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Runoff hydrographs using Snyder and SCS synthetic unit hydrograph methods: A case study of ungauged watersheds of Imam Turki Bin Abdullah Royal Nature Reserve (ITBA) - Saudi Arabia

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Abstract: Background: The estimation of surface runoff and discharge peak using the Snyder's model and SCS Dimensionless UH (SCS-DUH) method are one of the best alternatives solutions appropriate for analyzing the hydrologic systems in the ungauged watersheds. These two methods were applied to estimate the discharge peak and design their hydrographs in the drainage basins of Royal Nature Reserve (Imam Turki Bin Abdullah) in Saudi Arabia. - Aims: To estimate the discharge peak by applying Snyder's model and SCS-DUH method using the morphometric parameters deriving from the SRTM DEM30m and three rainstorms of 40, 50 and 60mm. - Methods: The estimation of discharge peak (Qp) using Snyder's model was depended on the SRTM DEM30m outputs and the hydrology parameters of the duration (Td) of Unit Hydrograph (UH), time to peak (Tp), time base of the UH (Tb), UH width at 50% and 75% of the peak discharge. However, the estimation of the discharge peak by The SCS-DUH method was computed using the drainage area (A), the direct runoff (Qd) and the time to peak (Tp). The direct runoff was determined by the runoff ratio 0.20 of the unimproved areas, proposed by the Soil Conservation Service (SCS). But, the time to peak was computed using the average of the concentration time obtained from Johnstone-Cross and Dooge models. The hydrographs design was done by the time ratio method recommended by the SCS. - Results: The estimated discharge peak computed by Snyder's model varies with a maximum of 93.4 to 2092.9 m3/s, an average of 61.1 to 1368.4 m3/s and a minimum of 28.7 to 644.0 m3/s in Al Shuwaiki and Khtal watersheds, respectively. The estimated discharge peak computed by SCS-DUH method was ranged from 21.5 to 482.3 m^3/s for the rainstorm of 40mm in Al Suwayki and Khtal, respectively, from 28.5 to 602.9 m^3/s for the rainstorm of 50mm and from 34.1 to 723.5 m^3/s for the rainstorm of 60mm, in Um Nqy and Khtal, respectively. - Conclusion: The hydrology study of ungauged basins in Royal Nature Reserve (ITBA) shows the great potential of the integrated emplyement of GIS technics and the hydrology models to estimate the discharge peak and design their hydrographs.

Keywords: Discharge peak, runoff, Snyder model, SCS DUH, Watershed, Imam Turki Bin Abdullah Royal Nature Reserve (ITBA) - Saudi Arabia.

تصميم هيدروغراف الجريان السطحي بطريقتي سنايدر والمنحنى المائي الأحادي: دراسة حالة الأحواض غير المقيسة بمحمية الإمام تركي بن عبد الله الملكية - المملكة العربية السعودية

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المستخلص: موضوع الدراسة: يعتبر نموذج سنايدر وطريقة المنحنى المائي الأحادي للهيئة الأمريكية لحماية التربة من أفضل الحلول الكمية البديلة لتقدير وتحليل التدفق الأقصى للجريان السطحي في غياب القياسات الفعلية له بالأحواض المائية. ولقد تم تطبيق هاتين الطريقتين في تقدير الجريان السطحي وتصميم الهيدروغراف المائي المناسب له بأحواض هضبة التيسية بمحمية الإمام تركي بن عبد الله في المملكة العربية السعودية. - أهداف الدراسة: تتمثل أهداف الدراسة في تطبيق نموذج سنايدر وطريقة المنحنى المائي الأحادي للهيئة الأمريكية لحماية التربة باستخدام القياسات المورفومترية المشتقة من نموذج الارتفاع الرقمي SRTM DEM30m لتقدير التدفق الأقصى للجريان السطحي المناسب لعواصف مطرية قدره 40 ملم و50 ملم و 60 ملم. - منهجية الدراسة: اعتمدت منهجية الدراسة في تطبيق نموذج سنايدر على المخرجات المورفومترية لنموذج الارتفاع الرقمي SRTM DEM30m لتقدير التدفق الأقصى للجريان السطحي (Qp) الفترة الزمنية للتدفق (Td) وفترة وصول التدفق للذروة (Tp) وفترة الأساس لهيدروغراف التدفق (Tb) وعرض هيدروغراف الجريان عند 50% و75% من كمية التدفق. كما اعتمدت منهجية الدراسة في تطبيق طريقة الهيئة الأمريكية لحماية على مساحة التصريف (A) المحسوبة من نموذج الارتفاع الرقمي SRTM DEM30m والجريان المباشر (Qd) باستخدام معامل الجريان المقترح للأحواض المائية الطبيعية (0.20) من طرف الهيئة الأمريكية لحماية التربة. بينما تم تقدير فترة وصول التدفق للذروة (Tp) باستخدام متوسط زمن التركيز للحوض المائي المحسوب من تقديرات نموذجي جوهنستون- كروس ودوج. في حين تم تصميم المنحنيات المائية (هيدروغراف) للتدفق بتطبيق طريقة النسب الزمنية التي أوصت بها الهيئة الأمريكية لحماية التربة. - نتائج الدراسة: توصلت الدراسة إلى تقدير التدفق الأقصى والمتوسط والأدنى لكل حوض مائي بتطبيق نموذج سنايدر. وقد تراوحت قيم التدفق الأقصى بين 93.4 و 2092.9 م^3/ثانية والتدفق المتوسط بين 61.1 و 1368.4 م^3/ثانية والتدفق الأدنى بين 28.7 م^3/ثانية بحوضي الشوكي وخطال، على التوالي. كما تراوحت قيم التدفق المناسب للعاصفة المطرية 40 ملم بين 21.5 و 482.3 م^3/ثانية بحوضي الشوكي وخطال، على التوالي. بينما تراوحت قيم التدفق المناسبة للعاصفة المطرية 50 ملم بين 28.5 و 602.9 م^3/ثانية وقيم التدفق المناسبة للعاصفة المطرية 60 ملم بين 34.1 و 723.5 م^3/ثانية بحوضي أم النقاء و خطال، على التوالي. - الخلاصة: أظهرت نتائج الدراسة إمكانية التوظيف المتكامل لتقنيات نظم المعلومات الجغرافية وتطبيق النماذج الهيدرولوجية في تقدير التدفق الأقصى وتصميم المنحنيات المائية المناسبة له بالأحواض المائية التي لا تحتوي على قياسات فعلية للجريان السطحي.

الكلمات المفتاحية: تدفق الذروة، الجريان السطحي، نموذج سنايدر، نموذج المنحنى المائي الأحادي، حوض مائي، محمية الإمام تركي بن عبد الله، المملكة العربية السعودية.

1- Introduction

Morphometric measurements are a very reliable base for collecting quantitative data necessary for any study aimed at designing geomorphological or hydrological models for drainage basins, because they provide the necessary measurements for landforms that make the design of appropriate mathematical and laboratory models possible from an applied point of view, and morphometric analysis provides a huge amount From the information related to the various elements of the water network such as the type, shape and number of morphometric variables compounded to it, and given the great correlation between the characteristics of the water network and the geomorphological and hydrological characteristics of the river drainage basins, the accuracy of the morphometric analysis helps a lot in investigating many geomorphological and hydrological data for the river drainage basins, and this is what is indicated He must conduct similar studies, and then determine the dynamic and hydrological behavior of these basins and the degree of severity of floods and their impact on human activities, as well as knowing the possibility of carrying out development projects such as irrigation projects and water harvesting by making use of its water resources, and determining the type of these technologies that are compatible with the characteristics of the land and soil. and water drainage (Al-Karbouli, 2022).

The demand of water increases continuously from year to year due to population increase in different countries. Studies of water and its management in arid areas are essential. The prediction of runoff from an ungauged watrsheds, is the main problem in hydrological studies of arid zones (Hrachowitz *et al.* 2013). So, several hydrologic models were developed at different climatic zones to better compute the runoff and its peak discharge in ungauged bains. In general, the hydrologic models proposed are the simplified simulation of the complex hydrologic system (Behailu Shemlis, 2004). The widely hydrologic models used for developing a synthetic hydrograph for ungauged watersheds have been proposed by Bernard (1935), Snyder (1938), McCarthy (1939) and Clark (1945). The recent International Association of Hydrological Sciences (IAHS) initiative on prediction in ungauged basins (PUB) has opened opportunities to carry-out research in data poor or ungauged basin (Sudhakar et al., 2015).

A vast amount of literature exists treating the various unit hydrograph methods and their development (Salami et al., 2017). Jones [2006] reported that Sherman in 1932 was first to explain the procedure for development of the unit hydrograph for watersheds of (5000 km^2) or less. Chow et al. [1988] discussed the derivation of unit hydrograph and its linear systems theory. Furthermore, Viessman et al [1989], Wanielista [1990] and Arora [2004] presented the history and procedures for several unit hydrograph methods. Ramirez [2000] reported that the synthetic unit hydrograph of Snyder was derived from the study of 20 watersheds located in the Appalachian Highlands and varying in size from 25 to 25 000 km^2. But, the dimensionless unit hydrograph was developed by the Soil Conservation Service and obtained from the UH's for a great number of watersheds of different sizes and for many different locations (Ramirez, 2000). Wilson [1990] also reported that in 1938, McCarthy proposed another method of hydrograph synthesis but in that same year Snyder proposed a better known method by analyzing a larger number of basins in the Appalachian mountain region of the United States. Salami [2009] applied three unit hydrograph methods (Snyder, SCS and Gray) for developing the runoff hydrograph of lower Niger River basin at downstream of the Jebba Dam. In this study Snyder and SCS methods were used to generate peak runoff hydrographs of rainfall depth of various return intervals for selected rivers in south west, Nigeria.

This paper presents the results of estimated overland flow of ungauged watersheds on At-Taysia plateau, Saudi Arabia, using the Snyder synthetic unit hydrograph. In this research an attempt was made to compute the peak discharge for a 34 ungauged catchment extended in arid zone of northeastern in Saudi Arabia by applying two different approaches: Snyder synthetic unit hydrograph method and SCS-DUH model.

2- Study area

The selected case catchments are located in the At-Taysiah plateau between the longitudes $43^{\circ}20'$-$44^{\circ}50'$ East and the latitudes $27^{\circ}30'$-$29^{\circ}00'$ N (Fig. 1). The basins morphometric measurements were derived using a Digital Elevation Model (DEM) provided by USGS (United States Geologic Survey), with a grid resolution of 30 m. The extracted morphometric informations show :

(a) A drainage area with 12 km^2 in Al Shawuki basin and 2063 km2 in Al Hisiki basin.

(b) A mean elevation with 504.5 m in Al Awja basin and 660.5 m in Dughymiyah basin.

(c) A basin length with 5 km in Umm Suruj basin and 104 km in Al Hisiki basin.

(d) An average slope with 0.04% in Hawaya basin and 0.84% in Umm Al Rilan basin.

Based on the land resources map at scale 1:500000 edited in 1994 by the Ministry of Agriculture, the mainly land covers and soil types of the selected catchments are The hill and rock outcrops, pediplaine with deep soils, dunes, sand sheets, degraded plain and alluvial plain.

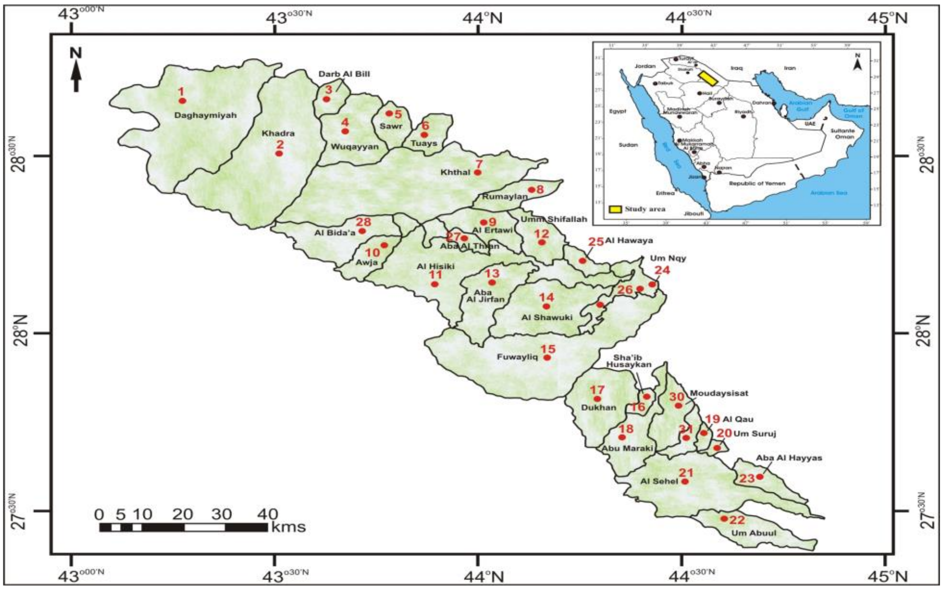


Figure 1 : Geographic location of Studied watersheds.

Study area

The selected catchments are extended in the same topographical context formed in At-Taysiyah plateau, in the northern part of Saudi Arabia. the total drainage area is composed by 34 catchments located in arid zone, often exposed in winter to the formation of clouds and fog. The climatic influences are related to the air masses coming from the central Asia mountains. In summer, the thunderstorms are accompanied by the significant rainfall. During spring, the climate is mild and pleasant, with the mean temperature ranged between 16 °C in Al Jawf (North) and 19°C in Hafr Al Batin (South). In the summer, the temperatures reached the maximum with an average ranged between 31 °C and 35 °C in Al Jawf and Hafr Al Batin, respectively. Relative humidity average varies from 15% and 57% in Al Jawf and Hafr Al Batin. With these climatic conditions,

the selected catchments become the most important source of the surface water resources in the Natural Park of At-Taysiah.

3- Research problem

The research problem lies in how to build a morphometric database, using modern software, to reach the most accurate results of morphometric characteristics, and then indicate their impact on the hydrological characteristics of the Turki Bin Abdullah basin, and how to employ them in the possibility of establishing water harvesting and supplementary irrigation projects in the basin and adjacent areas.

Research hypothesis:

The use of geographic information systems and remote sensing, based on satellite visualizations and digital radar elevation models, makes us get rid of the traditional methods of hydromorphometric measurements and build a high-accuracy database that contains accurate information and results on the morphometric characteristics of river basins, including the basin of the study area, and the hydrological behavior of any basin. It is affected by the engineering and topographical morphometric characteristics and characteristics of the drainage network, in terms of the discharge density, the nature of water waves, the degree of flood risk, the intensity of erosion and the amounts of sediment transported, and then we realize that the morphometric characteristics and their geomorphological and hydrological implications are of great importance in determining the best sites that can be used in the establishment of various harvesting technology projects watery.

4- Material and Methods

4-1- Estimation of Snyder's hydrograph

The geo-database for the studied basins has been created using topographic maps at (1:50000 and 1:250000) scales, satellite remote sensing images and land resources maps at (1:500000) scale. Theses maps were collected, geo-referenced, and digitized for deriving the themes such as contours, level points, streams, and watershed boundary. A digital elevation model (DEM) for 30 m has been used (Figure 2). The DEM has been considered as basis for delineation of sub-watershed boundary, geographical areas and longitudinal slopes of studied watersheds. The hydrological parameters such as watershed area, river length, and length of centroid have been derived using measurement tool in Arc-GIS.

The best known approach of developing the synthetic hydrograph is due to Snyder (1938). Snyder analyzed a large number of hydrographs from drainage basins in the Applachian Mountain region in USA ranging in the area from 25 to 25000 km^2 and selected the three parameters for the development of unit hydrograph, namely, time base (T), peak discharge (Q_p) and lag time (basin lag, t_p), and proposed the following empirical formulae for the hydrograph parameters : (Raghunath, 2006).

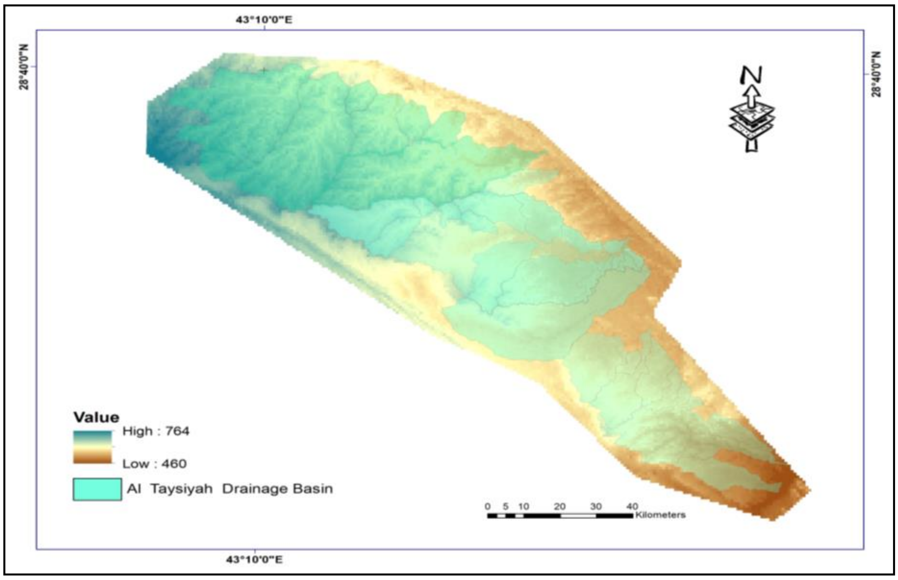


Figure 2: SRTM Dem of Studied watersheds.

(1) The Snyder standard lag time (T_{lag}):

$$T_{Lag}\,(hr) = C_t\,(L\,L_{ca})^{0.3} \qquad [1]$$

Where C_t is the Lag coefficient [0.2-2.2] dependent upon basin properties, L is the main channel length from basin outlet to upstream watershed, boundary (km) and L_{ca} is the main channel length from outlet to a point opposite the center of gravity (km).

(2) The duration of UH (T_d) :

$$T_d(hr) = \frac{T_{Lag}}{5.5} \qquad [2]$$

(3) Time of Peak (T_p):

$$T_p(hr) = \frac{T_d\,(hr)}{2} + T_{Lag}\,(hr) \qquad [3]$$

The terms T_d and T_{Lag} have been obtained from equation (2) and equation (3).

(4) Peak Discharge (Q_p) of watershed is calculated using below equation:

$$Q_p(m^3/s) = C_p\,\frac{A\,(km^2)}{T_p\,(hr)} \qquad [4]$$

Where, A: area of watershed (km^2), T_p(hr): time to peak and C_p: peak flow coefficient [2- 6.5].

(5) Peak flow per km^2 is calculated by the following equation:

$$q_p(m^3/s/km^2) = \frac{Q_p\,(m^3/s)}{T_p\,(hr)} \qquad [5]$$

(6) Time base of the UH is calculated in days as follows:

$$T_b(days) = 3 + \frac{3\,T_p\,(hr)}{24} \qquad [6]$$

Where T_p is the Time of Peak calculated by the equation (3).

(7) UH width at 50% and 75% of the peak discharge, can be calculated based on equations (7) and (8) :

$$W_{50} = \frac{5.6}{{q_p}^{1.08}} \quad [7]$$

$$W_{75} = \frac{3.21}{{q_p}^{1.08}} \quad [8]$$

Where q_p is the peak flow per km^2 calculated by the equation (5).

4-2- Estimation of SCS Dimensionless Unit hydrograph

The SCS dimensionless unit hydrograph relates ratios of time to ratios of low (Viessman et al., 1989; Ramirez, 2000). The required hydrologic parameters for constructing the hydrograph can be determined by adopting the equations (9) to (12).

- Peak discharge

The peak discharge cam be computed using the following equation : (Salami et al., 2017)

$$Q_p = \frac{0.208\ A\ Q_d}{t_p} \quad [9]$$

Where :

- Q_p is the peak discharge (m^3/s),
- A is the watershed area (km^2),
- Q_d is the runoff (mm),
- t_p is the time to peak (hr).

- Time to peak

Time to peak is obtained by applying two methods, which are related to the time of concentration and lag time of the catchment:

(a)-

$$t_p = \frac{t_r}{2} + t_{lag} \quad [10]$$

Where:

- t_r is the storm duration (hr),
- $t_{lag} = 0.6\ t_c$ (hr). where (t_c) is the time of catchment concentration. It can be estimated by applying several methods. In this study, the time of concentration is estimated using the average of Johnestone-Cross model (1949) and Dooge model (1973):

$$Tc(hr) = 0.4623 \frac{[L(km)]^{0.5}}{[S(m/m)]^{0.25}} \quad [11]\text{, Johnestone-Cross (1949)}$$

$$Tc(hr) = 0.365 \frac{[A(km^2)]^{0.41}}{[\ S(m/m)]^{0.17}} \quad [12]\text{, Dooge (1949)}$$

Where :

L (km) : The main stream length,

S(m/m) : The average slope of the catchment,

A (km^2) : The catchment area.

(b)- $$t_p = \frac{t_c + 0.133\, t_c}{1.72} \quad [13]$$

- Time base

Time base of the SCS-DUH is calculated in hours using time to peak as follows:

$$T_b(hr) = 2.67\, t_p(hr) \quad [14]$$

- Storm duration

The storm duration of the SCS-DUH is related to the Time base and time to peak. It can be computed by applying the following equation :

$$t_r(hr) = T_b(hr) - t_p(hr) \quad [15]$$

5- Results and discussion

The methods of unit hydrographs used to determine the peak runoff are; Snyder's and Soil Conservation Service (SCS).

5-1- Development of Unit Hydrographs (Snyder method)

For constructing the Snyder's synthetic hydrograph the following parameters were determined: peak discharge (Q_p), Lag time (T_{lag}), the time to peak (T_p), storm duration (t_r), the peak discharge per unit of watershed area (q'_p), the basin lag (t'_{lag}), the base time (t_b) and the widths of the unit hydrograph at 50% (W_{50}), and 75% (W_{75}) of the peak discharge. The table 2 summarized theses estimated parameters.

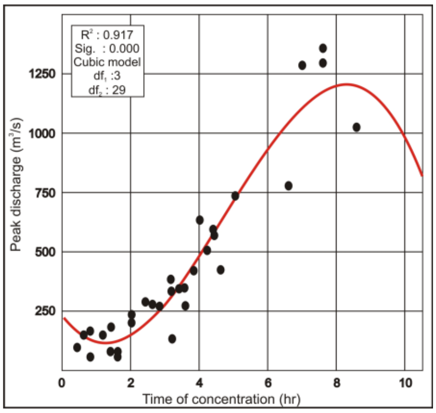
The parameters for generating the Snyder's hydrograph vary in the studied watersheds. So, the test of Normality Kolmogorov-Smirnov was used to determine the significance of the parameters distribution and their variance. The p-value of Komogorov-Smirnov test were less than the critical value 0.05 for the total parameters, except the T_{Lag} and T_p. Consequently, the data distribution of the total parameters is significantly different from the normal distribution.

The peak discharge is directly related to the drainage area (A), basin length (L), Lag time (T_{lag}), the time to peak (T_p), Time of concentration (Tc), and storm duration (t_r), (Table 3 and Figure 3).

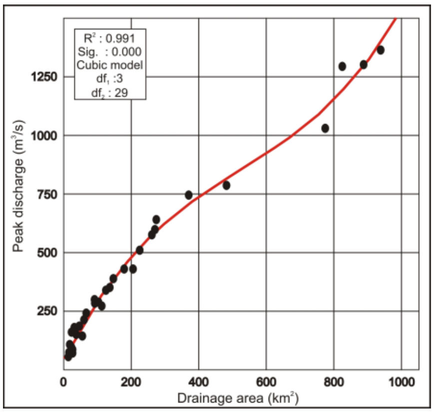
Table 2. Watershed characteristics for generating unit hydrograph (Snyder's method).

Wadi watershed	A (km^2)	L (km)	L_{ca} (km)	t_{Lag} (hr)	t_r (hr)	T_p (hr)	S (%)	Q_p (m^3/s) Max.	Mean	Min.
Khthal	935	65	35.8	2.9	4.8	3.2	0.28	2092.9	1368.4	644.0
Al Hisiki	2063	104	57.2	---	---	---	---	---	---	---
Dukhan	269	24	13.2	1.9	3.2	2.1	0.19	914.4	597.8	281.3
Husaykan	34	8	4.4	0.9	1.6	1.1	0.31	233.3	152.5	71.8
Abu Maraki	204	37	20.4	2.0	3.3	2.2	0.21	659.9	431.5	203.0
Mudaysisat	139	23	12.7	1.7	2.8	1.9	0.20	539.4	352.7	166.0
Al Qau	60	16	8.8	1.2	2.0	1.3	0.40	323.4	211.5	99.5
Al Tuays	94	14	7.7	1.4	2.4	1.6	0.14	425.6	278.3	130.9
Um Suruj	18	5	2.8	0.7	1.2	0.8	0.34	156.8	102.5	48.2
Aba Al Hayyas	92	20	11.0	1.4	2.3	1.5	0.41	436.5	285.4	134.3
Al Sehel	479	60	33.0	2.6	4.3	2.9	0.23	1202.7	786.4	370.1
Umm Buul	178	29	16.0	1.8	2.9	2.0	0.29	656.4	429.2	202.0
Fuwayliq	776	63	34.7	3.2	5.3	3.6	0.10	1577.5	1031.5	485.4
Aba Al Jirfan	273	26	14.3	1.8	3.0	2.0	0.37	980.4	641.0	301.7
Hawaya	53	13	7.2	1.6	2.6	1.7	0.04	218.8	143.1	67.3
Um Al Rilan	34	7	3.9	0.8	1.4	0.9	0.84	266.6	174.3	82.0
Ab Al Thrran	44	11	6.1	1.0	1.7	1.1	0.58	287.1	187.7	88.3
Ramaylan	125	24	13.2	1.6	2.6	1.7	0.33	521.6	341.1	160.5
khadra	825	48	26.4	2.7	4.5	3.0	0.23	1978.4	1293.6	608.7

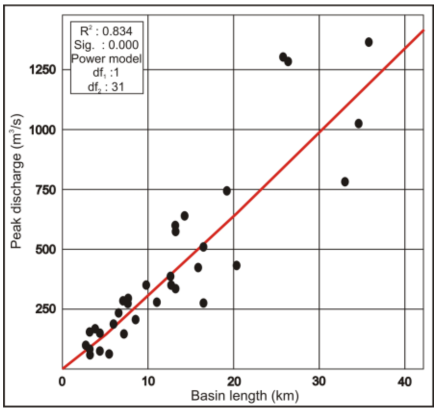
Wadi watershed	A (km^2)	L (km)	L_{ca} (km)	t_{Lag} (hr)	t_r (hr)	T_p (hr)	S (%)	Q_p (m^3/s) Max.	Mean	Min.
Duughaymiyah	888	47	25.9	2.9	4.8	3.2	0.14	1999.0	1307.0	615.1
Sawr	91	14	7.7	1.3	2.2	1.4	0.30	453.7	296.7	139.6
Tuaysn	94	13	7.2	1.4	2.3	1.6	0.15	437.8	286.2	134.7
Awja	108	30	16.5	1.7	2.8	1.8	0.28	425.2	278.0	130.8
Um Nqy	16	10	5.5	1.1	1.8	1.2	0.11	98.8	64.6	30.4
Al Suhyra	20	8	4.4	1.1	1.8	1.2	0.08	121.5	79.5	37.4
Al Shawuki	12	6	3.3	0.8	1.4	0.9	0.13	93.4	61.1	28.7
Al Shuwayki	372	35	19.3	2.1	3.5	2.4	0.28	1140.4	745.7	350.9
Duwayhi	21	6	3.3	1.0	1.7	1.1	0.07	136.3	89.1	41.9
Um Shifallah	135	18	9.9	1.6	2.7	1.8	0.14	536.8	351.0	165.2
Al Ertawi	145	23	12.7	1.6	2.6	1.8	0.32	593.9	388.3	182.7
Al Nasiryah	29	6	3.3	0.8	1.3	0.9	0.78	240.7	157.4	74.1
Al Bid	225	30	16.5	1.9	3.1	2.1	0.28	785.0	513.3	241.5
Wguain	259	24	13.2	1.9	3.2	2.1	0.18	884.3	578.2	272.1
Darb Al Bill	66	12	6.6	1.2	2.0	1.3	0.33	365.7	239.1	112.5



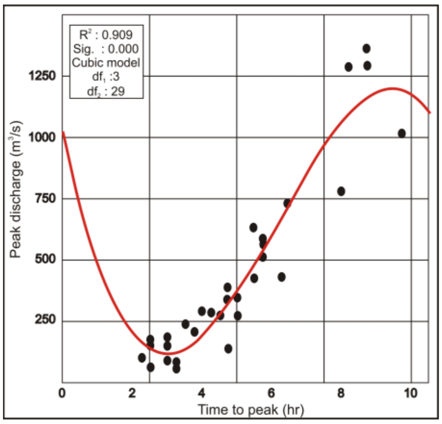
a : Time of concentration - Peak discharge.



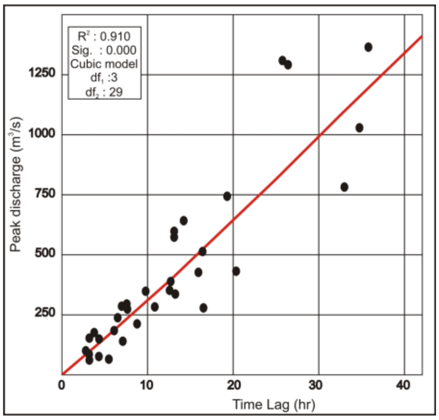
b : Drainage area and Peak discharge.



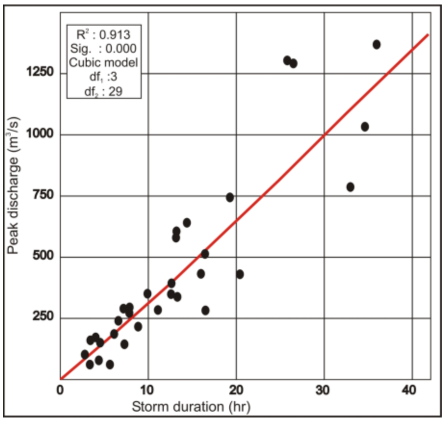
c : Basin length and Peak discharge.



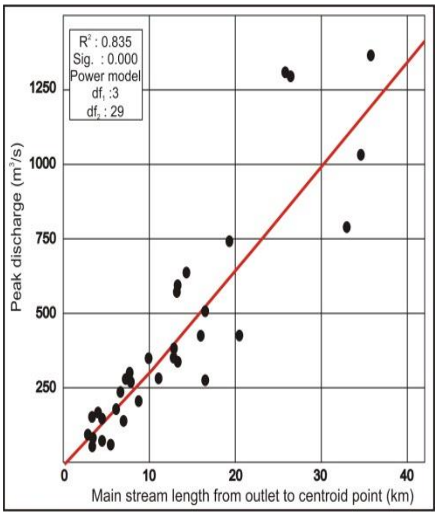
d : Ttime to peak and Peak discharge



e : Time lag and Peak discharge



f : Storm duration and Peak discharge.

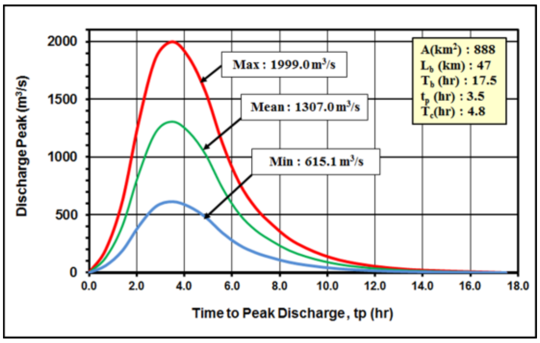


g : Main stream length from outlet to the centroid point and Peak discharge

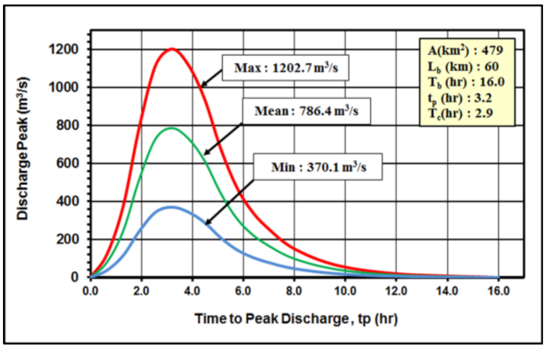
Figure 3 : The correlation between the parameters of Snyder's hydrograph and Peak discharge

The peak discharge varies in the watersheds with a drainage area. So, the total of the watersheds were classified using drain age area to analyze the spatial distribution of the peak discharge:

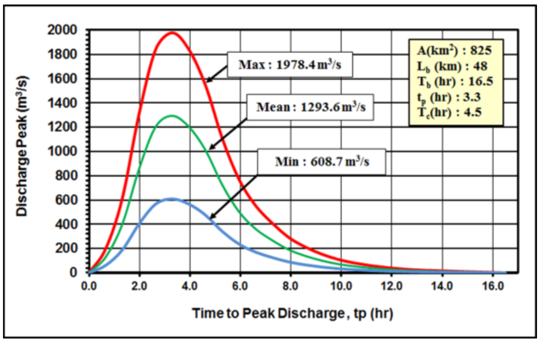
1- Large basins, with a drainage area ranged from 479 km^2 (Sehel) to 2063 km^2 (Al Hisiki). In these watersheds the peak discharge exceeds 1030 m^3/s (Figure 4).



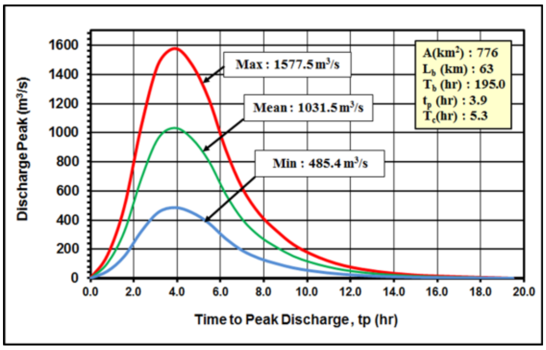
Wadi Dughaymiah



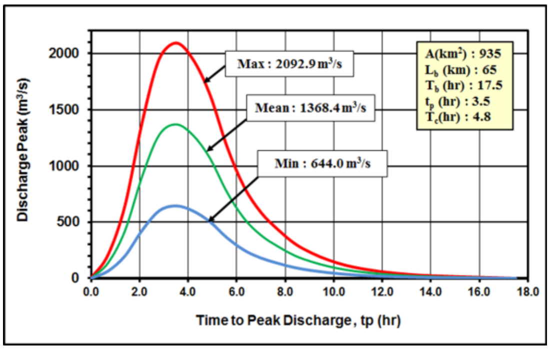
Wadi Sehel



Wadi Khadra



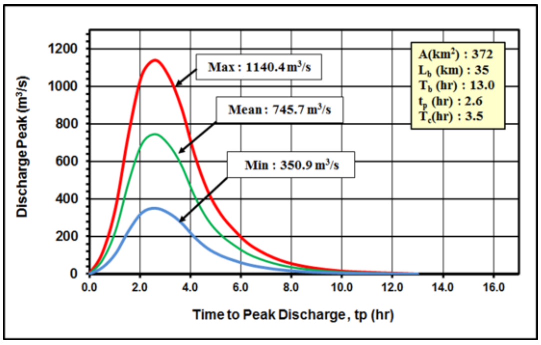
Wadi Fuwayliq



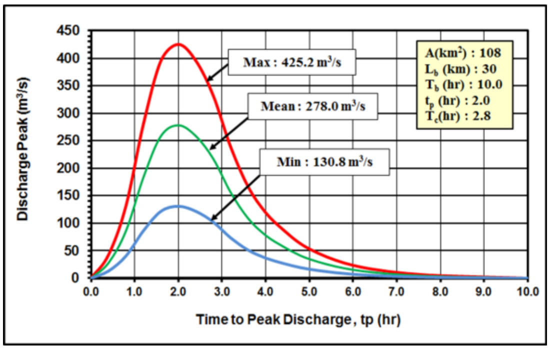
Wadi Khthal

Figure 4 : Snyder's Hydrographs of the largest watersheds

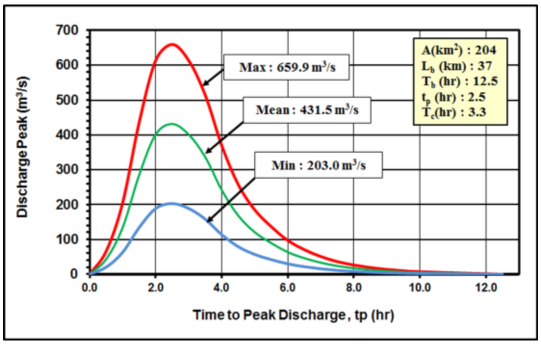
2- Medium basins, extended in drainage area ranged from 108 km^2 (Awja) to 372 km^2 (Shuwayki). The peak discharge of theses watersheds varies from 278 m^3/s (Awja) to 641 m^3/s (Aba Al Jirfan) (Figure 5).



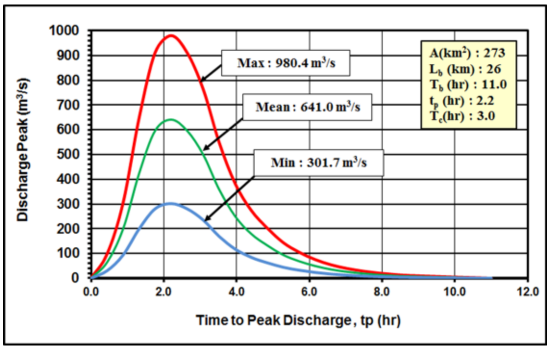
Wadi Shuwayki



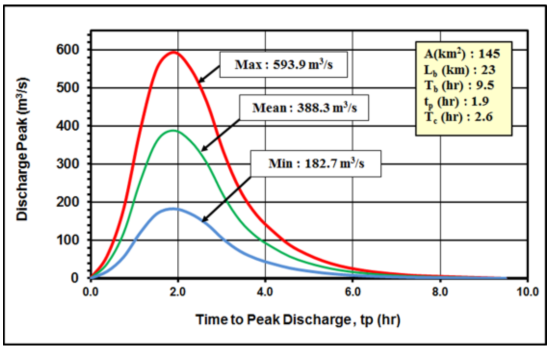
Wadi Awja



Wadi Abu Maraki



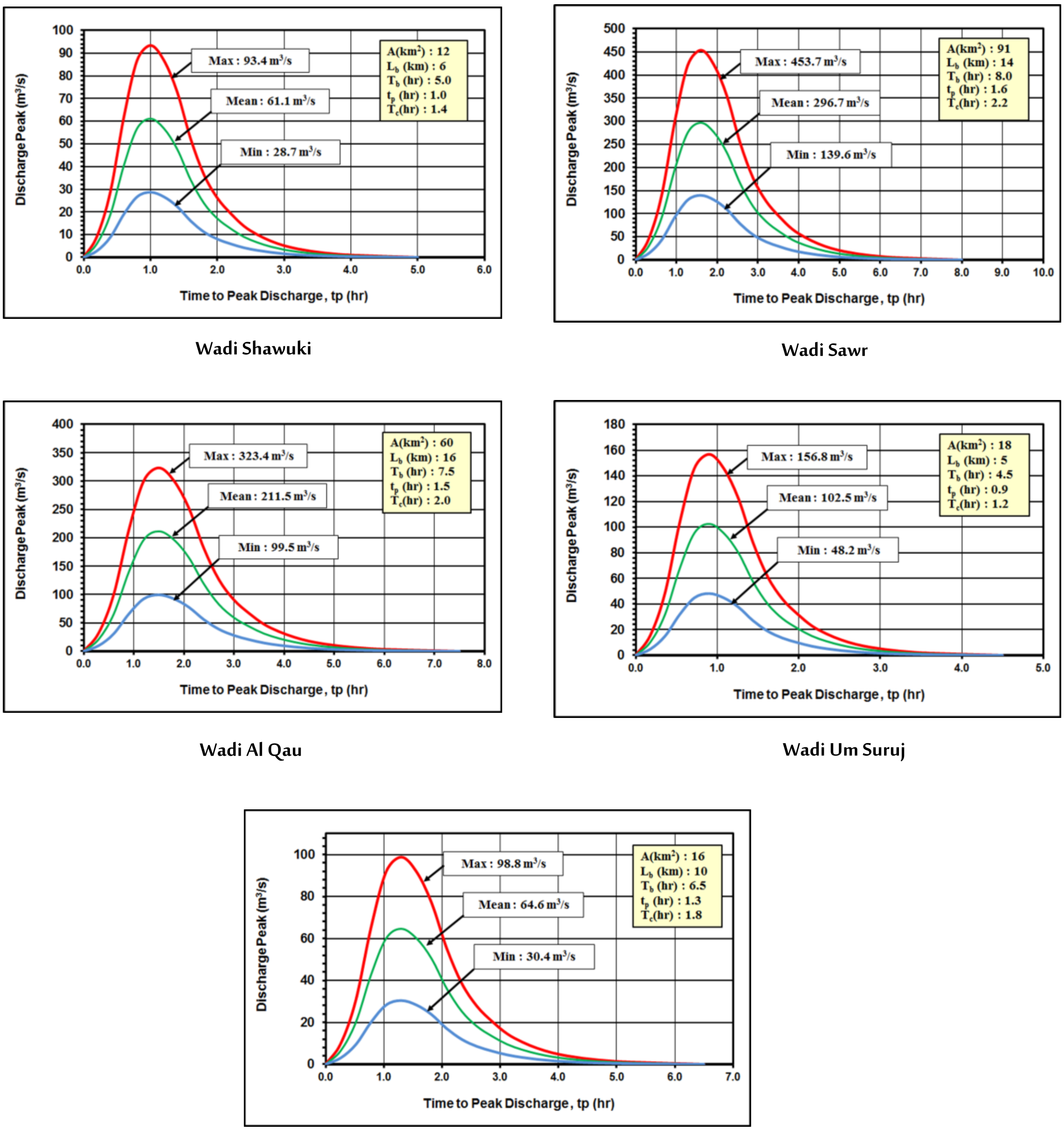
Wadi Aba Al Jirfan



Wadi Al Ertawi

Figure 5 : Snyder's Hydrographs **of the medium watersheds (sample)**

3- Small basins, with a drainage less than 100 km^2. The peak discharge of theses watersheds varies in 16 watersheds from 61.1 m^3/s (Shawuki)) to 286.2 m^3/s (Sawr) (Figure 6).



Wadi Shawuki **Wadi Sawr**

Wadi Al Qau **Wadi Um Suruj**

Wadi Um Nqy

Figure 6 : Snyder's Hydrographs of the small watersheds (sample)

5-2- Developı

The SCS synthetic unit hydrograph is the dimensionless unit hydrograph developed by the soil conservation service. The Synthetic unit hydrographs are developed along two main concepts:

- Every watershed has a unique unit hydrograph.
- All unit hydrographs can be represented by a single family of curves or a single equation.

The table 3 summarized the obtained results. Based on the results summarized in Table 3, the studied watersheds can be classified in 3 groups, using the obtained values of peak flows :

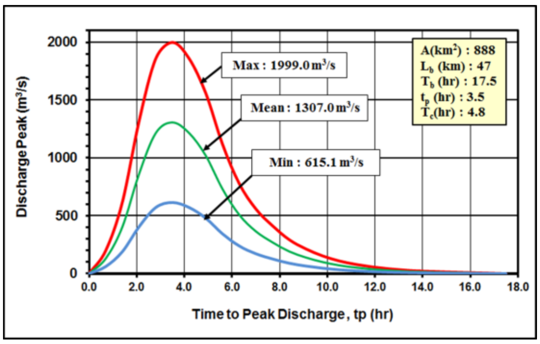
Table 3. Watershed characteristics for generating unit hydrograph (SCS-DUH method)

Wadi watershed	Tc_{aver}	t_b (hr)	T_{Lag} (hr)	T_p (hr)	t_r (hr)	q_p (m^3/s) P: 40mm Q: 8mm	P: 50mm Q: 10mm	P: 60mm Q: 12mm
Khthal	4.8	8.6	2.9	3.2	5.4	482.3	602.9	723.5
Al Hisiki	---	---	---	---	---	---	---	---

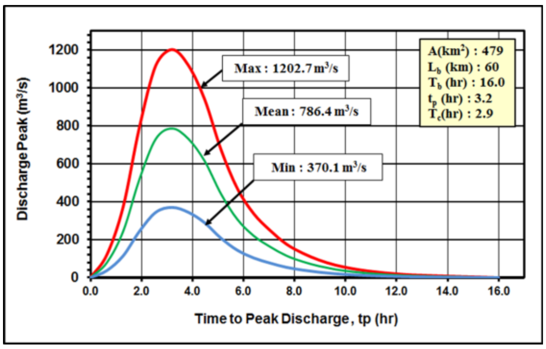
Wadi watershed	Tc_{aver}	t_b (hr)	T_{Lag} (hr)	T_p (hr)	t_r (hr)	q_p (m^3/s) P: 40mm Q: 8mm	P: 50mm Q: 10mm	P: 60mm Q: 12mm
Dukhan	3.2	5.7	1.9	2.1	3.5	210.7	263.4	316.1
Husaykan	1.6	2.8	0.9	1.1	1.8	53.8	67.2	80.6
Abu Maraki	3.3	6.0	2.0	2.2	3.7	152.1	190.1	228.1
Mudaysisat	2.8	5.0	1.7	1.9	3.1	124.3	155.4	186.5
Al Qau	2.0	3.6	1.2	1.3	2.2	74.5	93.2	111.8
Al Tuays	2.4	4.3	1.4	1.6	2.7	98.1	122.6	147.1
Um Suruj	1.2	2.2	0.7	0.8	1.4	36.1	45.2	54.2
Aba Al Hayyas	2.3	4.1	1.4	1.5	2.5	100.6	125.7	150.9
Al Sehel	4.3	7.7	2.6	2.9	4.8	277.2	346.5	415.7
Umm Buul	2.9	5.2	1.8	2.0	3.3	151.3	189.1	226.9
Fuwayliq	5.3	9.5	3.2	3.6	5.9	363.6	454.4	545.3
Aba Al Jirfan	3.0	5.4	1.8	2.0	3.4	225.9	282.4	338.9
Hawaya	2.6	4.7	1.6	1.7	2.9	50.4	63.0	75.6
Um Al Rilan	1.4	2.5	0.8	0.9	1.5	61.4	76.8	92.2
Ab Al Thrran	1.7	3.0	1.0	1.1	1.8	66.2	82.7	99.2
Ramaylan	2.6	4.6	1.6	1.7	2.9	120.2	150.3	180.3
Khadra	4.5	8.0	2.7	3.0	5.0	455.9	569.9	683.9
Duughaymiyah	4.8	8.6	2.9	3.2	5.4	460.7	575.8	691.0
Sawr	2.2	3.9	1.3	1.4	2.4	104.6	130.7	156.8
Tuaysn	2.3	4.1	1.4	1.6	2.6	100.9	126.1	151.3
Awja	2.8	4.9	1.7	1.8	3.1	98.0	122.5	147.0
Um Nqy	1.8	3.1	1.1	1.2	2.0	22.8	28.5	34.1
Al Suhyra	1.8	3.2	1.1	1.2	2.0	28.0	35.0	42.0
Al Shawuki	1.4	2.5	0.8	0.9	1.5	21.5	26.9	32.3
Al Shuwayki	3.5	6.3	2.1	2.4	3.9	262.8	328.5	394.2
Duwayhi	1.7	3.0	1.0	1.1	1.9	31.4	39.3	47.1
Um Shifallah	2.7	4.8	1.6	1.8	3.0	123.7	154.6	185.6
Al Ertawi	2.6	4.7	1.6	1.8	2.9	136.9	171.1	205.3
Al Nasiryah	1.3	2.3	0.8	0.9	1.5	55.5	69.3	83.2
Al Bid	3.1	5.5	1.9	2.1	3.5	180.9	226.1	271.4
Wguain	3.2	5.6	1.9	2.1	3.5	203.8	254.7	305.7

Using the data of the table 3, the total of the watersheds were classified using drainage area to analyze the spatial distribution of the SCS-DUH peak discharge :

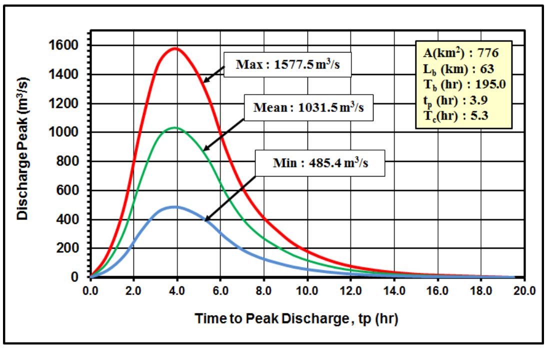
1- Large basins, with a peak discharge ranged from 277.2 m^3/s (Wadi Al Sehel) to 723.5 m^3/s (Wadi Khthal). (Figure 7).



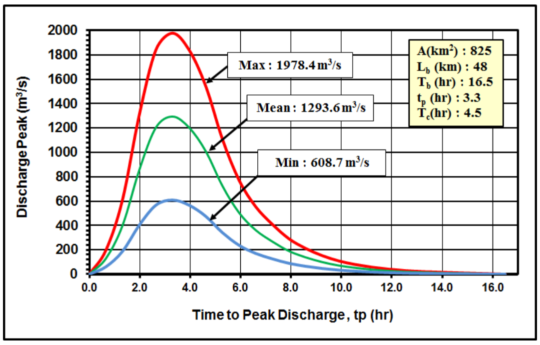
Wadi Dughaymiah



Wadi Sehel



Wadi Khadra



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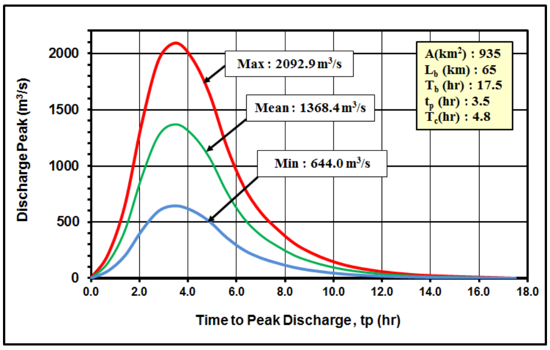
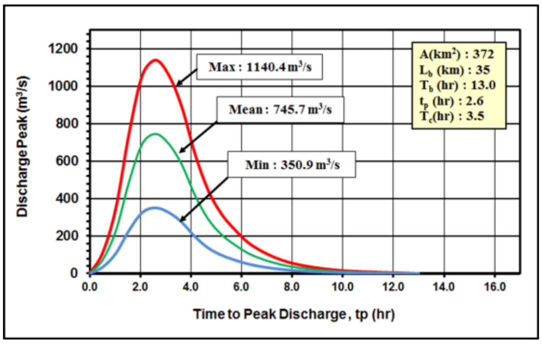


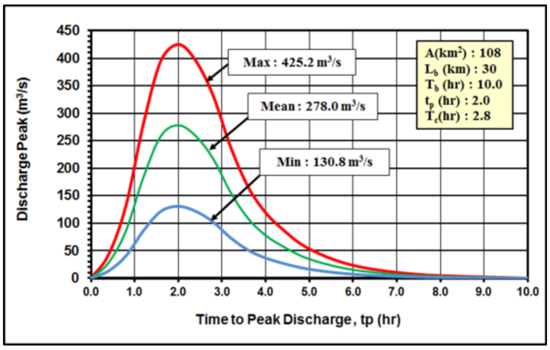
Wadi Khthal

Figure 7 : SCS-DU Hydrographs of the largest watersheds

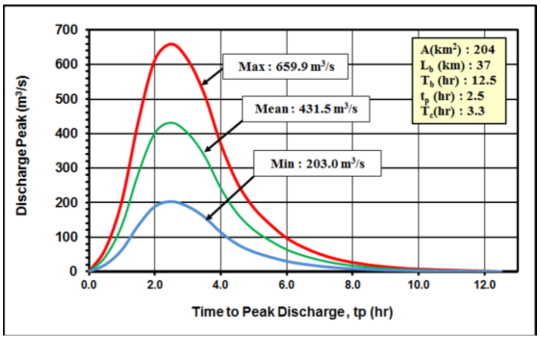
2- Medium basins, with a peak discharge ranged from 98.0 m^3/s (Wadi Awja) to 262.8 m^3/s (Wadi Al Shuwayki) (Figure 8).



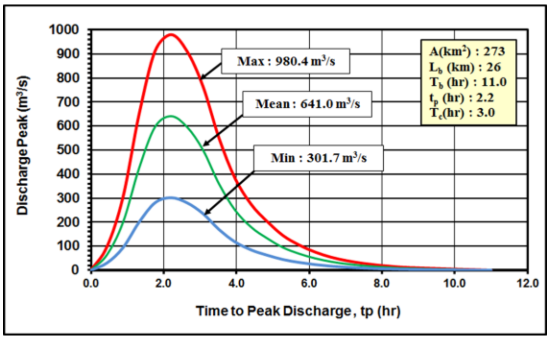
Wadi Shuwayki



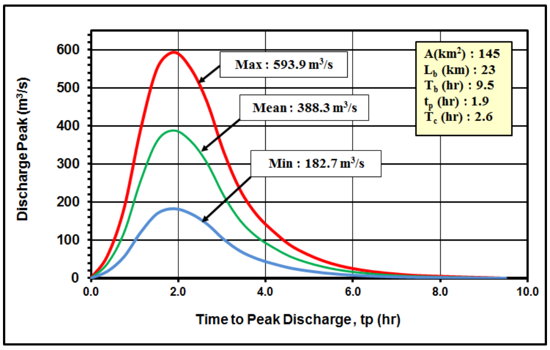
Wadi Awja



Wadi Abu Maraki



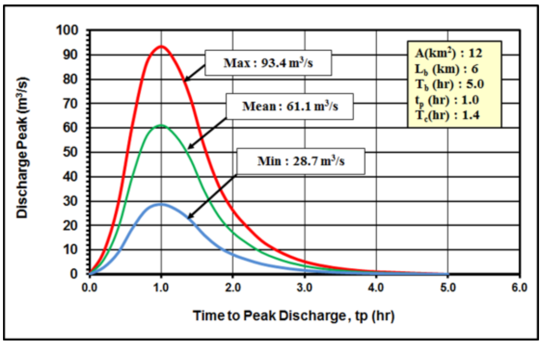
Wadi Aba Al Jirfan



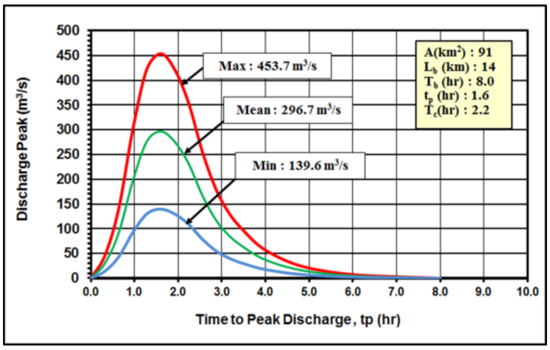
Wadi Al Ertawi

Figure 8 : SCS-DU Hydrographs of the medium watersheds (sample)

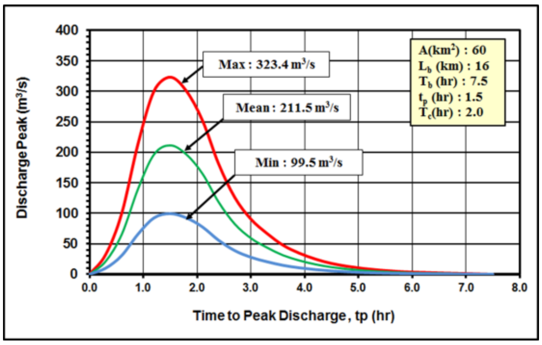
3- Small basins, with a peak discharge ranged from 21.5 m^3/s (Wadi Al Shawuki) to 100.9 m^3/s (Wadi Tuaysan) (Figure 9).



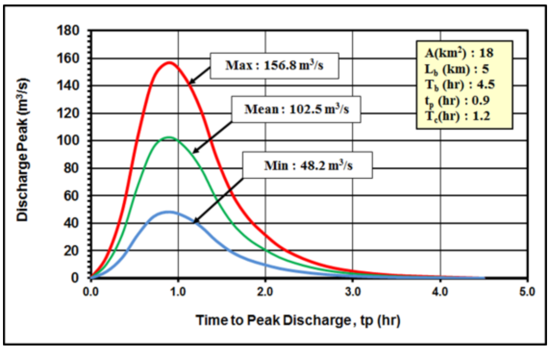
Wadi Shawuki



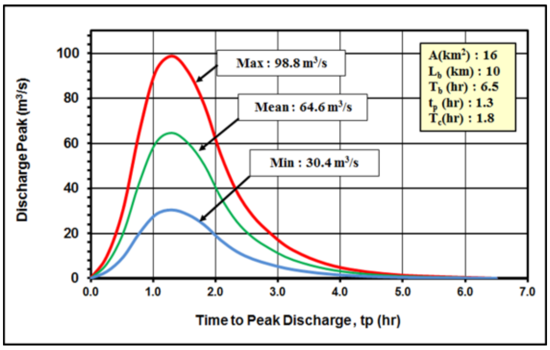
Wadi Sawr



Wadi Al Qau



Wadi Um Suruj



Wadi Um Nqy

Figure 9 : SCS-DU Hydrographs of the small watersheds (sample)

The average peak flows obtained with the Snyder model are 64.8%, 55.9% and 47.1% greater compared the corresponding peak flows determined by the SCS-DUH model deriving from the storms 40, 50 and 60mm respectively. The differences in the efficiency of the performance of the two models do not clearly reflect the ability of the watersheds to quickly convert rainfall into surface runoff. Therefore, it is better to use the peak discharge per unit of watershed area (q'_p) to determine the watersheds most capable of converting the rainfall into surface runoff (Figures 10 & 11).

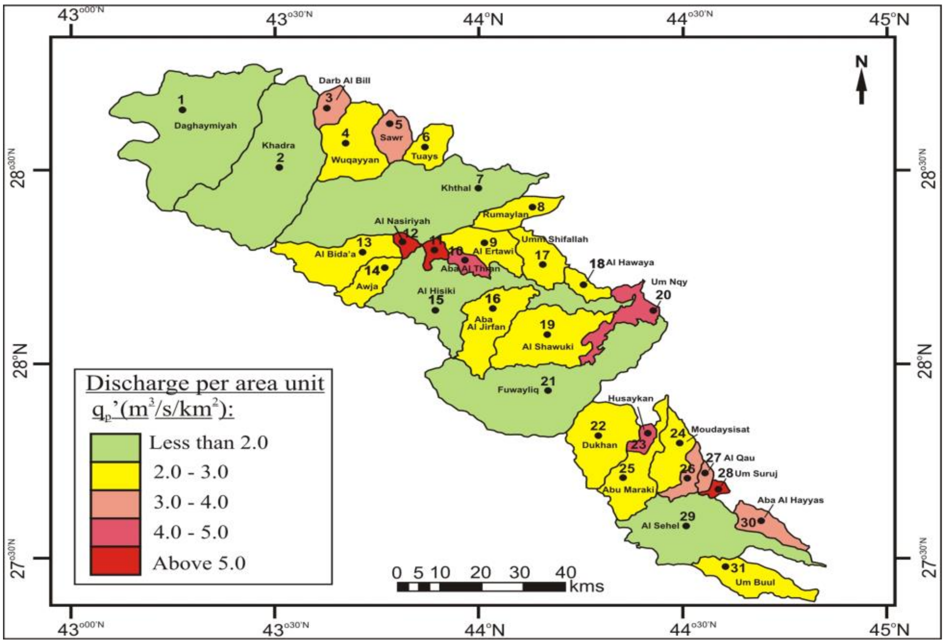


Figure 10: Spatial distribution of the discharge per area unit (Snyder's model) in the watersheds of At Taysiyah plateau.

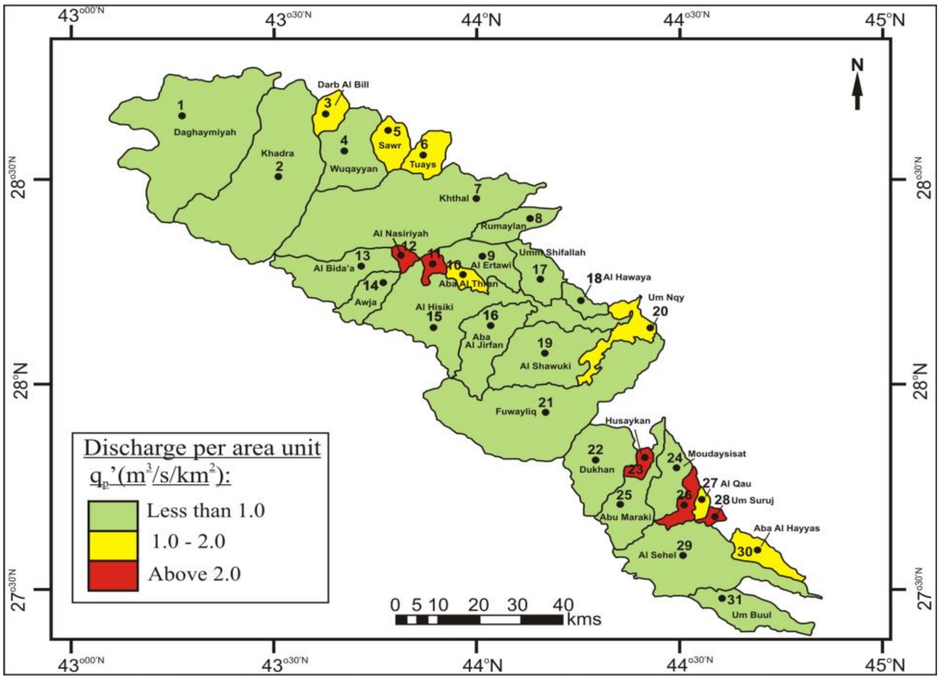


Figure 11 : Spatial distribution of the discharge per area unit (SCS-DUH model) of the storm 60mm in the watersheds of At Taysiyah plateau.

In addition, the variation in the spatial distribution of the mean discharge, the significance value of Kolmogorov-Smirnov test for the SCS-DUH (60 mm) and the average of Snyder's model is 0.028 and 0.033 with 33 degrees of freedom, respectively. Therefore, the data distribution of the discharge per area unit in the watersheds is different than the normal distribution.

Conclusion

Among all available models for runoff simulation in ungauged catchments, the Snyder's method and the SCS-DUH are widely used in hydrologic studies. However, the main difficulty of Snyder's method difficulty is the derivation of necessary coefficients (C_t and C_p). If this problem can be solved, this method can considered to be effective for runoff simulation in ungauged arid catchments such as the selected watersheds of Al Taysiyah plateau in Saudi Arabia.

The purpose of the research was to analyze the possibility of using the two models Snyder and SCS-DUH to determine design hydrographs in watersheds of Al Taysiyah plateau. So, the results show the Snyder's peak discharge less than 300 m^3/s in 16 watersheds with a drainage do not exceeding 100 km^2, from 300 to 750 m^3/s in 12 watersheds extended on drainage from 10 to 380 km^2 and above 750 m^3/s in 5 watersheds with a drainage area more than 470 km^2. In the other hand, the peak discharge of the SCS-DUH model for the storm 60mm do not exceed 100 m^3/s in 14 watersheds. It varies from 100 to 200 m^3/s in 10 watersheds, from 200 to 300 m^3/s in 5 watersheds and above 300 m^3/s in 4 watersheds.

Considering the obtained results, it was found that these two models can provide a suitable alternative to estimate the peak discharge in ungauged arid watersheds over Saudi Arabia. Evaluation of the efficiency of the two models may be available when actual data of runoff measurements are available in any watershed. The derivation of Snyder's coefficients can be also obtained using actual runoff data. Practical verification will be possible by using many statistical analysis and comparing them with the corresponding results obtained with other methods or with observed ones.

Acknowledgment

The study's targets come in line with the relentless efforts made by the Imam Turki bin Abdullah Reserve Development Authority in managing this reserve, as it exerted tremendous efforts through which it sought to re-develop environment in an attempt to bringing it to its fertile past again when the environmental-balance was dominant in all its parts.

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