91). It results in multiple forms, and this process is done through methods and processes that will be addressed as follows:

2.1.1.1.3.1. Dissolving

"This stage is considered one of the first processes in which chemical weathering takes place, and it means the ability of mineral components to dissolve in water, so its action depends on the amount of water and the response of rock components to the dissolution process" (Almusawe and Aburaheel, 2010: 161). The melting process turns hard sandstone into a brittle, loose-grained sandstone. These dissolution processes were observed in the composition of the convex Mishraq, where the Aleadhba was the most prominent example of this, as shown in Photograph 9.

PHOTOGRAPH 9. Weathering due to Solubility in Aleadhba Khusf (Solution Doline)

2.1.1.1.3.2. Hydration

It is known as the union of water with some of the minerals that make up the rocks, forming water minerals. Hydration may be on a regional scale that accompanies the processes of regional transformation, as happens during the transformation of the anhydrous gypsum layers into hydrated gypsum, and this is what is present in the study area within the formation of the hole, as in the following equation:

$CaCO_4 + 2H_2O \Longrightarrow CaCO_4 .2H_2O$

Local hydration processes also occur due to moisture, as the rocks swell and change their size (Alokade, 2011: 48). The process of hydration is present in the rock detectors related to the formation of the hole, especially in gypsum rocks, as the aqueous gypsum turns into aqueous gypsum in union with two parts of water, as shown in Photograph 10.

PHOTOGRAPH 10. Weathering by Hydration in Aleabid Village

2.1.1.1.3.3 Carbonation

"This process occurred as a result of dissolving part of the carbon dioxide in rainwater, forming carbonic acid. Which caused part of it to dissolve and result in dilute carbonic acid (H_2CO_3)" (Strahler, 1975: 15). And dilute carbonic acid can dissolve limestone and convert it to calcium bicarbonate (Mahsub, 2001: 63).

$CaCO_3 + H_2CO_3 = Ca(HCO_3)_2$

This process increases the cracks and separations between the rock parts and their expansion by melting, leaving behind insoluble materials in the form of weathering residues.

This process prevails in the Al-Fatha Formation, which results in many karst forms such as craters, karst eyes (springs), and the phenomenon of cavitation. Its effect is clearly visible in the rocks of the land features, especially in the limestone rocks in the village Al-Dabbas as shown in Photograph 11.

PHOTOGRAPH 11. Weathering by Carbonization in Al-Dabbas Village

2.1.1.1.3.4 Oxidation

This common geomorphic process occurs when the element of moisture combines with mineral components, oxidizing either in the form of iron oxides or aluminum oxides, etc., and the color of the soil changes to red or yellow as a result of this process. The occurrence of this condition is often weak in igneous and metamorphic rocks. Its activity is more in clay, sandy, and limestone rocks (Salama, 2004: 137), including the study area. As a result of the oxidation process, the rock turns from resistant to brittle rocks that are less resistant to operations and fragmented and crushed. This process significantly impacts weathering, as shown in Photograph 12.

PHOTOGRAPH 12. Oxidative Weathering in Alearbid Village

2.1.1.1.4. Ground Units Resulting from Water Erosion

Plant and animal life are essential elements in the chemical weathering process. The chemical and its activity determine the number of degradable materials through organic decomposition, which is a complex process that includes the formation of organic acids from rotting plants. These acids have the effect of dissolving some of the main mineral elements, such as iron, which the plant can derive from the soil as the main food material. It can be removed when washing the soil, and the iron turns into very complexions that penetrate and move down with the evaporated water of the rocks (Mahsub, 2001: 66), as shown in Photograph 13.

PHOTOGRAPH 13. Biological Weathering by Rotting Animals in Eadhaba Village

2.1.1.2. Erosion Process

It is defined as the process of disintegration and weathering of solid surface rocks that make up the surface of the earth's crust by the mechanical energy of the atmosphere and water, decomposing them and transforming them into small, disassembled parts and then transporting them to other places (Atallah, 2000: 155).

This process is one of the most important processes that change the features of the earth’s surface. Several factors control and affect it, such as slope, topography, soil characteristics and depth, method of land exploitation, climatic conditions, and density of vegetation cover. Wind and water are among the most critical factors causing erosion. Weathering and erosion work in solidarity with each other, as the weathering process is a precursor to the erosion process by dismantling and breaking up rocks without moving them (Goudie, 1985: 118-120).

Among the factors causing erosion in the study area are the running water and wind that break up the rocks and transfer them to other places. Erosion types that come to the fore, especially according to the prevailing climatic conditions in the region, can be discussed as follows:

2.1.1.2.1. Water Erosion

This type occurs as a result of running water and precipitation, where its fall is sudden and abundant, and this will reflect on the activity of water erosion in the area that works to transfer materials and fragments by means of attachment, rolling, jumping, and dissolving as they are transferred from high locations to neighboring low areas and demolish bridges and uproot rocks. Therefore, its effect is evident in areas with coarse and loose textured soils, which will contribute to the morphometric characteristics of the basins, as shown in Photograph 14.

PHOTOGRAPH 14. Water Erosion in Al-Kafur Village

Water erosion in general, including the study area, is classified into surface water erosion, which takes various forms in the study area, which we will explain in the following:

2.1.1.2.1.1. Splash Erosion

"It is also called the (Raindrop Splash) resulting from the collision of direct raindrops with loose soil particles. This type of erosion occurs after the fall of the rain showers. Then many scars left by the raindrops falling immediately after the rainstorm can be observed, and this is the beginning of erosion subsequent aqueous, as the flow of water takes it upon itself to transport particles to form other forms of erosion" (Gathwan, 2011: 103). This happens when the layer of soil immediately below the scar particles becomes saturated and then develops to erode the sluices.

2.1.1.2.1.2. Sheet Erosion

This type of flow is characterized by the fact that it does not take well-defined watercourses but rather is in the form of a cover or a thin membrane of water formed after rain showers and after saturation of the soil with water by eroding the crumbs resulting from weathering in the form of layers over the sloping lands, which prevails this type of erosion. The layers are present in the study area and the flat lands. It is found in all the plain areas, especially after heavy rain showers, as a water cover is formed after the saturation of the earth's surface. Excess precipitation causes a water membrane to move with all weathering products.

2.1.1.2.1.3. Rill Erosion

"This erosion develops due to small watercourses that are often short and parallel and are located on the upper slopes of the study area and have little erosion effect. Because these streams canalize all their energy to dig those steep slopes which is a transitional stage between random water flows and sloping waterways" (Gathwan, 2011: 104). Besides, these streams are often represented in the study area in the first and second ranks, as shown in Photograph 15.

PHOTOGRAPH 15. One of the Water Bodies in the Al-Ain Stream Basin

2.1.1.2.1.4. Groove (Gully) Erosion

"This type of erosion occurs when a group of short runoffs of surface water cause shallow soil erosion. It contributes to increasing the sculpting, erosion, and transfer of rocky fragments, boulders, and pebbles" (Almusawe and Aburaheel, 2010: 167) Photograph 16.

Conditions such as rock structure, slope, climate and the presence of vegetation are sensitive basic conditions for forming gully erosion.

PHOTOGRAPH 16. Gully Erosion in the Central Areas of the Al-Ain Stream Basin

2.1.1.2.2. Wind Erosion

Winds have a prominent and important role in shaping the earth's surface and changing its features. It is the second force after water in erosion, transport, and sedimentation. This erosion prevails in dry and semi-arid areas, including the study area, especially if it has been exposed to the weathering process. This will facilitate wind erosion as wind erodes the earth's surface by the processes of polishing, ablation, and emptying. Its action and speed depend on several factors, such as the degree of erosion, the nature of the surface formations, vegetation cover, soil moisture, the sizes of the transported grains, and friction force. The presence of vegetation cover with high soil moisture would help the soil cohesion and resist erosion processes. As for the nature of the terrain, it constitutes an obstacle to wind in its work if it has a relative terrain that reduces the speed of the wind and forces it to sediment (Darweesh and Taleb, 2011: 49). It is found in gypsum rocks dating back to the holes formation in Tertiary geological time.

2.1.2. Sedimentation Process

After the earth's surface is exposed to the two processes of weathering and then erosion, the carrier factor (wind/water) must lose its ability to carry the carried materials under certain conditions that force it to deposit them. The characteristics of the carrier factor are density and speed. For example, the river stream can roll and push sand and gravel when its speed is high, and when it loses its speed, it becomes unable to move the rock (Sanawi, 1979: 200).

The sedimentation process is defined as the last stage in which suspended substances in the water and air are deposited when the carrier cannot carry them.

This process is represented by different types in the study area, as discussed below.

2.1.2.1. Water Sedimentation

Water sedimentation occurs due to the transported waste, whether it is transported by torrents or river water. As a result of the slowing of the water’s speed and its inability to carry it to longer distances, it deposits it gradually along the course according to the gradation of the size of the transported sediments and the decrease in the slope, water discharge, and the speed of flow. It deposits large boulders and rocks near the upstream area to fine crumbs, mud, and silt, and fine particles and dissolved materials rise at the end of the valleys downstream (Abuganim, 2010: 95).

Most of the times in which the sedimentation process occurs in the study area are during heavy rains, and the occurrence of floods, the end of which is discharged into flood areas, and some of them are in the form of dissolved materials on the surface, forming multiple forms such as alluvial fans and valley bottom sediments. They are found in all the streams of the network of valleys under study, but not limited to, for example, in the basins of the Al-Ain, Hajar, and Gahanem.

2.1.2.2. Wind Sedimentation

The wind is of great importance as it is one of the most critical transport factors in nature that impacts shaping the surface of the earth. When the wind gradually loses from coarse to soft, and these materials are of varying size, their ability to carry materials and their speed decreases, they begin to sediment in a way that faces an obstacle that forces them to sediment to take several forms (Salama, 2004: 432).

2.1.3. Morphodynamical Processes

It expresses the current formations on the earth depending on erosion and accumulation. Some factors help in its occurrence, including the nature of the rocky composition of the slope, the degree of slope, and humidity, and this process takes several positions and manifestations without the intervention of erosion factors (Asal, 1984: 271). This process occurs in the study area as a result of the presence of cracks and joints and the exposure of rocks to the physical and chemical weathering process as a result of tectonic movements and the presence of solid rock layers based on these fragile layers, which makes them subject to pressure that forces them to slide down the slopes after heavy rains and water penetration in the cracks and joints. During the studies conducted on the region, two types of this process were identified:

2.1.3.1. Slow-Motion of the Earth’s Surface Material

This movement includes the slow flow of soil and rock aggregates downward in a creeping manner. It is not possible to witness this movement directly when it occurs except over time or through the accompanying phenomena that show the tendency (Sanawi, 1979: 324).

The sizes of the creeping materials range from rock masses, sand, and silt, and there is a percentage of water and its occurrence in the soil layers close to the surface of the earth and will be addressed as follows:

2.1.3.1.1. Soil Creep

This process arises and develops in slopes of moderate slope covered with soil. When exposed to the force of attraction, these soils lose their cohesion, disintegrate, and the surface layers crawl out of them. Soil creep on the slope angle, climatic conditions, and soil type (Salama, 2004: 156).

2.1.3.1.2. Debris Flow

This process is one of the most common slow movement patterns of materials in the area under study in an invisible way. Still, its effects are based on the separation of rock masses and their creep towards an inclined surface. Its occurrence is greater when the processes of freezing and thawing alternate with the succession of rock layers and the presence of cracks and joints that contribute to the disintegration and weakening of the rock. This process occurs in most slopes in the shoulder region of the valleys, as shown in Photograph 17.

PHOTOGRAPH 17. Debris Flow in the Marei Stream Basin

2.1.3.2. The Rapid Movement of the Materials on Earth Surface

These movements occur suddenly as the materials move from the top of the slopes to the bottom due to the effect of gravity. The sensible movement of rock fragments towards the bottom is called landslides. This movement consists of and varies according to the type and composition of rocks and includes the following types:

2.1.3.2.1. Rockfall (Fall of Rock Masses)

"This type of process occurs in areas of steep rocky ridges and cliffs, where blocks fall and collide with the ground without being rolled. This process occurs due to gravity and the effect of the interlocking joint system. It exceeds the amount of time during which it occurs several seconds, so it is rare to see it" (Aldarraji, 2009: 112).

It also occurs in the estuary areas of valleys after the exposure of dolomitic limestone to the chemical weathering process when water seeps into the rocks. This will help emerge several geomorphological forms, as shown in Photograph 18.

PHOTOGRAPH 18. Rockfall in the Gahanem Stream Basin

2.2. GEOMORPHOLOGIC LANDFORMS

The current topography constitutes the result of the interaction of geological structure and prevalent geomorphological factors, both in the Pleistocene and Holocene eras. James Hutton, the founder of modern geology, proposed the Principle of Regularity (Theory of Earth) in 1785 and emphasized the geological factor tested at the time, explaining the formation of the oldest rocks (O'Rourke, 1978). After determining the natural geographical components in the first chapter that control the emergence of relief in the basins of the area under study, it was necessary to refer to the forms prevailing in the area under study and according to the origin of the process being studied. He created every landform, and the topography was classified according to the ITC System, which is one of the best systems that have been relied upon in the Department of Geography and Geology in most parts of the world. It is based on its classification based on the nature of geomorphological factors and the processes responsible for the formation of phenomena as a basis for classification, and this is what is preferred by most geomorphologists in the world. Depending on this basis; the study area was divided according to the geomorphological Map 8 into the following landforms:

2.2.1. Structural Floor Units

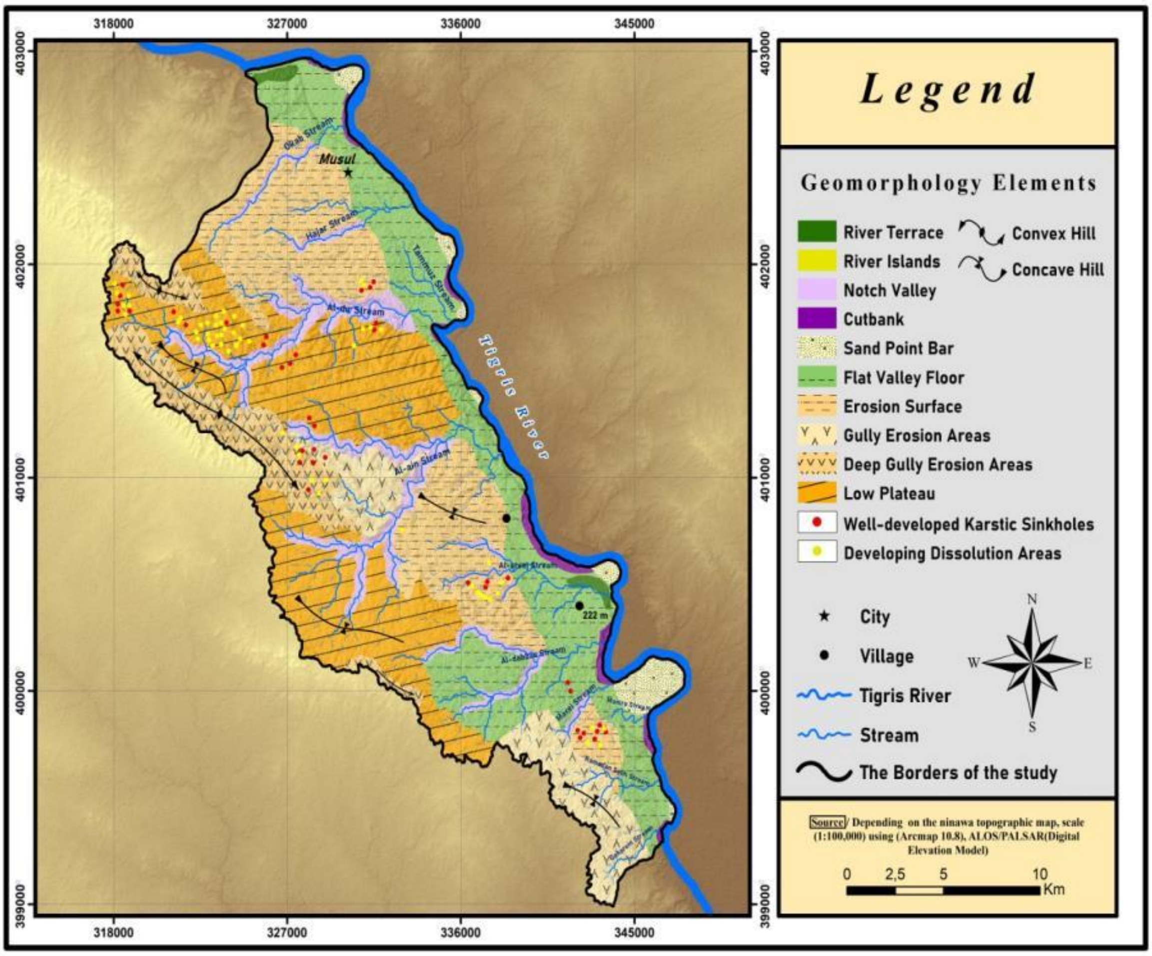
There are two types of structural structures in the area under study:

2.2.1.1. Convex Structural Floor Units

2.2.1.1.1. Convex Low Plateaus

Low plateau areas have an important place in the study area. "They are the torsions that occur as a result of tectonic movements, and the degree of inclination of the rock layers varies according to the type of rocks and the degree of their hardness and minerals" (Abualainain, 1981: 300). The low plateaus in the study area consist in terms of the geologic formation of the Orifice formation, which consists of a succession of rocks, water gypsum, lime, marl, rock salt, and clays. it occurs due to the exposure of rock masses to different ground pressures in their intensity and direction, which leads to the twist of the rocky layers and changing their geomorphological manifestations due to geological processes (Salama, 2007: 378).

The following is an explanation of the most important plateaus that fall within the study area.



MAP 8. Geomorphology Map of the Study Area

2.2.1.1.1.1. Convex Low Plateaus of Atshan

These plateaus extend in the northwest and southeast direction. It is a biconvex plateau extending in the length of 30 km and width of 4.5 km. These plateaus consist of two convex domes separated by a small corridor covered with aperture formations. Their length is 12.5 km, and the many streams were revealed in the heart of these plateaus.

The second dome is called Snow Dome, which is outside our study area and extends about 17 km. In this dome, the formation of Anjana, Euphrates, and Al-Juraibi was revealed in the heart of these mountains and the formation of the hole on their edges (Aljuburi, 1995: 15-16).

2.2.1.1.1.2. Convex Low Plateaus of Nokite (Nouquit)

They are bi-convex plateaus extending about 15 km in a northwest-southeast direction. They are unequal in the northeast direction. Since the northeastern tip of the plateaus is tilted at 37° and the southwestern part at 13°, a follicular formation is evident in the core of these low plateaus, which are often outside the study area. In contrast, a crater formation was detected on their side (Aljuburi, 1995:16). The convex low plateaus were formed in the study area at the end of the Tertiary period after the deposition of the follicular formation at the beginning of the Miocene. When the compressive tectonic force began to work in the deformation process that prevailed in the region, it was all toward the northeast and southwest, which is the prevailing direction in the region, and as we mentioned, these low fogs are all uneven (Nader, 1985: 87).

2.2.1.1.1.3. Convex Low Plateaus of Al-Qulayan

These mountains are located on the western and southwestern sides of the study area and have a northwest axial extension Photograph 19. It consists of limestone rocks feeding the surface and groundwater drainage network, which is also characterized by the edges of the cracks that have been exposed to water erosion and whose slopes were cut by a group of grooves that they occupied.

PHOTOGRAPH 19. Low Plateaus in Alilqalyan

2.2.1.1.1.4. Low Plateaus of Alaleel

They are longitudinal plateaus with a symmetrical slope in a northwest-southeast direction, starting from the western side of Hammam Al-Alil Center near the village of Tal Al-Hashem and ending on the right bank of the Tigris River near the Kita Village. It is about 14.5 km long and 14.5 km wide. The Tigris River in the Hammam Al-Alil area is characterized by being unstable with severe torsions, reflecting the instability of this site's base level (Alnish, 1999: 10).

2.2.1.1.1.5. Low Plateaus of Almishrag

Al-Mishraq lowlands fall within the range of the low plateaus to which all plateaus are attributed. The area is longitudinal and oriented towards the northwest and southeast. Therefore, they are asymmetrical plateaus inclined towards the south or southwest, and the extension of the axis of the chains continues on the right bank of the Tigris River by about 8 km, and the direction of the axis of the plateaus is from southeast to east, where the axis sinks in the left bank of the Tigris River, and the axis extends another 5 km south of the Upper Zab River (Alkahuaji, 1989: 12).

2.2.1.2. Concave Structural Floor Units

Here we will address only the most extensive concave low plateaus in the study area, which are:

2.2.1.2.1. Concave Low Plateaus of Alaleel

It is one of the most extensive concave plateaus in the region, as shown in the geomorphological map. It extends in a northwest-southeast direction parallel to the convex mountains of Hammam Al-Alil but is slightly shorter in length. It starts from Hammam Al-Alil Cement Plant and ends south of the Al-Jehuni Village on the Tigris River near Sakhr Al-Safina area (Alnish, 1999: 13).

2.2.1.2.2. Concave Low Plateaus of Nokite (Nouquit)

As can be seen from the geomorphological map, the low plateaus extend about (10 km) in a northwest-southeast direction, separating the convex plateaus of Atshan and Nokite. These plateaus are asymmetric in the south, limiting this aspect (Aljuburi, 1995: 16).

2.2.2. Erosion Floor Units

These units differ according to the type of operation (water-wind) and according to the factors affecting their formation, and they have been divided as follows:

2.2.2.1. Underground Units of Water Erosion Origin

2.2.2.1.1. Valleys Network

It is considered one of the most important forms prevalent in the region, which was formed due to water erosion processes. Its origin continued back to the rainy ages. Rain still plays its role in influencing it and increasing its ranks, depths, and development. The rocky variation directly impacted its formation because it takes place within weak formations with limestone rocks that do not resist the process of stripping (Oda, 1989: 18).

2.2.2.1.2. Alluvial Fans

One of the sedimentary shapes consisting of silt is closer to a triangle or conical. This phenomenon is formed at the end of the steeply sloped streams when sudden changes in gradient occur, as descending a valley from a high area to flat plain land, in which case the speed of water slows down suddenly and the deposition of portable materials forming a delta-like shape (Plummer, McGeary and Carlson, 1999). The sediments range gradually from the top of the fan to its end at the base (Mahsub, 2001: 89).

2.2.2.1.3. River Terraces

They are surfaces with relative flatness and varying amplitudes that occur due to water erosion, which is evidence of previous levels of the valley and rivers bottoms that were flowing in them and left them after deepening and changing the streams. It consists of boulders, gravel, sand, and silt (Al-Dulaimi, 2012: 279). This phenomenon also reflects the stage of rejuvenation of some valleys after they had reached an advanced stage of maturity (Karbel, 1986: 180).

"It also occurs as a result of river flooding when climatic changes occur, and an increase in the number of rainfalls that leads to a change in the relationship between the amount of drainage and sedimentation, and rocky bands and bands and fragments are exposed on both sides of the river equally or on one of its sides. Over time, these sediments gradually accumulate, forming river terraces" (Salama, 2004: 138). This phenomenon is found in the north of the study area, along the Tigris River to the south, as shown in Photograph 20.

PHOTOGRAPH 20. The Terraces of the River in the Hajar Stream Basin

2.2.2.2. Ground Units Resulting from Wind Erosion

2.2.2.2.1. Wind Caves

One of the forms resulting from the salinity process arises in areas with brittle sandstones of varying hardness when subjected to wind erosion when the wind movement is uneven in all places, which causes weak areas of adhesion to be exposed cavitation. In contrast, the solid, cohesive areas remain separating between holes and cavities (Abualainain, 1979: 623). These caves are affected by the northwest winds and appear on the surface of the high rocky slopes, as shown in Photograph 21.

PHOTOGRAPH 21. One of the Caves in Kaysuma Village

2.2.2.2.2. Solitary Hills

"Isolated hills are formed from limestone rocks due to the dissolution processes of their formations. The solid parts remain resistant to weathering processes and usually appear in the form of pillars," as shown in Photograph 22 (Aljalabe, 2018: 123).

PHOTOGRAPH 22. Solitary Hills

2.2.3. Sedimentary Floor Units

2.2.3.1. Wind Land Units

2.2.3.1.1. Sand Flats

Vast plains represent the main plateau in which valleys flow, and their surfaces are made of fine gravel, small crumbs, and soils resulting from the weathering process. The dunes are a sandy complex ranging in height from 30 cm-40 m and width between 1 m-1 km. They arise due to varying surface roughness so that it is coarse sand on the bottom and soft sand on the surface (Salama, 2004: 284). It is affected by several factors in its formation, such as wind speed and direction, surface topography, the origin and diameter of the transported grains, the source and size of sand, in addition to other factors such as overgrazing, cutting down trees, and climatic conditions that contributed to the lack of vegetation cover that helps stabilize the soil and protect it from disintegration (Alawadi, 1989: 3-11), this phenomenon prevails in most parts of the study area.

2.2.3.2. Water Sedimentary Units

2.2.3.2.1. Valley Bottom Sediments

It means the sediments that settled at the bottom of the valleys due to increasing their weight and the lack of water velocity and slope. These sediments vary in size, thickness, and type according to several factors, such as the valley's shape and its breadth. This helps the amount of sedimentation as in the study area. The water gradually deposits the loads of small and medium, leaving the large-sized fragments before the mouth of the valleys. As for the silt sediments and sands deposited in the Tigris River, these sediments are formed near the mouth of the valleys in the Tigris River, as shown in Photograph 23.

PHOTOGRAPH 23. Valley Bottom Sediments in Yunis Village

2.2.4. Karstic Landforms

Landforms of karst topography emerge in environments where rocks that have the property of dissolving by being affected by atmospheric-origin meteoric waters and acids are concentrated (Yazıcı, 2019b: 189). Some of these landforms will be explained in this section of the thesis.

2.2.4.1. Caves

They are natural cavities in rocks, whether on the surface or below (Monkhouse, 1983: 51). These caves are formed in the hollow of limestone rocks of deep thickness in the form of gaps and holes due to the presence of cracks. The separators and the dissolution speed of these rocks in the groundwater and their presence are related to the soluble rocks, as shown in Photograph 24.

PHOTOGRAPH 24. Karstic Cave Near the Mouth of Valley Huleila

2.2.4.2. Karst Eyes (Karst Springs)

Karst groundwater rises along these springs. These springs form in areas with limestone formations, which are openings through which water flows automatically. They occur in association with rainy climates and interconnection of cracks, as shown in Photograph 25 (Fayyad, 2008: 125).

PHOTOGRAPH 25. Karst Eye Near Al-Jumhuri Hospital on the Banks of the Tigris River

2.2.5. Floor Units of Human Labor

Man's role in changing the parameters of the earth's surface emerges as a result of recent development. The man was able to control the earth's surface and harness it to serve him in a manner that suited his requirements. By exploiting human settlements for human stability, building and deducting some parts of the rocky ridges, altering them, and reducing their slope, as well as the establishment of sand and gravel quarries in the study area as a result of the presence of limestone, sand, and gravel rocks, and these quarries will contribute to the activity of the processes of weathering and erosion, leaving behind large craters that change the features of the earth's surface. In addition to the exploitation of lands for agriculture, especially adjacent to the Tigris River, plowing them in various forms and sometimes exposing them to erosion as a result of their extensive use and depletion of their ability to be suitable for agriculture, and the establishment of a cement factory in Hammam Al-Alil south of the study area from human work leaves behind traces of change in the parameters of the earth's surface.

Its second constructive role lies in constructing roads, railways, and earth dams to benefit from the seasonal waters of the valleys and the construction of bridges to facilitate the passage of cars.

CHAPTER THREE

MORPHOMETRIC ANALYSIS OF THE BASINS IN THE RESEARCH AREA

The importance of morphometric analysis in geomorphology studies is increasing day by day. These methods constitute an important data source in determining the processes that have an impact on the geomorphology of a region. Removing the information of geomorphological units from the altitude values of the region (DEM-Digital Elevation Model) is defined as morphometry.

Morphometric analyzes are widely used in the study of different characteristics of basins in the world (Görgülü and Göl, 2021). These data, obtained with the help of morphometry, both the evolution of the drainage in the study area and the structural/lithological effects on this evolution (Avcı and Günek, 2015). “Morphometric studies are one of the modern trends in the study of river basins. The river is the basic unit for conducting morphometric research, being a survey unit in which it is determined indicators and characteristics that can be quantitatively measured, and are the basis for analysis, comparison, and classification, and have emerged” (Salama, 1980: 97). The purpose of the morphometric analysis is to numerically reveal the influence of internal and external factors that are effective in the morphological formation of a basin or a study area (Öztekinci and Coşkun, 2021: 258). The morphometric characteristics of the water drainage network of the study area basins by advanced automated methods and building a geographical database with morphometric variables based on advanced data sources represented by satellite visuals, digital elevation model DEM, and spatial analyzes. The developed method is to reach quick results compared to traditional methods. The digital model of relief (DEM) is one of its elements and the basis on which it depends to arrive at the properties related to the topography of valleys. Through it, information about the topography of the study area can be identified. Hydrological simulations of rainwater runoff using predictive methods are applied to digital data. The goal is to calculate numerical heights, inclinations, and surface features such as the boundaries of water basins and the drainage network.

The Definition of Morphometry

All standard or geometric basin characteristics that result from taking measurements Specific to water basins, including spatial, morphological, topographic, and water network characteristics and patterns of exchange, and from here we note that the morphometric properties are among the essential geomorphological properties of quantitative data, which depends on numerical data related to the measurement of lengths and areas.

The topographical map is one of the critical tools used in geographical studies in general. The study is nothing but a process of linking the different drainage network characteristics with each other and linking them to the geomorphological features. In particular, the topographical map contains more information related to the parts of the basin than other sources.

The availability of the map alone is not sufficient for the purpose, there are several things on which the extent of benefit depends which is accustomed to the researcher from using this method to reach his goal, and it is related to the researcher himself, such as the researcher's ability, experience, and practical knowledge in the practice of working with maps.

On the one hand, the topography and the geomorphological fieldwork, on the other hand (Sallum, 2012: 375), the scale of the drawing and the ability of the contour period and its role in showing the geomorphological forms appropriately.

The morphometric loading of a drainage basin is a product of the topographical appearance on which it is concentrated runoff water in the transfer of water from the source to the estuary.

It is crucial in loading pressures and influences on water resources in understanding geomorphological processes in general. This chapter will conduct the analysis and morphometric study of basins.

Table 11 presents the origins of the formulas of the morphometric analyzes used in the study.

Table 11. Morphometric Parameters, Their Formulas and References Applied to the Study Area

MORPHOMETRIC PARAMETER		FORMULA	REFERENCE
LINEAR PARAMETERS	Stream Length Ratio (Rl)	$Lu \,/\, Lu + 1$	Horton (1945)
	Bifurcation Ratio (Rb)	$Nu \,/\, Nu + 1$	Schumn (1956)
	Texture Ratio (Rt)	$Nu1 \,/\, P$	Smith (1950)
AREAL PARAMETERS	Circularity Ratio (Rc)	$A \,/ \left[\left(\frac{p}{\pi} /2 \right)^2 * \pi \right]$	Strahler (1964)
	Elongation Ratio (Re)	$(2 \sqrt{(A / \pi)}) / Lb$	Schumn (1956)
	Form Factor / Basin Shape (Rf)	$A \,/\, L^2$	Horton (1945)
	Drainage Density (Dd)	$\sum L / A$	Horton (1945)
	Stream Frequency (Fs)	$N \,/\, A$	Horton (1945)
	Infiltration Number (If)	$Fs \times Dd$	Faniran (1968)
RELIEF PARAMETERS	Basin Relief (Bh)	$Bh = Hmax - Hmin$	Hadley & Schumn (1961)
	Relief Ratio (Rr)	$Bh \,/\, Lbmax$	Schumn (1963)
	Hypsometric Curve (Hc)	$a / A \quad h / H$	Strahler (1952)
	Hypsometric Integral (Hi)	$Hmean - Hmin \,/\, Hmax - Hmin$	Strahler (1952)
	Gravelius Index (Compactness Coefficient) (Kg)	$P/2 * \left[\left(\int \frac{A}{\pi} \right) * \pi \right]$	Gravelius (1914)
	Ruggedness Number (Rn)	$Bh \times Dd$	Strahler (1958)

MORPHOMETRIC ANALYSIS OF THE BASINS IN THE RESEARCH AREA

3.1. Linear Morphometric Characteristics of the Basins

Determining the linear shape of the group of valleys of the study area, which is the main factor in the formation of the basin, is a priority compared to other parameters (Table 12). Linear morphometric standards applied in the basin; Basin Length (**L**), Maximum Basin Width (**W**), Stream Length Ratio (**Rl**), Bifurcation Ratio (and Bifurcation Stage) (**Rb**), and Texture Ratio (**Rt**).

Table 12. Linear Morphometric Characteristics of the Basins in Study Area

Stream name	L	W	Rl	Rb	Rt
Okab Stream	12.15	7.27	1.79	3.75	0.32
Hajar Stream	9.89	6.22	3.47	4	0.49
Tammuz Stream	6.48	5.07	1.16	3	0.40
Al-Dir Stream	24.14	9.44	5.45	4.33	1.15
Al-Ain stream	17.06	12.33	2.04	2.88	1.50
Al-Areej Stream	11.88	9.04	2.95	3.06	0.78
Al-Dabbas Stream	12.08	7.75	1.97	6.14	0.91
Marei Stream	5.87	2.64	1.73	2.5	0.36
Munira Stream	6.65	4.87	1.2	5	0.26
Ramadan Salih Stream	4.98	3.53	1.45	3.37	0. 59
Gahanem Stream	6.23	2.76	1.55	7	0.45

3.1.1. Basin Length (L)

"It is one of the important variables that are related to many of the characteristics of the drainage basin, and it is determined by the distance from the mouth of the valley to the maximum point of the basin circumference, which is represented by its end and separates it from the nearby basins from the source side" (Al-Dulaimi, 2012: 267). The basin values are shown in Table 12.

The largest basin length value was recorded as the Al-Dir Stream basin with 24.14 km, and the smallest value was recorded as the Ramadan Salih Stream basin with 4.98 km. In addition, the lengths of other basins in the study area are as follows: 12.15 km in the Okab Stream basin, 9.89 km in the Hajar Stream basin, 6.48 km in the Tammuz Stream basin, 17.06 km in the Al-Ain Stream basin, 11.88 km in the Al-Areej Stream basin, 12.08 km in the Al-Dabbas Stream basin, 5.87 km in the Marei Stream basin, 6.65 km in the Munira Stream basin, and 6.23 km in the Gahanem Stream basin.

3.1.2. Maximum Basin Width (W)

The largest width value measured perpendicular to the long axis in a basin is expressed as the Maximum Basin Width (W). It is an important parameter for the interpretation of the structure of the basin and the efficiency of fluvial erosion (Karataş, 2014). Fluvial erosion is more effective in basins with a larger maximum basin width. It can be seen in Table 12.

The maximum basin width of it is reached as the most considerable width in the Al-Ain Stream basin with 12.33 km, and the smallest width in the Marei Stream basin with 2.64 km. The rest of the basins' width was calculated as 7.27 km for the Okab Stream basin, 6.22 km for the Hajar Stream basin, 5.07 km for the Tammuz Stream basin, 9.44 km for the Al-Dir Stream basin, 9.04 km for the Al-Areej Stream basin, 7.75 km for the Al-Dabbas Stream basin, 4.87 km for the Munira Stream basin, 3.53 km for the Ramadan Salih Stream basin, 2.76 km for the Gahanem Stream basin.

3.1.3. Stream Length Ratio (Rl)

Studying the stream length rate is essential in determining the speed of the water flow, which decreases as the increased size. These values reflect the region's geological, topographical, and climatic nature, as shown in Tables 12 and 13.

$$R_l = Lu / Lu+1$$

Lu : Average stream length in a given index (km)

Lu+1: It is the average length of the stream in the upper sequence (km)

Table 13. Lengths (km) and Ratios ($R\iota$) of the Stream Orders in Basins in the Study Area According to the Strahler Method

Stream name	Length and ratio	Length ratio					Average
		1. Order	2. Order	3. Order	4. Order	5. Order	
Okab	Length	11.07	8.07	3.64	-	-	7.59
	Ratio	1.37	2.21	-	-	-	1.79
Hajar	Length	13.47	13.68	2.29	-	-	9.81
	Ratio	0.98	5.97	-	-	-	3.47
Tammuz	Length	1.83	5.18	2.62	-	-	3.21
	Ratio	0.35	1.97	-	-	-	1.16
Al-Dir	Length	65.71	28.95	12.49	14.12	-	30.31
	Ratio	2.26	2.31	0.88	-	-	5.45
Al-Ain	Length	72.86	33.05	24.14	9.27	4.61	28.78
	Ratio	2.2	1.36	2.6	2.01	-	2.04
Al-Areej	Length	19.89	12.84	8.85	1.51	-	10.77
	Ratio	1.54	1.45	5.86	-	-	2.95
Al-Dabbas	Length	31.07	23.85	8.97	-	-	21.29
	Ratio	1.3	2.65	-	-	-	1.97
Marei	Length	3.27	1.01	4.09	-	-	2.79
	Ratio	3.23	0.24	-	-	-	1.73
Munira	Length	3.93	3.27	-	-	-	3.6
	Ratio	1.2	-	-	-	-	1.2
Ramadan Salih	Length	7.74	3.89	4.19	-	-	5.27
	Ratio	1.98	0.92	-	-	-	1.45
Gahanem	Length	6.32	4.07	-	-	-	5.19
	Ratio	1.55	-	-	-	-	1.55

Stream length ratio results are 1.79 for the Okab Stream basin, 3.47 for the Hajar Stream basin, 1.16 for the Tammuz Stream basin, 5.45 for the Al-Dir Stream basin, 2.04 for the Al-Ain Stream basin, 2.95 for the Al-Areej Stream basin, 1.97 for the Al-Dabbas Stream basin, 1.73 for the Marei Stream basin, 1.2 for the Munira Stream basin, 1.45 for the Ramadan Salih Stream basin, and finally 1.55 for the Gahanem Stream basin.

As a general principle, basins with low stream length ratio (Rl) values are narrow and long, and basins with high stream length ratio (Rl) values are width and length are close to each other (Turoğlu and Aykut, 2019: 7).

3.1.4. Bifurcation Stage and Bifurcation Ratio (Rb)

Researchers such as Horton (1945), Strahler (1952), and Shreve (1967) have put forward many numerical methods regarding the bifurcation stages, bifurcation ratio, and order numbers of the tributaries of the rivers. Strahler's method has been applied to determine bifurcation data in this research. According to the Strahler method, bifurcation stages are the smallest channels formed in the source part of the basin Figure 9. The 2nd order, the tributary created by combining two 1st orders. In the 2nd order by connecting the two tributaries, the 3rd order is accepted, and in this way, the sorting system up to the main branch is revealed. On the other hand, the mainstream creates the last row and the most significant numbered string (Polat, 2019: 310), as seen in Map 9 and Table 14.

"The main branch of the stream forms the highest order in the drainage area" (Atalay, 2018: 157).

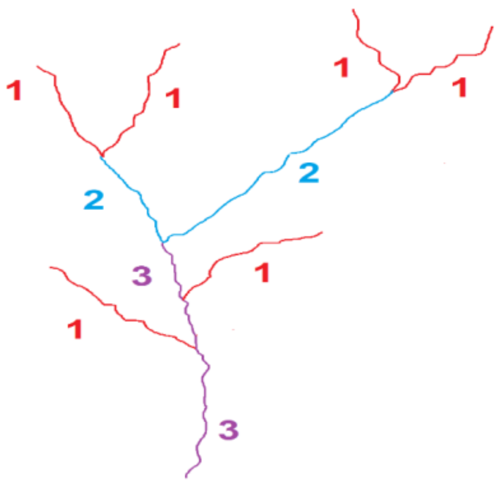


Figure 9. Sample of Strahler's Method (1952)

3.1.4.1. Bifurcation Stage

The determination of bifurcation stages and the number of stream orders on a field help the determination of the areas of flood and flood risk. Moreover, thanks to this indis, it is also possible to get an idea of the size of the basin, the affected by tectonic activities, geomorphological and lithological properties, climate, and vegetation. Because the fluvial process is formed according to the impact rate of these criteria (Polat, 2019). Longer and rare stream segments indicate the presence of more minor sloping basins (Turoğlu and Aykut, 2019: 7).

The valleys of the study area contained five (5) bifurcation stages (Table 14). The first stage contains 279 valleys, and their total lengths are 237.16 km. The second stage contains 71 valleys, and their total lengths are 137.86 km. The third stage contains 18 valleys, and their total lengths are 71.28 km. The fourth stage contains four (4) valleys, and their total lengths were 24.90 km, whereas the fifth stage contains just one (1) valley, and its total length is 4.61 km. The total stream order in the study area is 373, and their lengths are 475.81 km.

The first order of the Okab Stream basin contains 11 valleys with a total length of 11.07 km. The second order of the Okab Stream basin contains two (2) valleys with a total length of 8.07 km. The third order of the Okab Stream basin has one (1) valley with a total length of 3.64 km. Besides, the total number of the stream orders of the Okab Stream basin is 14, with a total length of 22.78 km.

The first order of the Hajar Stream basin has 15 valleys with a total length of 13.47 km, while the second order of the Hajar Stream basin has three (3) valleys with a total length of 13.68 km. The third order of the Hajar Stream basin has a number of riverbeds in it. It contains one (1) valley with a total length of 2.29 km, while the total stream orders of the Hajar Stream basin have 19 with a total length of 29.44 km.

The first order of the Tammuz Stream basin contains eight (8) valleys with a total length of 1.83 km. The second order of the basin has three (3) valleys with a total length of 5.18 km. The third order of the Tammuz Stream basin has one (1) valley with a total length of 2.62 km, while the total number is 12 with a total length of 9.63 km.

The first order of the Al-Dir Stream basin contains 67 valleys with a total length of 65.71 km, and the second order of the basin has 20 valleys with a total length of 28.95 km. And also, the third order of the Al-Dir Stream basin contains three (3) valleys with a total length of 12.49 km, while the fourth order has only one (1) valley with a total length of 14.12 km. The total value of the stream orders of the basin is 91 km, with a total length of 121.27 km.

The first order of the Al-Ain Stream basin has a number of stream courses in it. It contains 85 valleys with a total length of 72.86 km, and the second order of the valley number is 21 with a total length of 33.05 km. The third order has six (6) valleys with a total length of 24.14 km. The fourth order contains two (2) valleys with a total length of 9.27 km, and the fifth order of the basin contains one (1) valley with a total length of 4.61 km. The total valley number of the Al-Ain Stream basin is 115 km, with a total length of 143.93 km.

The first order of the Al-Areej Stream basin contains 27 valleys with a total length of 19.89 km. The second order number of the basin is seven (7) valleys with a total length of 12.84 km, and the third order number of the basin is three (3) valleys with a total length of 8.85 km. The fourth order of the Al-Areej Stream basin has one (1) valley with a total length of 1.51 km. The total number is 38, with a total length of 43.09 km.

The first order of the Al-Dabbas Stream basin has a number of river courses in it. It contains 37 valleys with a total length of 31.07 km. The second order of the basin has seven (7) valleys with a total length of 23.85 km, while the third order of the basin has one (1) valley with a total length of 8.97 km. The total river stream order number of the Al-Dabbas Stream basin is 45 with a total length of 63.89 km.

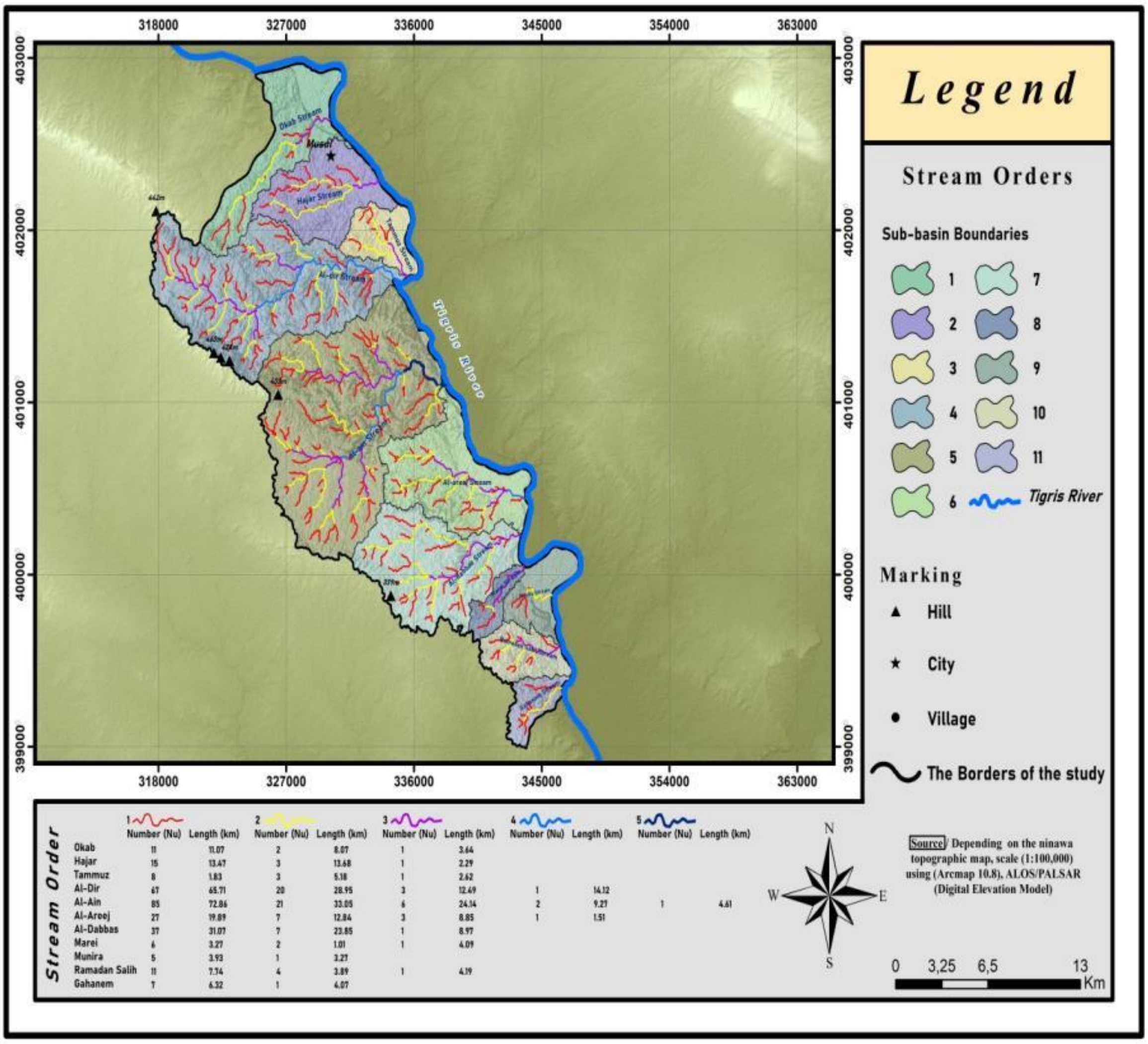
The first order of the Marei Stream basin contains six (6) valleys with a total length of 3.27 km, while the second order of the Marei Stream basin contains two (2) valleys with a total length of 1.01 km. The third order of the basin has one (1) valley with a total length of 4.09 km. The whole stream order number of the Marei Stream basin is 9, with a total length of 8.37 km.

The first order of the Munira Stream basin has five (5) valleys with a total length of 3.93 km. The second order number of the basin is one (1) valley with a total length of 3.27 km. The total stream number of the basin is 6, with a total length of 7.20 km.

The first order of the Ramadan Salih Stream basin contains 11 valleys with a total length of 7.74 km. The second order of the basin contains four (4) valleys with a total length of 3.89 km, while the third order number is one (1), with a total length of

4.19 km. The total stream order number of the Ramadan Salih Stream basin is 16, with a total length of 15.82 km.

The first order of the Gahanem Stream basin has a number of stream courses in it. It contains seven (7) valleys with a total length of 6.32 km. The second order number of the basin is one (1) valley with a total length of 4.07 km. The Gahanem Stream basin has a total of eight (8) stream orders with a total length of 10.39 km, as shown on Map 9.



MAP 9. Numbers (Nu) and Lengths of Stream Orders (km) of the Basins in the Study Area According to Strahler Method

Table 14. Numbers (Nu) and Lengths of Stream Order (km) of the Basins in the Study Area According to Strahler Method

STREAMS	STREAM ORDERS											
	1		2		3		4		5		Total	
	Number (Nu)	Length (km)	Number (Nu)	Length (km)	Number (Nu)	Length (km)	Number (Nu)	Length (km)	Number (Nu)	Length (km)	Number (Nu)	Length (km)
Okab	11	11.07	2	8.07	1	3.64	-	-	-	-	14	22.78
Hajar	15	13.47	3	13.68	1	2.29	-	-	-	-	19	29.44
Tammuz	8	1.83	3	5.18	1	2.62	-	-	-	-	12	9.63
Al-Dir	67	65.71	20	28.95	3	12.49	1	14.12	-	-	91	121.27
Al-Ain	85	72.86	21	33.05	6	24.14	2	9.27	1	4.61	115	143.93
Al-Areej	27	19.89	7	12.84	3	8.85	1	1.51	-	-	38	43.09
Al-Dabbas	37	31.07	7	23.85	1	8.97	-	-	-	-	45	63.89
Marei	6	3.27	2	1.01	1	4.09	-	-	-	-	9	8.37
Munira	5	3.93	1	3.27	-	-	-	-	-	-	6	7.20
Ramadan Salih	11	7.74	4	3.89	1	4.19	-	-	-	-	16	15.82
Gahanem	7	6.32	1	4.07	-	-	-	-	-	-	8	10.39
Total	279	237.16	71	137.86	18	71.28	4	24.90	1	4.61	373	475.81

3.1.4.2. Bifurcation Ratio

Bifurcation ratio = The number of streams in one order / the number of streams in the next order.

As seen in Table 15, it becomes clear that the bifurcation ratio may range mostly between 3-5 in the study area. This indicates the similarity of the basins in terms of climatic and geological terms.

Considering the number of stream indexes and their bifurcation ratios in the study area, given in Table 15, the following conclusions were reached.

The total number of stream orders in the Okab Stream basin was 14 and the average bifurcation ratio was 3.75. The Hajar Stream basin has 19 orders and its average bifurcation ratio is 4. Tammuz Stream basin has 13 orders and its average bifurcation ratio is 3. Al-Dir Stream basin has 91 orders and its average bifurcation ratio is 4.33. Al-Ain Stream basin has 115 orders and its average bifurcation ratio is 2.88. Al-Areej Stream basin has 38 orders and its average bifurcation ratio is 3.06. Al-Dabbas Stream basin has 45 orders and its average bifurcation ratio is 6.41. Marei Stream basin has 9 orders and its average bifurcation ratio is 5, Ramadan Salih

Stream basin has 16 orders and its average bifurcation ratio is 3.37. Gahanem Stream basin has 8 orders and its average bifurcation ratio is 7.

According to these results, the Gahanem Stream basin has the highest bifurcation ratio among the 11 basins in the study area, and the Marei River basin has the lowest. The bifurcation ratio of the Tammuz, Al-Dir, Al-Dabbas, and Ramadan Salih stream basins increased from the 1st to the 2nd order. In the Al-Areej Stream basin, the bifurcation ratio increased while passing from the 2nd to the 3rd order. In the Al-Dir Stream basin, there was a decrease in the transition from the 2nd to the 3rd order. The increase is generally associated with the displacement of the rock type with a less permeable variety (Polat, 2019), and the decrease with faulting (Atalay, 2018). However, no tectonic elements were encountered in the research area.

Table 15. Bifurcation Ratios of the Stream Orders in the Study Area According to the Strahler Method Method

Stream name	Stream Order Number and Length Ratio	Bifurcation Ratio					Total Stream Order and Average Bifurcation Ratio
		1. Order	2. Order	3. Order	4. Order	5. Order	
Okab	Number	11	2	1	-	-	14
	Ratio	5.5	2	-	-	-	3.75
Hajar	Number	15	3	1	-	-	19
	Ratio	5	3	-	-	-	4
Tammuz	Number	8	4	1	-	-	13
	Ratio	2	4	-	-	-	3
Al-Dir	Number	67	20	3	1	-	91
	Ratio	3.35	6.66	3	-	-	4.33
Al-Ain	Number	85	21	6	2	1	115
	Ratio	4.04	3.5	3	1	-	2.88
Al-Areej	Number	27	7	3	1	-	38
	Ratio	3.85	2.33	3	-	-	3.06
Al-Dabbas	Number	37	7	1	-	-	45
	Ratio	5.28	7	-	-	-	6.14
Marei	Number	6	2	1	-	-	9
	Ratio	3	2	-	-	-	2.5
Munira	Number	5	1	-	-	-	6
	Ratio	5	-	-	-	-	5
Ramadan Salih	Number	11	4	1	-	-	16
	Ratio	2.75	4	-	-	-	3.37
Gahanem	Number	7	1	-	-	-	8
	Ratio	7	-	-	-	-	7

The bifurcation ratio in the fourth order is determined as 2 in the Al-Dir Stream basin, 2 in the Al-Ain Stream basin, 1 in the Al-Areej Stream basin.

The bifurcation ratio in the fifth order is 1 in the Al-Ain Stream basin.

The average bifurcation ratios are 3.75 for Okab Stream basin, 4 for Hajar Stream basin, 3 for Tammuz Stream basin, 4.33 for Al-Dir Stream basin, 2.88 for Al-Ain Stream basin, 3.06 for Al-Areej Stream basin, 6.14 for Al-Dabbas Stream basin, 2.5 for Marei Stream basin, 5 for Munira Stream basin, 3.37 for Ramadan Salih Stream basin, and 7 for Gahanem Stream basin.

Basins in which the excess of stream order numbers and bifurcation stages are also inherent to more significant basins. In contrast, the order level and the number of bifurcations are low are smaller basins. This shows that the setup of the stream network installation in great basins is an advanced phase. Under similar conditions, large basins mean the amount of water accumulated in the mainstream (Öztekinci and Coşkun, 2021: 304).

According to these results, it was seen that the stream basin with the highest flood generation potential in the study area was Marei, with a ratio of 2.5. Another basin closest to it with a value of 2.88 is Al-Ain. The stream basin with the highest bifurcation rate was Gahanem, with a value of 7. The second closest stream to this result is Al-Dabbas, with a ratio of 6.14. It can be ranked all the basins in the study area from the highest risk of flooding to the least as follows: Marei Stream basin (2.5), Al-Ain Stream basin (2.88), Tammuz Stream basin (3), Al-Areej Stream basin (3.06), Ramadan Salih Stream basin (3.37), Okab Stream basin (3.75), Hajar Stream basin (4), Al-Dir Stream basin (4.33), Munira Stream basin (5), Al-Dabbas Stream basin (6.14), Gahanem Stream basin (7).

It is noted that there is a discrepancy in the ratios of the basins of the study area, and this is evidence of the difference in the quality of rocks between the basins.

3.1.5. Texture Ratio (Rt)

"The texture ratio parameter expresses the extent of the erosion of the earth's surface and the extent of its intersection with waterways. The closer the valleys are to each other and the greater their numbers, this indicates the severity of their rupture" (Mazara and Al-Barudi, 2005: 218).

The coarse texture of the basins was divided according to the distribution of the waterways in them into three categories: less than four (4) streams/ km^2 (Smith 1950) and between 4-10 streams/ km^2 medium texture and more than ten (10) streams/ km^2 fine texture (Aburaya, 2007: 63). The basin tissue parameter is extracted according to the following equation (Al-Dulaimi, 2017: 82), as shown in Table 12.

$$Rt = Nu1 / P$$

$Nu1$: Total number of 1st orders

P: Perimeter of the basin (km)

The total of the basins of the whole study area is less than eight (8) streams/km, where the texture ratio is coarse according to the Morisawa division. According to the results that appeared by applying the equation to the basins of the study area, According to the results that appeared by applying the equation to the basins of the study area, it was found that the highest value appeared in the Al-Ain Stream basin 1.50. The Al-Dir Stream basin is 1.15, the Al-Dabbas Stream basin is 0.91, and the Al-Areej Stream basin is 0.78. The results of the basins were of medium height, according to the apparent results. The basin of Ramadan Salih was 0.59, the Hajar Stream was 0.49, the Gahanem Stream basin was also 0.45, and the Tammuz Stream basin was 0.40. The result of the remaining basins with the lowest slope was 0.36 in the Marei Stream basin, 0.32 in the Okab Stream basin, and 0.26 in the Munira Stream basin. These low texture ratio values show that permeability is very hight in the basins depends on the rock types.

3.2. Areal Morphometric Characteristics of the Basins

Linear coefficients are opportunities to explain the drain network, while the area parameters allow the interpretation of the drainage network and the entire basin surface. Spatial morphometric criteria applied in the basin; Basin Area (**A**), Basin Perimeter (**P**), Circularity Ratio (**Rc**), Elongation Ratio (**Re**), Form Factor / Basin Shape (**Rf**), Drainage Density (**Dd**), Stream Frequency (**Fs**), and Infiltration Number (**If**) (Table 16).

Table 16. Areal Morphometric Characteristics of the Basins

Stream name	A	P	Rc	Re	Rf	Dd	Fs	If
Okab Stream	38.30	33.96	0.41	0.57	0.25	0.59	0.36	0.21
Hajar Stream	34.60	30.18	0.47	0.67	0. 35	0.85	0.54	0.45
Tammuz Stream	14.70	20	0.46	0.66	0.35	0.65	0.81	0.52
Al-Dir Stream	94.10	58.2	0.34	0.45	0.16	1.28	0.96	1.22
Al-Ain stream	127.36	56.43	0.50	0.74	0.43	1.13	0.90	1.01
Al-Areej stream	46.70	34.57	0.49	0.64	0. 33	0.92	0.81	0.74
Al-Dabbas Stream	55.10	40.6	0.41	0.69	0.37	1.15	0.81	0.93
Marei Stream	7.30	16.33	0.34	0.51	0.21	1.14	1.23	1.40
Munira Stream	15.40	18.69	0.55	0.67	0.34	0.46	0.38	0.17
Ramadan Salih Stream	15.80	18.55	0.57	0.90	0.63	1	1.01	1.01
Gahanem Stream	10	15.49	0.52	0.57	0.25	1.03	0.80	0.82
Total	459.36	434						

3.2.1. Basin Area (A)

The study of the basin area is of great importance because it is an important morphometric variable that has an impact on the volume of water discharge inside the basin. The larger the basin area, the greater the amount of rain received and the more increase in the water surplus. As for the small area of the basin size, the effectiveness of geomorphological processes in the basin as a result of the decrease in the rate of evaporating and leaking water, and that the small area of the basin helps to cover rainstorms that contribute to the rapid formation of water flow in most of the tributaries of the basin that feed its course, thus increasing the amount of water drainage (Okam, 2013: 241). "The spatial characteristics and their dimensions are among the important variables in the geomorphological analysis of the basins. Because it has to do with the lengths and numbers of streams, the volume of water flow and sediments, and the shapes reflected from them. In addition, the dimensions of the basin are among the basic variables in calculating many other morphometric characteristics" (Hamad, 2013: 169). It is clearly seen when looking at Table 16.

The total area of the basin in the study area is **459.36 km^2**, where there is a discrepancy in the area of the water basins in the study area. There is a total of 11 stream basins in the study area. These are the basins of Okab Stream, Hajar Stream, Tammuz Stream, Al-Dir Stream, Al-Ain Stream, Al-Areej Stream, Al-Dabbas Stream, Marei Stream, Munira Stream, Ramadan Salih Stream, and Gahanem Stream from the northwest to the southeast. The largest value in terms of the area is in the Al-Ain Stream basin with an area of 127.36 km^2, and the smallest value is for the Marei Stream basin with an area of 7.30 km^2.

The rest of the basins' information is recorded as follows: The area of the Okab Stream basin is 38.30 km^2, the area of the Hajar Stream basin is 34.60 km^2, the area of the Tammuz Stream basin is 14.70 km^2, the area of the Al-Dir basin is 94.10 km^2, the area of the Al-Areej Stream basin is 46.70 km^2, the area of the Al-Dabbas Stream basin is 55.10 km^2, the area of the Munira Stream basin is 15.40 km^2, the area of the Ramadan Salih Stream basin is 15.80 km^2, the area of the Gahanem Stream basin is 10 km^2.

3.2.2. Basin Perimeter (P)

"It is one of the morphological variables of the basin formation and refers to the water dividing line separating the basins" (Al-Dulaimi, 2012: 211). The benefit of the basin circumference is to clarify the basin's breadth and spread as the length of the basin circumference increases, its expansion, spread, and geomorphological development increase. But if the circumference becomes smaller, its danger increases due to the lack of water losses, high run-off, and the frequent occurrence of strong torrents. It is related to many morphometric characteristics, such as the shape of the basin, its elongation, width, and length, as shown in Table 16.

The Arc GIS program was used to obtain the length of the perimeter of the basins in the study area. The Al-Dir Stream basin has the largest perimeter with 58.2 km, and the Gahanem Stream basin has the smallest perimeter with 15.49 km.

The rest of the basins of the study area were recorded which the perimeter of the Okab Stream basin is 33.96 km, the Hajar Stream basin is 30.18, the Tammuz Stream basin is 20 km, the Al-Ain Stream basin is 56.43 km, the Al-Areej Stream basin is 34.57 km, the Al-Dabbas Stream basin is 40.6 km, the Marei Stream basin is 16.33 km, the Munira Stream basin is 18.69 km, and the Ramadan Salih Stream basin is 18.55 km.

3.2.3. Circularity Ratio (Rc)

"This coefficient expresses how close the shape of the basin is to the circular shape. High values refer to the circular shape of the basin, and low values close to zero indicate the proximity of the basin shape to the rectangular shape and irregularity in its shape and zigzag lines for dividing the water. These values are confined between 0-1, and it is identified according to the following equation" (Jawda, 1991: 318-319) as shown in Table 16.

$$R_c = A \,/ \left[\left(\frac{p}{\pi} /2 \right)^2 * \pi \right]$$

P: Basin perimeter length (km)

A: It is the basin area (km²)

It is reached the value of 0.41 in the Okab Stream basin, 0.47 in the Hajar Stream basin, 0.46 in the Tammuz Stream basin, 0.34 in the Al-Dir Stream basin, 0.50 in the Al-Ain Stream Basin, 0. 49 in the Al-Areej Stream basin, 0.41 in the Al-Dabbas Stream basin, 0.34 in the Marei Stream basin, 0.55 in the Munira Stream basin, 0.57 in the Ramadan Salih Stream, and 0.52 in the Gahanem Stream basin.

We have noticed that all the basins of the study area are close to the rectangular shape. This has important geomorphological and hydrological indications. It indicates that the basins are still at the beginning of their cycle and that the water dividing lines run in a zigzag and irregular way, in addition to the predominance of the retrograde processes. As for the hydrological significance, it is characterized by the increase in the length and depth of the sewers at the lower levels, the poor arrival of the drainage waves to the main channel, which increases the high indication of the flood risk, especially in the lower parts of the basins as shown in Table17.

3.2.4. Elongation Ratio (Re)

This ratio indicates how close or far away the shape of the basin is from the rectangular shape. The elongation ratio is the ratio of the diameter of a circle of the same area as the basin to the maximum basin length [1–6], moving away from the rectangular shape and approaching the circular shape (Alluhaibi, 2001: 59).

Table 17. Elongation Ratio (R_e) and Basin Shape Classification according to its Value (Strahler, 1964).

Elongation Ratio (R_e)	**Basin Shape**
> 0,9	Circular
0,9 – 0,8	Oval
0,8 – 0,7	Less Long
0,7 – 0,5	Long
< 0,5	Too long

We extract the elongation ratio according to the following equation (Schumn, 1956; Korly, 2016: 66).

$$Re = (2\sqrt{(A/\pi)})/Lb$$

As shown in Table 16, it is clear that the elongation ratio of the basins in the study area amounted to 0.57 in the Okab Stream basin, 0.67 in the Hajar Stream basin, 0.66 in the Tammuz Stream basin, 0.45 in the Al-Dir Stream basin, 0.74 in the Al-Ain Stream basin, 0.64 in the Al-Areej Stream basin, 0.69 in the Al-Dabbas Stream basin, 0.51 in the Marei Stream basin, 0.67 in the Munira Stream basin, 0.90 in the Ramadan Salih Stream basin, and finally the Gahanem Stream basin 0.57.

It has been seen, the Al-Dir Stream, too long, the basins of the Okab Stream Hajar Stream, the Tammuz Stream, the Al-Areej Stream, the Al-Dabbas Stream, the Marei Stream, the Munira Stream were, the Gahanem Stream were long, the basins of the Al-Ain Stream. was less long, and the Ramadan Salih Stream was oval (Table 17).

This corresponds to the product of the circulatory ratio, and the elongation ratio has important geomorphological and hydrological significance. The water basin, whose shape is close to elongation, indicates that the region is greatly affected by the structure (multi-directional linear structures, plateaus, faults, and cracks). So that erosion processes do not interfere with the shape of the basin because the rocks are often very resistant to erosion processes which contribute to the predominance of vertical erosion processes. There is no lateral erosion, which contributes to an increase in the width of the basin, and the elongation of the basin indicates that the basin is in the youth stage. This is characterized by the speed of the water current and the severity of the slope and the prevalence of vertical erosion, as well as the drainage system is not integrated, and the basin consists of large dependent tributaries with which are connected large numbers of small tributaries. They try to prolong their courses through retrograde erosion, and the areas of water division are wide, and their borders are not clear. Besides, the sedimentary output of rectangular basins is relatively limited due to its twice the current capacity (Salama, 2007: 178-179).

As for the hydrological indication, the water basin, which takes the form of a rectangle, has a more regular water discharge due to the delay in the arrival of water to the mainstream and within different times, which exposes it to water loss. Especially since the study area is characterized by drought, which leads to a decrease in the indication of flood risk due to the delay in the arrival of water to the mainstream (Aldarraji, 2019: 94-95). On the negative side, the increase in water losses in such (dry) areas reduces the possibility of benefiting from it.

Atalay (2018: 177) believes that the evaluation of formulas and computer programs is insufficient in flood events. It is also necessary to determine the amount of water that passes into the surface stream with precipitation and the water carrying capacity of the stream beds. Unfortunately, this evaluation could not be made now because there are no flow stations in the study area.

3.2.5. Form Factor / Basin Shape (Rf)

“It is one of the oldest mathematical equations in morphometric studies (Sallum, 2012: 550). This parameter gives an idea of the consistency of the different parts of the basin, as it refers to both the length and width concerning the area, and its output ranges from zero to one. Low values indicate that the basin is close to the triangular shape, which indicates the asymmetry of the general shape of the basin” (Al-Dulaimi, 2017: 78).

The average values indicate an increase in the basin's length compared to its width, so the basin is closer to the rectangular shape in this case. High values indicate the consistency of the width with the length which is closer to the square shape, and this coefficient is extracted according to the equation (Al-Dulaimi, 2018: 97) for basins as follows Table 16.

$$Rf = A / L^2$$

A: Basin area (km^2)

L:It is the maximum length of the basin (km)

It is seen that the form factor value of the basins detected as 0.25 for the Okab Stream basin, 0.35 for the Hajar Stream basin, 0.35 for the Tammuz Stream basin, 0.16 for the Al-Dir Stream basin, 0.43 for the Al-Ain Stream basin, 0.33 for the Al-Areej Stream basin, 0.37 for the Al-Dabbas Stream basin, 0.21 for the Marei Stream basin, 0.34 for the Munira Stream basin, 0.63 for the Ramadan Salih Stream basin, and finally 0.25 for the Gahanem Stream basin.

These low values indicate the proximity of the shape of the basins to the triangular shape, the inconsistency in their general shape, their area, and the similarity of their geomorphology, climatic conditions, lithologic structure. The decrease of this coefficient has important hydrological indications as it affects their water drainage system. When the basin takes the shape of a triangle, and the upstream region takes the shape of the tip of the triangle and its base at the estuary, this is consistent with most water basins, as the bottom of the triangle forms the water division areas. The head of the triangle creates the downstream region (Abdalhusain, 2012: 212).

3.2.6. Drainage Density (Dd)

The first work on drawing attention to the study of the density of drainage belongs to Horton, an American geomorphologist. This researcher indicated a strong relationship between the lengths of watercourses and the area of the basins (Safialdin, 1997: 198). The drainage density directly relates to the topographical and climatic conditions and the nature of the rock structures that are resistant to the erosion factors. The climate and the shape of the earth's surface are responsible for the difference in the drainage density by 97%. It can be obtained by dividing the sum of the Total drainage length in the basin by the basin's total area.

"Density of longitudinal drainage is extracted according to the following equation" (Makulla, 1986: 33) (Table 16).

$$Dd = \sum L / A$$

$\sum L$: Total drainage length (km)

A: It is the basin area (km²)

When applying the equation to the basins of the study area, it becomes clear that the ratio of longitudinal density was similar for all basins. It is 0.59 for the Okab Stream basin, 0.85 for the Hajar Stream basin, 0.65 for the Tammuz Stream basin, 1.28 for Al-Dir Stream basin, 1.13 for the Al-Ain Stream basin, 0.92 for the Al-Areej Stream basin, 1.15 for the Al-Dabbas Stream basin, 1.14 for the Marei Stream basin, 0.46 for the Munira Stream basin, 1 for the Ramadan Salih Stream basin, and finally 1.03 for the Gahanem Stream basin. The percentage was very low in the Tammuz basinThe main reasons for the low density of longitudinal drainage are the nature of limestone, dolomite, and clay rocks, the lack of rain, and high evaporation/transpiration.

3.2.7. Stream Frequency (Fs)

"The numerical density of drainage (river frequency) is extracted according to the following equation" (Aljumaile, 2013: 144):

$$Fs = N / A$$

N: Total number of streaming directories

A: It is the basin area (km²)

It is clear from Table 16 that the density values of all basins recorded are close to each other. It is 0.36 for the Okab Stream basin, 0.54 for the Hajar Stream basin, 0.81 for the Tammuz Stream basin, 0.96 for the Al-Dir Stream basin, 0.90 for the Al-Ain Stream basin, 0.81 for the Al-Areej Stream basin, 0.81 for the Al-Dabbas Stream basin, 1.23 for the Marei Stream basin, 0.38 for the Munira Stream basin, 1.01 for the Ramadan Salih Stream basin, and finally 0.80 for the Gahanem Stream basin. It is also a medium and low percentage due to the same reasons explained earlier.

3.2.8. Infiltration Number (If)

The infiltration number of a basin is obtained by multiplying the stream frequency of the basin by the drainage density. This feature provides clues to the properties of the basins about infiltration (Rai, Chaubey, Mohan and Singh, 2017; Rai, Mishra and Mohan, 2017; Rai, Chandel, Mishra and Singh, 2018):

$$If = Fs \times Dd$$

Fs: Stream Frequency

Dd: Drainage Density

Infiltration Number (If) shows the relationship between drainage density and stream frequency. It indicates the presence of many ephemeral streams or long streams in the study area. If the percentage is low, this means a high infiltration ratio in an area. If the rate is high, it reflects a low infiltration in the study area.

The value of infiltration number in the study area is shown in Table 16. This value is 0.21 in the Okab Stream basin, 0.45 in the Hajar Stream basin, 0.52 in the Tammuz Stream basin, 1.22 in the Al-Dir Stream basin, 1.01 in the Al-Ain Stream basin, 0.74 in the Al-Areej Stream basin, 0.93 in the Al-Dabbas Stream basin, 1.40 in the Marei Stream basin, 0.17 in the Munira Stream basin, 1.01 in the Ramadan Salih Stream basin, and finally 0.82 in the Gahanem Stream basin. It is concluded that the permeability of the basins in the study area was high, and the surface flow was low. It also shows that the gradient values are low in the basins.

3.3. Relief Morphometric Characteristics of the Basins

The relief features of the basin express its three-dimensional structure. These features can be used in determining the basin relief of the study area such as Elevation (**E**), Slope (**Si**), Aspect (**As**), Basins Relief (**Bh**), Relief Ratio (**Rr**), Hypsometric Curve (**Hc**), Hypsometric Integral (**Hi**), Gravelius (Compactness) Coefficient (**Kg**), Ruggedness Number (**Rn**) (Table 18).

Table 18. Relief Morphometric Characteristics of the Basins

Stream name	Bh	Rr	Hi	Kg	Rn
Okab Stream	173	0.014	0.35	1.54	0.10
Hajar Stream	121	0.012	0.42	1.44	0.10
Tammuz Stream	74	0.011	0.25	1.47	0.040
Al-Dir Stream	230	0.009	0.47	1.69	0.29
Al-Ain Stream	215	0.012	0.48	1.41	0.24
Al-Areej Stream	137	0.011	0.37	1.42	0.12
Al-Dabbas Stream	176	0.014	0.51	1.52	0.20
Marei Stream	110	0.018	0.63	1.70	0.12
Munira Stream	87	0.013	0.32	1.34	0.040
Ramadan Salih Stream	122	0.027	0.53	1.31	0.12
Gahanem Stream	113	0.018	0.59	1.38	0.11

3.3.1. Elevation (E)

According to Map 10 and Map 11 showing the elevation and topographic characters, it is seen that the heights in the study area vary between 185 m and 440 m, represented by the two folds (Atshan and Nouquit).

As the lowest elevation in the region, which lies within the southeast side, as shown in Figure 10 and 11, the heights in the basins of the study area can be classified into three categories as follows:

The first category takes place between the levels of altitude 335-440 m above sea level and is represented by relatively high peaks, steep slopes, plateaus, and rough lands, and they are the areas unsuitable for human use.

The second category is located between two levels at an altitude of 245-285 m above sea level. These parts include the areas of erosion that are exposed to geomorphological processes, and the lands are suitable for grazing.

The third category, which is around the height of 185 m, includes the areas of the collecting plains, which are exploited by permaculture, irrigated agriculture, and residential complexes.

The height levels in the study area are shown in Table 19. Elevations between 180-230 m cover an area of 41.26 km^2 and 8.98%. The area between 230-260 m was

69.67 km^2 and 15.17%. The elevations of 260-280 m have an area of 55.86 km^2 and 12.16%. The area of the lands between 280-300 m^2 was 66.78 km^2, and the percentage was 14.54. The surface area of 300-320 m elevations is 69.86 km^2 and 15.21%, the surface area of 320-340 m elevations is 73.12 km^2 and 15.92%. 44 km^2 and 9.58% between 340-360 m, 23.77 km^2 and 5.18% between 360-380 m, 9.7 km^2 and 2.11% between 380-400 m, 5.29 km^2 and 1.15% between 400-440 m covers the area.

According to the altitude categories, the total area was calculated as 459.31 km^2. There was no significant difference with the total area of the study area of 459.36 km^2.

Table 19. Elevation Values, Their Areas and Percentages in the Study Area

Elevation (m)	Area (km^2)	The ratio (%)
180-230	41.26	8.98
230-260	69.67	15.17
260-280	55.86	12.16
280-300	66.78	14.54
300-320	69.86	15.21
320-340	73.12	15.92
340-360	44	9.58
360-380	23.77	5.18
380-400	9.7	2.11
400-440	5.29	1.15
Total	459.31	100

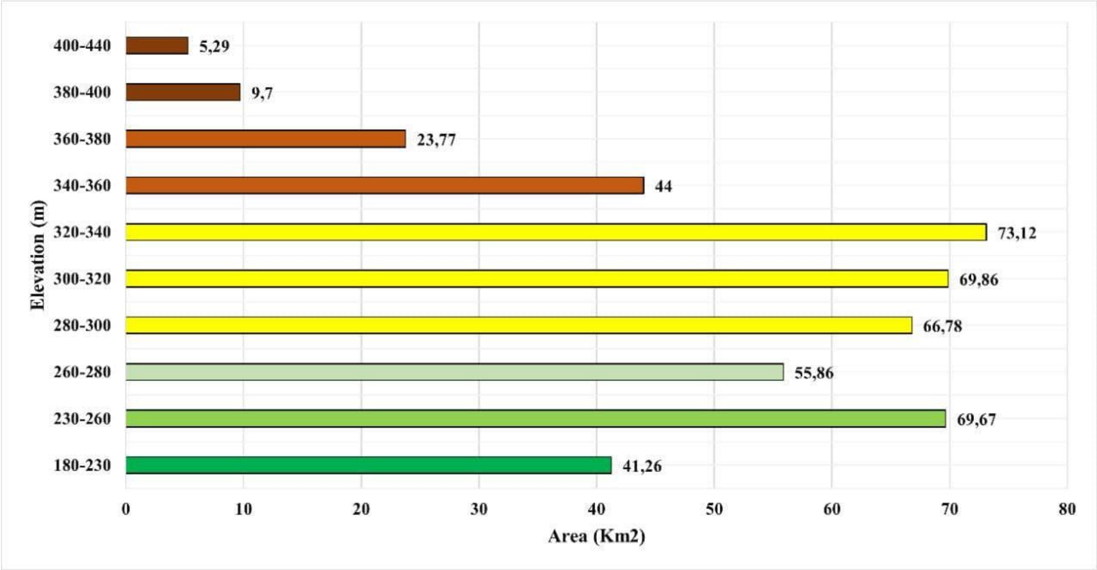


Figure 10. Altitude Categories in the Study Area

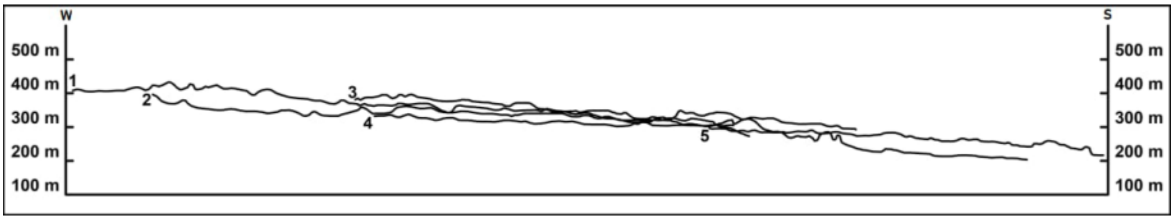
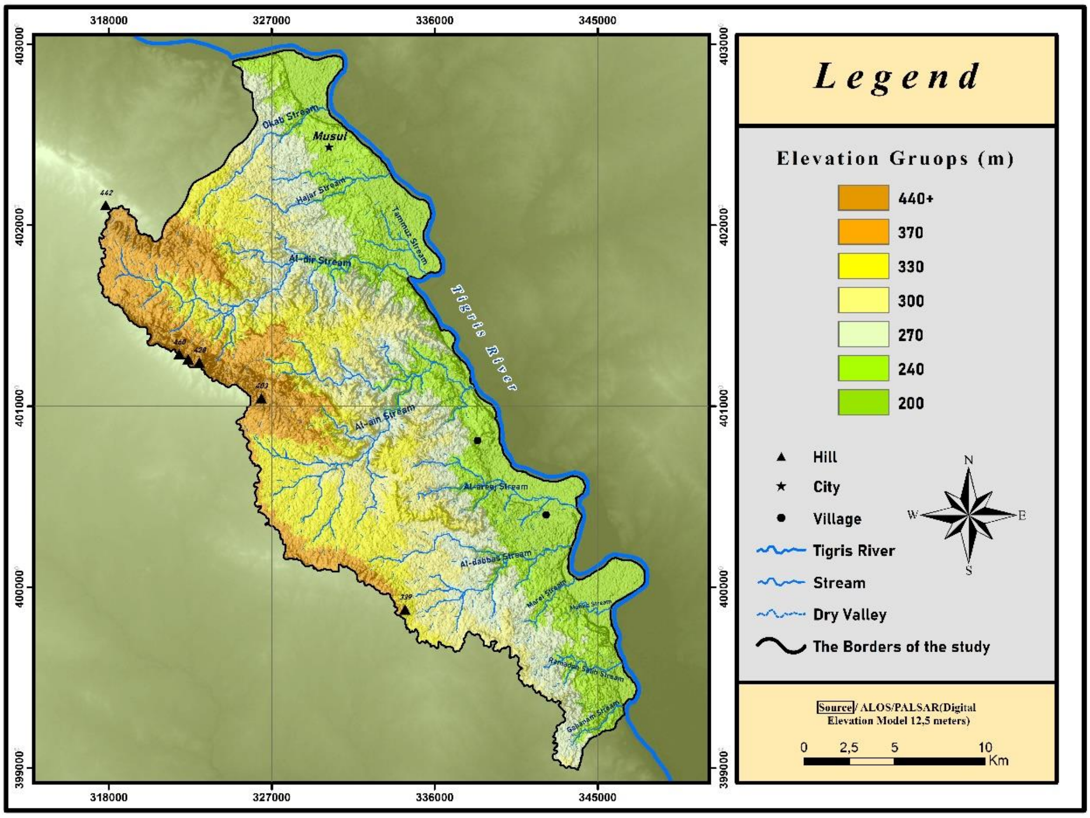
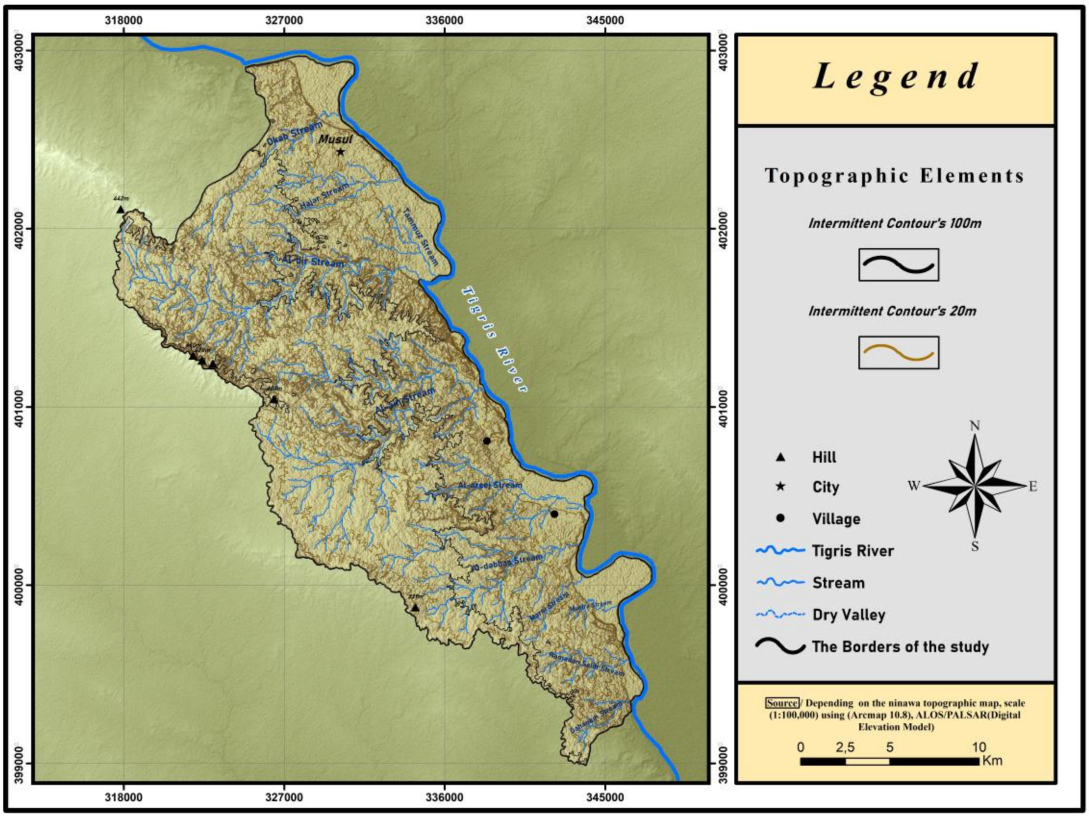


Figure 11. Profiles Showing Different Elevation Level Groups in the Study Area



MAP 10. Map of Digital Elevation Model (DEM)



MAP 11. Topographic Map of the Study Area

3.3.2. Slope (Si)

"It means the degree of inclination of the earth's surface from the horizontal plane, and it is a sensitive system associated with demolition and construction factors" (Musa, 2014: 64).

The study of slopes and the analysis of their essential characteristics, which helps understand the features of the mass movements, has a vital role in acquiring water valley basins, certainly hydrogeomorphological characteristics. The slope controls the vertical and horizontal movement of water. The study area is divided into six sections, as shown in Table 20 and Map 12.

Table 20. Slope Values, Their Areas and Percentages in the Study Area

Slope (°)	Degree slope	Area/ km^2	The ratio%
1	0° - 2°	48.15	10.483
2	2° - 5°	169.78	36.964
3	5° - 10°	169.69	36.945
4	10° - 20°	63.09	13.736
5	20° - 30°	7.44	1.619
6	30°+	1.16	0.253
Total		459.31	100

In the light of the classification mentioned above, the lands of the study area are identified as follows:

Flatland range

It includes lands with a slope not exceeding 2°, which are plain lands with a slight incline. It has flat areas that were covered with sediments transported from higher areas by erosion processes. The regions constitute an area of 48.15 km^2 and account for 10.4% of the area.

Slightly undulating slope range

This range spreads adjacent to the plains and undulating lands. These lands occupy a gradient of 2°-5°. These areas are characterized by light ripples and cover an area of 169.78 km^2 of the area with a percentage of 36.9%.

Range of undulating land

This range includes areas whose slope ranges between 5°-10°, and this range constitutes an area of 169.69 km^2 with a percentage of 36.9% of the region's total area. Water flows reduce the chances of filtration and penetration of the sub-surface layers and then increase the volume of discharges at the mouth of the basins on the Tigris River.

The scope of the cut-off lands

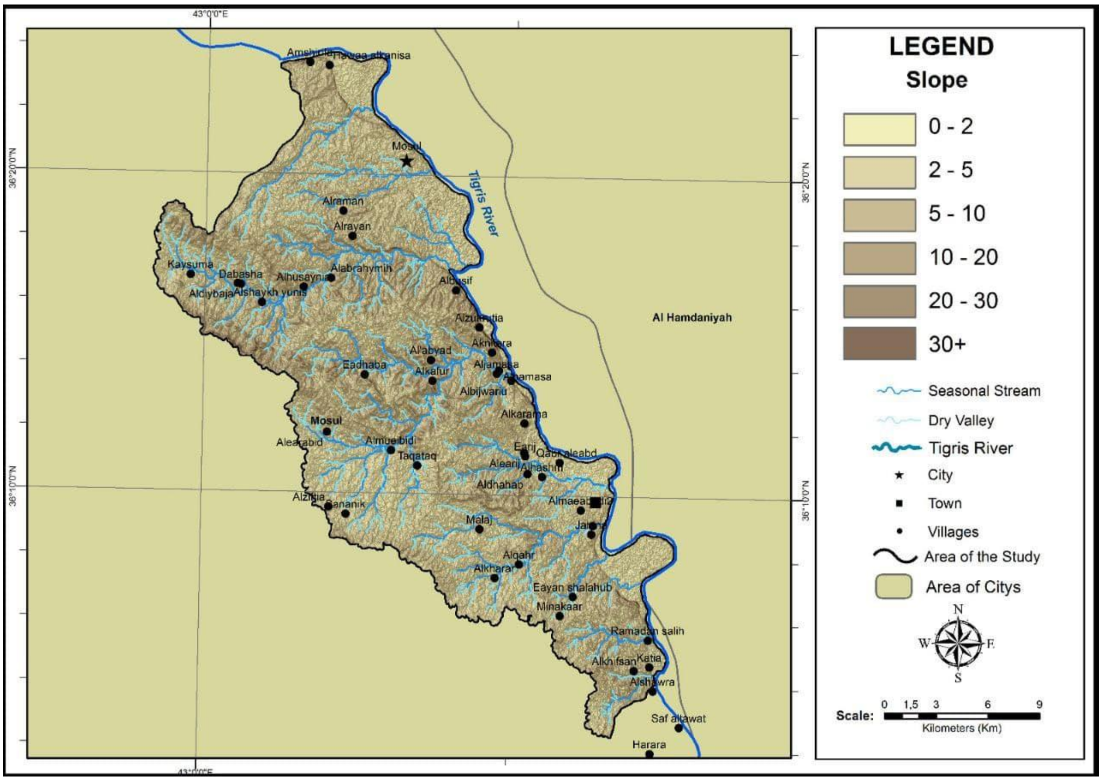
The slope ratio in this group ranges between 10°-20°. These values constitute an area of 63.09 km^2 with a percentage of 13.7% of the total study area. The lands of this range comprise the water division areas of the valley basins and separate the basins from each other.

Highlands points

The slope ratio in this group ranges between 20°-30° and constitutes an area of 7.44 km^2 with a percentage of 1.6% of the total study area.

The range with the most significant slope

The slope ratio in this range is between +30° and constitutes a small percentage where its area is 1.16 km^2, with a percentage of 0.25% of the total study area as shown on Map 12.



MAP 12. Slope Map of the Study Area

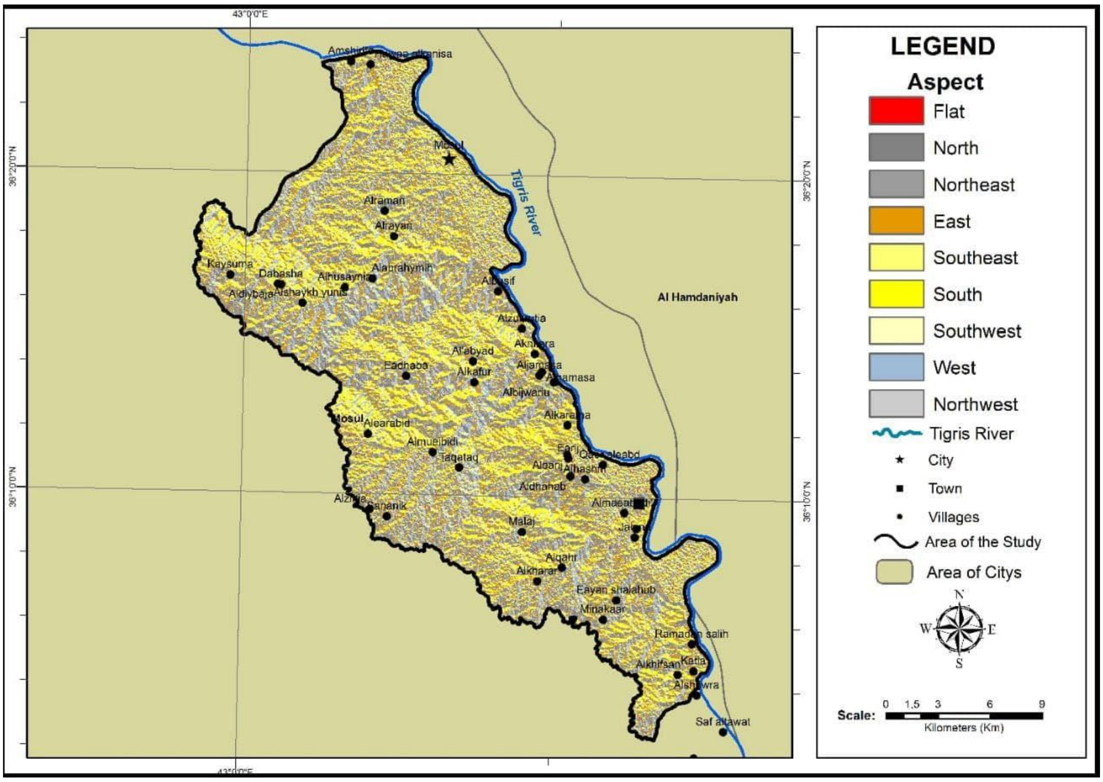
3.3.3. Aspect (As)

Aspect affects whether it receives the sun's rays and precipitation (Erol, 1988). Knowing the direction of the gradient has many benefits that help predict the direction of surface water movement, especially in high areas, as well as in determining the areas facing the sun and the appropriate conditions for the formation of vegetation cover and the ability of the soil to retain moisture. According to Table 21 and Map 13, the slope in the region varies. The most inclined direction was the northeast direction, with an area of approximately 77.22 km^2 and 16.81%.

The second largest slope direction group in the study area is the north direction (76.44 km^2 area and 16.64%), and the third largest slope direction group is the southeast (63.32 km^2 area and 13.78%). The area of the east direction, which follows this with a small margin, is 63.23 km^2 and has a share of 13.76%. Looking at the other aspects, it is the south with 57.31 km^2 and 12.47%, the northwest with 48.82 km^2 and 10.62%, the southwest with 38.22 km^2 and 8.36%, and finally the west with 31.98 km^2 and 6.96%. The area of flat areas was 2.77 km^2 and the percentage was 0.6.

Table 21. Slope Directions, Their Areas, and Percentages in the Study Area

T	Slope direction	Area/km^2	The ratio %
1	FLAT	2.77	0.6
2	N	76.44	16.64
3	NE	77.22	16.81
4	E	63.23	13.76
5	SE	63.32	13.78
6	S	57.31	12.47
7	SW	38.22	8.36
8	W	31.98	6.96
9	NW	48.82	10.62
Total		459.31	100



MAP 13. Aspect Map of the Study Area

3.3.4. Lateral and Longitudinal Profile Characteristics of the Streams in the Study Area

3.3.4.1. Longitudinal Profiles

"A cartographic slope expresses the extent of the water basin's ability to deepen vertically, and by the longitudinal section, it means the arc that represents the slope and extension of the watercourse with extreme precision from the beginning of the source to the lowest point in the slope" (Bahaire, 1979: 122).

The importance of studying the longitudinal sections of the water valleys lies in the geomorphological and hydrological studies because they reflect the regressive characteristics of the valley section and the extent of its impact on the water flow and its sedimentary capacity, and the importance of its effect on changing the parts of the valley and taking its current shape. The longitudinal sections appear sloping within the areas where the rocks are complex and highly resistant to the natural vegetation. There are two main reasons for the presence of parts or a steep point within the longitudinal sector of the valley, which are:

The First Reason

Structurally, the presence of hard rocks in these parts of the valley has not deepened its path to a significant deformation. The formation of the very steep section in the Al-Ain Valley basin can be attributed to a fracture like this.

The Second Reason

The decrease in the base level at which the water flow ends leads to the emergence of a steep slope that slowly retreats towards the source, depending on natural conditions. In comparison, the longitudinal sector of a low slope appears within the areas where the rocks are of low hardness and resistance and the stability of the water flow system. One of its examples is located in the Al-Areej Stream basin (Jad, 1984: 83-84).

The longitudinal sectors of the basin water drainage describe a geomorphological stage when the section approaches the convex form. This indicates the imbalance between erosion and sedimentation (youth stage). When it is flat horizontally, and its concavity decreases from the center, it shows the balance stage (maturity). When it straightens at the bottom (concave), this shows the location of imbalance (aging).

It is clear from the figures below that all the longitudinal sections of the valleys under study showed a balance between the water division areas and the downstream area, which indicates that the whole valleys are from the rainy period of the Quaternary geological time (Pleistocene) (Figures 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, and 22). For this reason, its sections are going through the end of the maturity stage and the beginning of the aging stage. The current dry climate conditions (Holocene) affected them because the current climate cannot develop such valley networks, as shown in the First Chapter.

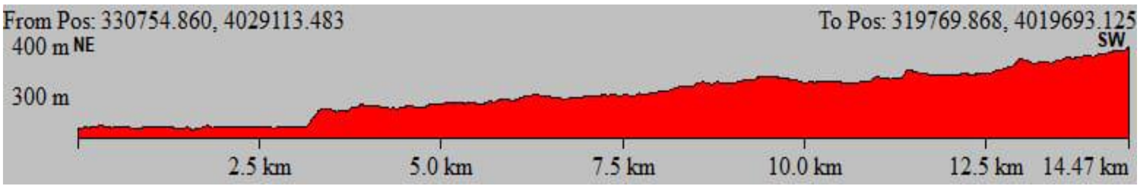


Figure 12. Longitudinal Profile of the Okab Stream Basin

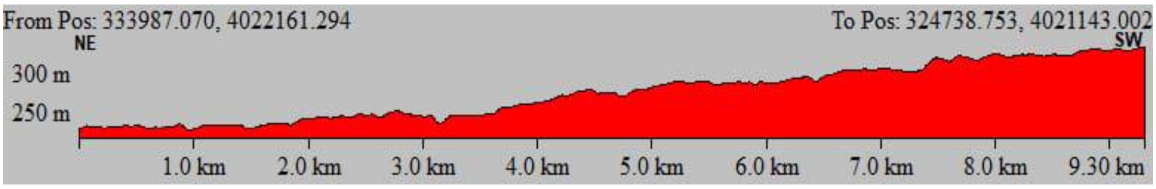


Figure 13. Longitudinal Profile of the Hajar Stream Basin

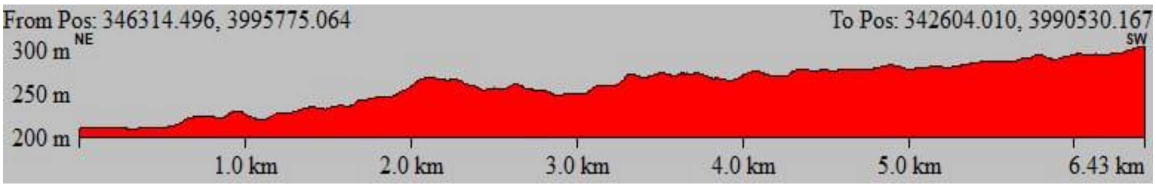


Figure 14. Longitudinal Profile of the Tammuz Stream Basin

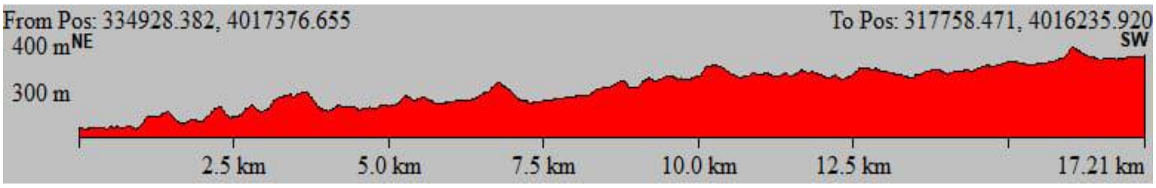


Figure15. Longitudinal Profile of the Al-Dir Stream Basin

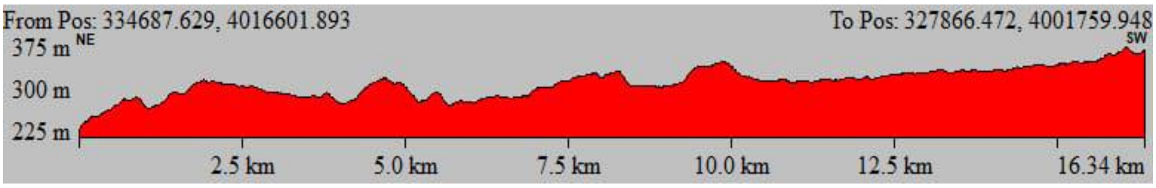


Figure 16. Longitudinal Profile of the Al-Ain Stream Basin

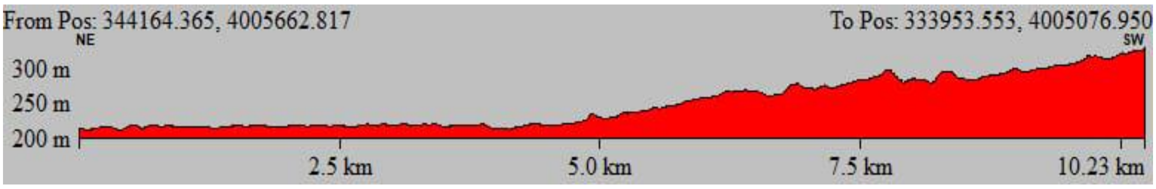


Figure 17. Longitudinal Profile of the Al-Areej Stream Basin

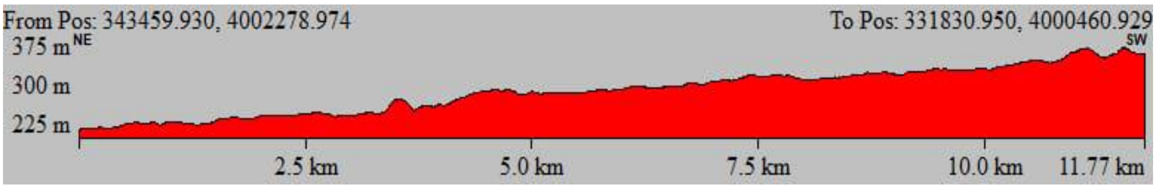


Figure 18. Longitudinal Profile of the Al-Dabbas Stream Basin

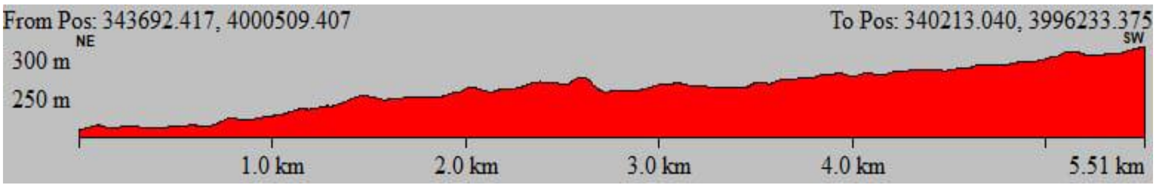


Figure 19. Longitudinal Profile of the Marei Stream Basin

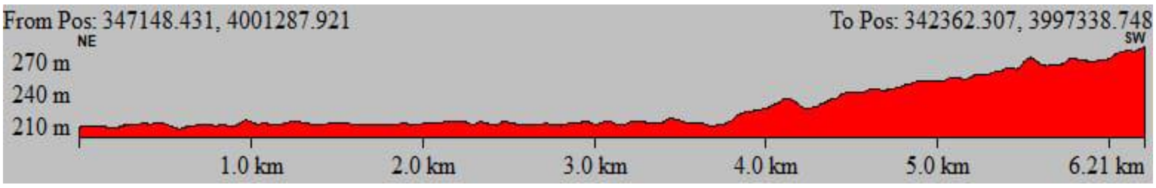


Figure 20. Longitudinal Profile of the Munira Stream Basin

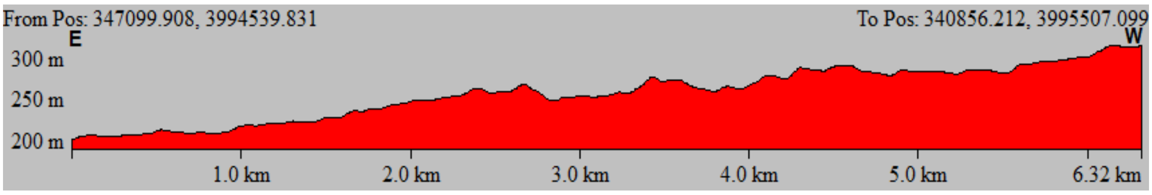


Figure 21. Longitudinal Profile of the Ramadan Salih Stream Basin

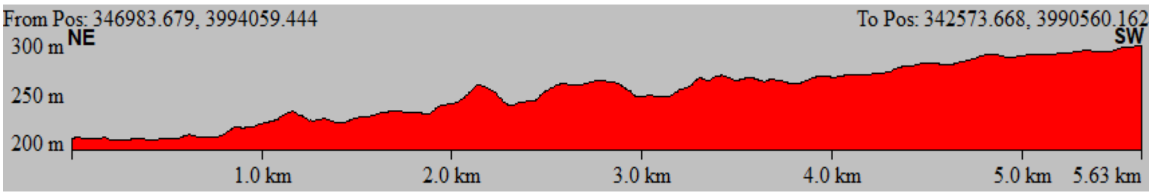


Figure 22. Longitudinal Profile of the Gahanem Stream Basin

3.3.4.2. Transversal Profiles

Profiles contribute to determining the geomorphological development stages of the valley, the extent of geomorphological processes (erosion and sedimentation), associated phenomena, and indicate V-shape valleys. It is described as the stage of youth and maturity if the valley compares the letter 'U'.

But if it has divergent sides and a broad base, it is described as the stage of aging. The cross-section is affected by the same factors involved by the longitudinal sections. The cross-sections of the studied valleys have been discussed, starting from the upstream region, then the middle, and ending with the downstream area. From the observation of the following figures, it is evident:

The Okab Stream Basin (Source Cross-Section)

This section is 250-1012 meters in length and is between a height of 234-237 meters in the southeast. This section is in the stage of maturity, as shown in Figure 23.

The Okab Stream Basin (Middle Cross-Section)

This section consists of 0.5-3.18 km and is between a height of 290-310 meters in the southeast. It is in a stage of maturity that tends to age, as shown in Figure 24.

The Okab Stream Basin (Estuary Cross-Section)

This section is 1-5.10 km long and is 360-420 meters high in the southeast. As seen in Figure 25, it can be said that the valley is in its youth phase due to the letter 'V' appearance.

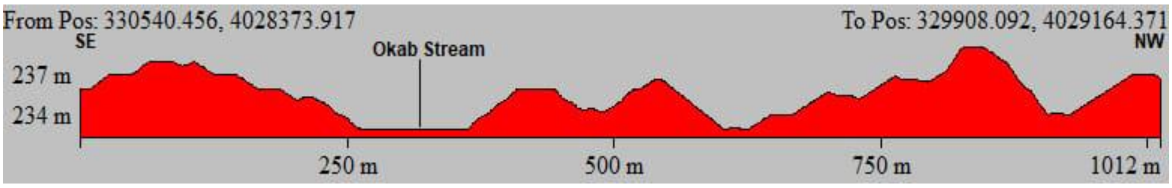


Figure 23. Cross-Section of the Water Division Areas of the Okab Stream Basin

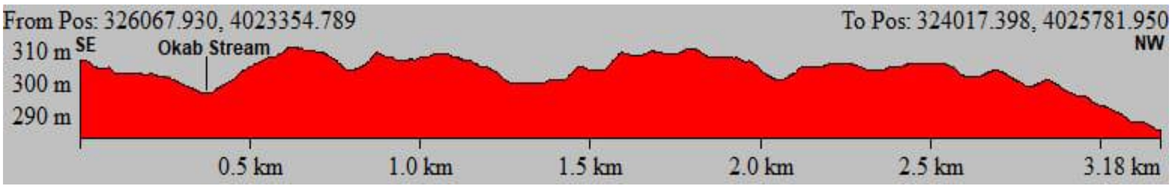


Figure 24. Cross-Section of the Middle of the Okab Stream Basin

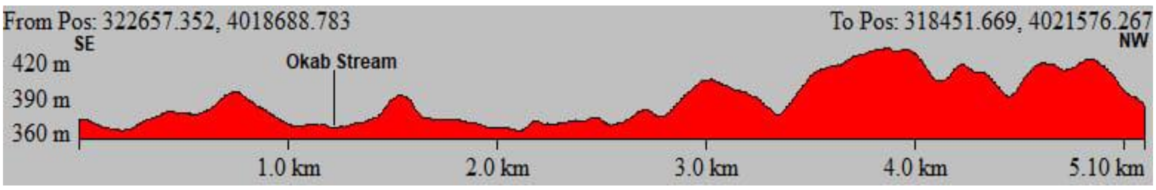


Figure 25. Cross-Section of the Mouth of the Okab Stream Basin

The Hajar Stream Basin (Source Cross-Section)

This section is 4.45-05 km and takes place between a height of 225-255 meters in the southeast, where the valley is in its aging stage, as shown in Figure 26.

The Hajar Stream Basin (Middle Cross-Section)

This section extends 1-5.11 km and takes place between a height of 270-290 meters in the southeast. The valley is at the youth stage's end and the maturity stage's beginning, as shown in Figure 27.

The Hajar Stream Basin (Estuary Cross-Section)

This section is 125-945 meters and is located between a height of 227-333 m in the southeast. The valley is at the end of the maturity stage and the beginning of the aging stage, as shown in Figure 28.

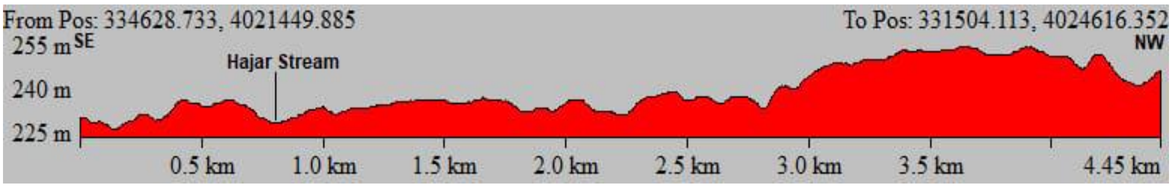


Figure 26. Cross-Section of the Water Division Areas of the Hajar Stream Basin

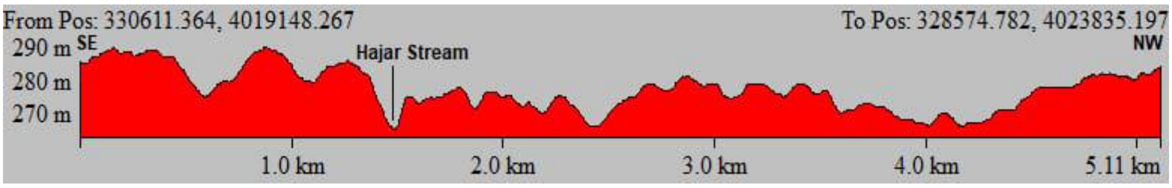


Figure 27. Cross-Section of the Middle of the Hajar Stream Basin

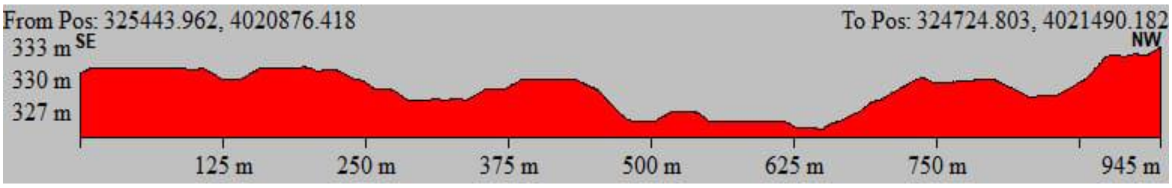


Figure 28. Cross-Section of the Mouth of the Hajar Stream Basin

The Tammuz Stream Basin (Source Cross-Section)

This section consists of an area of 250-1115 meters and is located between a height of 205-210 m in the southeast, where the valley is in the stage of maturity, as shown in Figure 29.

The Tammuz Stream Basin (Middle Cross-Section)

This section is formed between an area of 2.5 km-15.99 km and is located between a height of 200-300 meters in the southeast. The valley is in the stage of maturity, as shown in Figure 30.

The Tammuz Stream Basin (Estuary Cross-Section)

This section consists of an area of 250-1179 meters and is located between a height of 290-310 meters in the southeast. The valley is at the end of the maturity stage, the beginning of the aging stage, as shown in Figure 31.

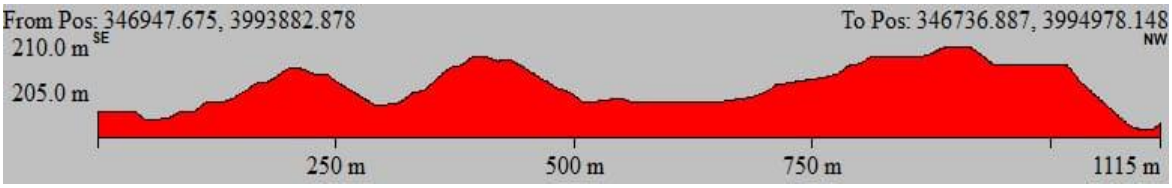


Figure 29. Cross-Section of the Water Division Areas of the Tammuz StreamBasin

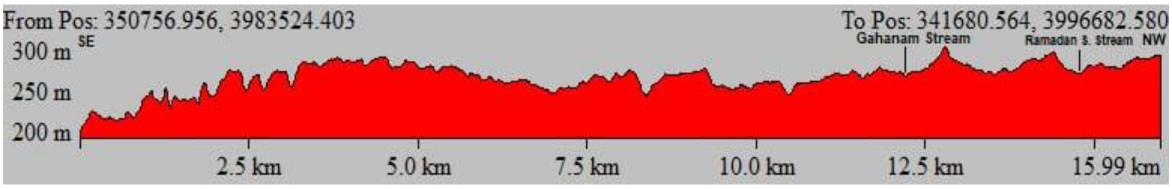


Figure 30. Cross-Section of the Middle of the Tammuz Stream Basin

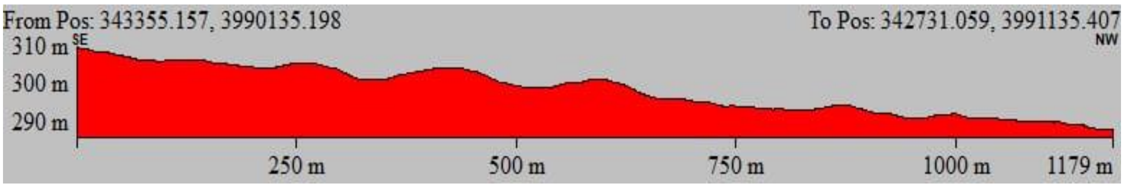


Figure 31. Cross-Section of the Mouth of the Tammuz Stream Basin

The Al-Dir Stream Basin (Source Cross-Section)

This section consists of an area of 250-1695 meters and is located between a height of 230-250 m in the southeast. The valley is in the mature stage, as shown in Figure 32.

The Al-Dir Stream Basin (Middle Cross-Section)

This section is formed between an area of 1-6.85 km and is located between a height of 300-360 meters in the southeast. The valley is in the mature stage, as shown in Figure 33.

The Al-Dir Stream Basin (Estuary Cross-Section)

This section consists of an area of 250-1726 meters and is located between a height of 380-420 meters in the southeast. The valley is at the end of the maturity stage, the beginning of the aging stage, as shown in Figure 34.

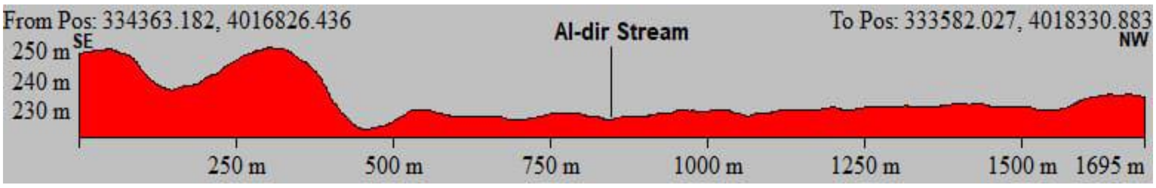


Figure 32. Cross-Section of the Water Division Areas of the Al-Dir Stream Basin

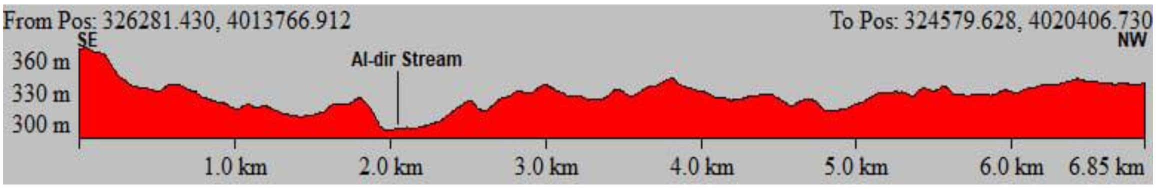


Figure 33. Cross-Section of the Middle of the Al-Dir Stream Basin

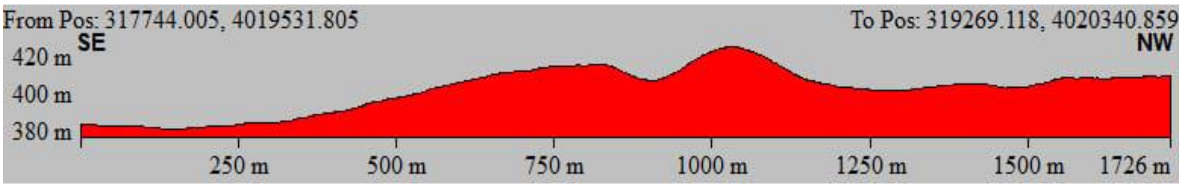


Figure 34. Cross-Section of the Mouth of the Al-Dir Stream Basin

The Al-Ain Stream Basin (Source Cross-Section)

This section consists of an area of 1-6.74 km and is located between a height of 250-300 meters in the southeast. The valley is in the stage of maturity, as shown in Figure 35.

The Al-Ain Stream Basin (Middle Cross-Section)

This section consists of an area of 1-9.16 km and is located between a height of 300-375 meters in the southeast. The valley is in the mature stage, as shown in Figure 36.

The Al-Ain Stream Basin (Estuary Cross-Section)

This section is formed between an area of 0.5-3.71 km, where it is located between a height of 270-350 meters in the southeast. The valley is in maturity, as shown in Figure 37.

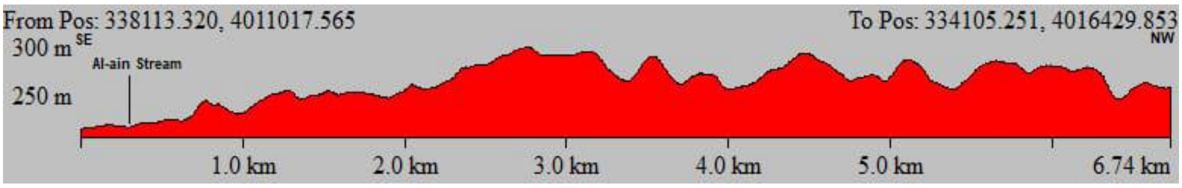


Figure 35. Cross-Section of the Water Division Areas of the Al-Ain Stream Basin

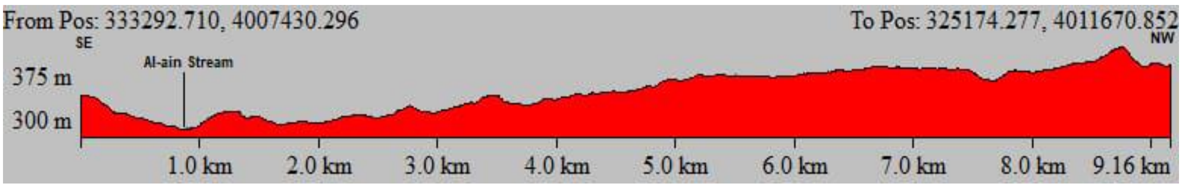


Figure 36. Cross-Section of the Middle of the Al-Ain Stream Basin

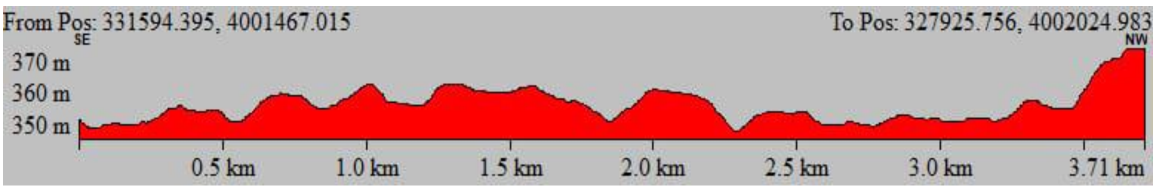


Figure 37. Cross-Section of the Mouth of the Al-Ain Stream Basin

The Al-Areej Stream Basin (Source Cross-Section)

This section consists of an area of 125-957 meters and is located between a height of 210-213 meters in the southeast. The valley is in the youth stage, as shown in Figure 38.

The Al-Areej Stream Basin (Middle Cross-Section)

This section is formed between an area of 1-6.75 km and is located between a height of 240-280 meters in the southeast, and the valley is in the stage of maturity, as shown in Figure 39.

The Al-Areej Stream Basin (Estuary Cross-Section)

This section consists of an area of 0.5-3.61 km, which is located between a height of 310-330 meters in the southeast. The valley is at the end of the maturity stage, the beginning of the aging stage, as shown in Figure 40.

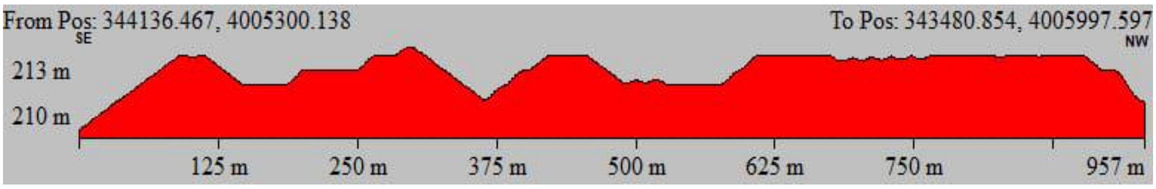


Figure 38. Cross-Section of the Water Division Areas of the Al-Areej Stream Basin

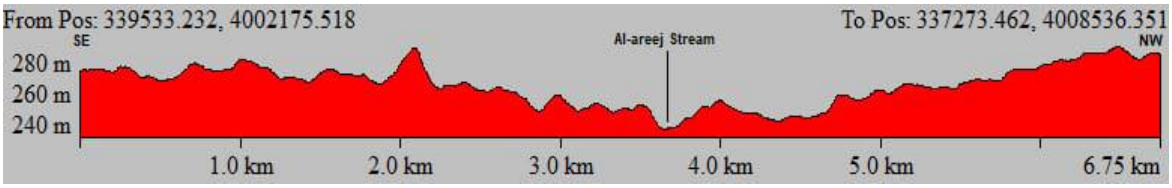


Figure 39. Cross-Section of the Middle of the Al-Areej Stream Basin

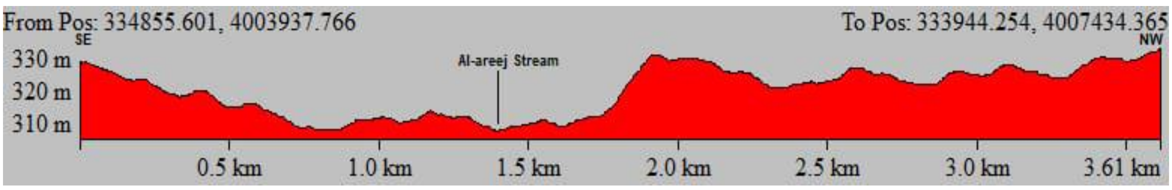


Figure 40. Cross-Section of the Mouth of the Al-Areej Stream Basin

The Al-Dabbas Stream Basin (Source Cross-Section)

This section is formed between an area of 0.5-2.89 km, where it is located between a height of 210-230 meters in the southeast. The valley is in the stage of maturity, as shown in Figure 41.

The Al-Dabbas Stream Basin (Middle Cross-Section)

This section consists of an area of 1-8.07 km, located between a height of 280-320 meters in the southeast. The valley is in the aging stage, as shown in Figure 42.

The Al-Dabbas Stream Basin (Estuary Cross-Section)

This section consists of an area of 250-1966 meters, located between a height of 345-360 meters in the southeast. The valley is in the aging stage, as shown in Figure 43.

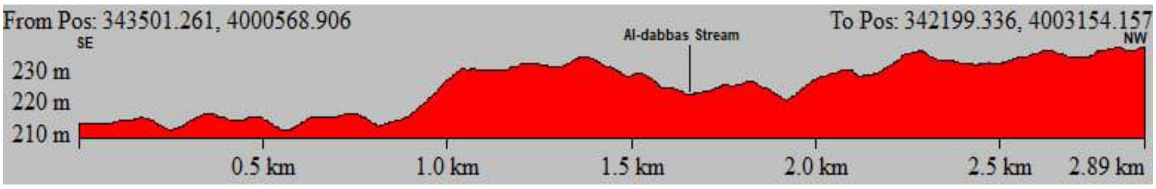


Figure 41. Cross-Section of the Water Division Areas of the Al-Dabbas Stream Basin

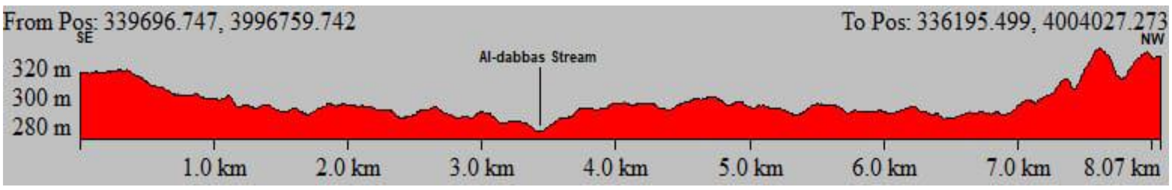


Figure 42. Cross-Section of the Middle of the Al-Dabbas Stream Basin

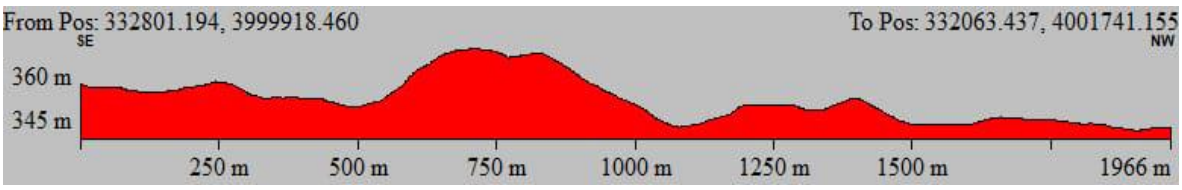


Figure 43. Cross-Section of the Mouth of the Al-Dabbas Stream Basin

The Marei Stream Basin (Source Cross-Section)

This section consists of an area of 50-294 meters, which is located between a height of 211.5-214.5 meters in the southeast. The valley is in the stage of maturity, as shown in Figure 44.

The Marei Stream Basin (Middle Cross-Section)

This section is formed between an area of 250-1156 meters, which is located between a height of 255-270 meters in the southeast. The valley is in the stage of late maturity and the beginning of its aging, as shown in Figure 45.

The Marei Stream Basin (Estuary Cross-Section)

This section consists of an area of 50-436 meters, which is located between a height of 210-320 meters in the southeast, and the valley is in the aging stage, as shown in Figure 46.

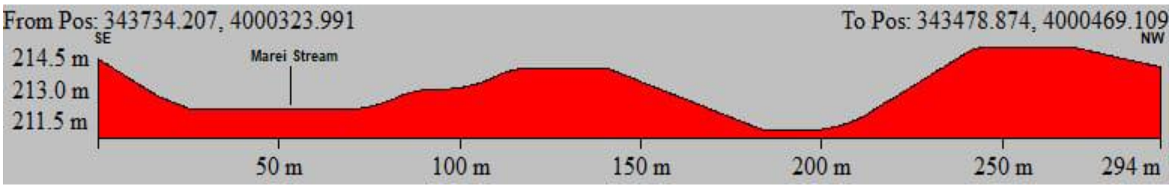


Figure 44. Cross-Section of the Water DivisionAreas of the Marei Stream Basin

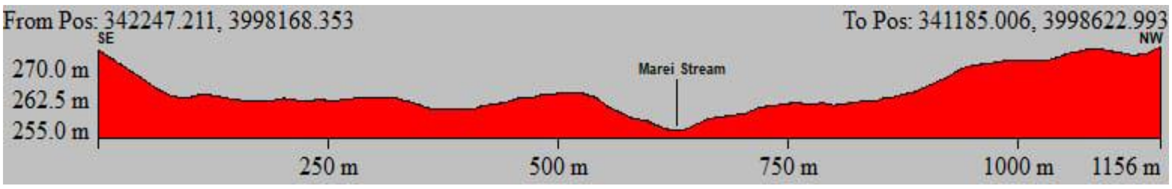


Figure 45. Cross-Section of the Middleof the Marei Stream Basin

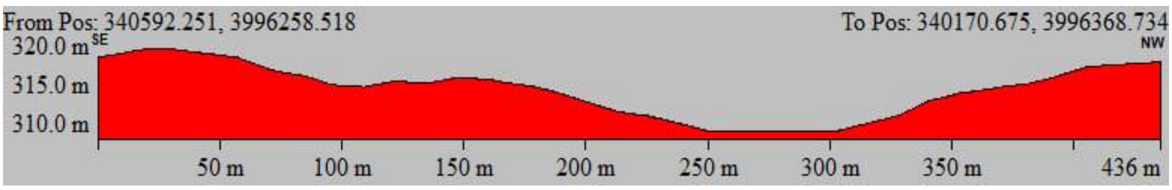


Figure 46 Cross-Section of the Mouth of the Marei Stream Basin

The Munira Stream Basin (Source Cross-Section)

This section consists of an area of 250-1949 meters, which is located between a height of 207-213 meters in the southeast. This valley is in the stage of maturity, as shown in Figure 47.

The Munira Stream Basin (Middle Cross-Section)

This section is formed between an area of 1-5.20 km, located between a height of 210-240 meters in the southeast. The valley is at the end of the maturity stage and the beginning of its aging stages, as shown in Figure 48.

The Munira Stream Basin (Estuary Cross-Section)

This section consists of an area of 125-587 meters, which is located between a height of 280-285 meters in the southeast. The valley is in the aging stage, as shown in Figure 49.

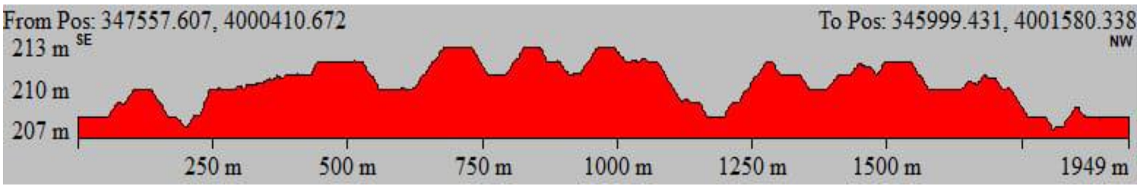


Figure 47. Cross-Section of the Water Division Areas of the Munira StreamBasin

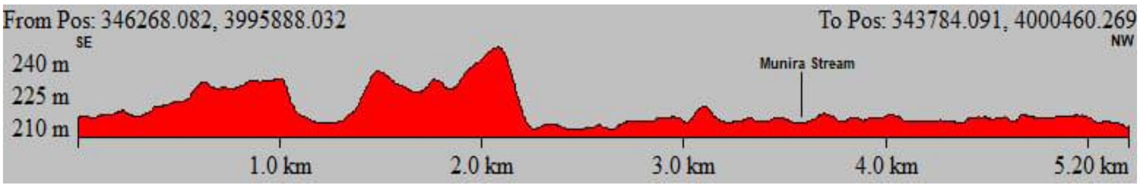


Figure 48. Cross-Section of the Middle of the Munira Stream Basin

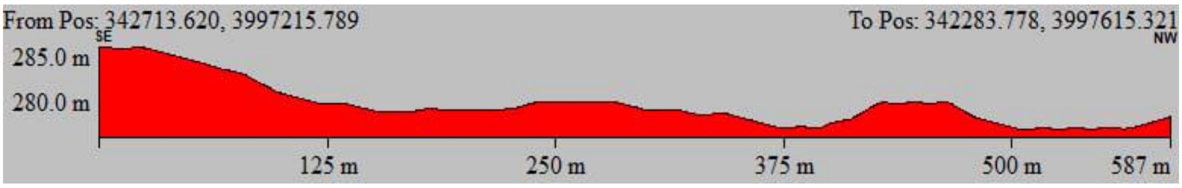


Figure 49. Cross-Section of the Mouthof the Munira Stream Basin

The Ramadan Salih Stream Basin (Source Cross-Section)

This section is formed between an area of 0.5-2.87 km, and is located between a height of 290-310 meters in the southeast. The valley is in its youth stage, as shown in Figure 50.

The Ramadan Salih Stream Basin (Middle Cross-Section)

This section consists of an area of 0.5-3.48 km and is located between a height of 260-300 meters in the southeast. The valley is in its youth stage, as shown in Figure 51.

The Ramadan Salih Stream Basin (Estuary Cross-Section)

This section consists of an area of 0.5-2.43 km, where is located between a height of 210-240 meters in the southeast. The valley is in the aging stage, as shown in Figure 52.

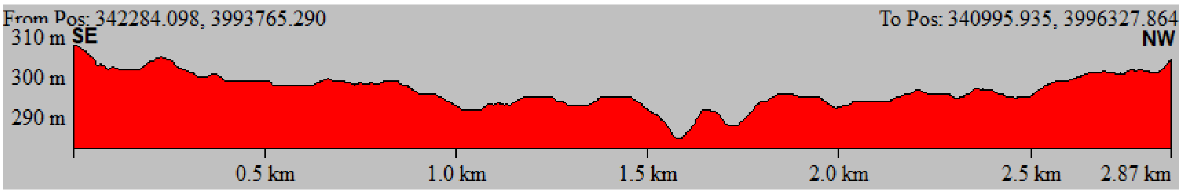


Figure 50. Cross-Section of the Water Division Areas of the Ramadan Salih Stream Basin

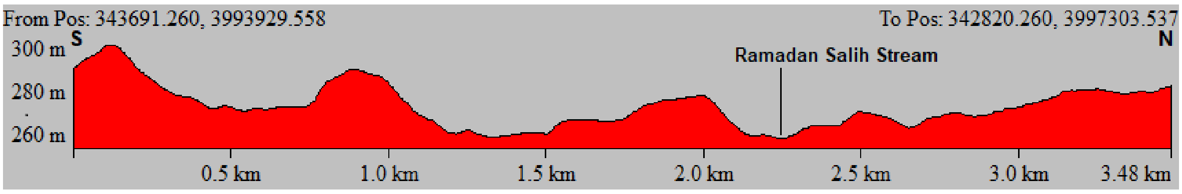


Figure 51. Cross-Section of the Middle of the Ramadan Salih Stream Basin

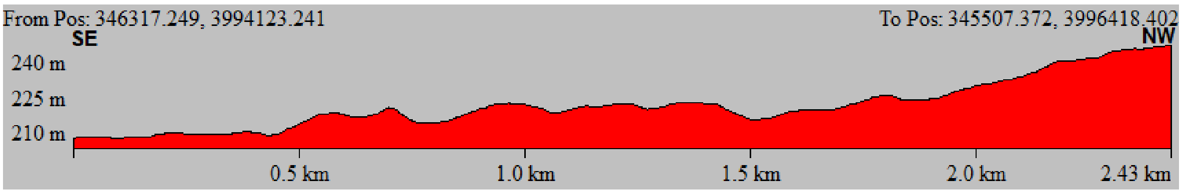


Figure 52 Cross-Section of the Mouth of the Ramadan Salih Stream Basin

The Gahanem Stream Basin (Source Cross-Section)

This section consists of an area of 0.5-2.21 km, where is located between a height of 290-310 meters in the southeast. The valley is in the stage of maturity, as shown in Figure 53.

The Gahanem Stream Basin (Middle Cross-Section)

This section consists of an area of 0.5-2.56 km, where is located between a height of 200-300 meters in the southeast. The valley is in its aging stage, as shown in Figure 54.

The Gahanem Stream Basin (Estuary Cross-Section)

This section consists of an area of 250-1179 meters, where is located between a height of 290-310 meters in the southeast. The valley is in the aging stage, as shown in Figure 55.

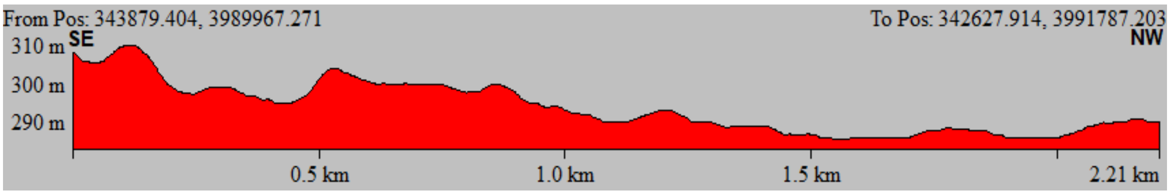


Figure 53. Cross-Section of the Water Division Areas of the Gahanem Stream Basin

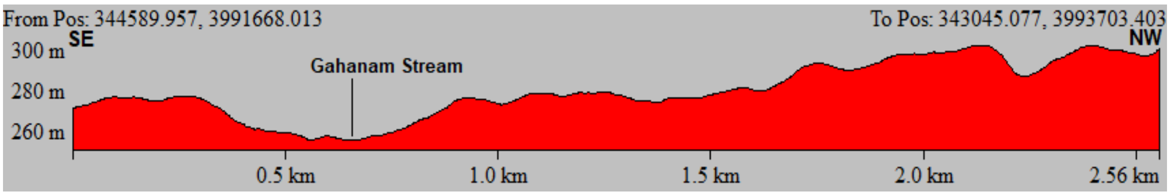


Figure 54. Cross-Section of the Middle of the Gahanem Stream Basin

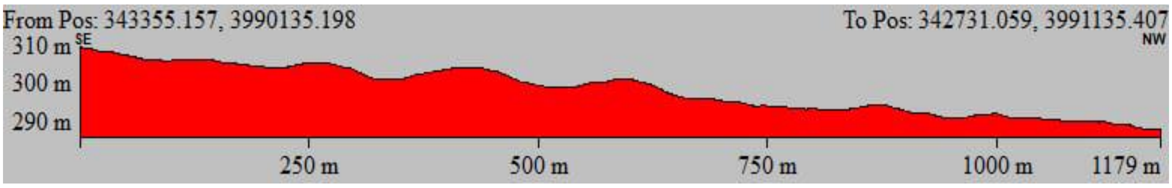


Figure 55. Cross-Section of the Mouth of the Gahanem Stream Basin

3.3.5. Basin Relief (Bh)

The basin relief is between the highest and lowest points of the basin. It is known as the elevation difference of the basin (Strahler, 1958). Slope and rough conditions, the functioning of the fluvial process, the effectiveness of erosive activities, vegetation type and density, soil properties, changes in climatic parameters, the amount and type of precipitation, the amount and speed of flow are affected and shaped according to the degree of the basin relief.

$$B\mathrm{H} = Hmax - Hmin$$

$Hmax$: Maximum high point in the basin (m)
$Hmin$: It is the minimum high point in the basin (m)

When applying the equation to the basins of the study area, the results were as follows: 173 in the Okab Stream basin, 121 in the Hajar Stream basin, 74 in the Tammuz Stream basin, 230 in the Al-Dir Stream basin, 215 in the Al-Ain Stream basin, 137 in the Al-Areej Stream basin, 176 in the Al-Dabbas Stream basin, 110 in the Marei Stream basin, 87 in the Munira Stream basin, 122 in the Ramadan Salih Stream basin, and 113 in the Gahanem Stream basin Table 18.

3.3.6. Relief Ratio (Rr)

"Relief ratio is an important measure for understanding the topographical nature of the basin and the consequent determination of the velocity of water flow, the volume of discharge, and the amount of sediment transported. The higher values of the relief ratio indicate the speed of water reaching the downstream area" (Aldarraji, 2019:94-95) and the decrease in the concentration of surface runoff time and the height of the flood crest (Salama, 1980). The increase in the processes of water erosion and sediment and the multiplicity of landforms such as flood fans, and the smallness of the area basin, and on the contrary lies the sign of low values (Abdalhusain, 2012: 222). The equation is extracted according to the following formula (Almaliki, 2016: 195):

$$Rr = B\mathrm{h} / Lbmax$$

Bh: Maximum basin relief (m)
Lbmax: Maximum basin length (m)

It is clear in Table 18 that the lowest percentage is in the Al-Dir Valley basin at 0.009, and the highest percentage is in the Ramadan Salih Stream at 0.027. The rate of the rest of the basins was as follows: 0.014 in the Okab Stream basin, 0.012 in the Hajar Stream basin, 0.011 in the Tammuz Stream basin, 0.012 in the Al-Ain Stream basin, 0.011 in the Al-Areej Stream basin, 0.014 in the Al-Dabbas basin, 0.018 in the Marei Stream basin, 0.013 in the Munira Stream basin, and finally 0.018 in the Gahanem Stream basin. It is seen that the ratios are extremely low. Considering the small basin areas, the low relief ratio (Rr) indicates that the surface flow and the flood susceptibility are low (Arslantaş Dik, 2021: 158)

3.3.7. Hypsometric Curve

"The hypsometric parameter is one of the best quantitative variables for understanding the relationship between the basin's topography and surface erosion by surface runoff. It is an important time scale that expresses the basement stage that the drainage basin goes through. It also indicates the rock materials that have been removed by erosion and the materials that are still waiting for their turn in the erosion process" (Salama, 1980: 102).

It also means an accurate description of the shape of the longitudinal sector of the river valley in proportion to the area and relief, as well as giving it an indication of the size of the rough topography that will form in the future sediments transferred to the downstream environment (Alluhaibi, 2011: 371).

"The value of this arithmetic coefficient is constantly decreasing as the activity of the base stage of the water basins reaches its lowest in the aging stage and is extracted according to the following equation" (Makulla, 1986: 42).

$$x=a/A \quad y=h/H$$

a: Relative area
h: Relative height

Hypsometric curve (Hc) shows the height of land from the surface of the earth, from which sea level contour lines are initiated. The hypsometric approach was proposed by Schumn, Miller, and Langbein and applied its year 1958 (Dawood, 2002: 198).

According to Ashur (1984), it is a quantitative method describing the morphology of the water basin, through which it is possible to infer the basement stage reached by the basin quantitatively and accurately.

It is easy to compare the various river basins, regardless of their different areas and heights. By representing the curve, the part located above the curve of the area of the square that consists of two axes represents the amount of what was removed from the rock mass by erosion, and the area under the curve represents the remaining rock mass, represents materials located above the local base level (Makulla, 1986: 43).

Depending on the values of the hypsometric curve, two axes were plotted to represent the vertical axis, the relative height, and the horizontal axis represents the close area. The curve was near the middle, but the basin had reached senescence if slightly flattened the slope downwards (Strahler, 1958) before.

In this regard, the hypsometric curve should not be relied upon in the regression analysis, as it is a statistical curve that is not a topographical sector. Still, the researcher can partially depend on the part in which an evident change appears in the search for the reason of the severity or slowness of the regression in this part, as it may be the result of widening. The area or its narrowness in a level category causes the steepness or slowness of the gradient. Still, it is not correct to analyze the regression (Jad, 1984: 112) as mentioned in the figures below.

The Okab Stream basin has just completed its maturity stage and entered the old age stage, as shown in Figure 56.

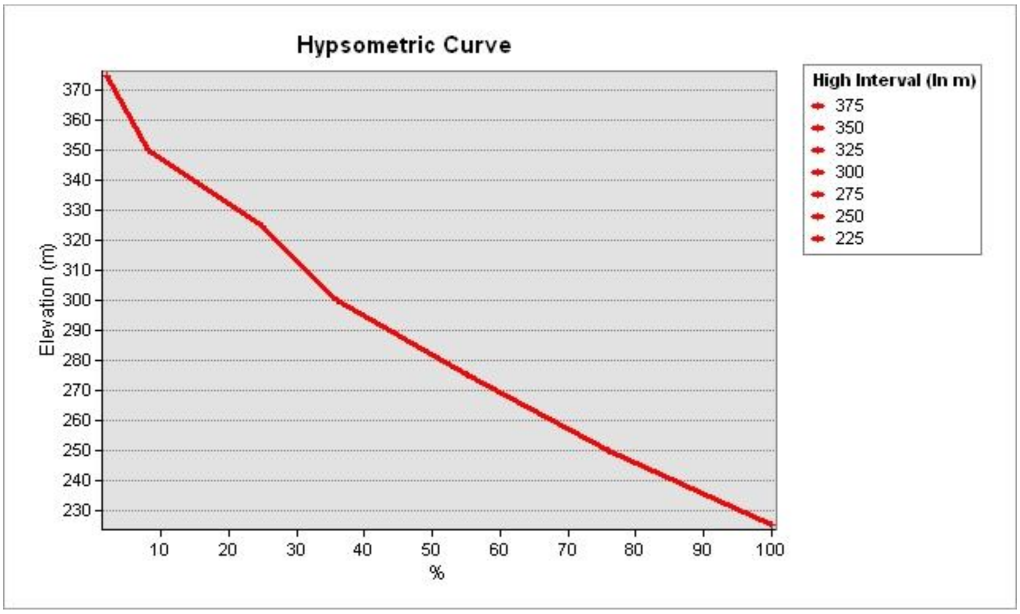


Figure 56. Hypsometric Curve of the Okab Stream Basin

The Hajar Stream basin is undergoing a stage of maturation because the curve has no more convexity, as shown in Figure 57.

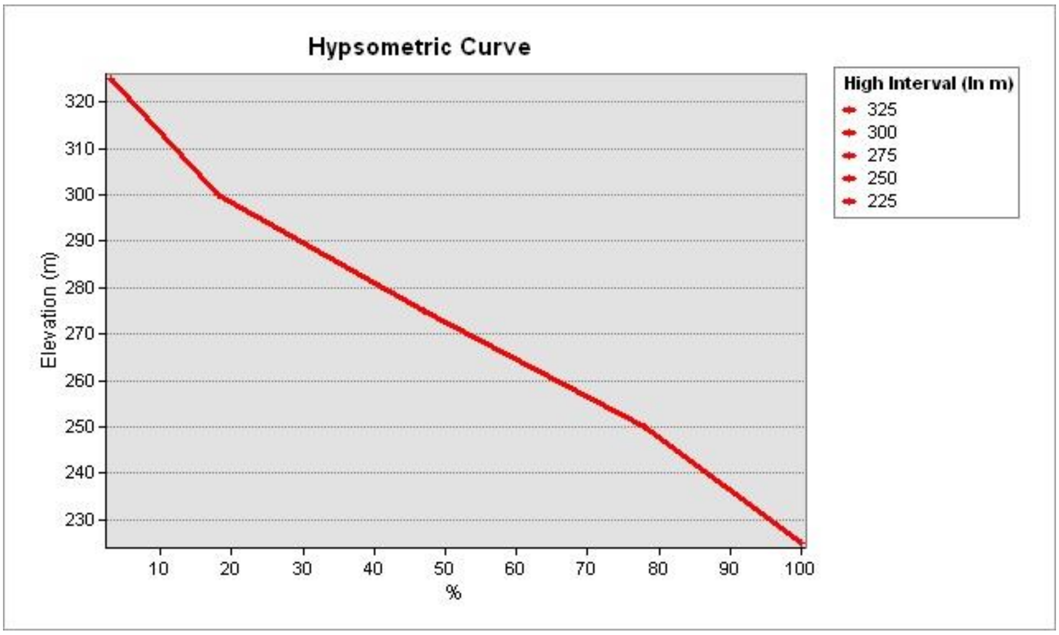


Figure 57. Hypsometric Curve of the Hajar Stream Basin

The Tammuz Stream basin is going through the old phase, as shown in Figure 58. It is the oldest basin in the study area.

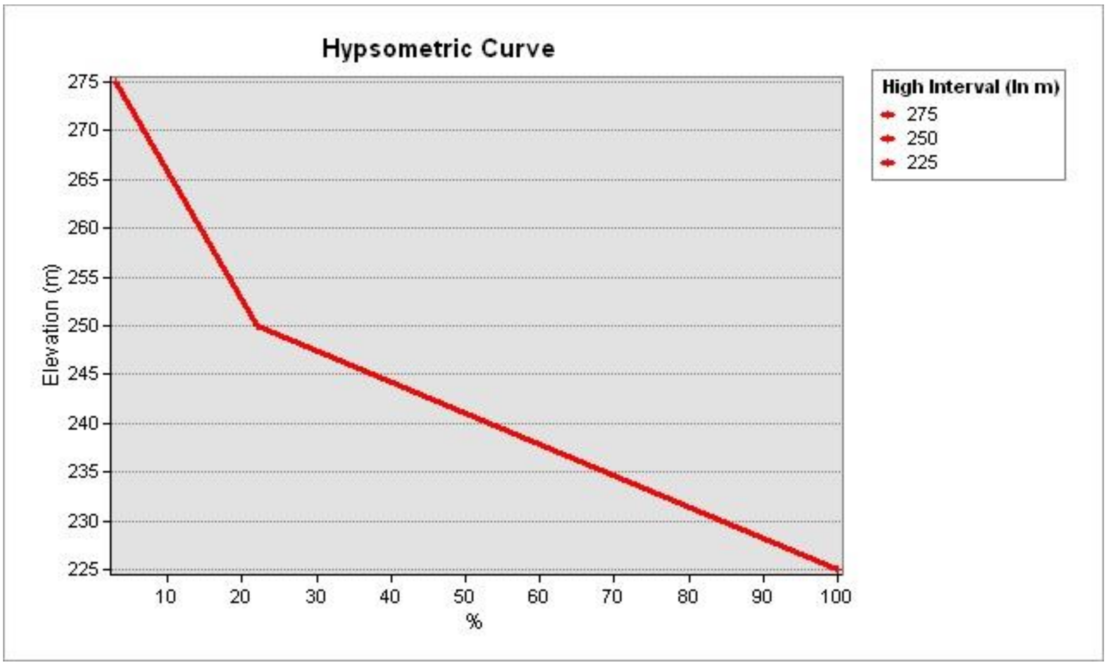


Figure 58 Hypsometric Curve of the Tammuz Stream Basin

The Al-Dir Stream basin is in the mature stage, as shown in Figure 59.

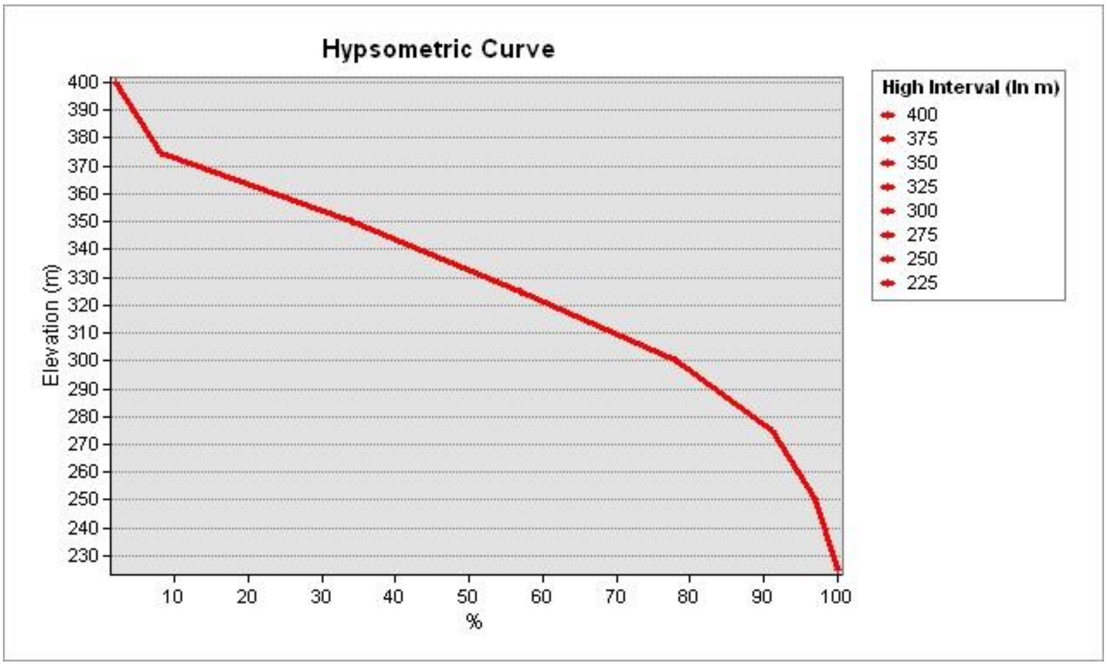


Figure 59. Hypsometric Curve of the Al-Dir Stream Basin

The Al-Ain Stream basin is going through the maturity stage, as shown in Figure 60.

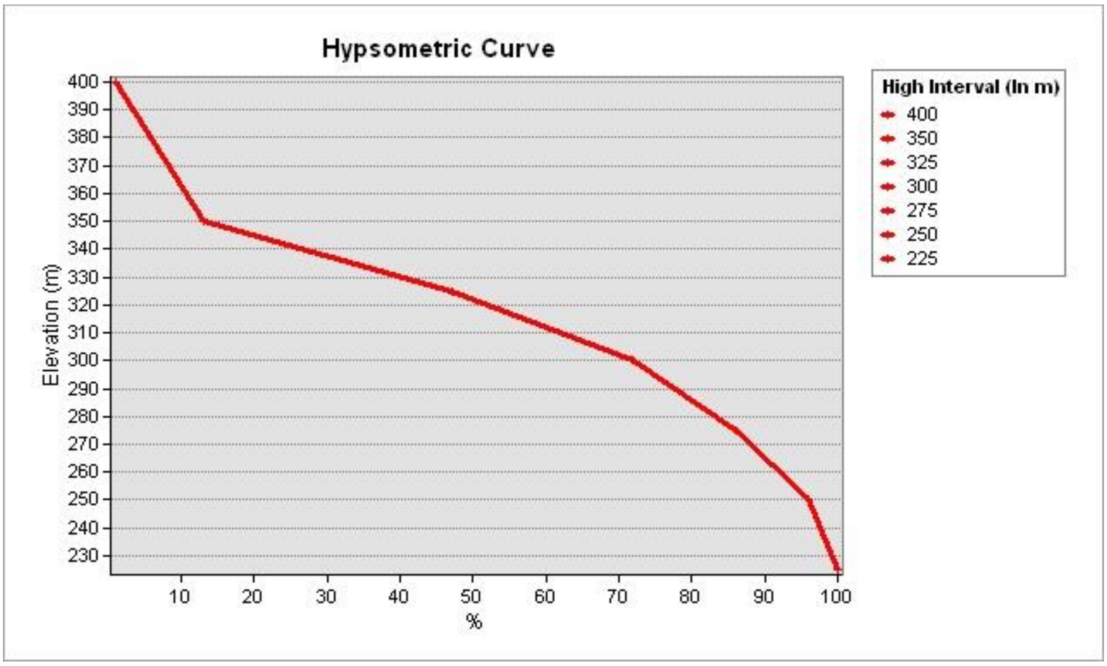


Figure 60**.** Hypsometric Curve of the Al-Ain Stream Basin

The Al-Areej Stream basin is approaching the old age stage, as shown in Figure 61.

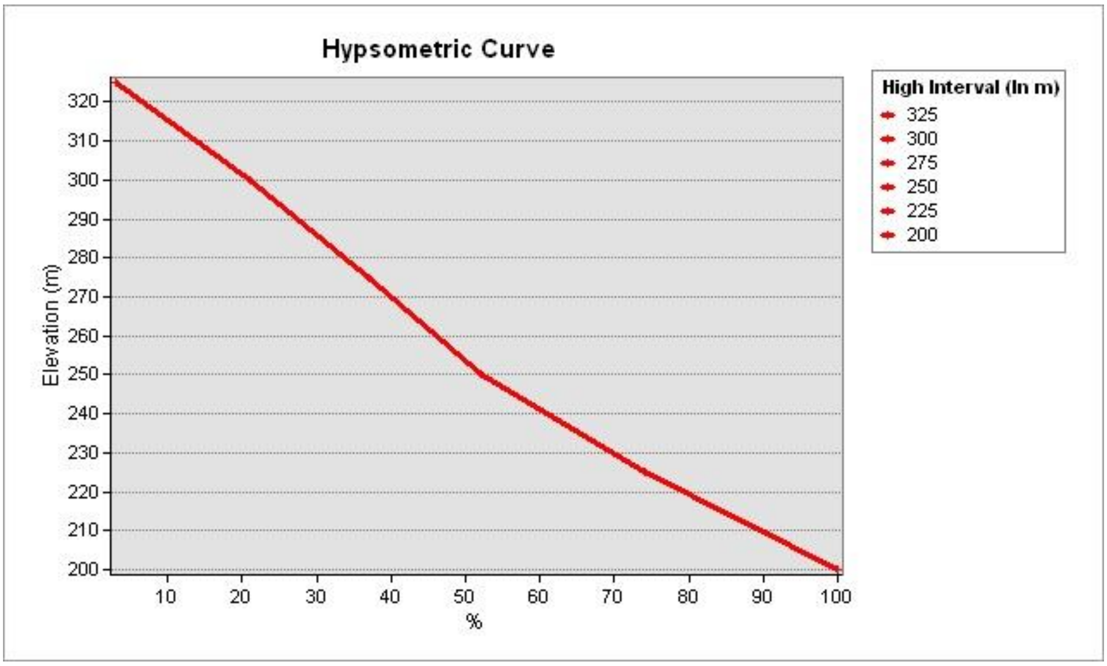


Figure 61. Hypsometric Curve of the Al-Areej Stream Basin

The Al-Dabbas Stream basin is going through the mature stage, as shown in Figure 62.

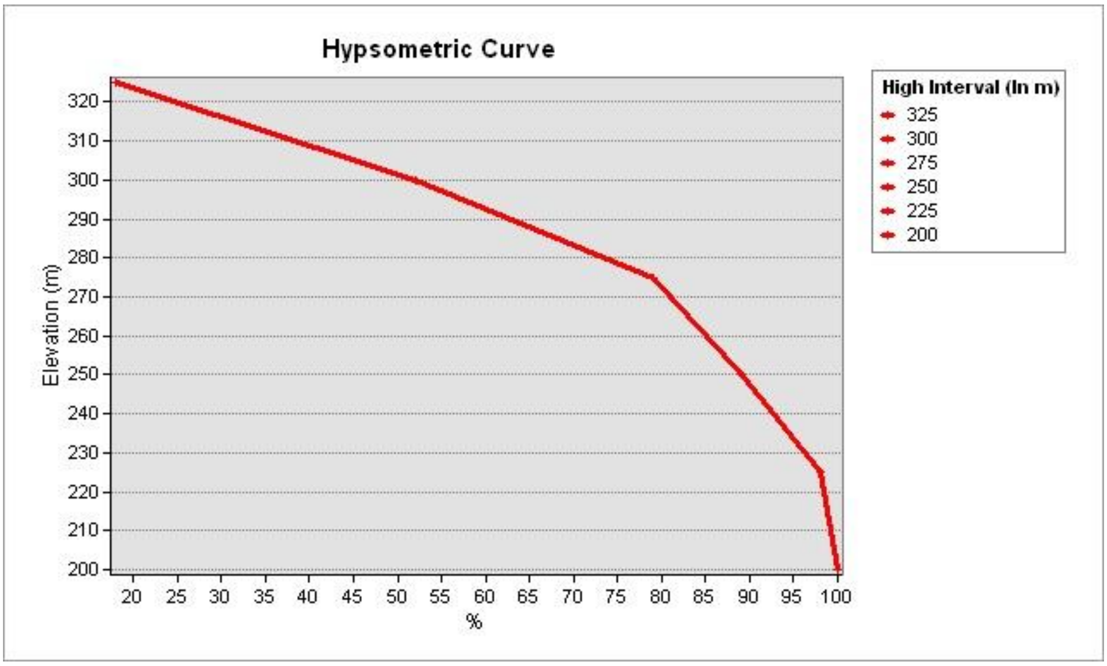


Figure 62. Hypsometric Curve of the Al-Dabbas Stream Basin

The Marei Stream basin is going through its youthful phase because the curve is convex, as shown in Figure 63. It is the youngest basin in the study area.

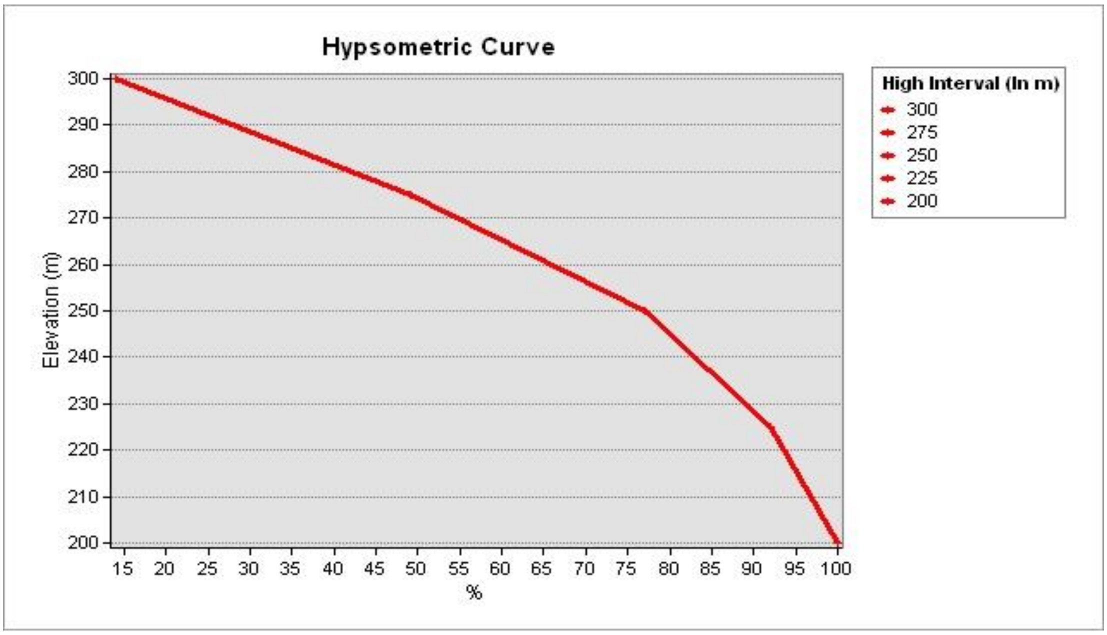


Figure 63. Hypsometric Curve of the Marei Stream Basin

The Munira Stream basin has entered the aging phase, as shown in Figure 64.

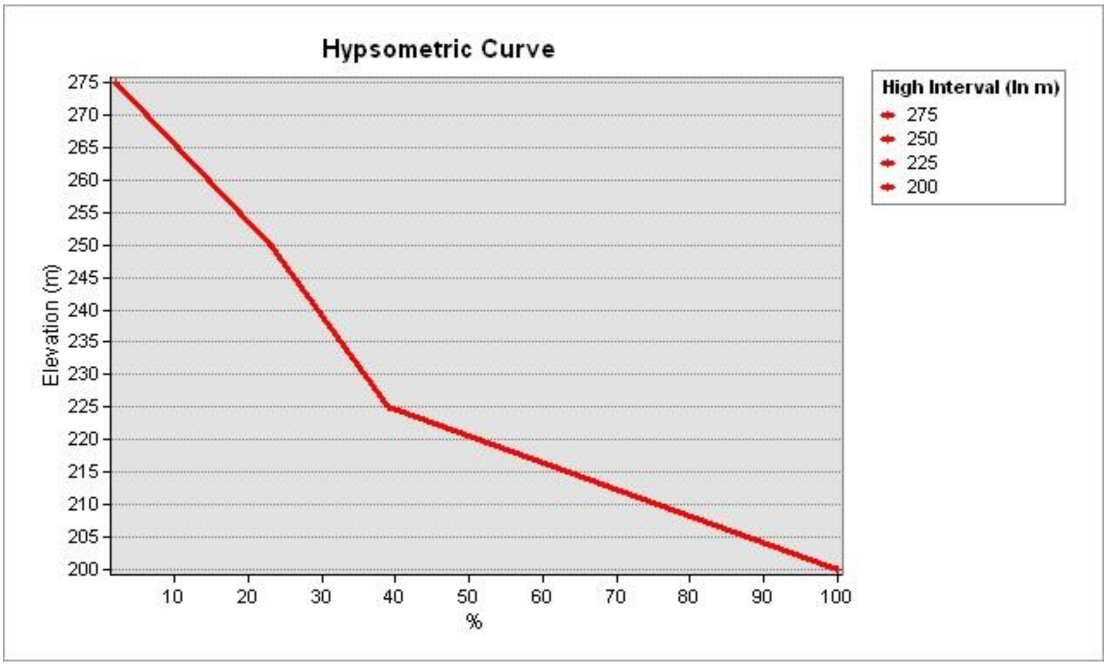


Figure 64. Hypsometric Curve of the Munira Stream Basin

The Ramadan Salih Stream basin passes through maturity, as shown in Figure 65.

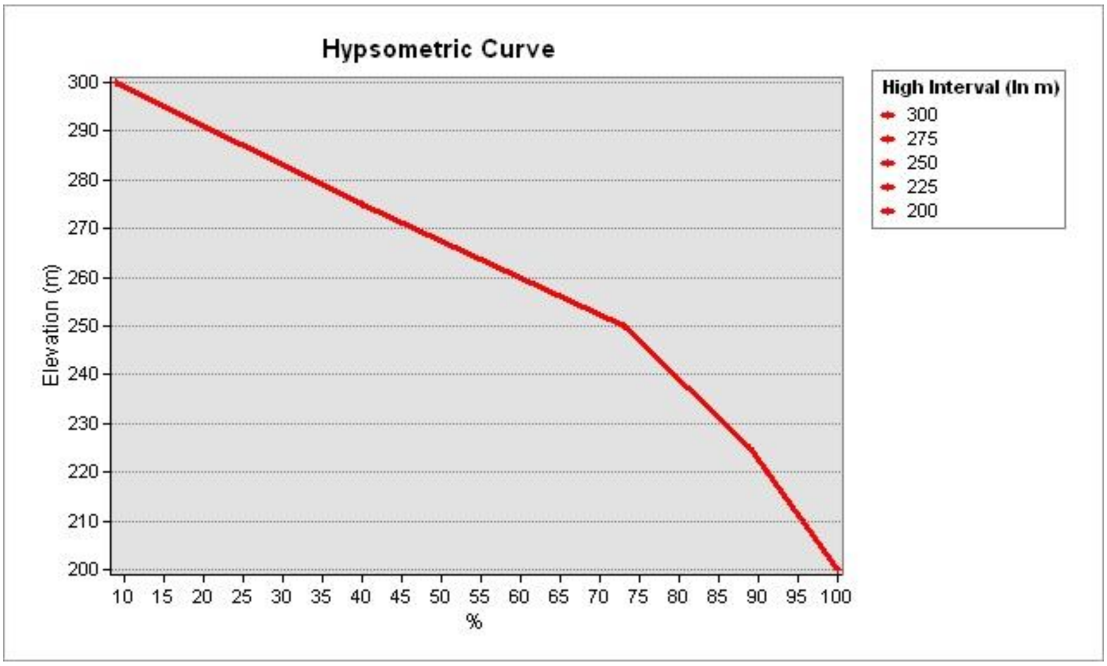


Figure 65. Hypsometric Curve of the Ramadan Salih Stream Basin

The Gahanem Stream basin is going through the maturity stage, as shown in Figure 66.

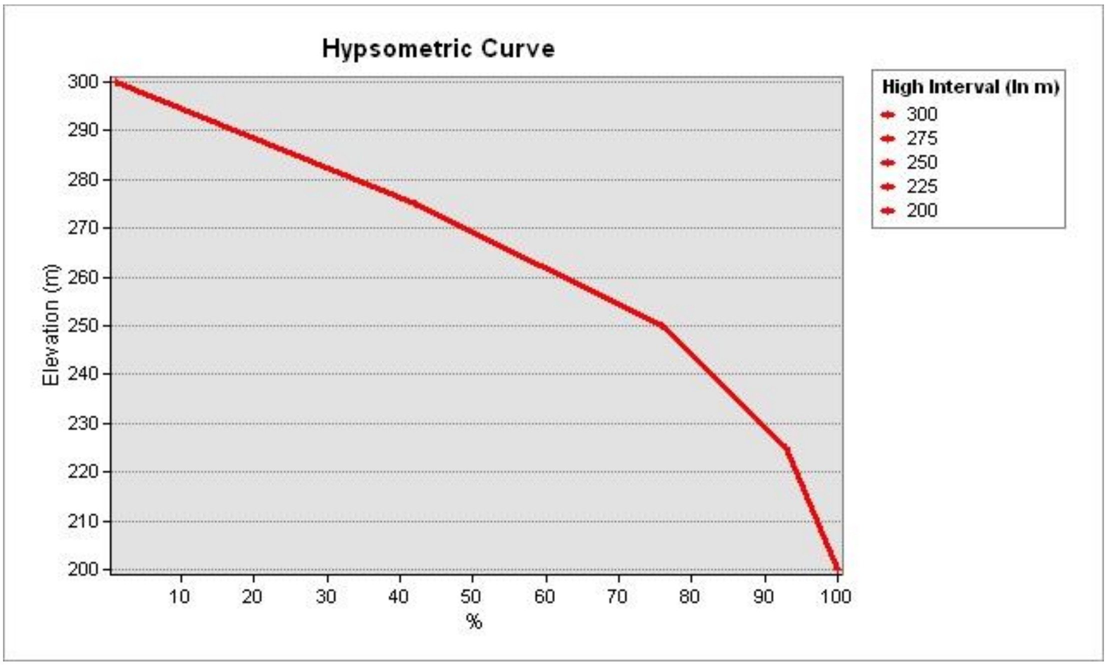


Figure 66. Hypsometric Curve of the Gahanem Stream Basin

3.3.8. Hypsometric Integral (Hi)

This parameters numerical value ranges from 0 to 1. hypsometric in the specified range integral values, mean basin elevation-minimum basin elevation difference obtained by dividing the maximum basin elevation-minimum basin elevation difference. The hypsometric integral values obtained as a result of the calculation are 0.60 and above. Values are youth, values between 0.35-0.60 are maturity, values less than 0.35 characterize the topography in the peneplain phase.

"Hypsometric integral is one of the important morphometric parameters because of showing the relationship between current and ancient relief volumes. In addition, to measure the degree of basin erosion and determine the time that the water basin has traveled in its basement cycle" (Alwaili, 2012: 112). This is represented by the basins that we're able to capture the watercourses that are less powerful than them, provided that these have reached an advanced stage in their basement cycle, that is, the values of the hypermetric integration are directly proportional to the period, and low values indicate the opposite (Abualainan, 1999: 84).

The hypsometric integral is extracted according to the following equation (Ali, 2001: 103).

$$Hi = H\ mean - Hmin / Hmax - Hmin$$

$Hmean$: Mean elevation of the basin (m)

$Hmax$: Maximum high point of the basin (m)

$Hmin$: Minimum high point of the basin (m)

Table 22. Hypsometric Integral Values of the Basins in the Study Area

Basin Name	*Hmean*	*Hmax*	*Hmin*	*Hi*
Okab	272.38	383	210	0.35
Hajar	257.85	327	206	0.42
Tammuz	222.78	278	204	0.25
Al-Dir	316.50	437	207	0.47
Al-Ain	303.48	415	200	0.48
Al-Areej	244.83	330	193	0.37
Al-Dabbas	282.24	367	191	0.51
Marei	256.27	307	197	0.63
Munira	213.99	273	186	0.32
Ramadan Salih	250.34	307	185	0.53
Gahanem	252.07	298	185	0.59

It is clear from Table 18 and Table 22 that the lowest value in the Tammuz Stream basin was recorded at 0.25, and the highest value was recorded in the Marei Stream basin at 0.63. The rate of the rest of the basins is as follows: 0.35 in the Okab Stream basin, 0.42 in the Hajar Stream basin, 0.47 in the Al-Dir Stream basin, 0.48 in the Al-Ain Stream basin, 0.37 in the Al-Areej Stream basin, 0.51 in the Al-Dabbas Stream basin, 0.63 in the Marei Stream basin, 0.32 in the Munira Stream basin, 0.53 in the Ramadan Salih Stream basin, and finally 0.59 in the Gahanem Stream basin.

The Marei Stream basin (0.63) is the only basin in the young stage of the study area. In addition, the Gahanem Stream basin (0.59) has just left its youth stage behind. The Ramadan Salih basin (0.53) is at the stage of maturity very close to the youth. Young basins have high flow velocity, strong erosion force, and very low sedimentation.

The basins of Al-Areej (0.37), Hajar (0.42), Al-Dir (0.47), Al-Ain (0.48), Al-Dabbas (0.51), and Ramadan Salih (0.53) are in the maturity stage. Munira (0.32) and Okab (0.35) basins have just left the maturity stage and entered the old age stage. Against the young stage, mature and old basins have characteristics such as unclear slope and roughness, low flow velocity, weak erosion force, and increased sediment accumulation. The Tammuz Stream basin (0.25) is the oldest one in the study area and its erosion ability is very weak. It is in the sedimentation stage now.

3.3.9. Gravelius (Compactness) Coefficient (Kg)

The coefficient of integration expresses the extent of consistency and homogeneity between the basin circumference and the collecting area of the basin and the size of the regularity or zigzag of the water dividing line. It is not understandable that low values indicate the increase in the drainage basin area at the expense of the length of the basin circumference and the lack of zigzag and regularity of the water dividing line. Low values indicate an increase in the drainage basin area at the expense of the length of the basin circumference, the lack of tortuousness and regularity of the water division line, and the progress of the basin in its under cycle. In contrast, high values indicate an increase in the length of the basin circumference concerning its aggregate area, irregularity, and tortuousness of its surroundings, and the novelty of its under cycle (Almaghazi, 2015: 82-83), and the integration coefficient is calculated according to the equation (Moustafa, 1998: 263):

$$G_g = P/2 * \left[\left(\int \frac{A}{\pi} \right) * \pi \right]$$

P: Basin perimeter length (km)

A: It is the basin area (km^2)

As shown in Table 18, it is clear that the value of the coefficient is high in the Okab Stream basin, which the ratio reaches 1.54 For the rest of the basins, values are as follows: 1.44 in the Hajar Stream basin, 1.47 in the Tammuz Stream basin, 1.69 in the Al-Dir Stream basin, 1.41 in the Al-Ain Stream Basin, 1.42 in the Al-Areej Stream basin, 1.52 in the Al-Dabbas basin, 1.70 in the Marei Stream basin, 1.34 in the Munira Stream basin, 1.31 in the Ramadan Salih Stream basin, and finally 1.38 in the Gahanem Stream basin. High values indicate the irregularity and meandering of the water division lines and the newness of the basins in their geomorphological cycle. This result is consistent with the conclusions of the previous equations.

3.3.10. Ruggedness Number (Rn)

The ruggedness number is one of the most critical morphometric parameters for river basins. It measures the interrelationship between more than one variation (basin relief, drainage density, and the basin area).

“Then, it starts to rise to be able to reach the maximum at the beginning of the maturity stage, and it continues to decline again from the end of the underage cycle.” (Taim, 2015: 78). The ruggedness number increases with the rising of the basin density and the rising of the drainage density. The ruggedness number is extracted through the following equation (Abualainain, 1999: 85):

$$Rn = Bh \times Dd$$

Bh: Basin relief (m)
Dd: Drainage density

Applying the equation to the basins of the study area showed us through Table 18 that the ruggedness number was low and close in all the basins of the study area, were recorded the highest value in the Al-Dir Stream basin, 0.29. In contrast, the Munira Stream basin, and the Tammuz Stream basin recorded the lowest percentage, 0.04. The rate achieved in the rest of the basins of the study area was 0.10 in the Okab Stream basin, 0.10 in the Hajar Stream basin,0.24 in the Al-Ain Stream basin, 0.12in the Al-Areej Stream basin, 0.20the Al-Dabbas Stream basin, 0.18 in the Al-Dabbas Stream basin, 0.12 Stream Marei basin, 0.12 in the Ramadan Salih Stream basin, in the Gahanem 0.11

These values indicate that the basins are at the beginning of their erosion cycle due to the nature of the region’s rocks, which are one of the most responsive rocks to water erosion processes.

3.4. Stream Drainage Patterns

"The study of water patterns helps to understand and explain many geomorphological phenomena because the water discharge pattern is a reflection of the factors represented by the geological structure, land movements, and climatic conditions" (Al-Obaidi, 2012: 121). The study area contains mostly dendritic drainage (tree) patterns.

3.4.1. Dendritic Drainage (Tree Style)

"This type of river drainage appears in the rock layers consisting of flat sedimentary rocks. This pattern reflects the relative homogeneity in the gradient characteristics, climatic characteristics, and rock discoveries. The convergence of the waterways represents it with the other at sharp angles" (Abualainan, 1995: 460). This pattern can be seen in Figure 67.

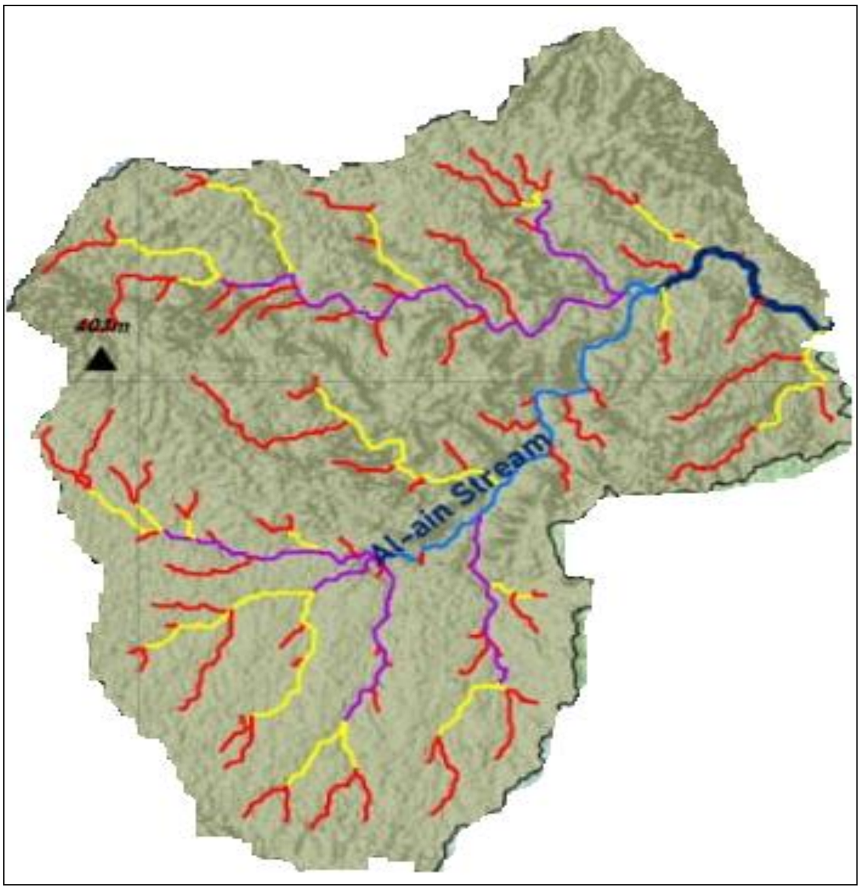


Figure 67. Dentritic Drainage Pattern Sample in the Study Area

CHAPTER FOUR

RESULTS

4.1. Discussion

In this master's thesis, the geomorphological features of the selected study area on the coast of the Tigris River in the Nineveh region of Iraq and were evaluated based on the morphometric analyzes for selected basins. There are 11 river basins in the study area, all of which flow into the Tigris River. They can be listed from north to south as follows: The Okab Stream basin, the Hajar Stream basin, the Tammuz Stream basin, the Al-Dir Stream basin, the Al-Ain Stream basin, the Al-Areej Stream basin, the Al-Dabbas Stream basin, the Marei Stream basin, the Munira Stream basin, the Ramadan Salih Stream basin, and the Gahanem Stream basin.

Basin analyzes using Geographical Information Systems are used by many researchers. Among them; Akar (2006), Uzun (2014), Utlu and Özdemir (2018) studies can be counted. There are similarities in some aspects and some results between our research and the exemplary article studies. For example, in the studies of Utlu and Özdemir (2018) on the morphometry of the Biga Stream, the stream frequency values of some tributaries were found to be low value, which is similar to the values of the basins in this thesis. As a result of this, the permeability amounts in the compared basins are quite high. In the morphometric analysis study conducted by Uzun (2014) on Lale Creek, it was determined that the basin is in the maturity stage according to the hypsometric integral value. Most of the basins examined in this study, which form some tributaries of the Tigris from the southwest, also pass through the maturity stage. In this respect, the two studies are similar.

Within the geological units that make up the study area, there are limestone, gypsum, marl, rock salt, clay, and clastic sedimentary rocks belonging to the Tertiary period and alluviums belonging to the Quaternary period.

Climatic factors have affected the morphometry of the basins in the study area. It is observed that rainy and dry periods follow each other in the region. According to the values recorded at Mosul Meteorology Station, Thornthwaite Method was applied, and it was determined that the climate, which is the most important criterion controlling the erosion-deposition balance, has Semi-arid climate characteristics.

The study area is mostly composed of shrubs and grasses, including thorny plants such as carob, steppe grasses, weeds, and sedge. Most of these plants are used for grazing, and some of them are used for alternative medicine. There are many thorny plants such as wormwood, akool, sidr, belladonna, and khila that adapt themselves to dry climatic conditions thanks to their deep roots and pointed leaves covered with a waxy layer. These plants have a great influence on karstic development, especially in the formation and development of dissolution cavities.

There are two types of soils in the study area, they are flood soils and dry gypsum soils.

It is observed that the most common drainage type in the research area was dendritic drainage.

Among the common landforms in the study area; large areas of low plateau, hilly areas, erosional surfaces, gully erosion areas, V-shaped valleys, river terraces, flood plains, sand islands, and karst pits have been identified. In addition to chemical dissolution and physical disintegration due to water, mass movements and wind effect are also intensely effective in the region. There are also karst eyes (springs) in the region. When the topographic features were examined, it was determined that severe gully erosion occurred especially in the upper part of the basin, and the geological structure helped the formation of respectively severe slopes.

4.2. Conclusions

Geographic Information Systems and morphometric analysis methods were used to determine elevation, slope, aspect, and other geomorphological features in the study area. The results of the linear, areal, and relief parameters provided a lot of information about the terrain.

These results are given below:

- The lengths of the basins in the study area are as follows: 12.15 km of the Okab Stream basin, 9.89 km of the Hajar Stream basin, 6.48 km of the Tammuz Stream basin, 24.14 km of the Al-Dir Stream basin, 17.06 km of the Al-Ain Stream basin, 11.88 km of the Al-Areej Stream basin, 12.08 km of the Al-Dabbas Stream basin, 5.87 km of the Marei Stream basin, 6.65 km of the Munira Stream basin, 4.98 km of the Ramadan Salih Stream basin, and 6.23 km of the Gahanem Stream basin.

- The maximum width of the basin was determined through the GIS program. Looking at the maximum basin width of the 11 basins, the following data were obtained: 7.27 km in the Okab Stream basin, 6.22 km in the Hajar Stream basin, 5.07 km in the Tammuz Stream basin, 9.44 km in the Al-Dir Stream basin, 12.33 km in the Al-Ain Stream, 9.04 in the Al-Areej Stream basin, 7.75 km in the Al-Dabbas Stream basin, 2.64 km in the Marei basin, 4.87 km in the Munira basin, 3.53 km in the Ramadan Salih Stream basin, 2.76 km in the Gahanem Stream basin.
- Basins with a low stream length ratio are long, while those with a high stream length ratio are more circular. When the Rl value of the streams in the study area was examined, it was determined that the order from the longer basins to the more circular ones was as follows: Tammuz (1.16), Munira (1.2), Ramadan Salih (1.45), Gahanem (1.55), Marei (1.73), Okab (1.79), Al-Dabbas (1.97), Al-Ain (2.04), Al-Areej (2.95), Hajar (3.47) and Al-Dir (5.45). According to these results, it can be said that the drainage time of the waters is the longest in the Tammuz Stream basin and the least in the Al-Dir Stream basin.
- The basins in the study area have a maximum of 5 bifurcation stages. The total number of first orders in all basins is 279, and the length is 237.16 km. The second orders are 71 in total and are 137.86 km long. The third order number is 18 and its length is 71.28 km, the fourth order is 4 and its length is 24.90 km. The fifth order number that makes up the last order is only 1 and its length is calculated as 4.61 km. The number of orders is 373 in total and the length is 475.81 km.
- Looking at the bifurcation ratio values, the following values were obtained: 3.75 for the Okab Stream basin, 4 for the Hajar Stream basin, 3 for the Tammuz Stream basin, 4.33 for the Al-Dir Stream basin, 2.88 for the Al-Ain Stream basin, 3.06 for the Al-Areej Stream basin, 6.14 for the Al-Dabbas Stream basin, 2.5 for the Marei Stream basin, 5 for the Munira Stream basin, 3.37 for the Ramadan Salih Stream basin and 7 for the Gahanem Stream basin. When the bifurcation ratio value of the basins in the study area was

examined, it was determined that the order from the basins with lower flood risk to those with higher flood risk was as follows: Gahanem, Al-Dabbas, Munira, Al-Dir, Hajar, Okab, Ramadan Salih, Al-Areej, Tammuz, Al-Ain and Marei.

- The maximum texture ratio value is in the Al-Ain Stream basin 1.50. The texture ratio in other basins was determined as follows: 1.15 in the Al-Dir Stream basin, 0.91 in the Al-Dabbas Stream basin, 0.78 in the Al-Areej Stream basin, 0.59 in the Ramadan Salih basin, 0.49 in the Hajar Stream basin, 0.45 in the Gahanem Stream basin, 0.40 in the Tammuz basin, 0.36 in the Marei Stream basin, 0.32 in the Okab Stream basin, and 0.26 in the Munira Stream basin. These results show that all basins in the study area are less steep and rough and have a very high permeability.
- The study area covers a total area of 459.36 km^2. Among the 11 studied stream basins, the largest is the Al-Ain Stream basin (127. 36 km^2), and the smallest is the Marei Stream basin (7.30 km^2). As the basin area grows, the planning and implementation of the investments to be made will also increase. Considering the areas of other basins in the study area; it has been observed that the Okab Stream basin has an area of 38.30 km^2, the Hajar Stream basin has an area of 34.60 km^2, the Tammuz Stream basin has an area of 14.70 km^2, the Al-Dir Stream basin has an area of 94.10 km^2, the Al-Areej Stream basin has an area of 46.70 km^2, the Al-Dabbas Stream basin has an area of 55.10 km^2, the Munira Stream basin has an area of 15.40 km^2, the Ramadan Salih Stream basin has an area of 15.80 km^2, and the Gahanem Stream basin has an area of 10 km^2. The size of the basin is a priority factor in determining and designing the investments planned to be made in the region in the coming years.
- The basin perimeter with the most extended circumference in the region is the Al-Dir Stream basin with 58.2 km. The basin with the shortest perimeter is the Gahanem Stream basin, with 15.49 km. Perimeter measurements of other basins are 33.96 km for Okab, 30.18 km for Hajar, 20 km for Tammuz, 56.43 km for Al-Ain, 34.57 km for Al-Areej, 40.6 km for Al-Dabbas, 16.33 for Marei, 18.69 km for Munira, and 18.55 km for Ramadan Salih.

- Circularity ratio (Rc) values are calculated as 0.41 in the Okab Stream basin, 0.47 in the Hajar Stream basin, 0.46 in the Tammuz Stream basin, 0.34 in the Al-Dir Stream basin, 0.50 in the Al-Ain Stream basin, 0.49 in the Al-Areej Stream basin, 0.41 in the Al-Dabbas Stream basins, 0.34 in the Marei Stream basin, 0.55 in the Munira Stream basin, 0.57 in the Ramadan Salih Stream basin, and 0.52 in the Gahanem Stream basin. When the circularity ratio value of the basins in the study area is examined, it has been determined that the order from the more elongated basins to the more circular ones is as follows: Al-Dir, Marei, Okab, Al-Dabbas, Tammuz, Hajar, Al-Areej, Al-Ain, Munira, Gahanem, Ramadan Salih.
- Elongation ratio (Re) the study area amounted to 0.57 in the Okab Stream basin, 0.67 in the Hajar Stream basin, 0.66 in the Tammuz Stream basin, 0.45 in the Al-Dir Stream basin, 0.74 in the Al-Ain Stream basin, 0.64 in the Al-Areej Stream basin, 0.69 in the Al-Dabbas Stream basin, 0.51 in the Marei Stream basin, 0.67 in the Munira Stream basin, 0.90 in the Ramadan Salih Stream basin, and finally the Gahanem Stream basin 0.57. It has been seen, the Al-Dir Stream, too long, the basins of the Okab Stream Hajar Stream, the Tammuz Stream, the Al-Areej Stream, the Al-Dabbas Stream, the Marei Stream, the Munira Stream were, the Gahanem Stream were long, the basins of the Al-Ain Stream. was less long, and the Ramadan Salih Stream was oval. When the elongation ratio value of the basins in the study area is examined, it has been determined that the order from the more longitudinal basins (low flood susceptibility) to the more circular ones (high flood susceptibility) is as follows: Al-Dir Stream, Marei Stream, Gahanem Stream, Okab Stream, Al-Areej Stream, Tammuz Stream, Munira Stream, Hajar Stream, Al-Dabbas Stream, Al-Ain Stream, Ramadan Salih Stream.
- Form factor (Rf) value of the basins has been calculated as 0.25 for the Okab Stream basin, 0.35 for the Hajar Stream basin, 0.35 for the Tammuz Stream basin, 0.16 for the Al-Dir Stream basin, 0.43 for the Al-Ain Stream basin, 0.33 for the Al-Areej Stream basin, 0.37 for the Al-Dabbas Stream basin, 0.21 for the Marei Stream basin, 0.34 for the Munira Stream basin, 0.63 for the Ramadan Salih Stream basin, and finally 0.25 for the Gahanem Stream basin. When the basin shape (form factor) value of the basins in the study

area is examined, it has been determined that the order from the more longitudinal basins to the more circular ones is as follows: Al-Dir, Marei, Okab, Gahanem, Al-Areej, Munira, Hajar, Tammuz, Al-Dabbas, Al-Ain, and Ramadan Salih.

- Drainage density (Dd) values are 0.59 for the Okab Stream basin, 0.85 for the Hajar Stream basin, 0.65 for the Tammuz Stream basin, 1.28 for the Al-Dir Stream basin, 1.13 for the Al-Ain Stream basin, 0.92 for the Al-Areej Stream basin, 1.15 for the Al-Dabbas Stream basin, 1.14 for the Marei Stream basin, 0.46 for the Munira Stream basin, 1 for the Ramadan Salih Stream basin, and finally 1.03 for the Gahanem Stream basin. The low drainage density values depend on the permeability and evaporation is high, and the precipitation is very low.
- Stream frequency (Fs) values are also very low in the study area. Namely: 0.36 for the Okab Stream basin, 0.54 for the Hajar Stream basin, 0.81 for the Tammuz Stream basin, 0.96 for the Al-Dir Stream basin, 0.90 for the Al-Ain Stream basin, 0.81 for the Al-Areej Stream basin, 0.81 for the Al-Dabbas Stream basin, 1.23 for the Marei Stream basin, 0.38 for the Munira Stream basin, 1.01 for the Ramadan Salih Stream basin, and finally 0.80 for the Gahanem Stream basin. When the elongation ratio value of the basins in the study area is examined, it has been determined that the order from the low flood susceptibility to the high flood susceptibility ones is as follows: Okab Stream, Munira Stream, Hajar Stream, Gahanem Stream, Al-Arurcation ratioeej Stream, Al-Dabbas Stream, Tammuz Stream, Al-Ain stream, Al-Dir Stream, Ramadan Salih Stream, Marei Stream.
- The low infiltration numbers (If) of the studied basins indicate high permeability. This value is 0.21 in the Okab Stream basin, 0.45 in the Hajar Stream basin, 0.52 in the Tammuz Stream basin, 1.22 in the Al-Dir Stream basin, 1.01 in the Al-Ain Stream basin, 0.74 in the Al-Areej Stream basin, 0.93 in the Al-Dabbas Stream basin, 1.40 in the Marei Stream basin, 0.17 in the Munira Stream basin, 1.01 in the Ramadan Salih Stream basin, and finally 0.82 in the Gahanem Stream basin. This parameter also shows that the gradient values are low in the basins. When the elongation ratio value of the basins in the study area is examined, it has been determined that the

order from the low flood susceptibility to the high flood susceptibility is as follows: Munira Stream, Okab Stream, Hajar Stream, Tammuz Stream, Al-Areej Stream, Gahanem Stream, Al-Dabbas Stream, Al-Ain Stream, Ramadan Salih Stream, Al-Dir Stream, Marei Stream.

- The basin relief values of the basins were calculated as follows: 173 in the Okab Stream basin, 121 in the Hajar Stream basin, 74 in the Tammuz Stream basin, 230 in the Al-Dir Stream basin, 215 in the Al-Ain Stream basin, 137 in the Al-Areej basin, 176 in the Al-Dabbas Stream basin, 110 in the Marei Stream basin, 87 in the Munira Stream basin, 122 in the Ramadan Salih Stream basin, and 113 in the Gahanem Stream basin.
- The relief ratio (Rr) values in the basins were calculated as follows: 0.014 in the Okab Stream basin, 0.012 in the Hajar Stream basin, 0.011 in the Tammuz Stream basin, 0.009 in the Al-Dir Stream basin, 0.012 in the Al-Ain Stream basin, 0.011 in the Al-Areej Stream basin, 0.014 in the Al-Dabbas Stream basin, 0.018 in the Marei Stream basin, 0.013 in the Munira Stream basin, 0.027 in the Ramadan Salih Stream basin, and finally 0.018 in the Gahanem Stream basin. These low values indicate that the slope values in the basins are low. When the bed slopes of the rivers decrease, their erosional abilities also decrease. On the other hand, streams flowing in valleys with high slopes cause a lot of erosion. In the study area, especially in the lower basins, the erosion effect has decreased and deposition processes have become the dominant process.
- The highest hypsometric integral value was found in the Marei Stream basin with 0.63 and the lowest value was found in the Tammuz Stream basin with 0.25 in the study area. It can be said that sedimentation processes for Tammuz Stream basin have come to the fore. The Marei Stream basin (0.63) is the only one still in its youth stage in the region. The Gahanem Stream basin (0.59) has just left its youth period behind. Again, the Ramadan Salih Stream basin (0.53) is at the stage of maturation very close to the youth. Erosion processes seem to be relatively strong in the mentioned basins. According to their hypsographic integral values, Al-Areej (0.37), Hajar (0.42), Al-Dir (0.47), Al-Ain (0.48), and Al-Dabbas (0.51) basins were determined to be in the maturation stage. The Munira (0.32) and Okab (0.35)

stream basins have completed their maturity stage a short time ago and entered the old age stage.

- Gravelius coefficient (Kg) value is the highest in the Okab Stream basin which the ratio reaches 1.54 The other basins' values are as follows: 1.44 in the Hajar Stream basin, 1.47 in the Tammuz Stream basin, 1.69 in the Al-Dir Stream basin, 1.41 in the Al-Ain Stream basin, 1.42 in the Al-Areej Stream basin, 1.52 in the Al-Dabbas Stream basin, 1.70 in the Marei Stream basin, 1.34 in the Munira Stream basin, 1.31 in the Ramadan Salih Stream basin, and finally 1.38 in the Gahanem Stream basin. The high values of the coefficient indicate the irregularity of the water section lines and the incomplete geomorphological development. When the Gravelius index value of the basins in the study area is examined, it has been determined that the order from the more longitudinal basins to the more circular ones is as follows: Marei, Al-Dir, Okab, Al-Dabbas, Tammuz, Hajar, Al-Areej, Al-Ain, Gahanem, Munira, and Ramadan Salih.
- The ruggedness number was low and close in all the basins of the study area, were recorded the highest value in the Al-Dir Stream basin, 0.29. In contrast, the Munira Stream basin, and the Tammuz Stream basin recorded the lowest percentage with 0.040. The rate achieved in the rest of the basins of the study area was 0.10 in the Okab Stream basin, 0.10 in the Hajar Stream basin, 0.24 in the Al-Ain Stream basin, 0.12 in the Al-Areej Stream basin, 0.20 in the Al-Dabbas Stream basin, 0.12 in the Marei Stream basin, 0.12 in the Ramadan Salih Stream basin, and 0.11 in the Gahanem Stream basin.
- Saleh (1989) pointed out some of the most critical factors that affect the severity of flooding factors including rainfall characteristics, drainage networks, drainage orders, drainage characteristics, water loss (evaporation and infiltration), and environmental and human processes. Since there are natural differences in results between morphometric parameters, the characteristics of the drainage were taken into account in determining the highest probability of flood risk in this study. Among Saleh's suggestions, it was seen that the most important elements associated with morphometry belonged to drainage. Also, Özdemir (2016) states that drainage density is perhaps the most important morphometric parameter of the basin. For this

reason, the results of the drainage density were taken as the basis when listing the probability of flood risk in the basin. Accordingly, the order of the basin from the highest probability of flood risk to the lowest can be as follows: The Al-Dir Stream basin, the Al-Dabbas Stream basin, the Marei Stream basin, the Al-Ain Stream basin, the Gahanem Stream basin, the Ramadan Salih Stream basin, the Hajar Stream basin, the Al-Areej Stream basin, the Tammuz Stream basin, the Okab Stream basin, the Munira Stream basin.

- In the study area, human-induced water pollution is more common in the lower parts of the basins. While water pollution can be seen especially in the 3rd and 4th orders, there is no water pollution in the 1st and 2nd orders. With the negative effects of the Sulfur Factory in the study area, the Al-Dabbas River basin shows more water pollution than the other 10 stream basins.
- Since the study area has been under the influence of war for many years, most of the population migrated with the destruction of their villages. Before the war, wheat and barley were cultivated in the fertile lands on the banks of the Tigris River, and cattle and sheep were raised, but today it has decreased a lot. Since the river basins in the region are mostly dry due to the semi-arid climate, the rivers cannot be utilized much. The natural vegetation in the region is also destroyed or very weak. The existence of soil types that develop due to arid and semi-arid climatic conditions and their not being fully horizontal yet do not make land use attractive in the region.
- Natural environmental conditions cause a small number of people living in the region to face various problems. Among the most important problems faced by the public during land use are siltation, low groundwater, erosion, stoniness, alkalinity, and salinity due to excessive evaporation.
- GIS-based analysis of various morphometric parameters of stream basins is of great importance in terms of effective and efficient evaluation and protection of the natural resources available in the basins.

4.3. Recommendations

- Since there are no flow stations on any of the rivers, it is primarily necessary to establish hydrological stations in the places to be determined to measure the monthly and annual water discharge amount.
- Small dams or regulators should be built on seasonal river valleys to prevent water from being wasted in the Tigris River.
- It is thought that investments can be made in the natural resources represented by plaster and lime by establishing a factory that manufactures building materials in order to eliminate unemployment.
- The existing transport network in the area needs to be improved, as most of the highways in the study area, especially the secondary ones, suffer from ground failures.
- Projects should be developed in order to use the karstic springs in the region adequately and optimally for medical and tourism purposes.
- Since the time and duration of the precipitation are not known exactly, it is recommended to invest in the plains for livestock and agriculture, which constitute the livelihood of the people.
- Although the vegetation in the study area is not very common, precautions should be taken to protect the vegetation as they are used for grazing and medicinal purposes.
- Small caves and karst sinkholes in the region should be protected for touristic purposes and transferred to the future as geomorphological heritage.
- Afforestation works in some parts of the basins, and correct land use will be beneficial in terms of water retention and erosion prevention.

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LIST OF TABLES

LIST OF FIGURES

LIST OF MAPS

LIST OF PHOTOGRAPHS

RESUME

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