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Hydrological Modeling of the Morphometric Characteristics of Valleys Southeast of Wasit Governorate

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Abstract: The study of morphometric characteristics represents one of the modern approaches to studying watersheds, which are directly related to natural factors, the most important being the water sources of these basins. Therefore, the river drainage basin is considered the basic unit for conducting quantitative research on river basins. Measuring the natural features of river systems or valleys is a recent development in the field of applied geomorphology, which relies on statistical and mathematical analysis to describe the terrain. Studying morphometric characteristics helps analyze the basin's shape, erosion stages, and landforms that develop due to variations in erosion and deposition processes. This analysis can be useful in various practical applications, such as soil conservation, water resource management, and numerous engineering structures. Morphometric characteristics can be processed and analyzed within a set of laws, mainly based on Horton's laws (1945), as well as the laws proposed by several researchers like Miller (1952), Strahler (1958), and Schumm (1954).

Keywords: Hydrological Modeling, Morphometric Characteristics, River Basin, River Discharge.

1. Introduction:

The study of hydrological modeling has an important role in analyzing the volume of sediments in any area. Through research into the reality of the area, it was found that these sediments are due to the unstable pavement and their source is the valleys sloping from the eastern side of the Iraqi Iranian border, which were formed by heavy rains in the form of torrents that sweep sand, gravel, clay and silt. They are one of the factors of erosion, transport and sedimentation in river valleys. The most important forms resulting from them are the fan functions and sediments filling the valleys, which were formed from rocky materials of various sizes and were deposited due to the weak ability of running water to carry them. They were clearly observed in the study area as one of the most widespread forms in it due to the suitability of many geological, topographic and climatic factors, which will be explained in detail in this study by relying on the field study as well as the modern and different technologies represented by geographic information systems and their important role in accurately visualizing the reality of the surface of the study area and preparing (maps, tables and various forms) based on the database that was collected in the office and in the field as well as Satellite and space visualizations of the region, through which the different surface features (topography, slope, morphometry, surface) are identified. This method helps to shorten time and effort and deals with a huge amount of data and information and converts it into quantitative and statistical data using mathematical equations and converting the results into map models to understand and simplify reading and infer the size of the region's sediments, as the region is characterized by its simple slope, so sediments of different shapes and sizes are deposited in it by torrents brought by the valleys sloping from the eastern side of the study area.

The study revolves around a main problem: Do the natural and hydrological characteristics affect the size and quantity of sediments in the study area? Several secondary problems branch out from the main problems, which are:

1- What is the effect of morphometric characteristics on the sediments of the region?

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2- What is the role of water erosion in the size of the sediments, and what are the resulting shapes?

3- How suitable is the size of the sediments for land use?

The hypothesis comes to explain the studied phenomenon, which the study proves to be true or false. The study revolves around a main hypothesis, which is: The natural and hydrological characteristics have a clear effect on the size and quantity of sediments in the study area. As for the secondary hypotheses, they are:

1- The morphometric characteristics have a clear role in the different sediments of the region.

2- The diversity of the role of water erosion in the region and its effect on the sediments and the formation of several forms in the study area.

3- Sediments have an important role in the widespread uses in the study area.

The importance of the study is to know the size of the sediments in the study area and how these sediments were formed and the role of the natural characteristics and morphometric and hydrological characteristics in their formation and to know the shapes that were formed in the region and the uses to reach the preparation of hydrological modeling to calculate the size of the sediments in the selected valleys southeast of Wasit Governorate.

The study aims to:

1- The study aims to know the role of natural characteristics affecting the size of sediments in the study area.

2- The effect of morphometric and hydrological characteristics on the size of sediments and building map models to represent them based on geographic information systems and field study.

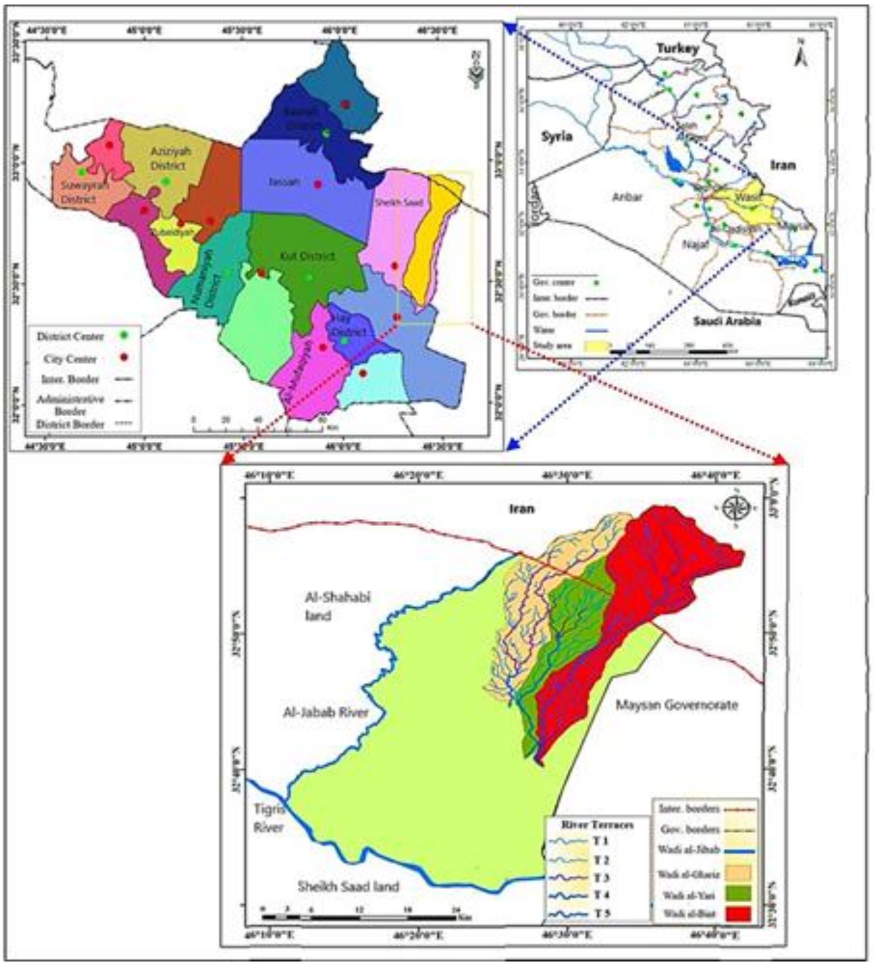
3- Identifying the role of erosion processes in the formation of sediments represented by fan indicators and benefiting from them in several economic uses.

4- Classification of sediment volume calculation and analysis of the factors affecting it.

The study area is located between latitudes (=09, -33, 320 - =35, -58, 320) north and longitudes (=11, -17, 460 - =51, -41, 460) as shown in Map (1-1).

2- Geographical location:

The region is located southeast of Wasit Governorate, bordered to the north by the Jabab River, to the south by Maysan Governorate, to the east by the Republic of Iran, and to the west by the Tigris River, as shown in map (1). The area of the region is (1191 km2). The feeding area is located outside the Iraqi borders within Iranian territory and originates from the Iranian Tonl Mountains. These valleys form fan valleys at their end.



Map (1): The Astronomical and Geographical Location of the Study Area

Source: Based on the General Commission for Surveying, map at a scale of 1:25,000, 1996; and Digital Elevation Model (DEM) using ArcMap GIS software, version 10.8.

Modeling of morphometric characteristics of valleys in the study area:

These studies showed that the morphometric characteristics of water basins are the result of natural factors according to their quantitative morphometric classifications, whether area, network, or topographic. Each method has its advantages and disadvantages, as it deals with one aspect of morphometric analysis (McCullagh, 1986, p. 27). Morphometric analysis of drainage basins helps to identify the characteristics of the drainage network and the factors that affect the formation of the earth's surface and to interpret these shapes by knowing the hydrological characteristics and the extent of development they have reached and then knowing the quantities of sediments transported to the outlets of these streams. Morphometric characteristics are directly affected by the geological and topographical structure of the region as well as the climate and vegetation cover, as any change in these factors leads to a clear change in the morphometric characteristics of the water network of the basin (Al-Salihi, 2004, p. 127).

The GIS technology provides us with advanced programs to conduct morphometric analyses that were adopted in this study represented in the third level (Toolbox- Spatial Analyst - Hydrology) based on accurate data with a high degree of spatial resolution represented in (satellite visualization, and digital elevation model DEM) that helps us draw the water drainage network accurately and clearly, which is reflected in the results of the morphometric analysis, thus saving effort and time. Therefore, the study relied on the analysis of space and topographic visualizations and data from meteorological monitoring stations in preparing drainage network maps, determining the ranks of the streams, calculating morphometric variables, and conducting measurements for the valleys (Al-Ghariz and Al-Yar'a Al-Bint) and using statistical equations to study and estimate the size of the peak floods in the study area. The morphometric characteristics include the following:

Modeling the spatial characteristics of the valleys of the study area:

The study includes the total area of the river basins, which helps in knowing these valleys in terms of volumetric characteristics and calculating many morphometric characteristics related to the formal characteristics of the river valleys and their networks in the study area, which are represented by the following:

Table (1) : The spatial characteristics of the valleys of the study area

<table>
<tr><th>The Basin</th><th>Length of the basin perimeter / km</th><th colspan="2">Width of the basin rate/km</th><th>Ideal basin length/km</th><th>Actual basin length/km</th><th>Area ratio%</th><th>Pond area/km2</th></tr>
<tr><td rowspan="3">Wadi Al-Ghareez</td><td rowspan="3">75.4</td><td rowspan="3">4.8</td><td>5.6</td><td rowspan="3">30.7</td><td rowspan="3">32.2</td><td rowspan="3">29.5</td><td rowspan="3">127.3</td></tr>
<tr><td>5.2</td></tr>
<tr><td>3.6</td></tr>
<tr><td rowspan="3">Wadi Al-Yaraa</td><td rowspan="3">65.1</td><td rowspan="3">4.7</td><td>6.4</td><td rowspan="3">28.9</td><td rowspan="3">30.8</td><td rowspan="3">21.6</td><td rowspan="3">93.1</td></tr>
<tr><td>5.9</td></tr>
<tr><td>1.9</td></tr>
<tr><td rowspan="3">Wadi al, Banat</td><td rowspan="3">97.4</td><td rowspan="3">7</td><td>12.4</td><td rowspan="3">37.6</td><td rowspan="3">41.8</td><td rowspan="3">48.8</td><td rowspan="3">210.4</td></tr>
<tr><td>2.4</td></tr>
<tr><td>6.2</td></tr>
<tr><td>Total</td><td>237.9</td><td colspan="2">49.6</td><td>97.2</td><td>104.8</td><td>100</td><td>430.8</td></tr>
</table>

Source: Based on DEM derivation in Arc map GIS V10.8 and Excel program

River Valley area:

Studying the area of drainage basins helps determine their close relationship with the water network system, as if all the morphological factors are similar, the volume and peak of the discharge are mainly due to the area of the drainage basin.

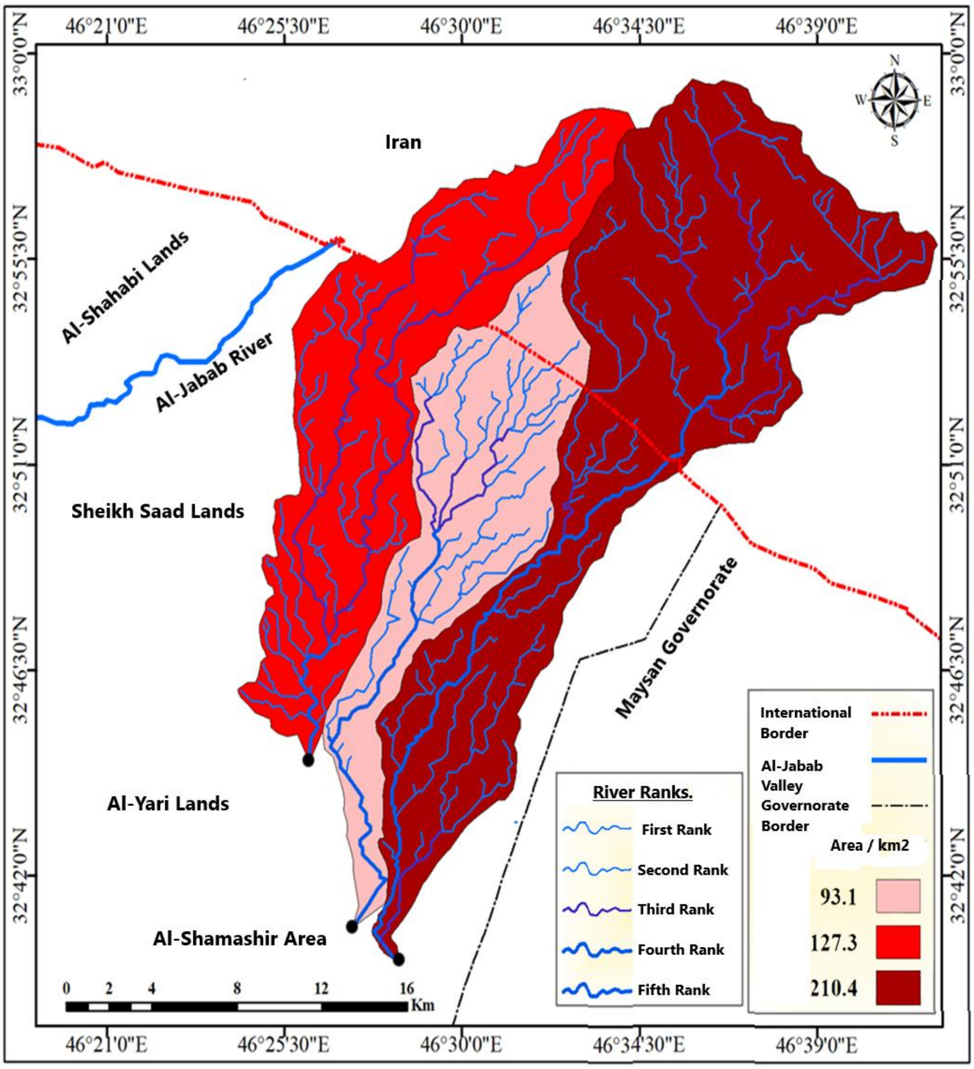
The area of Al-Ghariz Basin reached (127.3 km2) at a rate of (29.5%), the area of Al-Yari' Valley (93.3 km2) at a rate of (21.6%), and the area of Al-Bint Valley (210.4 km2) at a rate of (41.8%). The variation in the area of the valleys is due primarily to the effect of the geological structure lines and the natural characteristics of the rocks, in addition to the time period that the valleys have passed through their geomorphological cycle, as well as the amount of rainfall that the valleys receive, which increases according to the area of each valley, which helps in the activity of water erosion and increases the volume of transported sediments. As shown in Table (1) and Map (1).

3. River Valleys area:

The basin perimeter is one of the important indicators to clarify the extent of the basin's spread and width, as it represents the water division line for the basins that separate them and is used to know the width of the basin. The longer the basin perimeter, the more the basin area expands, as the longer the basin, the less the danger of running water, while the smaller the basin perimeter increases the risk of recurring floods (Al-Maliki, 2016, p. 189).

The circumference of Wadi Al-Ghariz reached (75.4 km), the circumference of Wadi Al-Yari' (65.1 km), and the circumference of Wadi Al-Bint (97.4 km). This difference reflects the severity of the tortuousness of the water division line of the valleys and the lack of symmetry in their shape. In addition, the danger of the valleys increases due to the smallness of their circumference as a result of the small water loss and the increase in the amount of running water resulting from heavy rainfall on specific days of the winter season on the border strip of the study area, which increases the floods that bring with them large amounts of sediments of different sizes and shapes, as shown in Table (1) and Map (2).

Map (2) Modeling of the classification of the area of the valleys of the study area



Source: Based on Table (1) and the digital elevation model (DEM) in Arc map GIS V10.8

Longest river valleys:

The length of the valley controls the duration of its water discharge and the sediments it carries through the speed of water flow (time of concentration, evaporation and seepage), so it has an important role in the hydrology of river valleys. The length of the water basin is known as the line that works to classify the drainage area of the water basin into two identical sections, and it is also known as the line that represents the axis of the water basin (Al-Waili, 2012, p. 72).

The length of the valley is measured in several commonly known ways, which are:

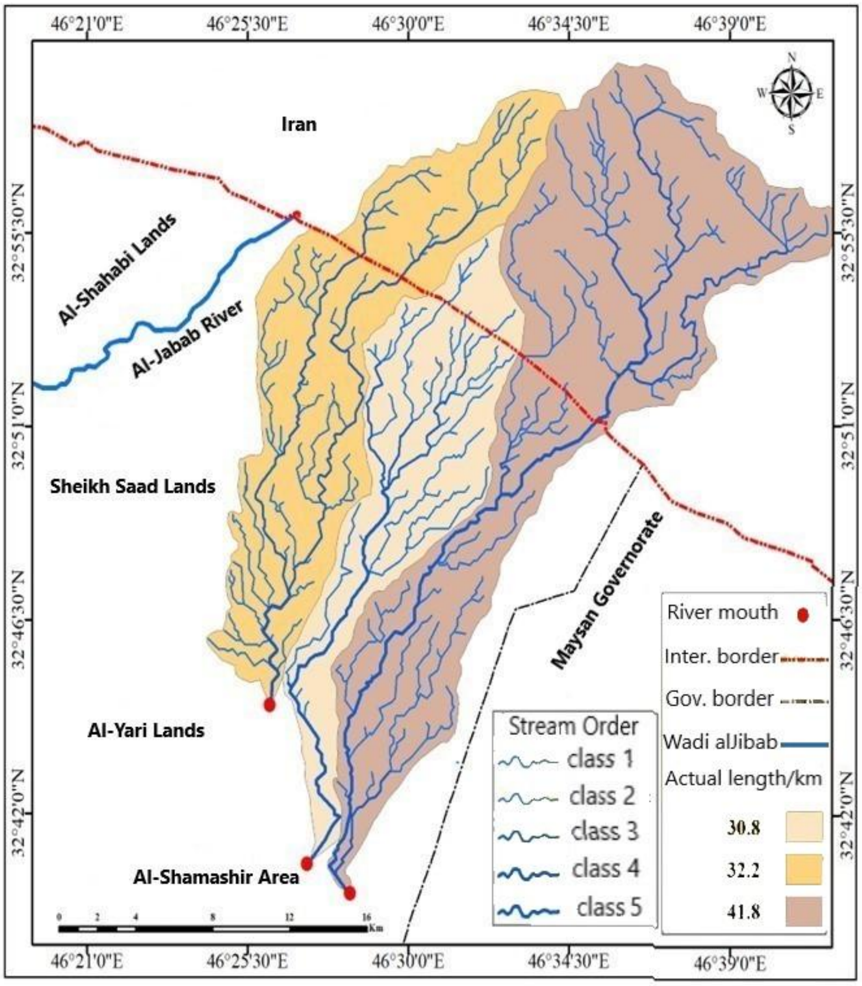
The Schumm method is one of the commonly used methods for finding the length of the water basin. It is a line extending from the lowest point in the water basin, which represents the (point of the basin's outlet), to the highest point in the water division area, which represents the (point of the basin's source).

Maxwell's method is one of the commonly used methods for finding the length of the water body, as the length of the basin can be determined by measuring the length of a line parallel to the main river channel from the estuary to the source.

These two methods were used to draw the length of the river valleys of the study area, as the ideal length based on the digital elevation model (DEM) for Wadi Al-Ghariz was (30.7 km), Wadi Al-Yari' (28.9 km), and Wadi Al-Bint (37.6 km), while the actual length for Wadi Al-Ghariz was (32.2 km), Wadi Al-Yari' (30.8 km), and Wadi Al-Bint (41.8 km). The use of GIS technology facilitated finding the length of the valleys by performing the work (Snapping), provided that the length of the water basin is parallel to the main channel.

The lengths of the valleys in the study area are almost short, which reduces seepage and evaporation, and thus increases the amount of running water. The area is exposed to floods, which helps in transporting sediments that increase the area of the fan valleys. As shown in Table (1) and Maps (2-3) and (2-4)

Map (3) Modeling classification of valley lengths (actual length) for the study area



Source: Based on Table (1) and the digital elevation model (DEM) in Arc map GIS V10.8

River Valleys display:

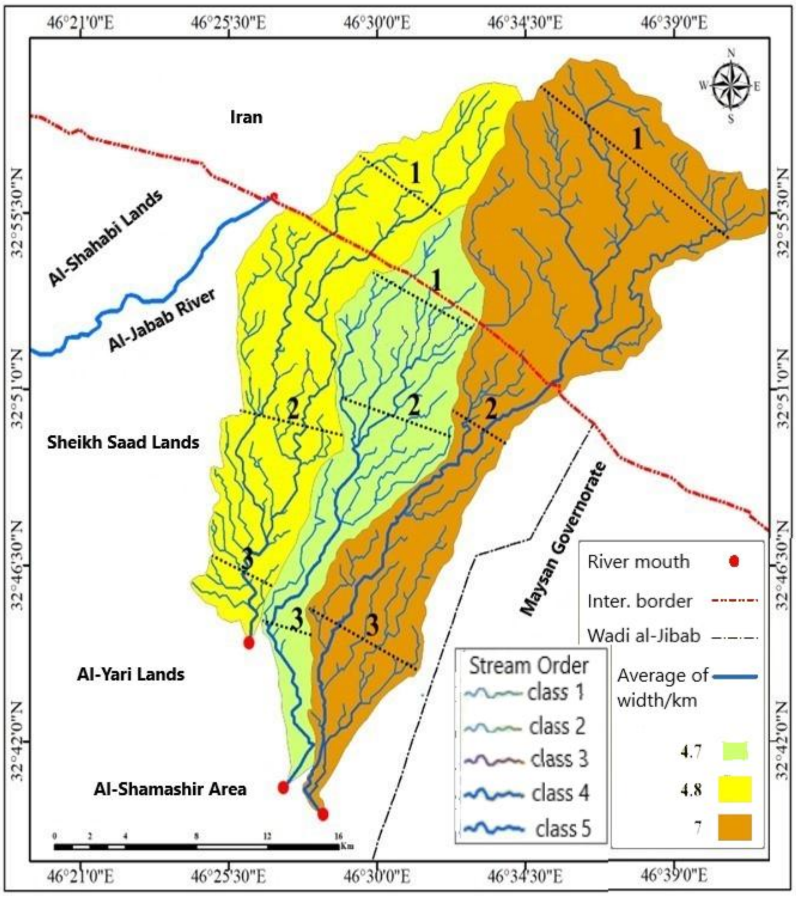
It is defined as the length of the distance between two points on the basin's perimeter that intersect completely perpendicular to the main valley's course. The width of the valley affects the amount of water in the course, as the wider the valley, the more water and its flow increases. It is one of the important indicators in determining the extent of the danger of floods due to its effect on the amount of running water (Alibrahimi, 2022, 485). The width of the basin was measured using a direct method using a digital elevation model with a spatial resolution of (30 m) to determine the widest parts of the basin and compare them to the maximum length of the drainage basin.

The width of Wadi Al-Ghariz is (4.8), the width of Wadi Al-Yari' is (4.7 km), and the width of Wadi Al-Bint is (7 km). Since the width of the valleys varies from the source to the mouth as a result of the difference in climatic characteristics and the degree of slope, the measurements are small. The region is exposed to repeated floods resulting from the increase in the amount of running water, which helped in transporting sediments because of water erosion activity and their deposition at the mouth of the valleys, as shown in Table (2-1) and Map (2-5).

4. Modeling the morphological characteristics of the valleys of the study area:

The morphological characteristics of drainage basins are compared with geometric shapes. Drainage basins of different sizes can be similar in geometric shape and can be similar in other geomorphometric characteristics because such similarity must result from the same geomorphometric factors and processes. The morphology of the shape of drainage basins is affected by three main factors: the natural characteristics of rocks, geological structure, and climatic characteristics (Abu el Enien, 2003, 191-211). The study of morphological characteristics has an important and influential role on the amount of running, seeping, and evaporating water and knowing the activity of water erosion that valleys are exposed to, and thus its effect on the volume of transported sediments, which is represented by the following:

Map (4) Modeling the classification of the valley width rate in the study area



Source: Based on Table (1) and the digital elevation model (DEM) in Arc map GIS V10.8

Modeling of drainage network characteristics:

River ranks:

One of the first to study the characteristics of the drainage network was (Horton), who divided the network into a group of ranks. Then came Strehler to modify the (Horton) model in (1953), as he reached a group of laws between the network variables and linked them to the type of rocks. The study area is currently characterized by its intermittent flow valleys that depend on the rain that falls in the winter and during specific days. Due to the ease of Strehler's method, it was adopted in the study, which states:

Small tributaries that do not have secondary tributaries flowing into them represent the first order. When two tributaries of the first order meet, they form a second order stream, and when the latter meet, they form a third order stream, and so on until it reaches the rank of the mainstream of the river, which represents the highest rank in the basin. Studying the ranks is important in knowing the size and width of the basin, determining water discharge patterns, estimating the speed of flow, predicting flood risks, and the size and quantity of transported sediments (Ali, 2012, p. 133).

Table (2) Number of riverbeds in the valleys of the study area

The Basin	Percentage %	Total number of river courses for all ranks	Number of river courses according to their rank in the basin				
			Fifth Rank	Fourth Rank	Third Rank	Second Rank	First Rank
Wadi Al-Ghareez	34.3	1684	0	1	40	563	1080
Wadi Al-Yaraa	27.4	1345	1	12	75	312	945
Wadi al, Banat	38.2	1876	1	16	94	645	1120

Source: Based on DEM derivation in Arc map GIS V10.8 and Excel

From the analysis of Table (2-6) and Map (2-18), we find that the total number of streams for all ranks in Wadi Al-Ghariz reached (1684) streams, representing 34.3%, as the number of streams in the first rank reached (1080) streams, the second rank reached (563) streams, the third rank reached (40) streams, and the fourth rank reached one stream. Meanwhile, the total number of streams for all ranks in Wadi Al-Yari' reached (1345) streams, representing 27.4%, as the number of streams in the first rank reached (945) streams, the second rank reached (312) streams, the third rank reached (75) streams, the fourth rank reached (12) streams, and the fifth rank reached one stream. As for Wadi Al-Bint, the total number of streams for all ranks reached (1876) streams, representing 38.2%, and it is the largest valley in the study area, as the first rank reached (1120) streams, the second rank reached (645) streams, the third rank reached (94) streams, the fourth rank reached (16) streams, and the fifth rank reached one main stream.

5. Discussions:

Lengths of river ranks:

It is considered one of the important measurements in morphometric characteristics as it represents a reflection of topographic, geological and climatic characteristics.

From the analysis of Table (2-7) and Map (2-18), we find that the lengths of the streams in Wadi Al-Ghariz reached (6585.6) km and a percentage of 34.1%, as the length of the streams in the first rank reached (2808) km, the second rank reached (3547) km, the third rank reached (220) km, and the fourth rank reached (10.6) km. As for Wadi Al-Yari', the length of the streams reached (4995.9) km and a percentage of 25.9%, as the length of the first rank reached (2457 km), the second rank reached (1966) km, the third rank reached (413 km), the fourth rank reached (1147.6 km), and the fifth rank reached (12.3 km). As for Wadi Al-Bint, the length of the streams reached (7703 km) and a percentage of 39.9%, and it is the largest valley in the study area, as the lengths of the first rank reached (2912 km), the second rank reached (4064 km), and the third rank reached (12.3 km). (517 km) 517 The fourth place reached (203.2 km) and the fifth place reached 6.8 (6.8 km).

Watercourse survival rate:

The watercourse survival rate of the basin is symbolized by the symbol (C) and expresses the amount of space needed to supply the network's channels with water. It is obtained by dividing the total area of the water basin by the total lengths of the channels for this basin according to the following equation (Majdi, 2002, p. 324).

$$C = \frac{1}{Dd} = \frac{A_U\,(Km^2)}{\sum L_U}$$

Where: C: The constant of the watercourse of the basin

∑▒L_U: The sum of the lengths of the watercourses of the basin (km)

A_(U): The total area of the watercourse (km2)

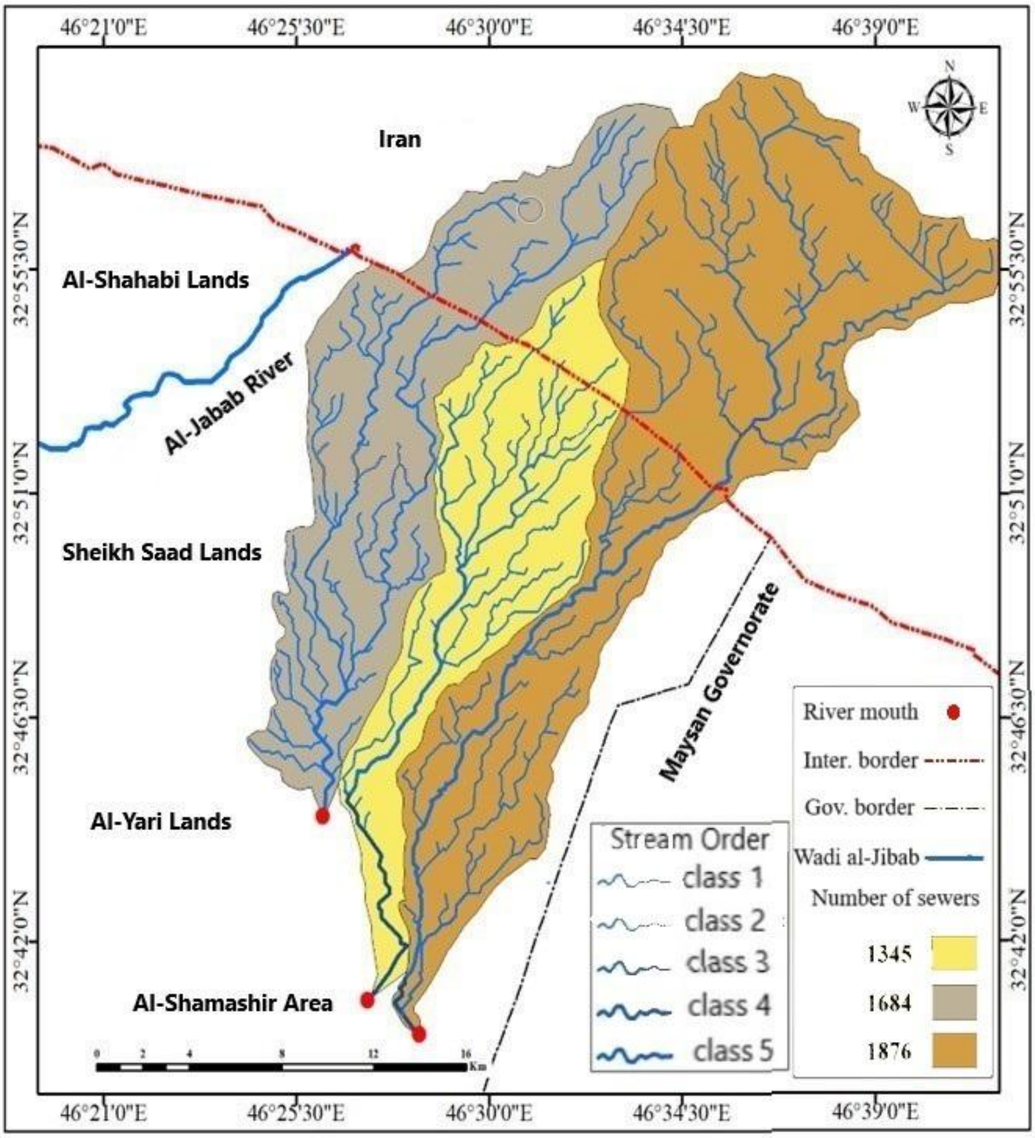
From the analysis of the equation results, we find that the average area unit required to feed one longitudinal unit (km) in Wadi Al-Ghariz was (0.019), Wadi Al-Yari' (0.018), and Wadi Al-Bint (0.27). It was found that the low values indicate surface runoff, and this is reflected in the amount of flood flow in the valleys and their risks to the region, as shown in Table (2-8) and Map (2-19).

Table (3): Stream survival rate and longitudinal and numerical density of valleys in the study area

The Basin	Population density	Number of river courses/km	Riverbed survival rate
Wadi Al-Ghareez	13.2	1684	0.019
Wadi Al-Yaraa	14.4	1345	0.018
Wadi al, Banat	8.9	1876	0.027

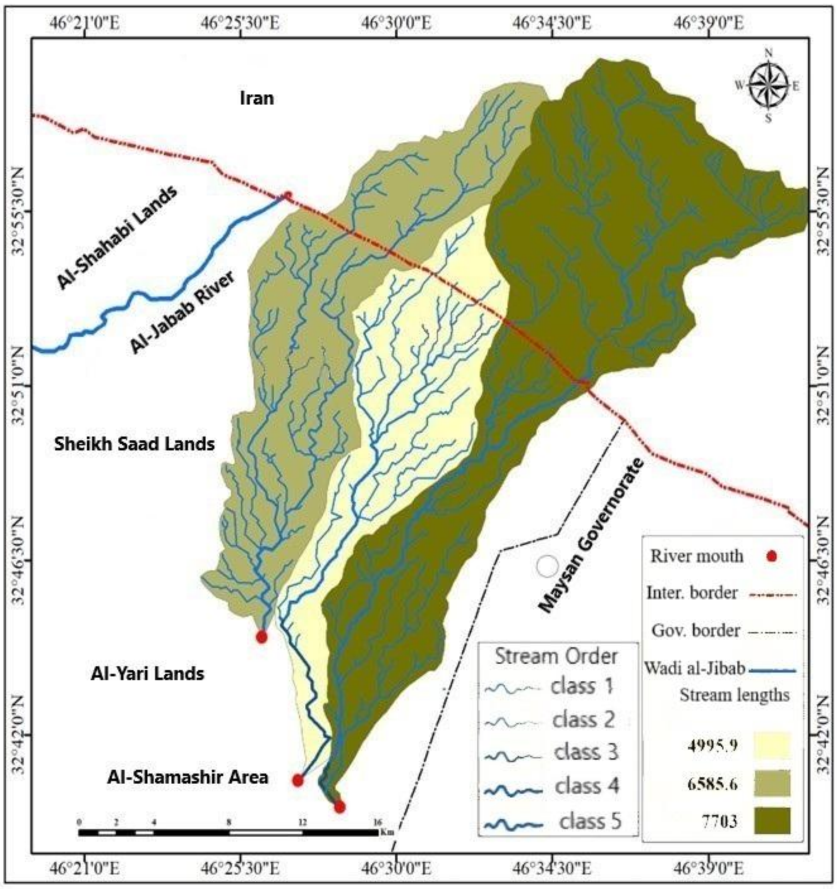
Source: Based on DEM derivation in Arc map GIS V10.8 and Excel

Map (5) Modeling classification of the number of valleys in the study area



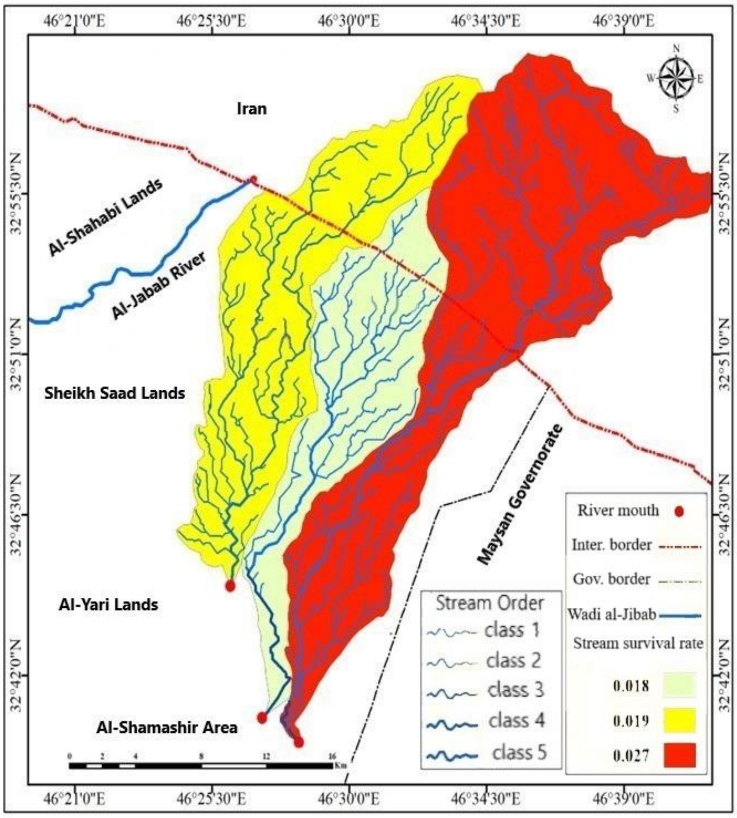
Source: Based on Table (2) and the digital elevation model (DEM) in Arc map GIS V10.8

Map (6) Modeling classification of the lengths of valleys in the study area



Source: Based on Table (2) and the digital elevation model (DEM) in Arc map GIS V10.8

Map (7) Modelling classification of stream survival rate of valleys in the study area



Source: Based on Table (2) and the digital elevation model (DEM) in Arc map GIS V10.8

Drainage density:

Drainage density is related to hydrology and geomorphology, as it gives the idea of the spacing between streams or the extent of surface interruption by streams and reflects the way running water flows and is affected by the geological nature, slope, amount of rainfall and its intensity (Al-Jubouri, 2018, p. 183). Density is divided into two types:

Population density:

The numerical density indicates the ratio between the number of streams available in a specific basin to the total area of the drainage basin regardless of their lengths in this area. In other words, it is expressed by the drainage density, the degree of drainage network texture, and the severity of the basin's intermittent with waterways. It is not necessarily related to the drainage density, but rather to the geological formation and structure that occurred over the geological ages, represented by cracks, fissures, and joints. The numerical density of the water basin is symbolized by the symbol (Fs), and it can be obtained from the result of dividing the total number of waterways in the water basin by the area of the water basin, according to the following equation (Al-Dulaimi, Al-Jabri, p. 249).

$$\boldsymbol{F_S} = \frac{\sum \boldsymbol{N_U}}{\boldsymbol{A_U}\,(\boldsymbol{Km^2})}$$

Where FS: Frequency of streams for the water basin

∑▒N_U: Total number of streams for the water basin

A_(U): Area of the basin (km2)

From the analysis of the equation results, we find that the average population density of Wadi Al-Ghariz reached (13.2), Wadi Al-Yari' (14.4), and Wadi Al-Bint (8.9). Thus, Al-Ghariz and Al-Yari' have a higher population density due to the nature of the area, and the increase in the number of channels is attributed to the amount of rainfall or the smoothness or roughness of the basin's terrain. Since the high values indicate the availability of a large number of channels, this increases the possibility of larger surface runoff forming torrents that carry sediments with them. As shown in Table (2-8) and Map (2-20).

Longitudinal density:

The longitudinal density is an indicator of the extent to which the basin is affected by water erosion processes and the severity of the basin's rupture and discontinuity, due to the relationship between surface runoff, soil infiltration, precipitation and evaporation. The increase in the amount of water flowing in the drainage basin leads to an increase in the basin and its discontinuity according to the nature of the basin's sediments, the width of the channel, the abundance of rainfall and the slope of the surface. The drainage density of the water basin is symbolized by the symbol (Dd) and can be obtained by dividing the sum of the lengths of the water basin's channels by the total area of the water basin according to the following equation (Ashour, 1986, pp. 473-496).

$$Dd = \frac{\sum L_U}{A_U\,(Km^2)}$$

Where Dd: discharge density of the water basin

∑▒L_U: total length of the waterways of the basin (km)

A_(U): total area of the water basin (km2).

From the analysis of the equation results, we find that the longitudinal density of Wadi Al-Ghariz reached (51.7), Wadi Al-Yari' (53.7), and Wadi Al-Bint (36.6). These are high values, which indicate the density of running water, the increase in water erosion processes, the severity of the basin's rupture and discontinuity, and the formation of floods, which increased the volume and quantity of sediments in the downstream area. As shown in Table (2-9) and Map (2-21).

Bifurcation ratio:

It is one of the important morphometric variables that control the discharge rate and describes the extent of merging that waterways undergo as their ranks increase, and the number of waterways decreases as their ranks increase. The branching ratio is symbolized by the symbol (R_(b)) and can be obtained from the following equation (Al-Du'an, 1999, p. 65).

$$R_b = \frac{Nu}{Nu+1}$$

Where R_(b): Bifurcation ratio

Nu: Number of channels for a given order

Nu+1: Number of channels for the next order

From the analysis of the equation results, we find that the average bifurcation ratio for Wadi Al-Ghariz was (14.2), Wadi Al-Yari' (5.29), and Wadi Al-Bint (6.29), which is a high ratio compared to that set by Strehler (3-5) for basins with similar landforms and climatic conditions. Since the results are high, they indicate an increase in the number of waterways in the higher rank as a result of water erosion activity that led to the recurrence of floods, which affected the size and quantity of sediments. This indicates the lack of similarity of the basin geologically, structurally, climatically, and topographically, as shown in Table (2-9) and Map (2-22).

Table (4) The branching ratio of the valleys in the study area

The Basin	1st Order	2nd Order	3rd Order	4th Order	5th Order	Average Branching Ratio
Wadi Al-Ghareez	1.9	14.1	40.0	1.0	0	14.2
Wadi Al-Yaraa	3.03	4.16	6.25	12.00	1.00	5.29
Wadi Al-Banat	1.74	6.86	5.88	16.00	1.00	6.29

Source: Based on DEM derivation in Arc map GIS V10.8 and Excel

Bend coefficient:

Waterways vary in the nature of their flow and discharge in the percentage of meander and are identified from the actual length to the ideal length, which means drawing a straight line starting from the source and ending at the mouth and is extracted from the following equation.

$$S = \frac{L_S}{L_v}$$

Where S: river meander coefficient

Ls: actual valley length (km)

Lv: ideal valley length (km)

If the value is (1,1), the channel is straight. If the value ranges between (1,1-1,4), it is winding. If it is more than (1,5), it is highly curving (Al-Dulaimi, 2017, pp. 189-190).

Table (5) The bending coefficient of the study area basins

Basin	Actual Stream Length (km)	Straight-Line Length (km)	Sinuosity Index	Classification (Smith)
Wadi Al-Ghareez	32.2	30.7	1.05	1 - Straight basin
Wadi Al-Yaraa	30.8	28.9	1.07	1.1–1.5 - Meandering basin
Wadi Al-Banat	41.8	37.6	1.11	>1.5 - Highly sinuous basin

Source: Based on DEM derivation in Arc map GIS V10.8 and Excel

From the analysis of the equation results, we find that the bending coefficient for Wadi Al-Ghariz reached (1.01), Wadi Al-Yara' reached (1.07), and Wadi Al-Bint reached (1.11), meaning that the valleys tend to meander according to Smith's classification as a result of the climatic conditions prevailing in the region, as rain falls in the winter and for specific days, which helps increase the volume of water discharge and the activity of erosion processes, which affected the recurrence of torrential floods with sediments that settle in the study area, forming fan functions, as shown in Table (2-11) and Map (2-23).

Waterway network patterns:

The amount of running water in the water basins is controlled by the nature of the terrain, its components and the climatic conditions. As a result of the variation in the geological structure, this led to variation in the drainage patterns. Three patterns are spread in the study area, represented by the tree pattern, the parallel pattern and the rectangular pattern. These patterns reflect the nature of the rocks of the region. These patterns were identified through satellite images, as shown in Map (2-23), and they are as follows:

Tree drainage pattern:

This type is prevalent in rocky areas with a homogeneous composition and structure, where waterways meet each other at sharp angles, are numerous and short, and take the form of trees (Al-Maliki, 2016, p. 203). Since the rocks of the region are sedimentary rocks of low hardness, and the rain falls heavily during the winter, this leads to an increase in the degree of branching of this type, as it works to collect rainwater quickly, which activates the process of severe erosion of the valley slopes and increases its load of sediments of different sizes and shapes to settle in the study area, as this type is widespread in the upper sources of Wadi Al-Bint.

Parallel discharge pattern:

This pattern prevails in areas whose slopes are formed of longitudinal concave depressions paralleled by longitudinal convexities, i.e. according to the rock and tectonic structure, it helps to create longitudinal channels that cut through the surface concave depressions and whose channels extend parallel to each other and at equal distances, as this pattern is widespread in the upper sources of Wadi Al-Yari'.

Rectangular drainage pattern:

This pattern prevails over rocks that contain joints and cracks that are followed by streams and meet each other at right angles, and the connection of the waterways to the mainstream is perpendicular, as this pattern is widespread in the middle of Wadi Al-Ghariz.

Modeling the hydrological characteristics of the valleys in the study area:

By hydrological modeling we mean simulating the surface runoff process that occurs in drainage basins from the first moment of rainfall until the end of the runoff. The great complexity of hydrological systems leads to the difficulty of describing and studying the actual characteristics of some hydrological processes in nature. This is due to the scarcity of field measurements (Khattab, Salim, p. 7).

Surface runoff is one of the important hydrological factors that affect erosion and sedimentation processes. Since the drainage basins are located in arid and semi-arid environments that depend on the amount of rainfall that falls suddenly during the winter, which helps to form large amounts of water flows causing floods in these environments, and since the drainage basins lack stations to measure floods and their discharge rate during the flood season that descends from the eastern hills on the eastern side of the Iranian border, the hydrological modeling was simulated based on the Snyder model, which was developed in (1938) because it is one of the oldest and most famous models applicable to desert drainage basins that do not have stations or water or rain data. It aims to estimate the risks of floods and their discharge rate by estimating the amounts and sizes of flow and estimating their time periods.

This model has been modified by many researchers and agencies, including the US Army Corps of Engineers. The Krebisch model (1940) and the Snyder model were relied upon, which achieved widespread because it depends on the characteristics of the drainage basin and its dimensions in dry environments where it is difficult to measure rainstorms. It can also be applied to any water basin with different climatic conditions because it does not depend on rainfall measurements or surface runoff values but rather depends on the morphometric characteristics of the basins. The model was applied after passing through several stages to determine the peak of the flood, and these equations were represented by the following:

Concentration time:

It represents the period of time between the start of rainfall at the farthest point in the basin and its accumulation to form surface water flows, thus forming torrents at the estuary. The shorter the concentration time, the faster the water flows and the higher the degree of danger of the torrent, and vice versa. Therefore, it is important in determining methods of averting the danger of torrents and is obtained from the following equation (Al-Maghazi, 2015, p. 82):

Concentration time = (mainstream length) 0.77 0.6628 / (average basin slope) 0.385

From the analysis of the equation results, we find that Wadi Al-Ghariz reached (3.4) hours, while Wadi Al-Yari' reached (2.5) hours, and Wadi Al-Bint reached (4.7) hours, which is the time period required for the water to reach the estuary from the farthest point in the basin. These are low values, which led to an increase in the risk of strong water flow in the valleys, forming torrential floods with sediments in large quantities of different shapes and sizes, as shown in Table (2-12) and Map (2-24).

Table (6): Concentration time, duration of excess rainfall, and response time to the study area's medications**:**

Basins	Time of Concentration (hours)	Excess Rainfall Duration (hours)	Lag Time / Response Time (hours)
Wadi Al-Ghareez	3.4	0.29	2.12
Wadi Al-Yaraa	2.5	0.19	1.30
Wadi Al-Banat	4.7	0.41	3.06

Source: Based on DEM derivation in Arc map GIS V10.8 and Excel**Duration of excess rainfall:**

The US Soil Conservation Service defines the duration of excess rainfall as the period required by the water basin to convert rainwater into surface runoff or to a torrent flow after the soil and rocky outcrops are saturated with water. This period is obtained from the following equation (Al-Buhaithi, 2018, pp. 53-54):

Rainfall surplus duration = 0.133 basin concentration time (hour)

From the analysis of the equation results, we find that the duration of the excess rainfall in Wadi Al-Ghariz reached (0.29) hours, in Wadi Al-Yari' (0.19) hours, and in Wadi Al-Bint (0.41) hours. The duration of the excess for the valleys was represented in hours for the rainwater to turn into surface runoff or torrent flow, as shown in Table (2-12) and Map (2-25).

6. Result

Response time (deceleration):

It is called the (first response) time and is defined as the time period between the peak of rainfall (in hours) and the peak of flow, i.e. the start of surface runoff until the actual runoff occurs, as the deceleration time is inversely related to the degree of danger of the flood, as the lower the deceleration time values, the greater the danger of the flood, which makes it difficult to take measures to confront the floods. The response period is controlled by the type of soil, the slope ratio, and the degree of permeability, and is obtained from the following equation (2) (Khattab, 2015, p. 21):

Response time (lag) = 0.6 concentration time in the basin

From the analysis of the equation results, we find that the response time values in Wadi Al-Ghariz reached (2.12) hours, in Wadi Al-Yari' (1.30) hours, and in Wadi Al-Bint (3.06) hours. This is what the valleys in the study area need for the actual flow to occur in their courses, and the decrease in values helped increase the risk of flooding in the study area due to the steep slope, as shown in Table (2-12) and Map (2-26).

Peak flow time:

It is the time period between the start of the surface runoff of the basin and the arrival of the peak flow. The peak arrival time is directly related to the basin response time. It is calculated from the following equation (Korgi, 1979, p. 66):

Peak flow time = 0.5 rainfall surplus time (hour) + basin response time (lag)

From the analysis of the equation results, we find that the peak flow time in Wadi Al-Ghariz was (2.26) hours, in Wadi Al-Yari' (1.39) hours, and in Wadi Al-Bint (3.26) hours. It is concluded that Wadi Al-Bint has the highest percentage among the valleys due to the length of the channel and the degree of slope, as shown in Table (2-13) and Map (2-27).

Table (7) Peak flow time, base time, and flood low period for the valleys of the study area

Basins	Time to Peak Flow (hours)	Length of Main Channel (LC) (km)	Base Time of the Flood (hours)	Recession Duration (hours)
Wadi Al-Ghareez	2.26	15.6	8.92	4.04
Wadi Al-Yaraa	1.39	13.3	8.12	2.46
Wadi Al-Banat	3.26	20.2	10.12	5.44

Source: Based on DEM derivation in Arc map GIS V10.8 and Excel

The time of arrival of the flow from the source to the outlet (the basic time of the flood):

The time of arrival of the flow from the source to the outlet is a very important property for its effect on the water plant as a result of the rainstorm. It is defined as the period of time required to drain the water completely from the source to the outlet, i.e. from the beginning of the torrent flow until the water returns to its normal level. It is calculated from the following equation (Al-Buhaithi, 2018, p. 21):

Tb=0.74 Ct (LLC)0.3

The equation symbols are represented by the following:

Tb: Time of arrival of flow from source to outlet L: Actual basin length (km)

LC: Length of basin from the center of the basin to the outlet point (km)

CT: A coefficient that depends on the characteristics of the basin, its value is (1.8 – 2.2)

From the analysis of the equation results, we find that the basic time of the torrent in Wadi Al-Ghariz was (8.92) hours, while in Wadi Al-Yari' (8.12) hours and in Wadi Al-Bint (10.12) hours. These are close values that helped activate the erosion process in the valleys as a result of the degree of slope and the increase in the transfer of sediments and their stability in the downstream area, forming fan functions. As shown in Table (2-13) and Map (2-28).

Low flow period:

It is known as the period of time it takes for the flood to return to its normal state. The period of the flood's decrease is affected by the period of the flood's base. As rainfall begins to decrease, the water levels begin to decrease, and its discharge decreases with a decrease in its flow speed. This period is calculated from the following equation (Horton.R E. (1932): p361):

Duration of low flow = 1.67 Duration of peak flow (hour)

From the analysis of the equation results, we find that the duration of the decrease in the torrent flow in Wadi Al-Ghariz reached (4.04) hours, in Wadi Al-Yari' (2.46) hours, and in Wadi Al-Bint (5.44) hours. The highest value was recorded in Wadi Al-Bint as a result of the spatial characteristics of this valley, which has a greater role in increasing the volume of sediments in the study area, as shown in the table.

Flow rate:

By flow velocity, we mean the volume of water passing through the cross-section of the river during a unit of time, i.e. it is a measure of the speed of water movement resulting from the volume of the water mass and the slope of the surface through the cross-sectional area of the river at a certain time. The speed of water flow in valley channels is one of the important hydrological parameters for drainage basins, as it determines the degree of danger of valleys and their ability to erode, transport and deposit. The speed of flow in waterways and valleys is measured in various ways, but it is difficult to measure it in the field except in the case of the availability of appropriate devices for that with the small area of the study. The speed of surface flow is inversely proportional to the time of concentration and the length of the main channel of the basin. Accordingly, the speed of surface flow is calculated from the following equation (Al-Dali, 2012, p. 284):

Flow rate = length of the water basin (km) / concentration time of the water basin (hour)

From the analysis of the equation results, we find that the flow speed in Wadi Al-Ghariz reached (9.5 km/h), in Wadi Al-Yari' (12.3 km/h), and in Wadi Al-Bint (8.9 km/h), and the highest value was recorded in Wadi Al-Yari'. This indicates that the valley is shorter than the other valleys, which helped in the activity of the erosion process and increased the load and its deposition in the downstream area, as shown in Table (2-14) and Map (2-30).

Table (8) Flow velocity and water flow quantity of the valleys of the study area

Basins	Flow Velocity (km/h)	Water Discharge (m^3/s)
Wadi Al-Ghareez	9.5	19.9
Wadi Al-Yaraa	12.3	15.9
Wadi Al-Banat	8.9	18.9

Source: Based on DEM derivation in Arc map GIS V10.8 and Excel

Water flow quantity Qp.

It is known as the maximum flow value of the torrents and is calculated according to the (Snyder) equation from the following equation (Al-Jaidi, 2015, p. 354).

Qp=2.78 CP (A/tp)

The equation symbols are represented by the following:

Qp: Peak discharge

CP: Flow coefficient, based on basin characteristics and ranges from 0.7 – 0.5

A: Area of basin in (km2)

tp: Time of flow from source to outlet

From the analysis of the equation results, we find that the flow rate (peak discharge) in Wadi Al-Ghariz reached (19.9 m3/s), in Wadi Al-Yari' 15.9 (15.9 m3/s), and in Wadi Al-Bint 28.9 (28.9 m3/s), and the highest value was recorded in Wadi Al-Bint, which indicates the breadth of the basin and the breadth of the water network, which provides large quantities of water inside the valley, which helped increase its sediment load, in addition to the nature of the slope of the region at the sources of the valleys, which gradually decreases at the mouth area inside the Iraqi lands in a flat plain area. As shown in Figure (2-1), Table (2-14), and Map (2-31).

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