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Hydro-Morphometric Analysis of Valley Awina Basin Northwest of Mosul - Iraq

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ABSTRACT

The Valley Awina is one of the dry valleys with non-permanent flow (seasonal flow), the valley is also a drainage area for the drainage water of the northern Al-Jazeera Irrigation Project. Valley Awina connects with several other valleys to form Valley Al-Mar, which ends at the Tigris River. An analysis of the results of the morphometric analysis was conducted, where the basin rank was sixth, and the total basin area was (1095.11 km^2), the length of Valley Awina was (57.54 km), and its average width was (21.96 km). Based on the drainage intensity of (0.6) and the value of the hypsometric coefficient of the basin, which was (2.74), As for the morphological characteristics, it was shown, according to the results of the morphometric analysis, that the shape of the basin is closest to elongation, the drainage pattern of this basin is of the tree type, and the height of the valley basin varies from (832 m) above sea level in its southern region to (350 m) above sea level in the estuary region, it thus gradually rises towards the south, several geological formations are exposed within the Valley Awina basin, represented by formations of the Tertiary and Quaternary geological ages, the determination of the hydro morphometric characteristics of Valley Awina reflected the nature of the influencing factors, such as the length of the basin, the number of water ranks, the Bifurcation ratio, the intensity of the valley's drainage, and other factors.

Keywords: Al-mur Valley, Awina Valley, Morphometric characters analysis, Water network.
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التحليل الهيدرومورفمتري لحوض وادي عوينة شمال غرب الموصل – العراق

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قسم علوم الارض التطبيقية، كلية العلوم، جامعة تكريت، تكريت، العراق

الملخص

يعد وادي عوينة من الأودية الجافة غير الدائمة الجريان (جريان موسمي)، كما يُعتبر الوادي منطقة تصريف لمياه بزل مشروع ري الجزيرة الشمالي. يتصل وادي العوينة بوادي بعدة أودية أخرى ليكونوا وادي المر الذي يصب في نهر دجلة، وقد أُجري تحليل لنتائج التحليل المورفمتري، حيث احتل الحوض المرتبة السادسة، وبلغت المساحة الكلية للحوض (1095.11 كم^2)، و طول وادي عوينة (57.54 كم) ومتوسط عرضه (21.96 كم)، وبناء على شدة التصريف البالغة (0.6) وقيمة معامل الانحدار للحوض والتي بلغت (2.74) فإن وادي عوينة يعتبر في مرحلة النضج، أما من حيث نتائج الخصائص المورفولوجية فقد تبين أن شكل الحوض أقرب إلى الاستطالة، ويتراوح ارتفاع حوض الوادي من (832 م) فوق مستوى سطح البحر في منطقته الجنوبية إلى (350 م) فوق مستوى سطح البحر في منطقة المصب، وبالتالي يرتفع تدريجيا نحو الجنوب، وتتكشف داخل حوض وادي عوينة عدة تكوينات جيولوجية تتمثل في تكوينات العصرين الجيولوجيين الثلاثي والرباعي، وقد عكس تحديد الخصائص الهيدرومورفمترية لوادي عوينة طبيعة العوامل المؤثرة مثل طول الحوض وعدد الرتب المائية ونسبة التشعب و شدة تصريف الوادي وعوامل أخرى.

INTRODUCTION

The study area suffers from the limitation of water quantities and the drying of some water wells in addition to the low level of groundwater in other wells that directly affect agricultural crops on the one hand and human life on the other, these depths are mainly affected by topographic, geomorphological features and nature in the area of the groundwater layer[1], the study of watershed plays an important role for any kind of developmental activities and sustainable management[2], in this research, the analysis of the hydro morphometric characteristics of the Valley Awina basin, which is one of the geomorphological characteristics that deal with the surface of the different land, was carried out because of the importance of this field in analyzing the characteristics of the water basin in terms of (the shape of the basin, its area and surroundings, the water mattresses of the basin, the lengths of the ranks and other characteristics) and their relationship with the geology of the basin and Changes in the results of the hydro morphometric analysis and their interpretation, and that the results of this research can be relied upon in the academic or field studies that concern the region and in the establishment of future water projects or in the sustainability of water resources, and there is also within the study area an irrigation project is the North Al-jazera Irrigation Project, which covers about half of the land of the study area, as this project is one of the important projects in Iraq, in which two methods of irrigation are used, spray irrigation and flood irrigation, and the immersion system followed is the surface flooding system and consists of a network of field drains parallel to the supply channels, and it is poured into the collected drain and sometimes directly into Valley Awina, where Valley Awina (part of Valley Al- Murr) is the main drain of the project, and it extends from the west to the east separating the project lands into two parts, and the rainwater descending from the surrounding lands, which flows together with other valleys, collects in the Tigris River.

MATERIALS AND METHODS

The digital elevation model (DEM) was adopted with a resolution of (12.5×12.5 m), where the

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satellite visualization was processed using Arc Map 10.8 program and through several mathematical processes, the hydro morphometric characteristics were determined and special maps were prepared, including the drainage network map, it was found that the basin is of the sixth degree and the (STRAHLER) method was adopted to classify the water tributaries, which is considered one of the easiest, most accurate and most acceptable ways to classify the water ranks, the area of the drainage basin was also calculated in addition to the rest of the hydro morphometric coefficients represented by (area, morphological, terrain and other water network characteristics).

Location of the study area

The study area is located between the longitudes (42° 00' 55" – 42° 26' 47 ") east, and the latitudes (36° 56' 27' ' – 36° 24' 48") north, northwest of Iraq near the city of Mosul 95 km (northwest of the city), it is located within the borders of Rabia sub-district of Tal Afar administrative district, in addition to the southern part of the study area, which is located within the north sub-district of Sinjar district, the area of the basin (1095.11 km^2), and part of the basin (the northwestern part) is located within the Syrian country (Figure 1).

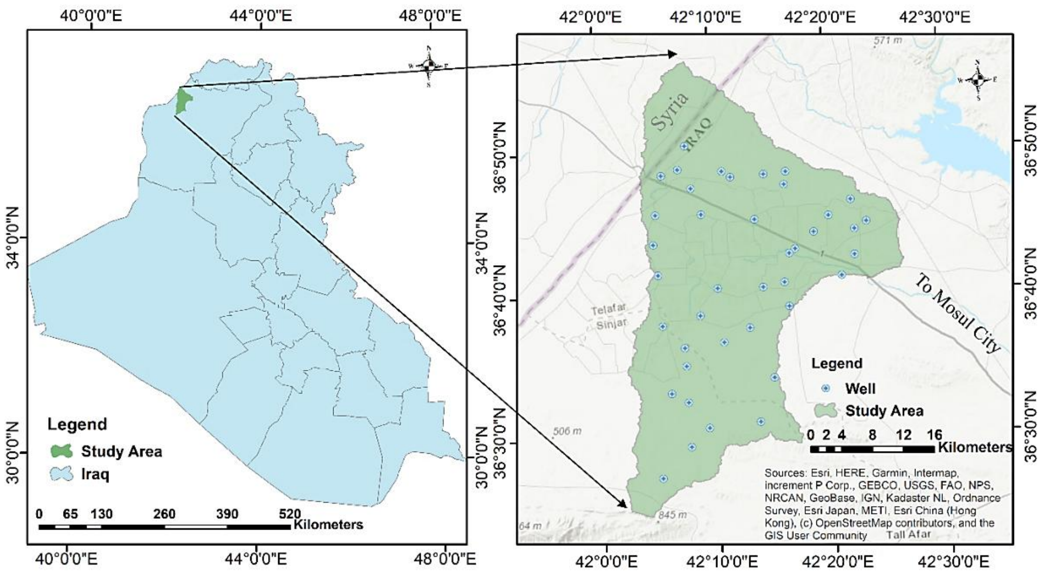

Fig. 1: Map showing the location of study area.

Justifications for the study

The morphometric analysis is very much useful in dealing with where information accessibility is limited data and other resources, and high soil variety[3], the lack of hydro morphometric studies for the region in general and for the Valley Awina basin in particular necessitated the need to conduct this research, and the absence of permanent surface water that can be exploited in the region, except for the North Al-Jazeera agricultural irrigation project (Figure 2), which is non-permanent (depends on the water level in the Mosul Dam Lake).

The region is also suffering from the decline in the amount of water due to drought, climate change and the fluctuation of the rainfall, in addition to the need to improve water management with the increase in demand for water, as this valley is the seasonal flow of runoff and is the only drainage area for the water of the land extracted from the North Al-Jazeera agricultural irrigation project.

Objectives of study:

The current study aims to assess the hydro morphometric characteristics of the Valley Awina basin and assess its reflection on the geological situation, which is the main step and factor in analyzing the results of the hydro morphometric values of the basin, to be a database to be referred to in the case of future projects or studies, the

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importance of studying hydro morphometric basins lies in analyzing and evaluating their morphological and hydrological characteristics, which helps in understanding the dynamics of surface runoff and erosion and managing water resources more efficiently, the most prominent benefits of this study are:

1. Assessment of Valley Awina Basin Runoff and Drainage: it helps in determining the amount of water that can flow through the basin and discharge, which is useful in water resources management.
2. Analysis of erosion and geomorphological changes: contributes to the study of the impact of water erosion on the basin terrain and the identification of areas most prone to erosion.
3. Water resources management: helps in planning dam and reservoir projects and improving the utilization of surface and groundwater by providing a database that can be referred to and used in such studies.
4. Environmental planning and land use: where it provides information about the suitability of the basin for agricultural and urban activities, taking into account the risk of flooding.
5. Natural disaster prediction: helps identify environmental hazards such as seasonal flooding and landslides, supporting appropriate precautionary measures.
6. Designing drainage networks and hydrological engineering: as they contribute to improving the planning and implementation of water-related infrastructure projects, such as canals, dams and reservoirs.

Thus, studying hydro morphometric basins provides basic data that helps in understanding and evaluating the basin's ability to collect, store and deliver water effectively, these values help in analyzing and designing sustainable management of water resources and assessing associated risks such as floods or droughts, sustainable management of natural resources, and environmental and engineering planning.

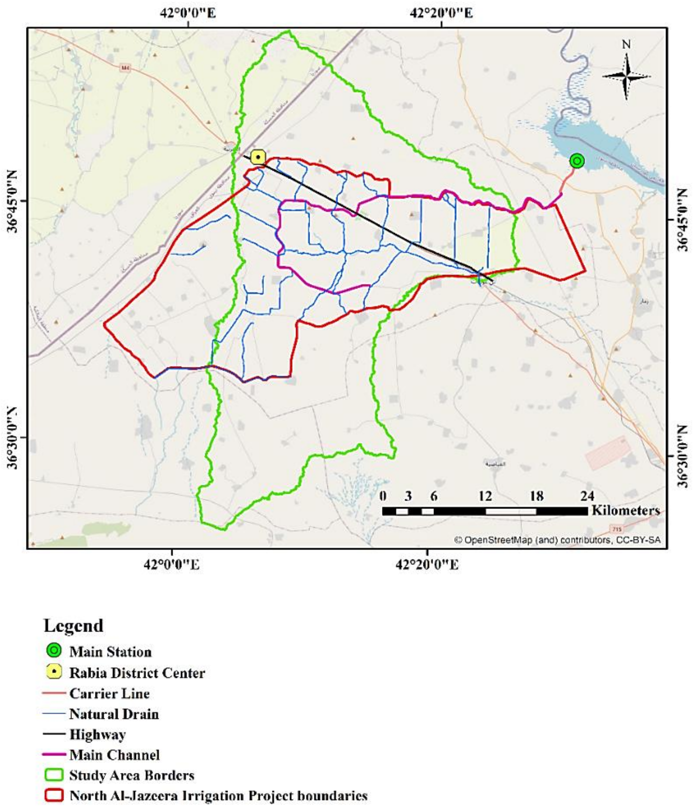

Fig. 2: Study Area and North Al-Jazeera Irrigation Project.

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Geological and Structural Study Area:

Tectonically, the study area is located on the western side of the Foothill-Zone within the unstable shelf of the Arabian Plate, within a subterranean concavity area (Geosyncline) covered with sediments extending between the Cretaceous and Holocene periods(4).

The Valley Awina basin is surrounded to the north by the Mashoradagh Anticline and to the south by the Sinjar " asymmetrical doubly plunging fold " (5) and Ashkaft Anticline, on the east and west sides it is bordered by the water dividing line, the valleys and wide plains form the main water basins in the region, and they are filled with sediments ranging in age between the (late Miocene) and the (Quaternary), and they are less complex than the folds in the areas of the high folds, the ages of the exposed formations in the study area range between (Eocene) and (Pliocene), in addition to the various types of quaternary sediments.

Geomorphology of the study area

The elevations of the study area cover between (350 meters) above sea level (the lowest point) and (832 meters) above sea level (the highest point) (Figure 3), through various pictures and maps, in addition to field trips in the study area, it was noted that the area mostly has landforms consisting of flat plateaus and flat plains interspersed with some valleys that result from the north and south towards the center of the study area, in addition to the mountainous heights in the south and north of the region, on the basis of which the basin boundaries were determined through watershed lines, the landforms are the result of important factors for it (the environment, climate, hydrology, and vitality), as its effects are intertwined between the forces of resistance and the forces of movement in shaping the land features, and due to the energy it carries, it changes the surface of the Earth through external processes (weathering and erosion forces), especially with the physical and chemical variables that play a fundamental role in topographical development, For example, weathering prepares rock fragments for various types of movement: air, water, and the climate element also has an active role in the active of geomorphological processes, the annual rainfall rate in the study area was (29.6) mm, the annual temperature rate was (19.2°C) and the annual relative humidity rate was (55.6%).

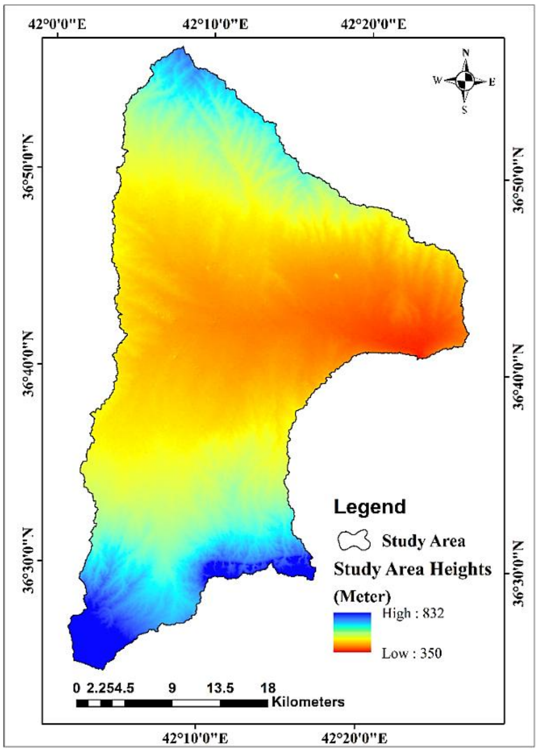

Fig. 3: A topographic map showing the heights of the study area.

CHARACTERISTICS OF THE DRAINAGE SYSTEM

The water basin was derived using the program (Arc Map 10.8) (Figure 4) to find the hydro morphometric coefficients in addition to the elevations of the region (highest and lowest point) through the digital elevation model (DEM) with a resolution of 12.5x12.5 meters, and through the results, it was found that the basin is of the sixth degree of the water ranks (Table 1), and the lengths and numbers of each rank were extracted and the length and width of the basin were calculated, these numerical, longitudinal and cadastral data were adopted in the calculations of the hydro morphometric characteristics of the Valley Awina basin.

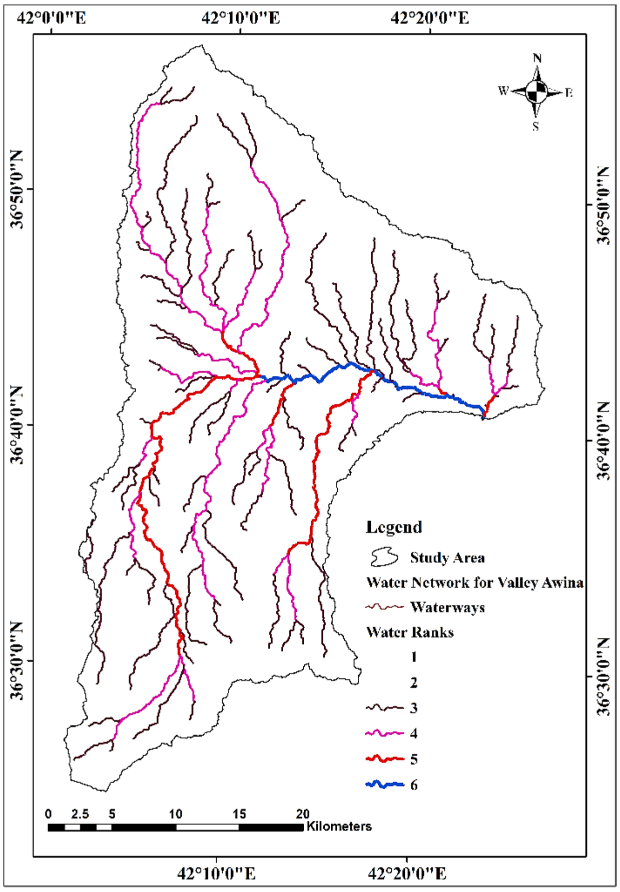

Fig. 4: The water network of the Valley Awina basin and the arrangement of waterways was derived from the (DEM) by Arc Map 10.8.

Bifurcation Ratio:

In basins that tend to rotate in their forms, the rate of bifurcation increases as a result of the speed of running water and the increase in drainage density over a period of time, which causes an increase in its danger, in basins that tend to elongate in their forms, the rate of bifurcation decreases as a result of the lack of speed of running water and the decrease in drainage density[6].

The bifurcation ratio was calculated because of its importance in controlling the surface drainage rate of the basin, and it was calculated by the ratio between the number of sewers in the rank to the number of sewers above it as in equation (1).

$$\text{(1) Bifurcation ratio} = \frac{\text{Number of waterways in the rank}}{\text{Number of waterways above it}}$$

The value of the bifurcation ratio for each rank according to the previous equation was between (1.53-2.66) at an average equal to (2.17) for all ranks, more than the bifurcation ratios in second and third ranks, and less than the bifurcation ratios in fourth and fifth ranks, and equal to the bifurcation ratio in first rank (Table 1).

Through the value of the bifurcation ratio, we conclude that the basin has a medium-density drainage network, which reflects a balance between surface runoff and infiltration to the soil, and that the drainage system does not face significant imbalances, especially since most of the geological deposits of the region are quaternary sediments represented by (sediments filling the valleys, sediments of valleys terraces, and sediments of slopes in addition to the remaining soil).

Table. 1: The numbers and lengths of the water ranks and the percentage of bifurcation of the Valley Awina basin.

No	Water mattresses	The number of valleys in each rank	rank Lengths water (km)	Bifurcation Ratio	Bifurcation ratio average
1	Rank I	1865	1100,01	2.17	2.17
2	Rank 2	858	564,05	1,53	
3	Rank 3	560	357,05	1,92	
4	Rank 4	291	160,44	2,66	
5	Rank 5	109	69,47	2,59	
6	Rank 6	1	22,5	--	

Sinuosity Index:

It represents the ratio of the true length of the main valley to its ideal length (the shortest distance between the upstream and downstream), as this coefficient reflects the problems caused by river turns increasing the coefficient of turn means increasing twists and thus increasing evaporation and filtration in the riverbed and the complexity of the geomorphological side on both sides of the bend[7].

- ✓ If the Sinuosity Index value = 1 indicates that the riverbed is perfectly straight.
- ✓ If the value is > 1 and less than 1.5, it indicates a low- sinuosity or semi-straight path.
- ✓ If the value is ≥ 1.5, it indicates a zigzag or entangled riverbed.
- ✓ If it is greater than 1.5, it means that the river is very twisted, that is, the environment is low-energy (the ground is flat).

$$\text{Sinuosity Index} = \frac{\text{true length of the main valley}}{\text{ideal length of the main valley}} = \frac{57.54}{36.76} = 1.56$$

The value indicates that the river course is zigzag (entangled), and the explanation for the result of the sinuosity Index value is that the low slope of the area allows the river to expand laterally, forming lateral zigzags.

Drainage Density:

Drainage density is defined as the ratio of the total length of the watercourses in the basin to the area of the basin. This ratio is an indicator of the extent of the development of the drainage network in the basin, as it reflects the impact of geological and climatic factors on the formation of the network.

Drainage density is an important factor in the study of water basins, as it affects the speed of water discharge and the ability of the basin to handle rainwater.

The density values of the lengths of the waterways indicate the relationship between river erosion on the one hand and the resistance of surface rocks on the other hand, and they also reflect the extent to which the basin responds to the rainfall intensity it receives[8], the drainage density is an indicator of the extent of the roughness and slope of the surface, as the drainage density increases in the lower basin due to the intensity of the surface slope and the spread of the waterways .

Mathematically calculated by the equation including(2). The result of the equation is shown in Table (2):

$$(2)\quad {}_{d}D = \frac{tL}{A}$$

- ${}_{d}D$ = Drainage density (km/km²).

- $_tL$ = The total length of all waterways in the basin (km).
- A = total area of the water basin (km²).

Drainage density = $\frac{\text{The total length of all waterways in the basin}}{\text{total area of the water basin}}$

Drainage density = $\frac{2273{,}53}{1095{,}11}$ = 2,08 (km/km²)

The value of the drainage density indicates a medium to moderate density, which means that there is a relative balance between the number of water channels and the size of the basin, it usually indicates that the rocks or soil in the basin is average permeability, that is, the soil allows moderate water infiltration with some runoff. The moderate drainage network indicates that the basin has natural water management that can be suitable for agriculture or the development of water resources without major problems such as drought or excessive flooding, that is, the water basin is relatively environmentally and hydrologically balanced.

The increase in the value of $_dD$ means an increase in the complexity of the drainage network, which indicates rough terrain and severe slopes, while low values indicate areas with less drainage and vegetation density or high permeability porous rocks.

Stream Frequency:

It is a measure used to determine the number of waterways (valleys or rivers) within the unit of area in the water basin, stream frequency is expressed by the equation (3) including The result of the equation is shown in Table (2):

(3) $F = \frac{N}{A}$

F = Stream frequency (number of waterways per unit area).

N = Number of waterways (Valleys or rivers) within the basin.

A = Area of the water basin (km²).

Stream frequency = $\frac{\text{Number of waterways within the basin}}{\text{Area of the basin}}$

Stream frequency = $\frac{3725}{1095{,}11}$ = 3.4 Valley /km²

This value indicates the presence of a drainage network of medium to high density, which reflects the ability of the system to discharge water effectively, as well as the presence of relatively low permeability soil or rocks, which leads to the formation of a larger number of waterways, that is, it indicates a sloping or moderate sloping terrain.

Relative Drainage Density

It is the ratio between the drainage density to the square of the longitudinal density or (stream frequency), which is one of the geomorphological measures that are used to assess the extent of spread and development of waterways within the water basin, as it reflects the relationship between the total length of waterways and their number within a certain area, this density is used to understand the degree of water erosion and the response of the water basin to rainfall.

The relative drainage density of the valleys can be calculated using the following equation:(4)

$$_dR = \frac{_dD}{F}$$

- $_dR$ =The relative drainage density (number of waterways /km).
- $_dD$ = Drainage density (km/km²).
- F = stream frequency (number of waterways per km²).

relative drainage density = $\frac{\text{Drainage density}}{\text{stream frequency}} = \frac{3.4}{4.3}$ = 0.8 valley / km

This value indicates that the topography of the basin is not very high or steep, but rather tends to be moderately rugged, which means that the basin may contain semi-level areas with some medium hills or heights, and terrain of this type is often suitable for a variety of activities, such as agriculture or the establishment of facilities and infrastructure, water discharge is balanced, which reduces the likelihood of sudden floods, erosion rates are not very high, and therefore, the soil and geomorphology are relatively stable.

✓ High values indicate the presence of long waterways compared to their number, which means that the basin is characterized by geological or climatic conditions that contribute to the formation of relatively long valleys.

✓ Low values indicate that watercourses are short but numerous, reflecting the impact of high slopes or incoherent soils that help form dense but short waterways.

Therefore, the relative drainage density of the valleys is important in:

✓ Basin rainfall response analysis**:** higher values indicate faster water drainage and more pronounced hydrological effects.

✓ Water planning and flood management**:** This density helps to estimate the vulnerability of the basins to flooding based on the Valley distribution pattern.

✓ Understanding geomorphological processes: Used in the study of the effect of erosion and the process of river sculpture in the formation of terrain.

Drainage Intensity:

Drainage intensity is a measure used in the analysis of water basins to determine the efficiency of hydrological drainage within the basin, it reflects the speed of transmission of discharge waves from parts of the basin towards the main channel to deliver them to the discharge peak, and is expressed by the relationship between stream frequency (F) and drainage density(${}_dD$), this concept was developed by, where it refers to the relationship between the number of watercourses and their length in relation to the area of the basin, Therefore, the intensity of the drainage is important in the analysis of flood risks, as it is inversely proportional to the intensity of the drainage. It is also important in the evaluation of hydrological erosion, as it refers to the period of water impact on the formation of the terrain. Finally, it is also useful in the management of water resources, as it contributes to the proper planning of land and the design of irrigation projects and dams. It can be calculated mathematically by equation :(5).

$$ {}_dI = \frac{F}{{}_dD} $$

- ${}_dI$ = Drainage intensity (number of waterways per unit length of waterway).
- F =Stream Frequency (number of waterways per km²).
- ${}_dD$ = Drainage Density (km/km²).

$$ \text{Drainage intensity} = \frac{\text{Stream Frequency}}{\text{Drainage Density}} = \frac{2.08}{3.4} = 0.61 $$

This value reflects that surface water is not very dense in drainage, which means that moderate amounts of runoff occur compared to the area of the basin, this value also indicates that the flow of water in streams and tributaries is moderate, which contributes to reducing the likelihood of sudden flooding or excessive erosion, this value is usually associated with water basins that have relative stability in terrain and water distribution.

The value of Drainage Intensity is affected by several factors, including the result of the equation is shown in Table (2):

✓ Geology and rock type**:** erodible rocks lead to increased Drainage Intensity, while hard rocks reduce it.

✓ Terrain and slopes**:** Areas with high slopes usually have greater drainage intensity.

✓ Rainfall**:** Areas with heavy rainfall have more developed drainage networks which increase the intensity of drainage.

✓ Vegetation and soil: Dense vegetation and soft soil absorb water, reducing surface drainage and reducing drainage intensity.

- High Drainage Intensity values: indicate that the basin contains a large number of waterways compared to its total length, indicating a terrain strongly affected by erosion and weathering.

Low Drainage Intensity values mean that the basin has few waterways compared to its length, which may be due to the rock's high resistance to erosion or low rainfall.

Table. 2: Characteristics of the drainage network of Valley Awina Basin.

Stream Frequency (Valley/km2)	Drainage Density (km/km 2)	Relative Drainage Density (Valley/ km)	Sinuosity Coefficient	Drainage Intensity	Bifurcation Ratio average
3.4	2.08	0.8	1.56	0.61	2.17

AREAL CHARACTERISTICS

The Areas dimensions of the basin and the relative relations between them relate to several factors, including the climate, the nature of rocks, and tectonic movements, the increase in water sculpture operations and the weak resistance of rocks lead to a decrease in the base level or the occurrence of river capture, the size of the basin also plays a fundamental role in controlling the volume of water flow, which contributes to the analysis and evaluation of hydrology by determining the appropriate quantitative relations, as well as by knowing the area of the basin, it will reflect the extent of the possibility of establishing a dam on that basin or determining the size of the reservoir of the dam and its optimal determination, as these characteristics were calculated (the real length of the basin, the ideal length of the basin, the width of the basin, the perimeter of the basin, the area of the basin, etc.) through (Arc Map 10.8) program and as shown in (Table 3).

Basin Length

It is defined as the distance between the farthest point in the basin (upstream) and even the lowest point in the basin (downstream) (Table 3), and it directly affects the concentration time "the time it takes for water to reach the main stream after rainfall", long basins lead to a gradual flow of water and reduce the risk of flash floods, while short basins respond quickly to rain, increasing the likelihood of rapid flooding, also, the relationship between the length and shape of the basin affects the efficiency of drainage, as long and slender basins are less efficient in drainage compared to circular, length is measured using Geographic Information Systems (GIS) techniques to obtain accurate estimates and analyze its impact on water flows.

Area, Perimeter, and Width, of Valley Awina

The area of the Valley Awina basin was measured by analyzing the water network from space data using the Arc GIS program, the total area of the basin was (1095.11 km^2), while the perimeter of the basin was (202.33 km). As for the length of the basin, there were two values: the real length, which was (57.54 km), while the ideal length was (36.76 km), which represents the closest distance between the upstream of the basin and its downstream, as for the width of the basin, 3 values were taken north, center, and south of the basin due to the difference in width dimensions, the average width of the basin, which was (21.96 km).

Table 3: Areal Characteristics of Valley Awina Basin.

Basin True Length (km)	Basin Ideal Length (km)	Basin width average (km)	Basin perimeter (km)	Basin Area (Km2)
57.54	36.76	21,96	202.33	1095.11

MORPHOLOGICAL CHARACTERISTICS:

The water basin is the geographical area through which water is collected and drained to a specific point, the morphological characteristics of the water basin are one of the basic and important factors in the study of hydrology, as they directly affect surface runoff, erosion, and water balance, and give a picture of the amount of water processing for the basin and its main valleys. These characteristics can be classified into several main aspects:

Circularity Ratio:

The Circularity Ratio expresses how close the water basin is to the circular shape, values close to

1 indicate circular basins, which means a faster response to water runoff and an increased likelihood of flooding, as for the lower values, they indicate irregular or longitudinal basins, which leads to slower water flow and a longer time distribution of drainage (which increases the amount of water filtering inside the ground), in other words, the increase in groundwater recharge, the rotation coefficient depends on the geological and terrain factors that affect the formation of the basin.

Mathematically calculated by the equation:

Circularity Ratio = the area of the basin (km^2) /the area of a circle whose perimeter is equal to the perimeter of the basin itself(km^2)As in Equation (6) including The result of the equation is shown in Table (4).

(6) Circularity ratio = $\frac{1095.11}{3259.48}$ = 0.335

The low value indicates that the aquarium has an elongated shape rather than a circular shape, which means that the water flow takes longer to reach the outlet of the basin, the elongated basin usually has a slower rainfall response than the circular aquarium, which reduces the likelihood of flash floods.

Elongation Ratio:

It is an engineering measure to determine the shape of the water basin based on its longitudinal and transverse dimensions, which affects the characteristics of surface runoff and hydrological drainage, it is calculated using the following equation (7):

(7) Elongation Ratio = (1.28) √ Basin Area (km²) / Basin Length (km).

Its value is between 0 and 1, values close to 1 indicate that the basin is inclined to the circular shape, resulting in rapid runoff and flood response, the lower values indicate that the basin is elongated (or longitudinal in shape), which leads to more gradual runoff and a time delay in drainage.

The benefits of calculating the elongation ratio are:

✓ Helps assess flood risk, as circular basins are more susceptible to flash floods.

✓ Contributes to understanding rainwater distribution and designing water resources management projects.

✓ They are used in geomorphological studies to assess the impact of geological formations on the shape of basins.

The elongation rate of the Valley Awina basin was (0.176), and this indicates that the basin is close to elongation, as the nature of drainage in this basin is more balanced and less than the basins with a circular shape or close to the circular shape, due to the length of the waterways at the expense of their width and then their loss of large quantities of water through long runoff(7). including The result of the equation is shown in Table (4).

Coefficient of Perimeter Compactness:

This ratio is extracted by comparing the perimeter of the basin with the perimeter of a circle that has the same area as the water basin, it is an indicator of the basin shape's proximity or distance from the circular shape, the higher the perimeter cohesion ratio is above 1, the more elongated the shape of the drainage basin is and the further away from the circular shape, the cohesion ratio of the perimeter is calculated by the following equation (7):

(7) Cp = 1/ √**1** / (***Circularity Ratio***) ⇨ Cp = $\frac{1}{\sqrt{\frac{1}{0.335}}}$ = = $\frac{1}{1.72}$ = 0.58

This value is considered medium to low and indicates that the basin is elongated (non-circular) and has a less complex and more regular shape, which means that water may collect and move more efficiently within the basin, and that water drainage occurs relatively slowly compared to circular basins.

Form Factor

The Form factor coefficient shows the consistency of the general shape of the basin parts, through the relationship between the basin area and the square of the basin length, where low values that move away from the correct number 1 indicate that the basin is close to the triangular shape, while high values close to the correct number 1 indicate that the shape is far from the triangle, and it is calculated by the following equation (8). including The result of the equation is shown in Table (4):

(8) Form factor $= \frac{Basin\ Area}{Square\ basin\ length} = \frac{1095.11}{3311.42} =$ 0.33

Since the result is far from the correct number 1, then this value indicates that the shape of the basin is approaching the shape of the triangle.

Table 4: Morphological Characteristics of Valley Awina Basin

Circularity Ratio	Coefficient of Perimeter Compactness	Elongation ratio	Form factor
0.33	0.58	0.17	0.33

RELIEF CHARACTERISTICS:

Relief characteristics are a crucial element in hydro morphometric analyses because they help in understand the relationship between the terrain shape and the water path within the basin, they also contribute to determining the stages of water and wind erosion and weathering processes and their role in shaping the Earth's surface, which are represented by the following:

Basin Relief:

It is the change in elevation within a waterway's basin, specifically the difference between the highest and lowest elevation[9], it is calculated mathematically using the following equation (9):

(9) Rb = H (m) - h (m)

Rb = Basin Relief, H = highest elevation, h = lowest elevation.

Rb = 832 (m) - 350 (m) = 482 m.

The highest point in the basin is 832 meters above sea level, while the lowest elevation is 350 m, which makes the basin relief equal to 482 m.

The percentage of basin relief in small basins greatly affects the increase in the speed of water waves, which leads to increased sediment transport.

Relief ratio:

It is the result of the difference between the highest and the lowest point in the basin divided by the true length of the basin, and expressed mathematically by the following equation(10):

(10) $Rr = \frac{Rb\ (m)}{Lb(km)}$

Rr = Relief ratio, Rb = Basin relief, Lp = Basin length.

Relief ratio $= \frac{832-350}{57.54} = \frac{482}{57.54} =$ 8.37 m\km

This value is considered an average value and expresses a state of equilibrium between water erosion processes and sediment transport processes and refers that the basin is still geomorphologically active.

Hypsometric Coefficient:

A topographic measure used in terrain analysis, which expresses the relationship between relative elevation "it is the ratio between the height of any contour line and the maximum height of the basin" and the relative area "the ratio of the area enclosed within any contour line and the perimeter of the basin to the total area of the basin itself ", (Table 5), it is a useful tool for studying the development of stream basins and determining the stages of geomorphological development of the terrain, the parts with a high slope indicate areas that are still in the youthful stage, as for the parts with a low slope, it indicates an advanced stage or the stage of aging. As shown in Figure (5).

We can express them in another way:

Relative elevation = the difference between the highest point and the lowest point on a given surface in a given geographical area.

Relative area = refers to the proportion of the area of a particular geographical area compared to a total or other standard area, this idea is used to determine the percentage formed by that area from a larger area, the area of a water basin compared to the total area in which it is located (Table 5).

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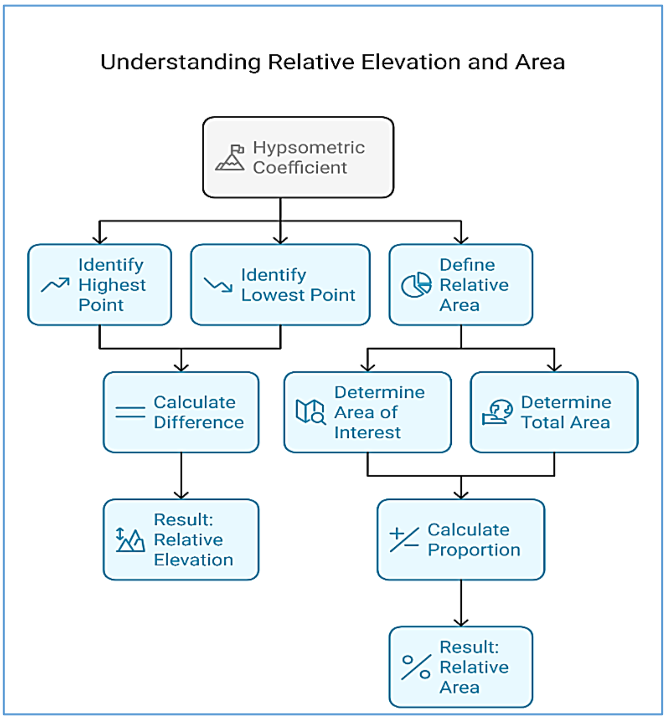

Fig. 5: A diagram showing the steps for calculating the hypsometric coefficient.

The relative elevation and area were calculated by (Arc Map 10.8), where the study area was divided into 10 values and the relative elevation and area were calculated for each value, where the results were as follows:

Table. 5: Relative elevation and area of the Valley Awina basin

Value	Lower elevation	Highest elevation	Relative elevation	Relative Area
1	350	398	0.101	1.000
2	399	446	0.200	0.644
3	447	494	0.300	0.248
4	495	542	0.399	0.076
5	543	591	0.501	0.022
6	592	639	0.600	0.006
7	640	687	0.699	0.003
8	688	735	0.799	0.002
9	736	783	0.89	0.001
10	784	832	1	0.000
Average			**0.550**	**0.200**

The hypsometric coefficient can be calculated by the following mathematical equation(11) :

(11) Hypsometric Coefficient $= \frac{\text{relative elevation}}{\text{relative area}} = \frac{0.55}{0.2} = 2.74$

An average of the values of relative elevation and relative area was taken and the equation of the hypsometric coefficient was applied, the value was equal to (2.74), as in Table 6:

Table. 6: Calculate hypsometric coefficient of the Valley Awina basin.

Meaning	Relative elevation (Average)	Relative Area (Average)	Hypsometric coefficient
Value	0.55	0.2	2.74

The value of the hypsometric coefficient indicates that erosion processes have not yet significantly affected, as shown in (Figure 6).

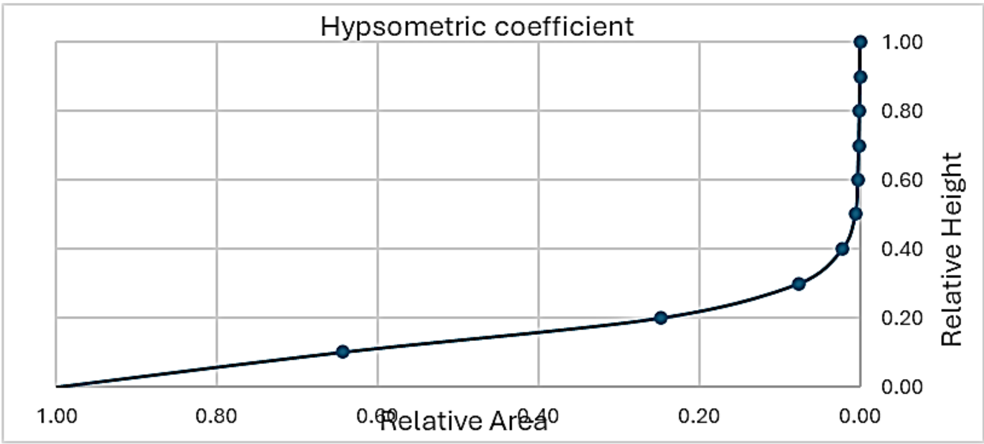

Fig. 6: A diagram showing the relationship between relative elevation and relative area.

Hypsometric Integration:

Hypsometric integration is one of the properties used to determine the time period that a drainage basin has covered within its erosion cycle, it indicates the age of the stream basin and represents the level of the erosion cycle in the stream basin, it is calculated from the relative relationship between the average and minimum elevations on the one hand, and the extent of the terrain on the other hand. As shown in Figure (7) and using Strahler method.

To calculate the value of hypsometric integration, we apply the following equation(12) including The result of the equation is shown in Table (7) [10]:

(12) $HI = Hmean\text{-}Hmin \,/\, Hmax\text{-}Hmin$

HI= Hypsometric integration, *Hmean* = Average elevation.

Hmin = minimum elevation in basin, *Hmax* = maximum elevation in basin.

Hypsometric Integration $= \frac{591-350}{832-350} = \frac{241}{482} = 0.5$

Based on the Strahler division [11] of erosion cycles:

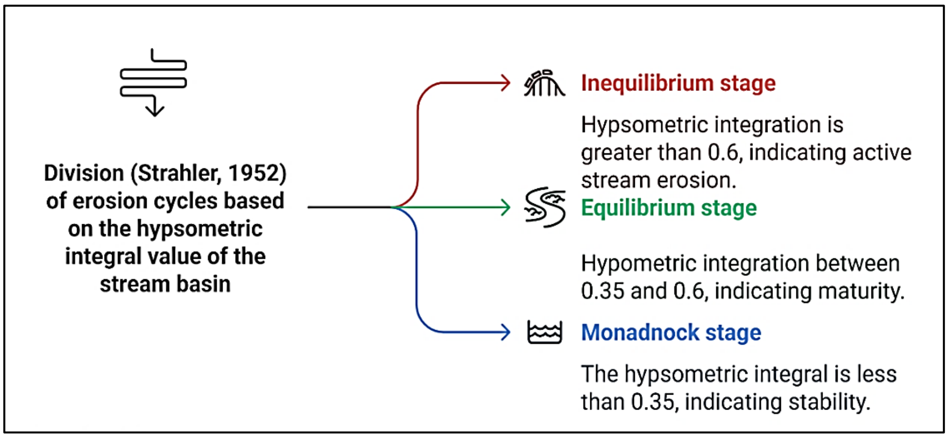

Fig. 7: Division (Strahler, 1952) of erosion cycles based on the hypsometric integral value of the stream basin.

The value of hypsometric integration is considered an average value, and we conclude from this value that the basin is in the period of maturity, where there is a balance between high terrain and eroded areas, and the hydrological system is in a state of development.

Basin Texture:

Basin texture is an important connotation in terms of basin analysis hydro morphometry, as it represents the amount of relative spacing between the drainage channels of stream networks[12], and we can know the extent of molting and cutting the surface of the ground, as the more crowded the drainage network lines, the greater the number of valleys and the closer to each other, we can calculate the amount of basin texture based on (10) by the equation below(13). including The result of the equation is shown in Table (7):

(13) Bt = ∑ (Ns)/P stream/(km)

Bt = Basin texture, Ns = number of streams, P = Basin perimeter

Bt = $\frac{3725}{202.33}$ = 18.4 stream/km

The basin texture was classified to four sections:

1. Very coarse: If the basin texture mean value is less than 2 valleys.
2. Coarse: If the basin texture mean is between 2-4 valleys.
3. Medium: If the basin texture mean is between 4-10 valleys.
4. Soft: If the basin texture mean is more than 10 valleys.

Based on the above classification, the basin texture is considered (soft), that is, the basin tends to retain water and has relatively little permeability, that is, the surface runoff of water is more than infiltration, which increases the chances of erosion.

Relative Relief:

The relative relief is an important indicator in measuring the severity of the ruggedness of drainage basins because it indirectly shows the degree of slope of the basin surface. The values are directly proportional to the degree of relief, and represent the ratio between the relief of the drainage basin and its perimeters[13], we can calculate the relative relief by the equation below(14) including The result of the equation is shown in Table (7):

(14) RR= Rb / P (m/km)

RR = relative relief, Rb = Basin Relief, P = Basin perimeter.

RR = 482/202.33 = 2.38 m/km

This ratio is considered small and expresses low values of rock resistance to the force of erosion factors, the increase in the basin's perimeter of the basin, and the abundance of its meandering compared to the basin's area, meaning that the basin is in the mature stage of the stream erosion cycle.

Table. 7: Relief Characteristics of Valley Awina Basin.

Relief ratio (m/km)	Hypsometric coefficient	Hypsometric Integration	Basin texture (stream/ (km)	Basin Relief (m)	Relative Relief (m/km)
8.37	2.74	0.5	18.4	482	2.83

CONCLUSIONS

The Valley Awina basin was studied for the purpose of benefiting from irrigation water that runs through this valley, even if it is seasonal, the large area of the basin increases the amount of running water, in addition to analyzing the hydro morphometric characteristics that we obtained from the hydro morphometric analysis, as it was compatible and as shown below:

Analysis and conclusions about the Valley Awina basin from the hydro morphometric point of view:

The shape of the basin and its stream drainage characterized by: The basin appears close to the triangle or trapezoid, indicating branched and winding stream drainage.and the extension of the basin (elongated) or relatively longitudinal, which may affect the speed of surface runoff and the distribution of water flows.

The stream network appears in a branch that refers to a tree drainage system (Dendritic Drainage Pattern) which is a common pattern in areas where rocks are relatively homogeneous. And the structure of the basin is represented by the presence of a main valley that extends in the center of the basin and is charge by several small tributaries, which enhances the effectiveness of drainage.

Topographical Characteristics characterized by the northern areas of the basin are less relief, while the southern and southwestern areas have more steep relief. and the presence of rugged relief in the south may affect the speed of surface runoff and increase erosion rates.

The results of the hydromorphometric characteristic equations indicated the following: Elongation Ratio indicates that the basin is close to elongation, which affects the period of rainwater reaching the main stream.The bifurcation rate of the valleys and branches is medium, that is, the basin has a relatively regular drainage network, and there is a balance between surface runoff and infiltration into the soil. The diversity in the geology of the area refers to the different types of soil and rocks, which affects the infiltration rates and runoff of the different basin areas. The basin has a medium-density drainage network, which reflects the system's ability to discharge water effectively, but it is prone to flooding in case of heavy rainfall.

1. **The geomorphological characteristics reflected:** The presence of diversity of geological formations, which may affect the water flow characteristics and hydrological behavior of the basin.Areas near the valley downstream appear to be more susceptible to sedimentation, which may indicate suitable groundwater catchment areas. and southern regions are more susceptible to erosion due to high slopes.

Recommendations

The Valley Awina basin has good potential to benefit from water, but it needs strategies to manage floods and erosion to preserve its natural resources and support sustainable development, which comes through these recommendations:

- Increase the number of studies to establish small dams or water reservoirs in areas with high drainage to collect water and benefit from it during periods of drought.
- Promote the use of surface water harvesting techniques.
- Design special sealed drainage channels in high slope areas to guide flood water and reduce its impact on residential and agricultural areas.
- Construction of water buffers and protective dams in the southern regions, where the risk of flooding is increased by rugged relief.
- Cultivation of natural vegetation in the southern regions to reduce soil erosion as a result of rapid runoff.
- Implement reforestation and land-use improvement programs in areas most vulnerable to erosion.
- Directing agricultural activity towards areas with fertile and stable soils, while avoiding agriculture in areas with high slopes.
- Encourage the use of modern irrigation methods such as drip irrigation to reduce water loss.
- Conduct additional hydrological and hydrogeological studies to determine the rate of runoff and determine the best locations for the establishment of water facilities.
- Install metering stations to periodically monitor water and rain flow to anticipate flooding and take necessary measures in advance.

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- Methodology: MOQ, NAK, SAS.
- Software & Analysis: MOQ.
- Investigation (Data Collection): MOQ, NAK, SAS.
- Writing - Original Draft: MOQ.
- Writing - Review & Editing: MOQ, NAK.
- Supervision: MOQ, NAK, SAS.

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