HYDROGEOMORPHOLOGY OF BAWASHASWAR WATERSHED IN NORTH EAST OF IRAQ

Sarkawt Ghazi Salar
Assistant Instructor
University of Sulaimani, College of Education- Kalar District

ABSTRACT:

The objective of this study is to submit the hydrogeomorphological properties of Bawashswar watershed to human benefit in the region especially for Kifri District through supplying drinking water, water for irrigation, extenuation and moderation of climate and diminution flood flow hazards by construction of a small dam across of the stream course.

The studied watershed is a part of Diyalah river basin at north east of Iraq, it lies between (34°40¯ – 34°57¯ N) and (44°56¯ – 45°11¯ E) and locates about 100 km at southeast of Kirkuk city. It locates within the low folded zone physiographically and the geological formations which outcrop in the study area from the oldest to youngest are Fatha formation, Injana formation, Mukdadiya formation, Bai Hassan formation and recent deposits.

This study revealed the influence of tectonic situation, type of rocks and climate on the two main properties of the watershed; first geomorphmetric properties which are included the drainage area, circularity ratio, elongation ratio, watershed length, form factor, relief ratio, watershed relief, watershed mean slope, stream course mean slope, stream length, drainage density, stream order, stream number, stream frequency, bifurcation ratio and the watershed drainage pattern; second is hydrology properties which included rainfall and surface runoff relation.

INTRODUCTION

Surface hydrology deals with the movement of water along the earth's surface as a result of precipitation and snow melt. Detailed analysis of surface water flow is highly important to such fields as municipal and industrial water supply, flood control, stream water forecasting, reservoir design, navigation, irrigation, drainage, water quality control, water-based recreation, and fish and wildlife management.

The relation between precipitation and runoff is influenced by various storm and basin characteristic. The land area over which the rain falls is called catchments and the land area that contributes surface runoff to any point of interest are called a watershed (Viessman and Lewis, 1996). According to Goudie (2004) and Salameh (2004) the land surface is complex and its morphometry varies from area to area with rock type and structure, climatic variables and their history, tectonic history and vegetation cover.

The studied area, Bawashaswar Watershed, is located about 100 Km southeast of Kirkuk City between longitudes $44^{o}\ 57^{-}$ – $45^{o}\ 12^{-}$ East and latitudes $34^{o}\ 40^{-}$ – $34^{o}\ 57^{-}$ North (Fig. 1).

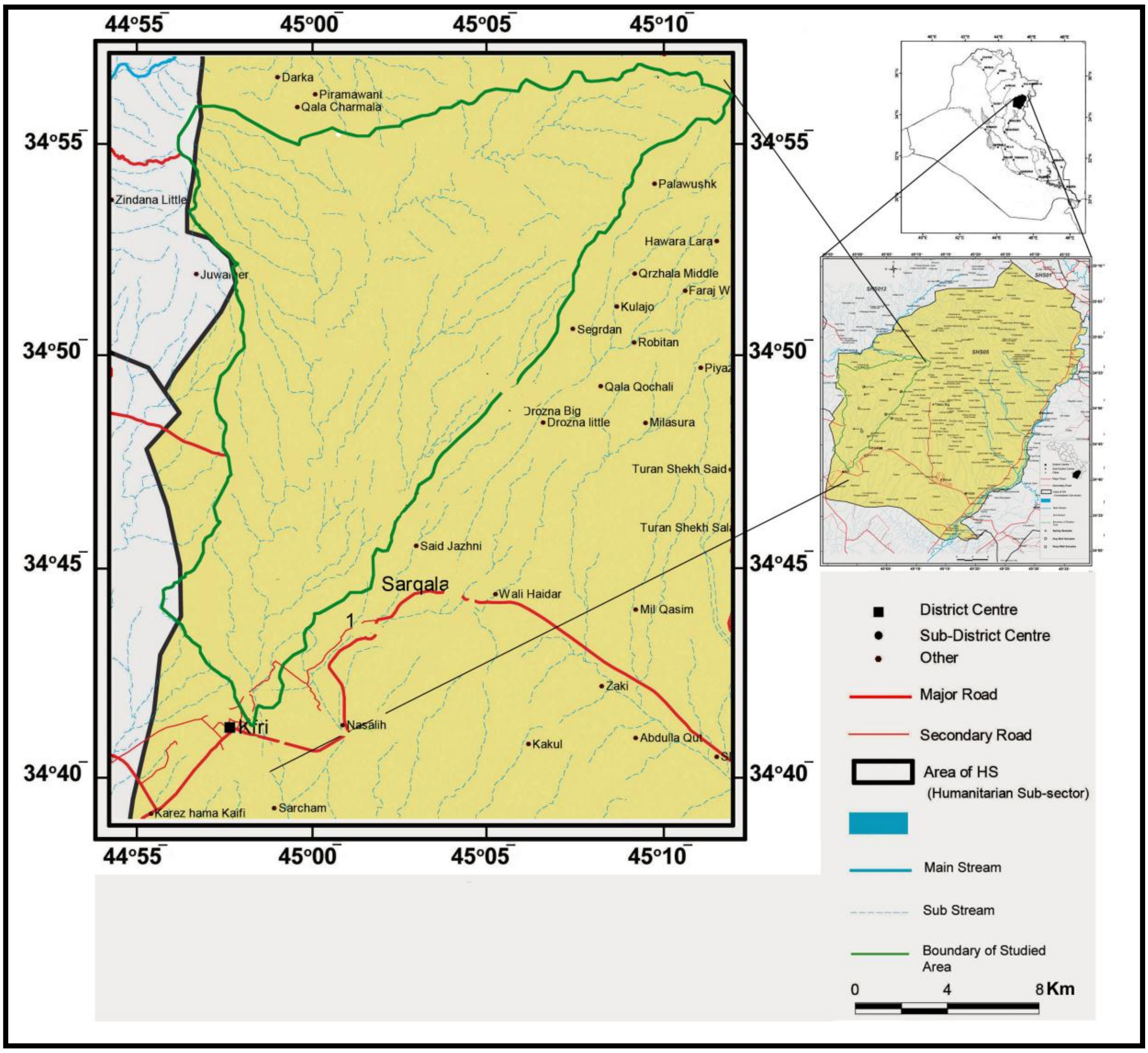

Fig. 1: Location of the studied area and samples location

The studied area has semi arid climate. Rainfall is of short duration and its mean annual is about 320 mm (Salar, 2006). Because of the semi arid climate, surface water, which flows during wet season, can be utilized and exploited very well at dry season for different uses like drinking and household uses domestic, livestock irrigation purposes and climate moderation at the studied area through building engineering structures especially small dams within the Bawashaswar watershed.

The objectives of this research are; to evaluate the morphometric and hydrological properties of Bawashaswar watershed.

TECTONIC AND STRUCTURE OF THE STUDIED AREA

Depending on Alkadhimi (1996), Bawashaswar watershed located within the Unstable Shelf at foothill zone. The upper part of the watershed is represented by Chamchamal-Arbil subzone, while the lower part of the watershed is represented by Hamrin subzone. It characterized by the presence of several structure features, like anticline folds, syncline folds, thrust faults and joints. The most conspicuous structures in the studied area are Kifri, and Kirkuk anticline folds separated by long syncline fold extending northwest southeast. They are double plunging folds their two noses plunging out of the studied area. Most of the anticlines are asymmetrical folds, the southwestern flanks are steeper than the northeastern flanks, their northeastern flanks over thrusted onto the southwestern flanks (Al-Naqib, 1959).

Another structure feature in the studied area is joints which are restricted to the sandstone beds of Injana Formation. Most of the joints are of (ac) and (bc) joint systems with dip angle ranging between (20^o) degrees to (90^o) degrees.

GEOLOGICAL SETTING

Geological setting of Bawashaswar watershed depends mainly on Bellen *et al.* (1959); Buday (1980); and Jassim and Goff (2006). The studied area is composed of different rock units, which are shown in Fig. (2), they are:

- **Fat'ha Formation**

Fatha Formation is characterized by the prevalence of evaporites. The rocks formation consists of anhydrite, gypsum and salt, inter bedded with limestone, marl and relatively fine grained clastics. The thickness of the formation is highly variable. The age of the formation is Middle Miocene.

- **Injana Formation**

Injana Formation consists of thin bedded, calcareous sandstone and red and green mudstones with one thin gypsum bed (20 cm thick) and a purple siltstone horizon. The calcareous sandstone contains oscillation ripple marks; they are overlain by fining upward cycles of sandstone, siltstone and red mudstone. In the central parts of the basin the formation consists predominately of uniform silty claystones or marls with anhydrite. In the northeast side of the basin the sands were derived from the rising Zagros and Taurus mountains.

The thickness of the formation is variable, due to subsequent erosion over major folds (Jassim and Goff, 2006). The age of the formation is usually accepted as Late Miocene.

- **Mukdadiya Formation**

Mukdadiya Formation usually starts with pebbly sandstones, especially in marginal areas. The alternations of thick bedded sandstones, siltstones and claystones characterize further part of the basins (towards its center). A general trend of decreasing grain size can be partly observed along the axis of the main deposition area (Buday, 1980). The age of the formation is Late Miocene - Pliocene.

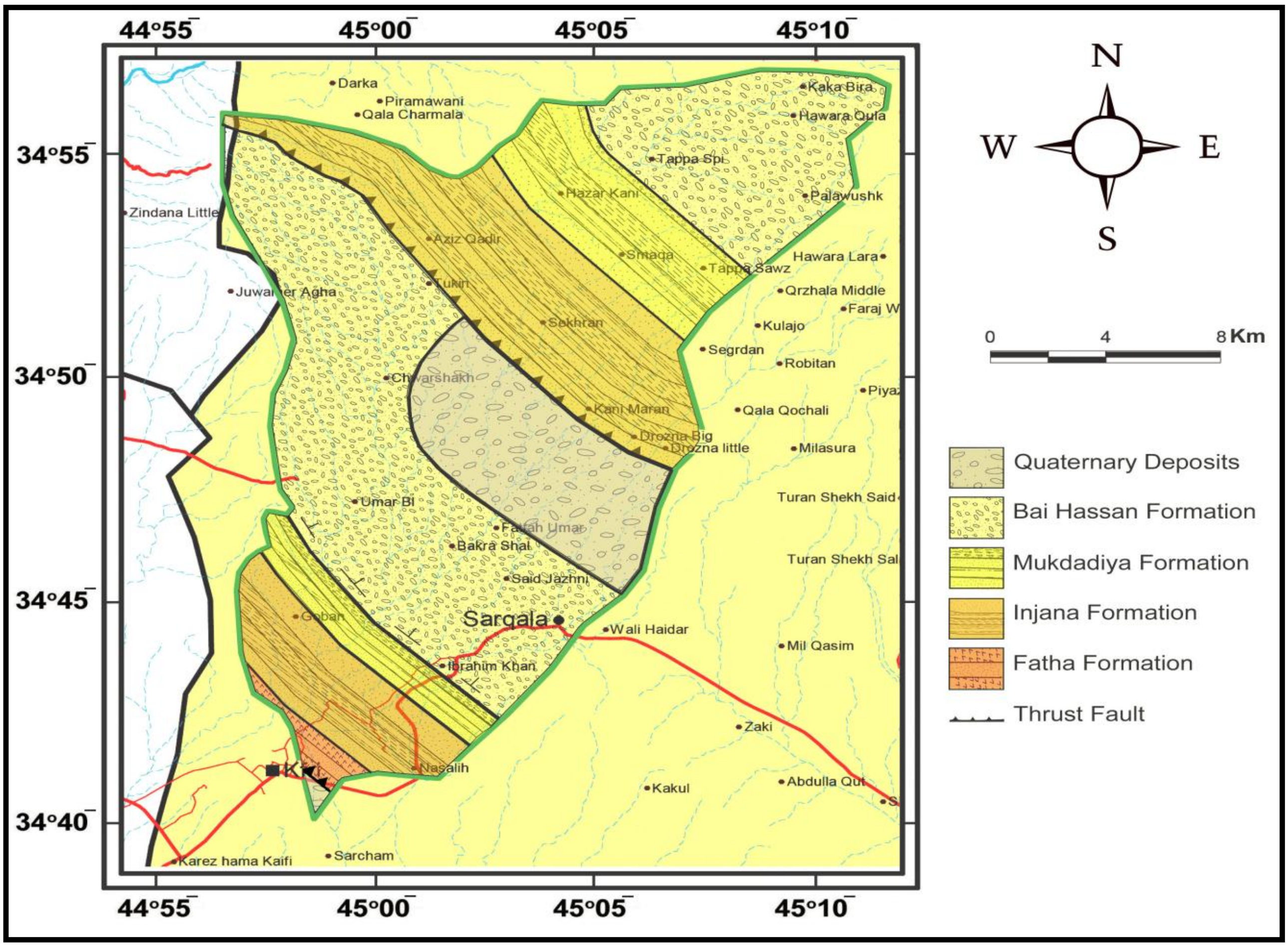

Fig. 2: Geological map of the studied area (Sissakian, 2000)

- **Bai Hassan Formation**

Bai Hassan Formation consists of alternation of conglomerates and claystones with sandstones and siltstones. These constituents show variation from one to other both laterally and vertically. The age of the formation is Late Pliocene - Pleistocene.

- **Quaternary Sediments**

Quaternary sediments consist of a mixture of various sediment sizes, which include gravels, pebbles, sands, silts and clays. The pebbles are mainly carbonates, which are derived from Mukdadiya and Bai Hassan Formation. These deposits are overlaying the Mukdadiya Formation and the differentiation between them is extremely difficult, due to the similarity in their lithology and absence of fossils in both units. The thickness of Quaternary sediments is variable in the studied area. The age of these deposits are Pleistocene – Holocene.

MORPHOMETRY OF A CATCHMENT

Morphometric properties of a Drainage Basin are quantitative attributes of the landscape that are derived from the terrain or elevation surface and drainage network within a drainage basin. Geomorphometry is the measurement and analysis of morphometric properties. Traditionally morphometric properties were determined from topographic maps using manual methods.

The development of morphometric techniques was a major advance in the quantitative description of the geometry of the drainage basins and its network. These parameters are useful in characterizing river basins and comparing their characteristics. For the first time it was proposed by Horton, in 1945.

The Morphometry parameters could be categorized into two major groups namely; the measured parameters and the calculated parameters:

- **Measured parameters**

It includes stream order, watershed area, axial length, stream length, watershed Perimeter.

- **Calculated Parameters**

The major calculated parameters of a basin are the basin shape, bifurcation ratio, circulatory ratio, elongation ratio, form factor, drainage density, and mean of stream length, stream frequency, watershed relief, relief ratio, relative relief, meandering factor and ideal length of Stream.

METHODOLOGY

The methodology of the present study is passed through two stages, which represented by field and office works and done as the following:

- **Field work**

The stream discharge measurements had been done at the outlet of Bawashaswar watershed, where there is engineering structure represented by a bridge. The depth of the stream measured twice a day at normal cases of climate of the region, while for the rainy days the measurements were done several time to conform to the rainfall measurements and to record the maximum depths (peak discharges) that correspond the rainfall storms. Then the discharge calculated by equation connecting between shape of hydraulic structure, depth of water (stream stage) and stream discharge.

- **Office work**

The morphometric properties of Bawashaswar watershed had been found depending on Soviet Union (1972) topographic map (with 20 m interval 1:100000 scaled) and google earth (2008) image (with 1:100000 scaled).

The rain fall data obtained from the Directory of Agriculture – Branch of Kifri for the period (2004 – 2005).

Watershed area (boundary line) was drawn through the center of highest elevation's saddles and closed contour lines by special computer software known as Adobe Illustrator.

Axial length of the basin is expressed as "the distance from the outlet to the most remote point on the basin". Length of the basin was measured according to the above rule in the present study.

Perimeter of the catchment can be obtained from the created outline of the basin, which is dependent upon the topography of the area. Perimeter of the catchment was measured using Adobe Illustrator.

Stream order; the method of Horton and Strahler was used to rank the stream.

Form factor defined as the ratio of basin area to the square of the basin length, using the following equation.

Where:

$R_f = A / L_b^2$ A = Basin area (km^2)

L_b = Basin length (km)

Compactness factor; the compactness factor was obtained from the ratio of the perimeter of the watershed to the circumference of a circle whose area is equal to that of the drainage basin (Gupta, 1999).

Where:

$= P / 2\sqrt{\Pi A}$ P= Basin perimeter (km)

A = Basin area (km^2)

Circulatory ratio obtained from the ratio of basin area (A) to the area of a circle (Ac) having equal perimeter as the perimeter of drainage basin.
Where:

$R_c = A / A_c$ $\quad$ A = Basin area (km^2)

A_c = Area of a circle (km2) (having equal perimeter as the perimeter of drainage basin)

Elongation ratio was defined as the ratio of diameter of a circle which has same area as the basin to the maximum basin length.
Where:

$R_l = D_c / L$ $\quad$ D_c = Diameter of a circle which has same area as the basin (km)

L = Basin length (Km)

The drainage density is defined as the length of all stream channels in the basin divided by the area of the basin.
Where:

$D_d = L_s / A$ $\quad$ L_s = Total length of all stream channels in the basin (Km)

A = Basin area (km^2)

To obtain the Stream frequency of the drainage basin; total Number of all stream channels in the basin were divided by the area of the basin.
Where:

$F_s = N_s / A$ $\quad$ N_s = Number of all stream channels in the basin (Km)

A = Basin area (km^2)

Length of overland flow was calculated as one-half of the reciprocal of the drainage density.
Where:

$L_g = 1 / 2D_d$ $\quad$ D_d = Drainage density of the basin (Km/ Km^2)

Bifurcation ratio for the watershed was defined as the ratio of number stream segments of a given order u divided by the number of stream segments of next higher order (u+1),
Where:

$R_c = N_u / N_{u+1}$ $\quad$ N_u = Number stream segments of a given order (u)

N_{u+1} = Number stream segments of a given order (u+1)

Time of concentration is the time it takes for water to travel from the most distant point of a watershed to the watershed outlet or some other down stream point of reference. Its can be calculated on the bases of Kirpich (1943) empirical formula.
Where:

$T_c = L^{1.15} / 7700\ H^{0.38}$

Tc is the estimated time of concentration, or the time for water to flow from the most distant point in the watershed to the watershed outlet, in hour; L is the length of the watershed along the main stream from the watershed outlet to the most distant ridge in ft.

Table 1: Length of streams, stream order and stream number of Bawashaswar watershed.

Stream order	Number	Stream Length (Km)	Mean of Stream Length (Km)	Bifurcation Ratio
1 (Red)	1403	608.201	0.434	-
2 (Yellow)	242	246.939	1.020	5.798
3 (Violent)	49	97.474	1.99	4.939
4 (Blue)	9	61.932	6.881	4.9
5 (Green)	3	16.64	5.547	3.333
6 (Black)	1	20.13	20.13	3
Total	1708	1051.316		

Table 2: Morphometric properties of Bawashaswar watershed

Watersheds Parameters	Units	Measurements
Main Stream Length	Km	50.46
Drainage Area	Km2	306.115
Watershed Perimeter	Km	97.551
Watershed Length	Km	32.701
Circle Diameter	Km	19.747
Drainage Density	Km/Km^2	3.434
Over land flow	Km	0.15
Stream Frequency	N/Km^2	5.58
Circularity Ratio	-	0.404
Elongation Ratio	-	0.604
Form Factor	-	0.29
Compactness factor	-	1.57
Watershed Relief	m (684-218)	466
Relief Ratio	m/Km	0.0143
Relative Relief	m/Km	0.005
Meandering Factor	-	1.301

Ideal length of Stream	Km	38.801
Time of Concentration	Hour	8.038

RESULTS AND DISCUSSIONS

- **Morphometric properties**

Bawashaswar watershed area was 306.115 km^2. Watershed area is land areas that drain elements on a Hydro Network. According to Gregory & Walling (1985) almost every watershed characteristics is correlated with the watershed area. Kale & Gupta, (2001) have stated that the larger basins have large average discharge.

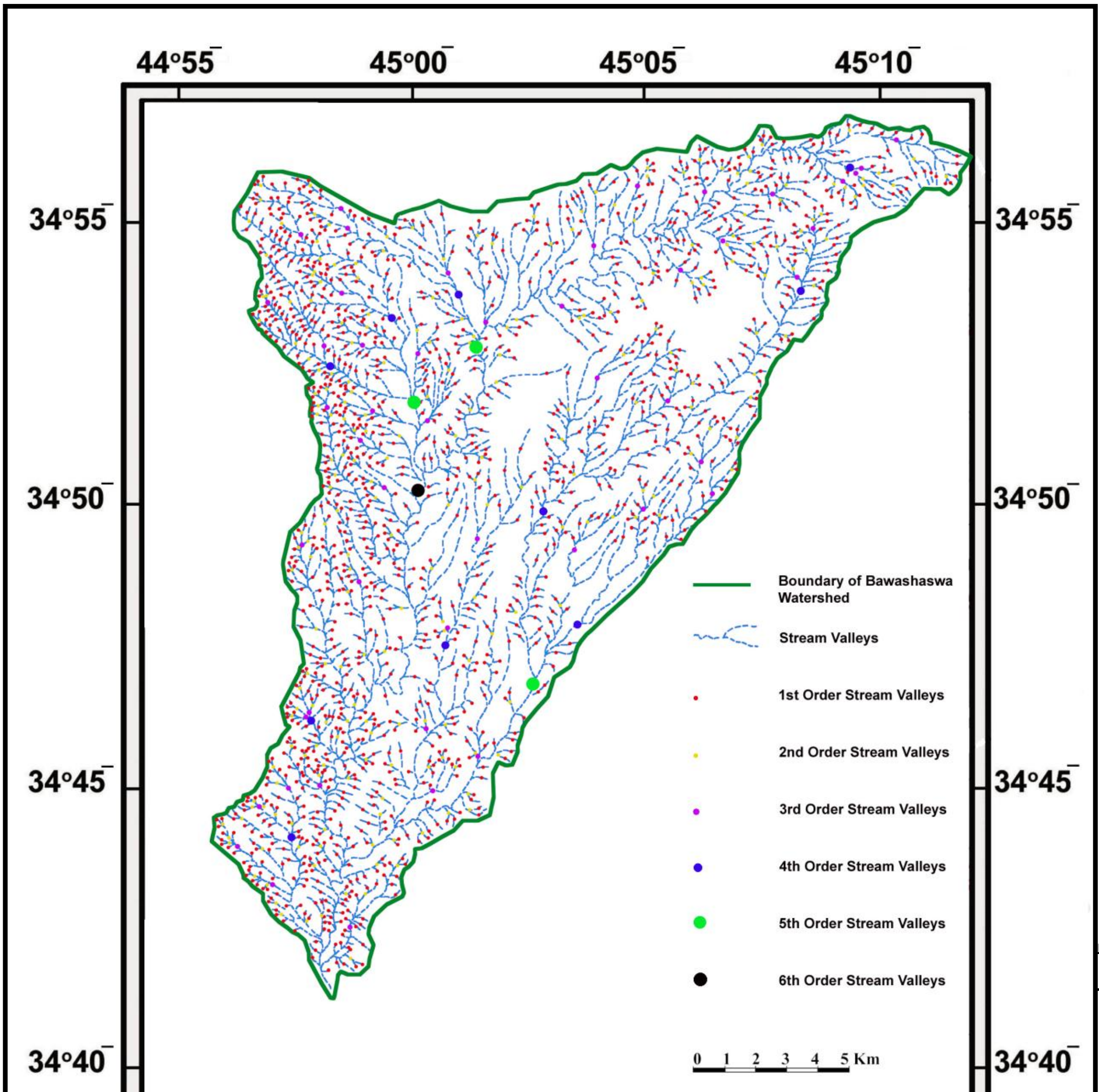

Fig. 3: Drainage network of Bawashaswar watershed.

The watershed length also indicates the lag time taken for the water to reach the outlet from its longest distance in the watershed after the rainfall. Together with mean slope, the axial length of the watershed affects the runoff to interact with the watershed. In the present study, the value of 32.701 km was indicated for the watershed.

Perimeter of the watershed was 97.551 km; it varies with its irregularity, which is based on the morphology of the area. Bifurcation ratio of Bawashaswar catchment indicates whether a basin is elongated or circular. Suresh (2000) has shown the high bifurcation ratio (R_b) is expected in the regions of steeply dipping rock strata, where narrow strike valleys are confined between the ridges. The results of the present study ranged from 3 to 5.8 for the watershed indicating natural drainage system characteristics.

Circulatory ratio of the present study was 0.404 which indicates shape of the watershed, the value, which deviate from 1, indicate highly irregular basins. According to Waugh (1995), shape of a basin has long been accepted that a circular basin is more likely to have a shorter lag time and a higher peak flow than an elongated basin.

Suresh (2000) has shown Elongation ratio ranges between 0.6 and 1.0 over a wide variation of climate and geologic types, for the regions of very low relief, the value of elongation ratio is found very close to 1.0, while for the areas involving strong relief and steep ground slope, the elongation ratio ranges from 0.6 to 0.8. The results of the present study indicated 0.604 which falls within 0.6 to 0.8 indicating strong relief and steep ground slope at the boundary area of the watershed in comparison with the middle part.

Form factor; if the basin is wider, the form factor will be comparatively higher. Consequently, much narrower basins have low form factor values. The low form factor is indicated in the elongated basin and high form factor is indicated in the wider basin (Gregory & Walling, 1985). The calculated value of form factor for the watershed was 0.29. The value falls in-between narrower and wider.

Compactness factor of the basin is used to express the basin shape, which is indicated by the deviation of the basin area from a circle having an equal area (Gupta 1999). The result of the watershed was indicated of 1.56, which reveals the in-between value for the watershed.

Time of concentration is used to show the pick discharge of the stream water and depending on the watershed properties and the intensity of the rainfall. The calculated the time of concentration for Bawashaswar watershed was 8.038 hours. It reflecting

- **Stream network**

The main or trunk stream and its tributary streams that drain the basin area collectively form the stream network. The spatial arrangement of a river and its tributary streams in a drainage net work is referred to as the drainage pattern of a basin (Gregory & Walling, 1985).

Figure 3 illustrates the stream network of Bawashaswar watershed, the stream orders varied from 1 to 6 and the total number of stream segments of all orders recorded was 1707. Orders of stream network indicated, 1403 of first orders, 242 of 2nd, 49 of 3rd, 9 of 4th, 3 of 5th, and one of 6th order streams.

Stream frequency & drainage density of the watershed were 5.58 (no. of streams per km^2) and 3.434 (km per km^2) respectively. According to Kale & Gupta, (2001) greater the drainage density and stream frequency in a basin, the runoff is faster, and therefore, flooding is more likely in basins with a high drainage and stream frequency. Strahler (1957) have described drainage density values less than 5.00 as course, from 5 – 13.7 as medium, from 13.7 – 155.3 as fine, and greater than 155.3 as ultra fine. In Britain values are usually well below 5 and on Dartmoor average 2.14 (Choeley & Morgan, 1962).

Length of overland flow is referred to as the distance of flow of the precipitated water, over the land surface to reach the stream. The results obtained for Bawashaswar watershed was 0.15 km. The overland flow is higher in the semi arid regions than in the humid and humid temperate regions, in addition absence of vegetation cover in the semi arid regions is primarily responsible for lower infiltration rates and for the generation of higher surface flow (Kale & Gupta, 2001). The low overland flow of Bawashaswar watershed clearly indicates well-developed stream network and heavy rainfall. Mean slope;

The slope of the watershed is resulted from the morphology of the area. The effect of high slope result in high velocity of flow, therefore it takes lesser time for the watershed runoff to reach the stream. Gupta (1999) has stated that the slope of the watershed is high which result in high peak flow after rainfall. According to the result Bawashaswar watershed indicates slow flow regimes.

- **Hydrological observation**

The stream discharge is measured at the stream outlet of catchment. Rainfall characteristics are characterized by short duration and high intensity. Annual rainfall based on year (2004–2005) is 251 mm.The monthly rainfall had a three main peaks distribution at (22/1/2005, 5/3/2005 and 11/3/2005), which they were (44, 35 and 25) mm (Fig. 5). The average monthly stream discharge during the period (2004–2005) had two peak of discharge corresponding with the dates of the rainfall peaks (Fig. 4). The affects of the rainfall storm on the stream discharge continued till the next day, when the stream reached its peak of discharge (48.846, 12.416 and 6.665 m^3/sec). This fact is conformed to the calculated time of concentration for Bawashswar watershed, which was 8.038 hours.

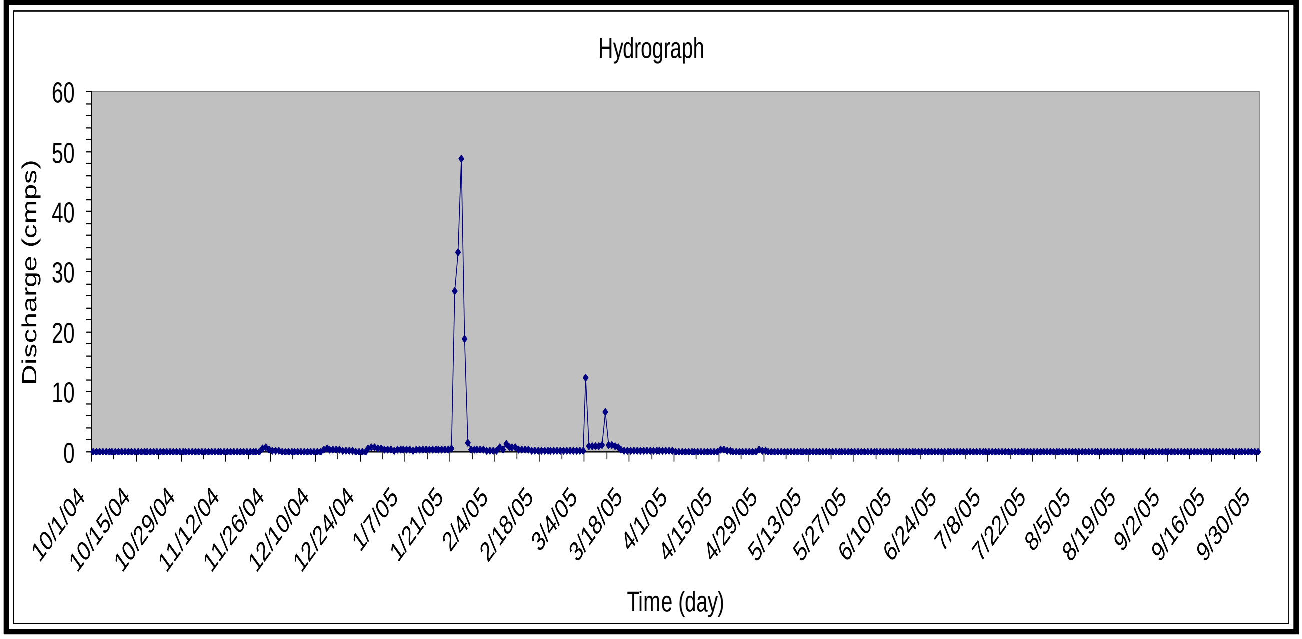

Fig. 4: Hdrograph of Bawashaswar watershed.

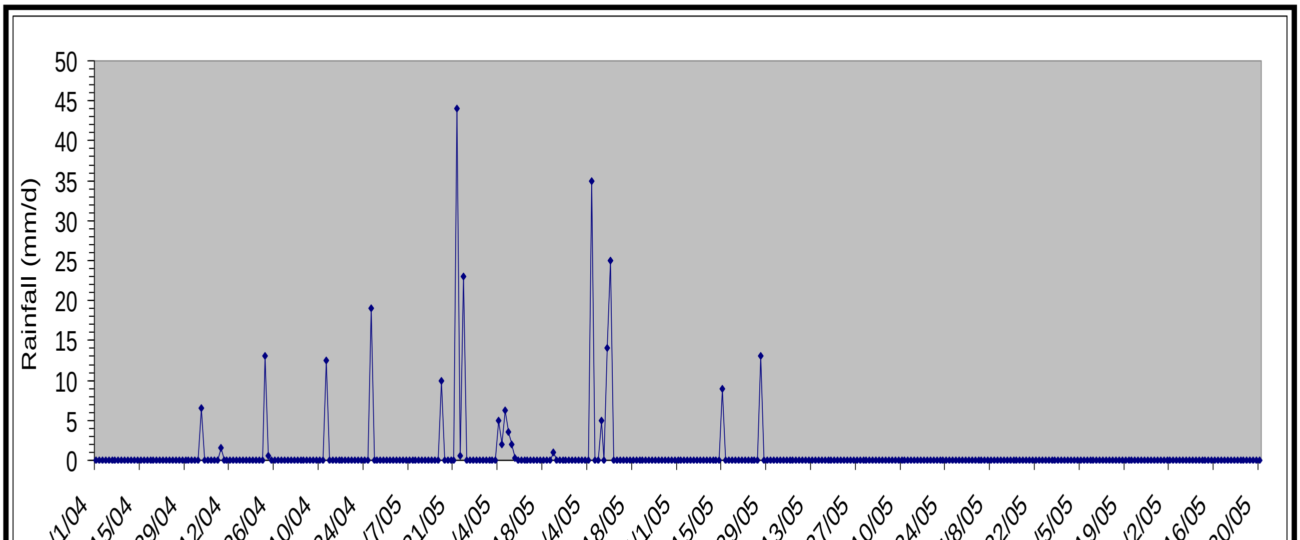

Fig. 5: Daily Rainfall representation of Bawashaswar waters

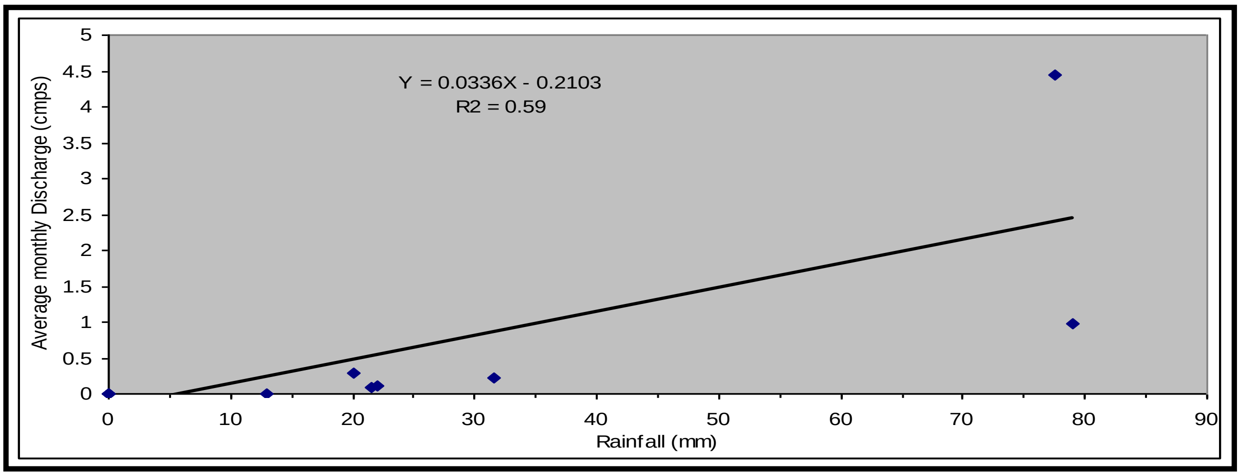

Fig. 6: Rainfall and average monthly discharge relationship

Figure 6 illustrate the relation between the rainfall and average monthly discharge and the relation formulated as following:

Y= 0.0336 X – 0.2103 Y = Average monthly discharge (cmps)

X = Monthly rainfall (mm)

0.0336 and 0.2103 are constant depending on the watershed characteristic.

Hence this reveals that Bawashaswar watershed hydrology is controlled by the following factors:

1- Shape properties and high morphometeric properties like stream order, stream number, stream frequency, and drainage density and bifurcation ratio. According to Aldlemi (2001) high stream order, stream number, stream frequency, and drainage density and bifurcation ratio causes high stream discharge.

2- According to Jassim and Goff (2006) the transmissivity of Mukdadiya formation and Quaternary sediments exposed in synclines reaches (200-300 m^3/day), while the transmissivity of Injana Formation is only (1-10 m^3/day). Therefore the permeability of the rocks differs due to variations in lithology of the geological formations that crop out in the region and this affect reflected on the rate of stream discharge.
3- Rainfall intensity has great influence on the occurrence of several the peaks of discharge.

CONCLUSION

The present study demonstrates that:

1- The tectonic and structural properties of the watershed characterized by presence two long anticlines, which they were Kifri and Kirkuk anticlines structures, extending northwest – southeast trending and separated by long and narrow syncline. The geological formations that exposed in the watershed area, from oldest to youngest, are Fatha, Injanah, Mukdadiyah and Bi Hassan Formations with Quaternary deposits.
2- The size, shape, morphometric and drainage network properties of Bawashaswar watershed greatly governed by type of geological rocks formations of the watershed, tectonic and structure of the rocks strata. The watershed is characterized by near elongate shape with high drainage network values.
3- Bawashaswar watershed hydrology is controlled by Shape properties and high morphometeric properties like stream order, stream number, stream frequency, and drainage density and bifurcation ratio. Also the affect of the rocks permeability is reflected on the rate of stream discharge. Different permeability is due to variations in lithology of the geological formations that crop out in the region. The intensity of the rainfall plays great influence for occurrence of peak discharges.

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المستخلص

تقع منطقة الدراسة بين دائرتي عرض (‾34°57 – ‾34°40) شمالا و خطي طول (‾45°11 – ‾44°56) شرقا، في شمال شرق العراق، بمسافة ١٠٠ كم الى جنوب شرق مدينة السليمانية ضمن حدود حوض نهر ديالى.

تتمثل مكاشف التكاوين الجيولوجية ،من الأقدم الى الأحدث ، بتكاوين فتحة و انجانة و مقدادية و باي حسن وترسبات العصر الرباعي. اذ تاخذ الظواهر التكتونية و التركيبية اتجاه شمال غرب – جنوب شرق ، وتتميز بوجود فالقي كفري و كركوك مع وجود طيتين محدبتين تتوسطهما طية مقعرة.

والهدف من هذه الدراسة هو استغلال الخواص الهيدروجيومورفولوجية لحوض باوشاسوار للفوائد البشرية في منطقة كفري المتمثلة بمياه الشرب و الري و تلطيف مناخ منطقة الدراسة و تقليل مخاطر الفيضان و ذلك ببناء السدود الصغيرة على مجرى النهر.

ان هذا البحث يبين تاثيرات الخواص التكتونية و التركيبية و نوعية الصخور و المناخ على خواص حوض باوشاسوار الجيومورفومترية والهيرولوجية.