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MORPHOMETRIC ANALYSIS OF THE AL-TEEB RIVER BASIN, SE IRAQ, USING DIGITAL ELEVATION MODEL AND GIS

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Key words: Morphometry; Stream order; Drainage texture; Drainage density; River basin; Iraq

ABSTRACT

Morphometric parameters of the Al-Teeb River Basin (TRB), located in the southeastern part of Iraq, are studied to evaluate the hydrological condition, developing of watershed management and the environmental effect. These parameters are calculated using GIS software and standard mathematical formulae as well as satellite image of the Digital Elevation Model (DEM). According to morphometric analysis results (TRB) has a total area of 1990 km^2 and is designated as 5th order basin, with maximum length about 112 km and average width about 17.83 km. The basin is strongly elongated with an elongation ratio of 0.45 and circularity ratio 0.15. The relief ratio of (17.30) m ⁄ km reflects the potential activity of water erosion in the basin and the basin is under intense relief and steep slope. The low value of drainage density in the Al-Teeb Basin of (0.47) km/km^2 can be attributed to highly resistant rocks, high topography, high to moderate lineaments, and high infiltration capacity which lead to coarse drainage texture. The hypsometric curve and hypsometric integral of (TRB) reveal that the basin is fully stabilized and approached the old stage.

تحليل الخصائص المورفومترية لحوض نهر الطيب، جنوب شرق العراق، بإستخدام النموذج الرقمي للتضرس و نظم المعلومات الجغرافية

سوسن عبد الرحمن إبراهيم

المستخلص

يتناول هذا البحث دراسة المعاملات المورفومترية لحوض نهر الطيب الذي يقع في الجزء الشرقي من العراق لتقييم الوضع الهايدرولوجي، تطورحوض التصريف والتاثيرات البيئية على الحوض. تم حساب هذه المعاملات باستخدام تقنيات نظم المعلومات الجغرافية، المعادلات الرياضية القياسية وبيانات الارتفاعات الرقمية (DEM). أظهرت النتائج بان حوض نهر الطيب يصنف ضمن الرتبة النهرية الخامسة وبمساحة حوض حوالي 1990 كم^2 وبمعدل طول قيمته 112 كم وبمعدل عرض 17.83 كم. يمتاز شكل الحوض بانه شديد الاستطالة وبمعدل استطالة يبلغ 0.45 ومعدل استدارة 0.15 و قيمة نسبة التضرس 17.3 م/كم والتي تعكس فعالية تعرية المياه العالية اضافة الى ان الحوض يمتاز بانحدار شديد. اما القيمة الواطئة لكثافة التصريف والتي تبلغ 0.47 كم/كم^2 فيمكن ان تعزى لعدة اسباب منها المقاومة العالية للصخور، الطوبغرافية العالية، كثرة الخطيات اضافة الى قابلية الترشيح العالية التي تؤدي الى نسيج تصريف خشن. تم دراسة التحليل الهبسومتري لحوض نهر الطيب الذي تضمن كلا من المنحنى والتكامل الهبسومتري وأظهرت النتائج ان الحوض مستقر تقريبا وقد وصل الى مراحله الاخيرة.

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INTRODUCTION

The Al-Teeb River Basin (RTB) is located in eastern Iraq, (Northeastern of Missan Governorate), between latitudes 32° 00' to 33° 01', and longitudes 46° 57' to 47° 28' (Fig.1). It is covering an area about 1990 Km^2.

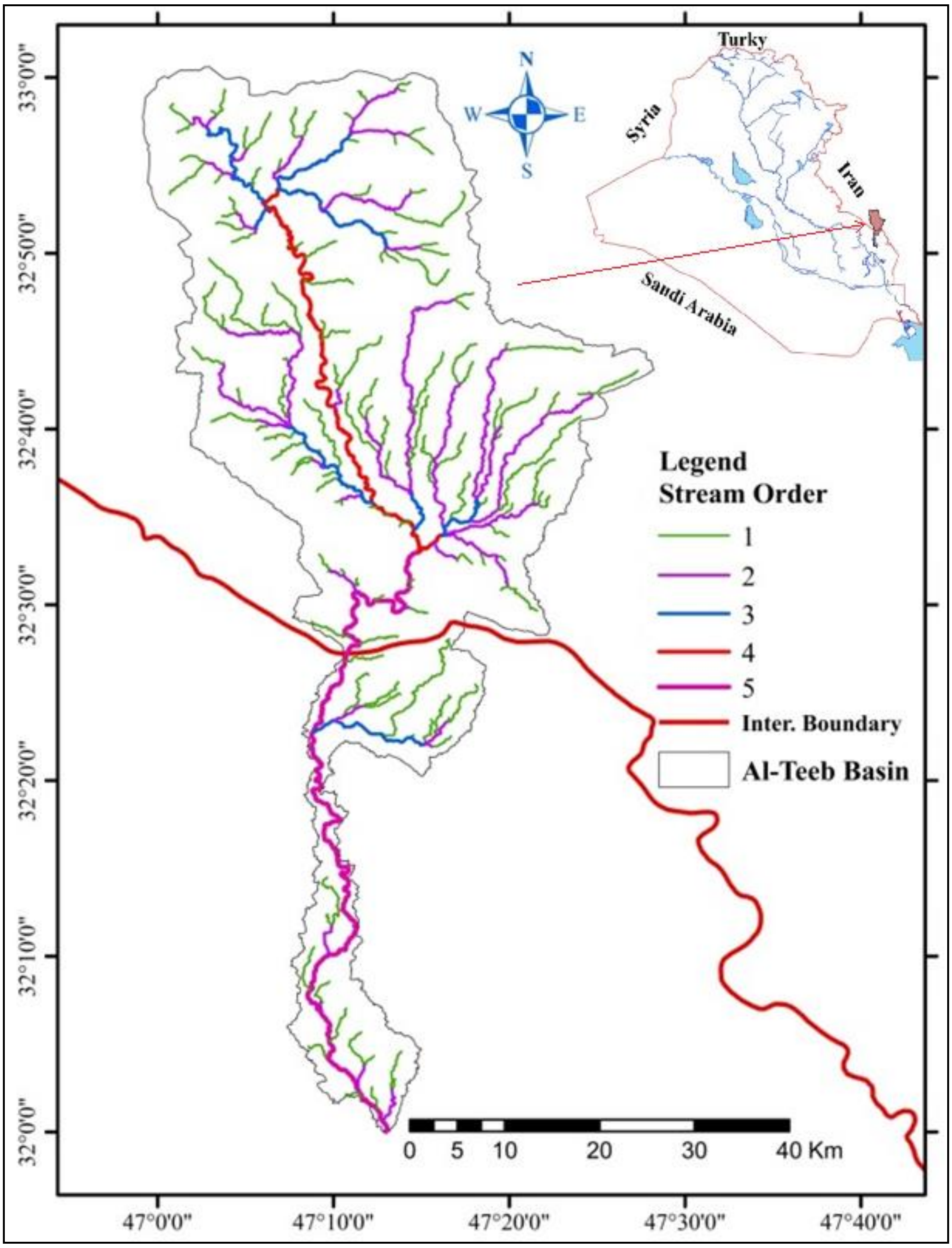

Fig.1: Location map and stream orders of the TRB within the Iraqi and Iranian territories

The Al-Teeb River is a seasonal river flows from the Iranian territories, enters Iraq at Al-Teeb station and outfalls in Al-Sanaf marsh east of Al-Amara City. The total length of Al-Teeb River in the Iraqi territory is about 63 Km. The elevation of Al-Teeb Basin ranges between 2 m in the downstream and 1934 m in the upstream above sea level. Morphometric parameters are characterized as quantitative description of the basin and basin specification, they include linearity, areal relief and gradient of the channel network and basin slope. Morphometric parameters are proved useful in identifying and planning groundwater potential zones and watershed management, of all natural water resources connected with the watershed.

The aims of this study are to: **(i)** define the drainage pattern of (TRB), **(ii)** identify the major morphometric parameters, which are affecting erosion intensity and their relationships to climate, relief and basin structures and **(iii)** determine the factors that may lead to failure of dams construction in the southeast of Iraq.

PREVIOUS STUDIES

There are many hydrogeological studies covering the downstream area of Al-Teeb River basin; all of which have been carried out in the Iraqi part of the basin. Hereinafter is a review of the most relevant of these studies:

Al-Kaabi (2009) found, through hydrochemical modeling of Al-Teeb area, that the ionic strength of groundwater samples increases with increasing the total dissolved solids, which ranges from a low value in the Mukdadiya and Bai-Hassan wells, at the hills of Himreen structure, to high value in the south and southwest of the study area. Atiaa *et al*. (2013) studied the applicability of two-parameter climate elasticity of stream flow index to assess the impact of global warming on regional hydrology of Teeb River watershed. The results indicate that the stream flow response to rainfall and temperature anomalies exhibits a non-linear relationship. Al-Kinani (2014) studied the hydrology of the surface water in TRB and referred to the effects of human activity, target storage and irrigation projects built in the upstream, on the amount of river recharge. Al-Ghanimi *et al*. (2015) carried out hydrogeological assessment of Al-Teeb Basin northeast of Misan Governorate and divided the aquifer in the study area to unconfined aquifer (Quaternary sediments), semi-confined aquifer (Bai Hassan Formation aquifer) and confined aquifer (Mukdadiya Formation aquifer). Al-Hasnawi (2016) studied the morphometric analysis of Al-Teeb fan in southeastern Iraq based on visual interpretation of the enhanced Landsat TM image, linked to digital interpretation by Arc GIS program. Al-Kubaisi and Al-Salih (2016) carried out assessment of water resources in Al-Teeb area and their suitability for different purposes.

GEOLOGICAL SETTING

Most of the Al-Teeb River Basin in the Iraqi territory is covered by Quaternary sediments of sands, silts and silty clays, whereas, the Tertiary rocks are restricted to the eastern and northeastern parts of the area. The Tertiary rocks are represented by undifferentiated Mukdadiya (Pliocene) and Bi Hassan (Pliocene – Pleistocene) formations. The Mukdadiyah Formation consists of monotonous sequences of interbedding of claystone and sandstone with some siltstone intercalation. The sandstone beds very often contain pebbles with different shapes and lithologies, therefore, they are considered as a typical fresh water mollas (Buday, 1980). The Bai Hassan Formation is composed of interbedding of conglomerate, claystones and sandstones (Barwary, 1993). In addition, several major normal and thrust faults are identified in the study area (Sissakian and Fouad, 2016) (Fig.2).

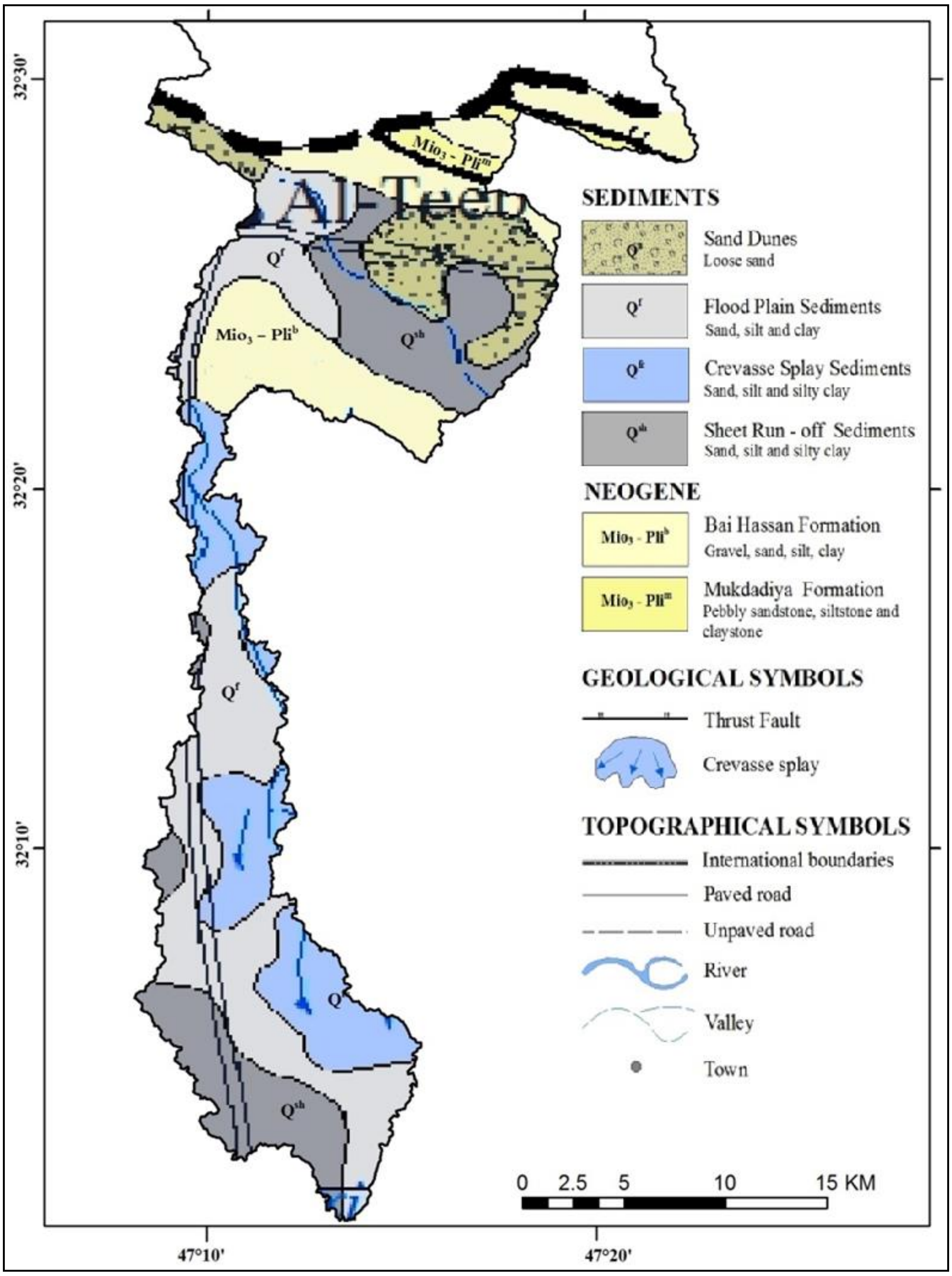

Fig.2: Geological map of TRB in the Iraqi territory
(after Sissakian and Fouad, 2016)

CLIMATE

The climate in the Al-Teeb region is characterized by hot dry summer and wet winter and the region can be classified under the conditions of arid regions according to Fookes *et al*. (1971). The characteristics of the climate are shown in Table 1, as recorded from data of Ali Al-Gharbi Meteorological Station during the period 1983 – 2012.

Table 1: Monthly mean values of climatic parameters recorded by Ali Al-Gharbi Meteorological Station during the period 1983 – 2012

Climatic parameters	Average mean	Total mean
Rainfall	---	126.27 mm
Temperature	25.19 °C	---
Wind speed	3.95 m/sec	---
Relative Humidity	45.74%	---
Evaporation	---	3433 mm

DATA USED AND METHODOLOGY

In the present study, morphometric characteristics, which include quantitative description of the basin and basins specification (such as linear, aerial, and relief parameters) are prepared using Digital Elevation Model (DEM) with spatial resolution data (30) m, Arc GIS software V. 10.4, and the standard mathematical formulae (Table 2).

Table 2: Methods used in the calculations of morphometric parameters of TRB

Morphometric parameters	Formula	Description	References
Basin width (B_w)	$B_w = A/L$	The ratio between the basin area (A) and the basin length (L).	Calculated by GIS tools.
Basin Elongation Ratio (R_e)	$(R_e) = 2(\sqrt{A/\pi})/L$	The ratio of the circle diameter of the basin area $2(\sqrt{A/\pi})$ to the basin length (L).	Schumm (1956)
Basin Circularity (R_c)	$R_c = 4\pi A/P^2$	The ratio between the basin area (A) to the area of circle (Ac) with the same Perimeter	Miller (1953)
Form Factor (Rf)	$Rf = A/L^2$	The ratio between the basin area (A) to the square of basin length (L^2).	Horton (1945)
Compactness Coefficient (Cc)	Cc = *p*/*pc*	The ratio between basin Perimeter (*p*) to the circle Perimeter (*pc*) with the same area as that of the basin.	Luchisheva (1950) (in Al-Saady *et al.*, 2016)
Relief Ratio (R_h)	$R_h = (H_{max} – H_{min})/B_L$	The maximum vertical distance (H_{max} – H_{min}) between the lowest and the highest points in the basin divided by basin length (B_L).	Schumm (1956)
Drainage Texture (Dt)	Dt = Nu/P	The ratio between the total numbers of streams of all orders (Nu) to the basin Perimeter (p).	Horton (1945)
Relative Relief (Rhp)	Rhp = R/P	The ratio between the basin relief (R) to the basin Perimeter (p).	Huggett and Cheesman (2002)
Ruggedness Number (Rn)	Rn = (R*Dd)/1000	Product the basin relief (R) by drainage density (Dd) divided by 1000.	Ozdemir and Bird (2009)
Mean Stream Length (LS')	LS' = Lu/Nu	Dividing the total stream length (Lu) by the number of segments (Nu) in the same order.	Strahler (1964)
Bifurcation Ratio (R_b)	$R_b = N_u/N_u + 1$	The ratio between the number of streams (Nu) of any given order to the number of streams in the next higher order (Nu+1).	Schumm (1956)
Basin Area (Ba)	A	The entire area drained by a stream or system of streams (A).	Calculated by GIS tools.
Drainage Density (D_d)	$D_d = \Sigma L/A$	The length of stream (L) channel per unit area of drainage basin (A).	Horton (1932)
Stream Frequency (F_s)	$F_s = \Sigma N_u/A$	The ratio between total number (Nu) of streams and area of the basin (A).	Horton (1932)
Hypsometric Curve	HC = (h/H)/(a/A)	Obtained by plotting the proportion of the total height (h/H) against the proportion of the total area (a/A).	Strahler (1952)
Hypsometric Integral	HI = (E mean _ E min/ E max _ E min)	The relative proportion of upland areas (E max) to lowland areas (E min) within a sample region.	Wood and Snell (1960)

RESULTS

The morphometric parameters of the study area are calculated using DEM and GIS tools and the results of these parameters are shown in (Table 3).

Table 3: Results of the morphometric parameters in Al-Teeb River Basin

Morphometric parameters	Value
Basin width (B_w)	17.83Km
Elongation Ratio (R_e)	0.45
Circularity (R_c)	0.15
Form Factor (Rf)	0.15
Compactness Coefficient (Cc)	2.51
Relief Ratio (R_h)	17.30 m/Km
Drainage Texture (Dt)	0.46
Relative Relief (Rhp)	4.86
Ruggedness Number (Rn)	0.91
Mean Stream Length (LS')	1^{rd} = 3.34 Km 2^{rd} = 7.2 Km 3^{rd} = 10.43 Km 4^{rd} = 29.43 Km 5^{rd} = 91.45 Km
Bifurcation Ratio (R_b)	1^{rd} = 4.11 2^{rd} = 4.25 3^{rd} = 4 4^{rd} = 2
Basin Area (Ba)	1990.8 Km^2
Drainage Density (D_d)	0.47
Stream Frequency (F_s)	0.09
Hypsometric Integral	0.21

DISCUSSION

- **Areal Morphometric Parameters**

– **Average Width (Bw):** The value of Bw in the TRB is (17.83 Km) and indicates increasing basin length relative to its width. The variance in the average width is due to the variance in th erosion rate, which is affected by rock types and slope. There is a proportional relationship between the average width and erosion in the basin (Al-Assadi, 2015).

- **Formal Morphometric Parameters**

– **Elongation Ratio (Re):** This ratio is considered an important index to classify the drainage basins into varying shapes: Circular (above 0.9), Oval (0.8 – 0.9), Less Elongated (0.7 – 0.8) and Elongated (< 0.7) (Pareta and Pareta, 2012). The (Re) value in the Al-Teeb Basin is (0.45) which reflects the elongated shape and indicates the young stage of evolution caused by intensive neotectonics activity (Al-Saady *et al*., 2016).

– **Circularity ratio (Rc):** There are many factors that affect the Rc of basins, including stream length, stream frequency, geological structures, land use, land cover, climate, relief and basin slope (Ali and Khan, 2013). The Rc value in the TRB is (0.15) and means that the basin is elongated and water division surrounding the basin is irregular and flexuous, thus, affecting the flow net length with low stream order near the water divide region (Al-Assadi, 2015).

– **Form Factor (Rf):** The value of this factor varies from zero (Highly elongated shape) to the unity 1 (Perfect circular shape). The form factor of the TRB is (0.159) and reflects the elongated form and low peak flow of the basin (Biswas, 2016).

– **Compactness Coefficient (Cc):** The basin shape is a perfect circle when (Cc) value is equal to **(1)**; square shaped when it increases to (1.128) and it could be very elongated shape when Cc value exceeds **(3)** (Zavoianu, 1985). The Cc value in the TRB is 2.51. According to the (Cc) parameter, the water will take long time to accumulate before the stage of peak flow (Al-Saady *et al*., 2016).

- **Morphometric Parameters**

– **Relief ratio (Rh):** The Rh is considered an important parameter to characterize basin relief because it explains the intensity of channel gradient and estimates erosion processes and stream sediment load. There is a positive relationship between relief ratio and gradient factor (Al-Amry, 2010). The Rh value in the TRB is (17.30) m/Km which reflects the potential activity of water erosion in the basin.

– **Drainage texture (Dt):** The Dt depends on many natural factors including: climate, vegetation, lithology, soil type, infiltration capacity, relief and stage of development (Ali and Khan, 2013). Drainage texture is classified into five different textures: very coarse (< 2), coarse (2 – 4), moderate (4 – 6), fine (6 – 8) and very fine (> 8) (Smith, 1950). The soft or weak rocks and absence of vegetation generate fine texture, while the resistant or massive rocks generate coarse texture. The Dt value in the TRB is 0. 46, which is classified under very coarse drainage texture. This indicates good permeability of subsurface materials and high infiltration capacity, low runoff rate and significant groundwater recharge (Hajam *et al*., 2013).

– **Relative Relief (Rhp):** There is inverse relation between Rhp with the degree of rock resistance and erosion factors in the same climatic conditions (Al-Assadi, 2015). The Rhp value in the TRB is relatively high (4.86) which suggest an increase in erosion rate.

– **Ruggedness number (Rn):** The Rn is classified according to its value into five classes; < 0.1: subdued morphology, 0.1 – 0.4: slight morphology, 0.4 – 0.7: moderate morphology, 0.7 – 1.0: sharp morphology and > 1.0: extreme morphology which includes badlands topography (Farhan *et al*., 2015). The Rn value in the TRB is high (0.91) and reflects an increase in peak discharge, mass movement, high sensitivity to soil erosion, long and steep slopes, and dynamic geomorphic processes.

– **Mean Stream Length (LS'):** The LS' value increases with increasing basin orders, because it is related to the drainage network size and its associated surface (Strahler, 1964). Generally, flat areas are characterized by high values of LS', while rigged or mountainous areas are characterized by low value of LS' (Al-Amry, 2010). The LS' values of the TRB are variable; ranging from 3.34 Km to 91.45 Km. which corresponds to changes in the basin slop and topography.

– **Bifurcation Ratio (Rb):** The Rb is an important parameter that ranges between 3 to 5 and reflects the bifurcation degree of the drainage network (Mesa, 2006).The low values of Rb in watershed characterize little structural disturbance, while the high values indicate mature topography and large variation in frequencies between progressive orders (Ali and Khan, 2013). Lower values of Rb also reflect geological heterogeneity, higher permeability and less structural control (Hajam *et al*., 2013). The variation in Rb values is almost related to asymmetry in the geology and climate of the TRB. The Rb value is low in the stream order 4 and it is high in the orders 3, 2 and 1 as shown. The relatively high bifurcation ratio indicates high topography, resistant rocks and low permeability (or low infiltration), and vice versa. The low Rb value refers also to the increase in flood peaks.

– **Basin area (Ba):** It represents one of the important geomorphic parameter to determine the drainage basin system, rainfall collection and run off concentration (Al-Saady *et al*., 2016). The TRB has a total area of (1990.8) Km^2.

– **Drainage density (Dd):** It is the degree of branched and spread drainage channels in a limited area and an indicator of geological and basin physiographic characteristics. The Dd is related to climate, tectonic activity, rock and soil type, basin shape, relief, filtration capacity and vegetative cover (Ali and Khan, 2013). Dd is classified into three types according to (Deju, 1971): poor (0.5), medium (0.5 – 1.5) and excellent (1.5). The Dd value in the TRB is 0.47. Low value of Dd can be attributed to highly resistant rocks, high topography, high to moderate lineaments, and high infiltration capacity which leads to coarse drainage texture (Nag, 1998).

– **Stream frequency (Fs):** It mainly depends on the rainfall amount, rocks nature, soil permeability and relief (Magesh *et al*., 2013). The Fs value in the TRB is (0.09) and refers to permeable subsurface material and low relief (Obi Reddy *et al*., 2004). Stream frequency is correlated positively with Dd and both of these parameters are used in measuring the space between stream channels in a drainage basin (Biswas, 2016). The morphometric analysis of TRB reveals that, the river catchments having the greater tendency to peak discharge in a short period of time because of elongated shape, high relief ratio (Rh), high ruggedness number, high bifurcation ratio and low value of mean stream length in the downstream.

- **Hypsometric Analysis**

These are important factors to describe the watershed conditions, which are related to the balance of erosion and tectonic activity. It includes two factors; Hypsometric curve and Hypsometric integral.

– **Hypsometric curve:** Hypsometric curve is essentially a graph shows the proportion of land area that exists at various elevations by plotting relative area (a/A) against relative height (h/H). Depending on the curve shape and forms are classified into three types; young stage, mature stage and old stage, which refer to the stages of basin dissection (Strahler, 1952). Convex-shaped curve associates with the young stage, while S-shaped curve corresponds with the mature stage and concave-shaped curve indicates on the old stage. With the progress of erosion, the shape of hypsometric curve changes from convex-up to essentially straight to concave-up (Schumm, 1956). Figure 3 shows the hypsometric curve of the studied area, which indicates that the basin is in the old stage of geomorphic evolution.

– **Hypsometric integral (HI):** The HI is a geomorphological parameter classified under the geologic stages of watershed development (Singh *et al*., 2008). The HI value provides information about the erosional stage of the basin, the tectonic, climatic, and lithological situation (Strahler, 1952). Strahler (1952), classified the HI into three group based on value: **1)** the old stage ($HI \leq 0.35$), in which the basin is fully stabilized; **2)** mature stage ($0.35 \leq HI \leq 0.60$), in which the basin development has attained steady state condition and

(3) the young stage (HI ≥ 0.60), where the basin is highly susceptible to erosion and is under development. The calculated HI value for Al-Teeb Basin is 0.21 which indicates old stage.

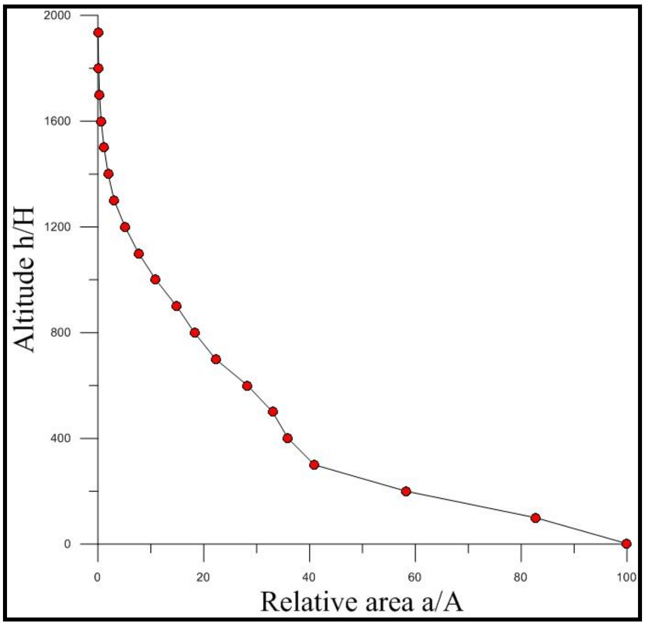

Fig.3: Hypsometric curve of the Al-Teeb River Basin indicating an old stage

CONCLUSIONS

The Al-Teeb River Basin is fully stabilized and deeply dissected basin. It is characterized by high permeable and high resistant rocks, high topography, high to moderate lineaments and high infiltration capacity leading to coarse drainage texture. It has an elongated shape, low drainage density with low peak flow for longer duration. The flat area of the basin is characterized by few and long streams, while the rigged or mountainous area is characterized by short and large number of streams. The easily eroded sediments are overloading the downstream basin with deposits after each heavy rainstorm. The morphometric characteristics of the Al-Teeb River Basin and the exceptional recurrent heavy rain storms, sharp morphology and poor land cover are factors causing greater runoff and increasing the influence of erosion in the river basin, which finally lead to flooding and dams failure. Therefore, most of the constructed dams in the east and southeast of Iraq failed by filling the reservoirs with loaded sediments.

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