Applicability of Hydrologic Modeling in Semi-Arid and Arid Region. Case Study : Wadi El-Melaha, Sinai, Egypt

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Abstract – *In arid and semi-arid regions, the problem of floods indicates the necessity for seeking ways to establish a relationship between the characteristics of basins and the occurrence of floods, by determining the factors influencing the hydrograph of these basins, and then accurately predicting the size and shape of these hydrographs in order to warn of floods; in relation to their time or intensity, or to design protection workings. In addition, rainfall-runoff process is complex and non-linear, so estimating rainfall-runoff is an important process for flood estimation. Moreover, the historical flow records are not available; it becomes necessary to use another tool such as hydrologic models that incorporates watershed characteristics to predict flow rates and the volume of runoff for the watershed. So, the purpose of this study is to investigate the applicability of hydrologic modeling in arid and semi-arid regions to simulate rainfall-runoff through the employing of HEC-HMS model using soil conservation services (SCS) curve number (CN) and SCS unit hydrograph (UH). Wadi El-Melaha was chosen in this study for two reasons: first, Wadi El-Melaha is a sub-basin of Wadi Sudr, which is an experimental catchment established by the Water Resources Research Institute (WRRI) in Sinai as part of an extensive monitoring effort to improve the understanding of the hydrologic processes in Sinai's arid and semi-arid basins. Second, this Wadi has rainfall and runoff data of two different storms that happened in two different years 1994 and 2011.*

Key Words: Wadi El-Melaha, Surface Runoff, Arid and Semi-Arid, Hydrologic model , HEC–HMS, SCS unit hydrograph.

1. INTRODUCTION

Storms and floods are a normal and inevitable part of climate variability that must be managed. We may not always control floods. Therefore, we should learn how we may deal with them while minimizing risks to human lives and infrastructure.

Flash floods are especially common in mountainous areas, where rapid snowmelt or heavy rainfalls are quickly transformed into runoff.Rainfall-runoff relationship performs a necessary role in a lot of aspects of catchment area management.The researchers hydrological are always seeked to establish (simulated hydrogragh and observed hydrogragh) models (1),Clarke R.T(2) and Ambroise B. (3), this models may be assorted into two objects: (kinematic or dynamic) and (empirical or conceptual).

The chosen any model builds on the catchment area and the objective of the hydrological forecast in this basin.The conceptual approach, in this study, is adopted for this models, we use a semi distributed hydrologic model of HEC-HMS (Hydrologic Engineering Center- Hydrologic Modeling System), which was developed by US Army Corps of Engineers in order to investigate the rainfall-runoff interactions in the semi-arid.

Alot of researchers have peformed great models using HEC-HMS program, which have achieved great results btween simulate and observed flow. Such as, Sintayehu L.G. emploied HEC-HMS program using Snyder unit hydrograph and exponential recession method for simulating the stream flow of upper blue Nile river Basin (4).

Norhan A. and al. used rainfall-runoff relations by HEC-HMS in arid area at wadi alaqiq in Saudi Arabia, (5). Sampath modeled the rainfall-runoff relations using HEC-HMS in tropical watershed in Sri Lanka (6). F. Meiling W. and al. used the HEC-HMS to simulate runoff in the semi-arid region of northwestern China (7). Laouacheria F. and Mansouri R. used HEC-HMS program by employing Frequency Storm to simulate the runoff in a small urban watershed in the North East .

Figure 1 shows the regions suffering from flash floods in Egypt and Wadi El-Melaha (research case study) is one of these regions.

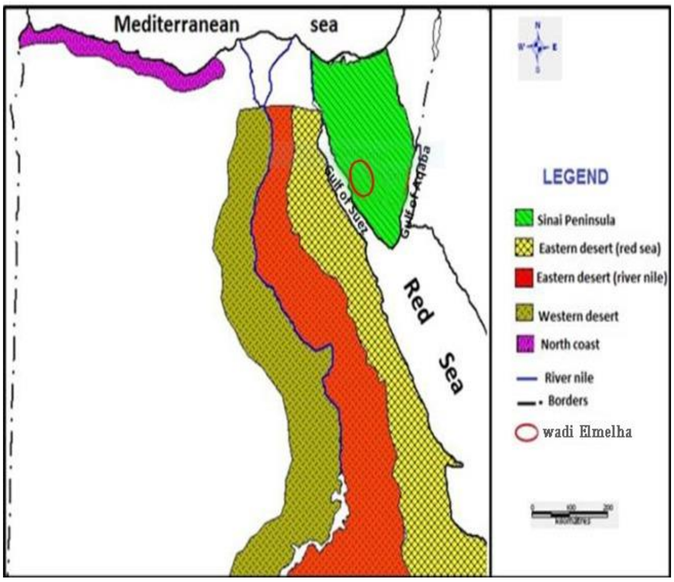

Fig -1: The regions suffering from flash floods in Egypt and Wadi El-Melaha.

A lot of scientists have used many models such as rainfall-runoff relationship, that trial to find simulated hydrogragh and observed hydrogragh. A lot of researches is being done in order that, rainfall-runoff prediction (Singh 1995). On the other hand, flash floods are a poorly understood phenomenon (Lin, 1999) and though it is difficult to control floods, yet it is possible to minimize its risks to human lives and infrastructures.
Over the last few decades, a large body of knowledge has been developed about the hydrological processes in arid and semi-arid environments (Yair and Lavee, 1985; Schick, 1988; Abrahams et al., 1988). Rainfall-runoff numerical models have become widely recognized as tools for studying hydrological processes, predicting hydrologic impacts of human activities and assessing available water resources. A large number of such models with different degrees of complexity are available for humid catchments (Singh, 2002).

(Eman A. Hassan, 2007) has created a comparison between the performance of three infiltration methods (SCS curve number, initial/constant, Green and Ampt) with rainfall and runoff data collected on a 450 km^2 catchment area located in the west part of Sinai Peninsula. HEC-HMS model and optimization trials were setup and the, and different objective functions were selected. The calibration process was done including six different objective functions corresponding to runoff volume and peak flow conservation. Finally, the results of calibration and validation described as following:

- Peak-Weighted RMS Error and Time-Weighted RMS Error gave minimum error values for the three infiltration methods.
- Green and Ampt's method ranked the best because of its accuracy in the simulation of runoff volume and peak flow.

(Punit Kumar Bhola and Ashish Singh, 2010) They mentioned that the methods used to calculate the runoff are (SCS-CN Method and (ANN)). Based on the analysis performed in SCS-CN and ANN method.

(Haitham Saad et al, 2013) used (FORM) in order to investigate the effect of the uncertainty of CN and Tlag. From the investigation, it was ensured that the method of SCS-CN is greatly indefinite when the rainfall average value is low. Egypt is the research case study and they used actual values for CN and rainfall data obtained from the data of satellite in order to determine the regions of acceptance of the SCS-CN method.

Finally, the results showed that SCS -global methodology should be avoided when the variation coefficient of rainfall is low (PCOV < 0.50) and SCS – CN used when the combination of Pmean and PCOV ranges between 0.02 and 0.04.

This paper introduces a methodology of the rainfall–runoff model, by using HEC-HMS model combined with DEM data, as an input for basin model in semi arid area in order to simulate the discharges for 2 storms 1994 and 2011 in Wadi El- Melaha , Sinai , Egypt. The purpose of this study is to investigate the applicability of hydrologic modelling in arid and semi arid areas to simulate rainfall-runoff through the employing of HEC-HMS model using Soil Conservation Services, (SCS) curve number (CN) and SCS Unit Hydrograph (UH).

2. METHODS AND DATA EXPLANATION

2.1Rainfall Precipitation

Rainfall time-series data are collected from (WRRI) for two diffierent storms 1994, 2011. The recording rainfall gauges are available within the watershed area, one weather station and few storage gauges. However, data from storage gauges will not be considered due to its poor data quality and resolution. Recording rainfall gauges are used to measure the intensity, duration for the watershed. Storage gauges are used to provide a basic data for the determination of the main rainfall for periods of one day or more.

In 2008, some of these gauges were damaged and replaced by digital rainfall gauges. There is only one runoff monitoring stations with water level recorder located at the outlet of the watershed. Figure 2a-b shows the locations of all the rainfall gauges, weathering station, and the water level recorder before and after the year of 2008.

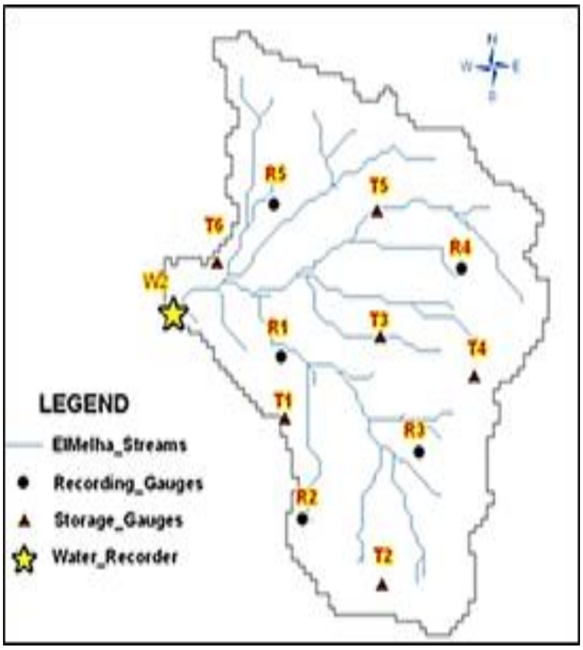

Fig -2-a: Before 2008.

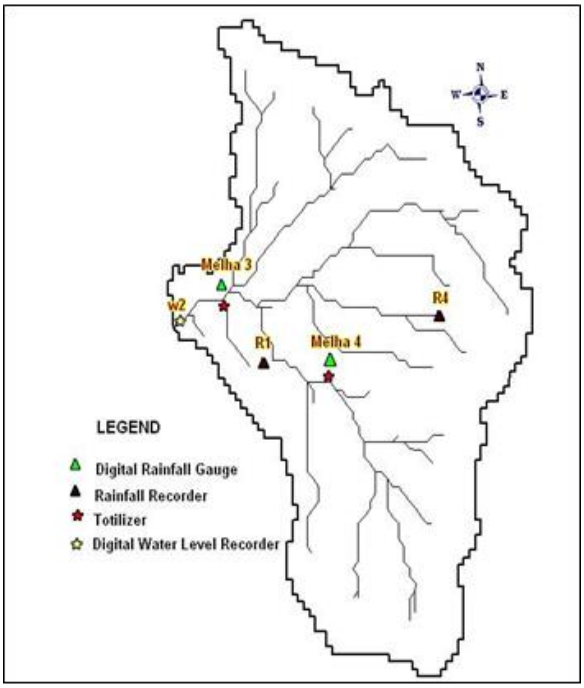

Fig -2-b: After 2008.

2.2 Methods

The objective in this paper is, for examining the (rainfall-runoff) relationship at (Wadi El- Melaha). To achieve the objectives of this research study, the methodology can be separated into main stages:

- Literature review and previous case studies;
- Data collection of rainfall, runoff, field data;
- Explanation the research area (Wadi El- Melaha);
- Explaining streams, and catchment Properties using WMS program;
- Explaining land use and soil properties of the basin, to conclude the curve number (CN);
- Explaining the Lag time using WMS program;
- Using available data to find simulated hydrogragh and observed hydrogragh;
- Comparison and done Calibrate for this model.

2.3 Explanation the Research Area

Wadi El-Melaha is a sub-basin of Wadi sudr which is considered one of the south-west Sinai wadis and covers a total area of about 600 km^2 and it drains directly in Gulf of Suez at Sudr town as shown in figure 3.

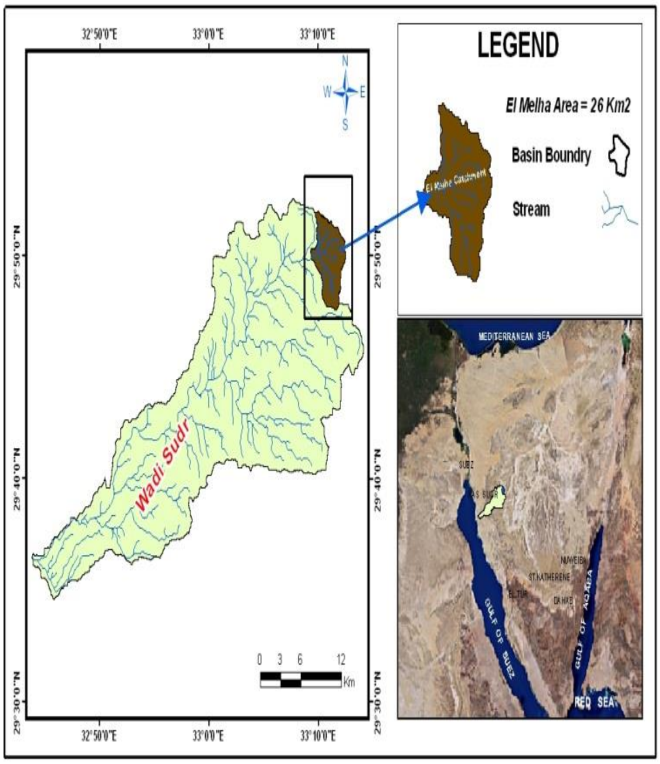

Fig -3: The general layout of wadi Sudr and wadi El Melha

Wadi El- Melaha covers an area of about 26 km^2, and extends between latitudes 29° 52' 30" and 29° 47' 30" N, and longitudes 33° 08' 30" and 33° 12' 30" E. Wadi Sudr is monitored by Water Resources Research Institute (WRRI) for Rainfall and runoff measurements since 1989 till now. The Basin slope is computed from Digital Elevation Model (DEM) by using the surface analysis tool available in Arc GIS software. It ranges from (0) degree to (87.4) degree, as shown in figure 4. The slope classes according to Canadian system of soil classification, 3rd edition, 1998.

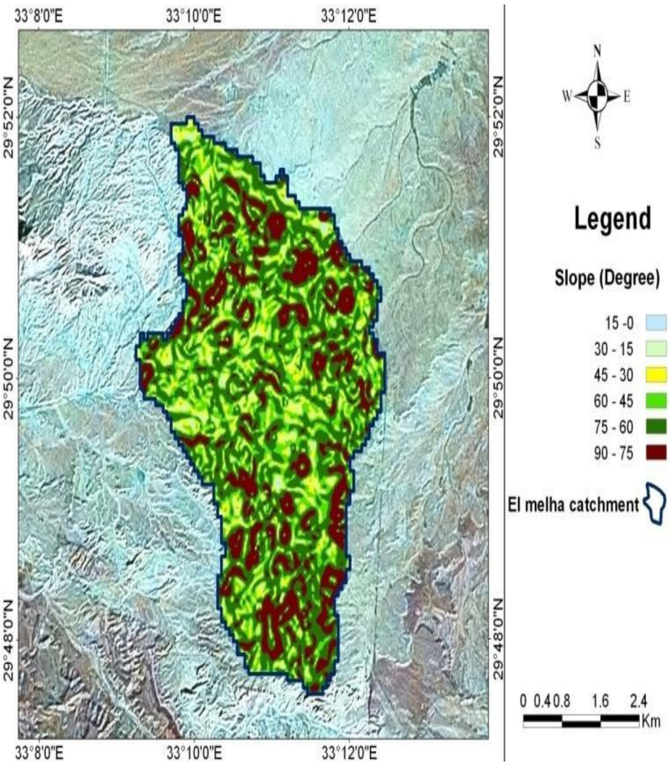

Fig -4: The slope map for El- Melaha Catchment

2.4 Topography of Wadi El- Melaha

The study area (Wadi El-Melaha) is located in the west central part of the Sinai Peninsula. Wadi El Melaha is one of the main sub catchments of wadi sudr which is considered one of the main wadis in Sinai peninsula wadis group draining to the gulf of Suez in the west, this region is characterized by rocky terrain with high mountains peaks spreaded, which are considered part of south

Sinai mountains, such as Gabal El – zarafa peak (686m), Gabal Al Disa peak (681 m) and Gabal Al Risha peak (528 m), and also high plateaus, such as El Tih plateau where study area is considered part of the western edge for this plateaus. These mountains and high plateaus cut a network of drainage water represented in the collection of old dry wadis fulled by water when heavy rains occur causing flash floods(WRRI 2010)

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The max elevation of the wadi is 575 m at the first reaches at Ras el-Gindi (old Fort) and reduces as we headwest until reaching an elevation of 470 m near the outlet of the wadi, as shown in figure 5. Table -1 shows The properties of wadi El-Melaha.

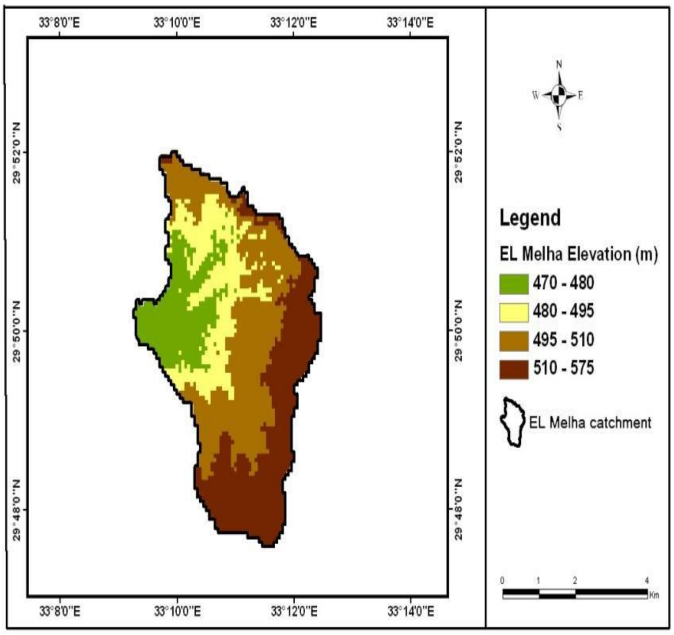

Fig -5: Digital Elevation Model for El –Melaha Catchment

2.5 Geology of Wadi El- Melaha

The geological properties of the study area have an good role in the surface water in addition groundwater studies. Surface water losses are variable from one area to another according to the geological units covering the area. On the other hand, the ground water movement and direction depend on the geological characteristic of the area. The tertiary's rocks cover most of the study area, especially Sudr formation which covers the catchments and thalwegs of Wadi El- Melaha. The geological units of the area in figure 6 range from Quaternary to Upper Cretaceous. Sudr Formation (Cretaceous- Paleocene) white to pale grey chalk, marly near the top fossiliferous.

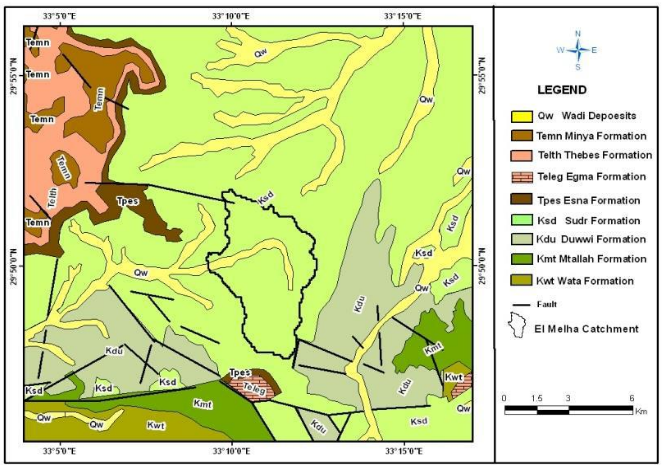

Fig -6: The superficial geological map showing the distribution of different soil types in Ras Sudr region.

2.6 Soil Properties of Wadi El- Melaha

Over 95% of the watershed area is desert land, and the rest of the area is bush land as shown in figure 7. The land use of the basin is obtained by digitizing the rigions boundaries from satellites images and according to the classification of the land use (Chow et al., 1988, and Hasanein 1989), it included Alluvial, Sandstone, Limestone and Basement rocks. Figure 8 Pictures show some features of wadi El-Melaha.

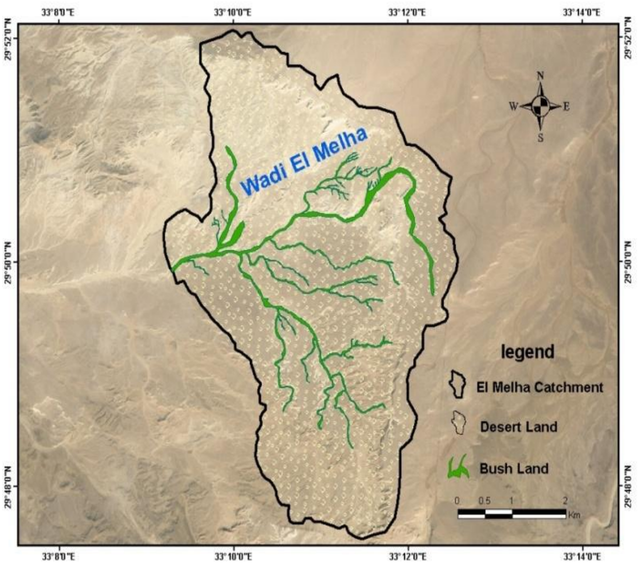

Fig -7: The land use map for El- Melaha catchment

Fig -8: Pictures show some feature of wadi El-Melaha

Table -1 : Characteristics of wadi El-Melaha

Characteristics	Description
1- Location	S-W of Sinai
2- Origin	Gable EL-Raha and Somar
3- Outlet	W. El-Melaha and Gulf of Suez
4- Surface Geology	Limestone; Upper Cretaceous; Cenomanian
5- Area (km^2)	26
6- Length (km)	5.5
7-Slope %	1.8

2.7 Climatic

The climate in Sinai Peninsula similar is characterize as desert area that includes extreme aridity, long hot rainless summer and mild winter. During the winter season some areas had high intensity rainfall that causes flash floods.Most rainfall is falling during the period from December to May. The rainfall in this region is subject to the influences of the Red Sea, Indian Ocean and the Mediterranean Sea. Because the study area is located in the west-central Sinai Peninsula, it’s affected by the Mediterranean Sea due to the Northern weather conditions and the red sea and Indian Ocean due to the southern weather conditions. Also, the Observed rainfall characterized with short duration and high intensities events.

3. HYDROLOGIC MODELING SYSTEM (HEC-HMS)

3.1Model Description

Both hydrological models; HEC-1 and HEC – HMS were used in this research but HEC-1 was used through WMS. These models are available in WMS as separate models and it classified as lumped models. HEC-HMS has a different simulation option than HEC-1 such as optimization option.
HEC – HMS model includes different methods to define the design storm such as (Gage Weights, SCS Storm, Specified Hyetograph…etc.). In addition to these options, it has different losses Hydrological model simulation estimation methods such as; SCS curve number, Initial and constant, etc. For runoff simulation, many unit hydrograph methods can be used such as; Clark UH – Kinematic Wave – SCS UH – Snyder UH – Mod Clark, etc. Finally, HEC – HMS has two techniques for flood routing; reach and reservoir routing.

Kinematic wave and Muskingum Cunge are among the methods to represent reach routing and it can be used to adjust the lag time of the result hydrographs and its peaks. Finally, the SCS unit hydrograph (UH) method will be used in this paper to calculate the observed flow. More over the SCS Curve Number (CN) method will be used to determine the losses rate and the simulating process will be done by using real storm form the data.

3.2 Data Preparation

The Hydrological model was built using HEC-HMS software and all the input data were prepared, such as the geometric characteristics of Wdi El-Melaha, rainfall data, runoff data, CN and Lag time. HEC-HMS model is applied to El- Melaha watershed using 2 real storms that took place in 1994 and 2011. Figure (9) shows the rainfall distribution during these two storms.

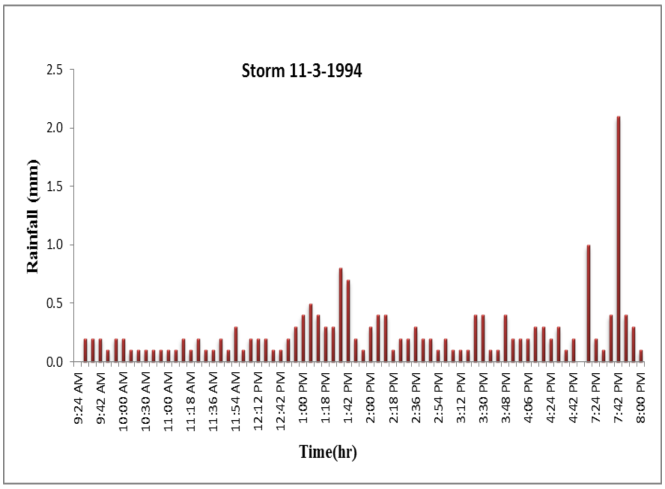

Figure -9-a Rainfall distribution storm 11-3-1994.

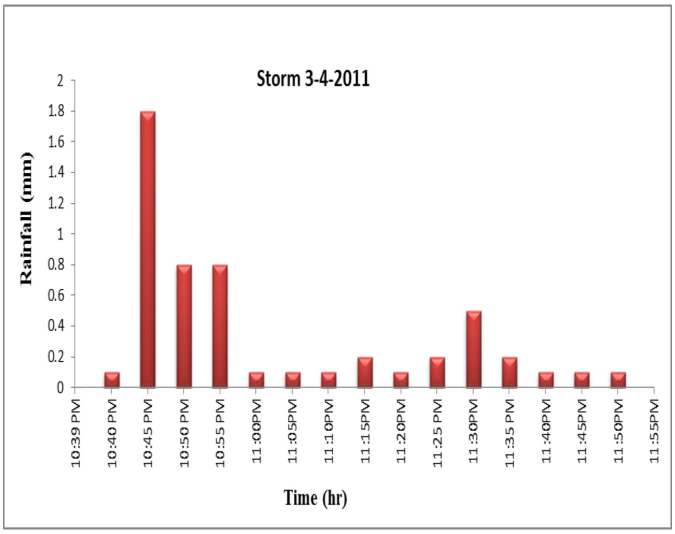

Figure -9-b Rainfall distribution storm 3-4-2011.

3.3 Infiltration

Soil sampling for infiltration estimate has been done in different site in Wadi El –Melaha, as shown in figure 10. The Criteria of soil samples selection are based on the watershed surface geology (Hasanein A. M.1989) . This wadi consists of two geological units: wadi deposits and sudr formation, as shown in figure 10. Samples are taken at two different depths; 30 cm and 60 cm. Sieve analysis and soil classification are carried out for all samples. The infiltration data is analyzed to estimate Green and Ampt parameters to establish a preliminary model setup (ogden and Saghafian, 1995).

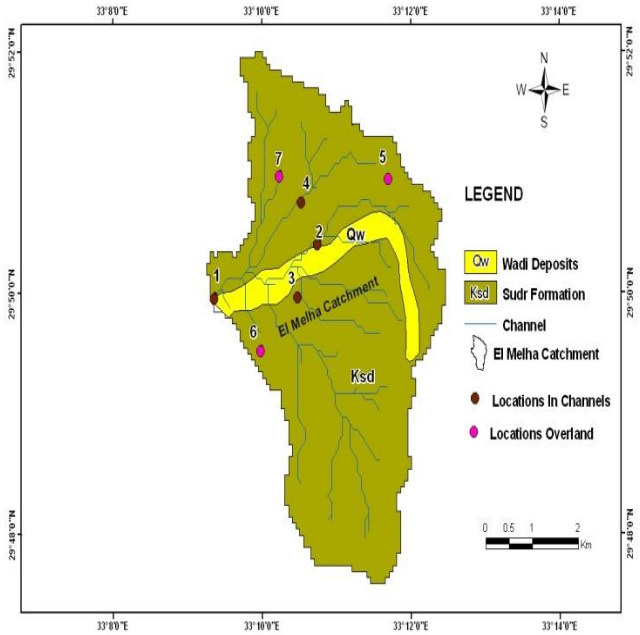

Fig -10: Location of infiltration sites in EL-Melaha catchment.

3.4 Loss Method SCS Curve Number (CN).

It handled the estimation of rainfall losses and represents one of the main inputs to the hydrological model, so the next paragraphs describe the methods for determination these inputs. First (about rainfall losses), the SCS Curve Number method was used for estimating these losses. For the application of this method, Soil Conservation Service (SCS) (1972) developed a method for computing rainfall losses as shown in the next equations and figure 11.

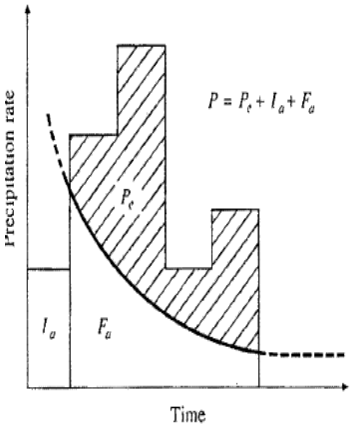

FIGURE 5.5.1
Variables in the SCS method of rainfall abstractions: I_a = initial abstraction, P_e = rainfall excess, F_a = continuing abstraction, P = total rainfall.

Fig -11: Schematic of the abstraction from rainfall storm (Chow et al, 1988).

There is some amount of rainfall called initial abstraction (Ia). When there is no runoff, the runoff is P - Ia. The approximation of the method equals the ratios between the two potential quantities, as shown in the next equations:

$$\frac{Fa}{S} = \frac{Pe}{P-Ia} \quad (1)$$

From the continuity principle

$$P = Pe + Ia + Fa \quad (2)$$

Combining (1) and (2) to solve for Pe gives

$$P_e = \frac{(P-Ia)^2}{P-Ia+S} \quad (3)$$

P: Areal Average Precipitation.

I_a: Initial abstraction.

P_e: Depth of excess rainfall or direct runoff.

Fa = continuing abstraction,

S: potential maximum retention.

Equation (5) is the essential equation for computing the depth of rainfall excess. By studying many small experimental catchments, an empirical relation is created.

$$Ia = 0.2s \quad (4)$$

On this basis

$$P_e = \frac{(P-0.2\,S)^2}{P+0.8S} \quad (5)$$

The curve number and S are related by

$$S = \frac{1000}{CN} - 10 \quad (6)$$

Plotting the data for P and Pe from many watersheds, the SCS found curves of the type shown in Figure 12. This figure shows CN relationship with cumulative rainfall and runoff and it is defined as 0 < CN < 100 .

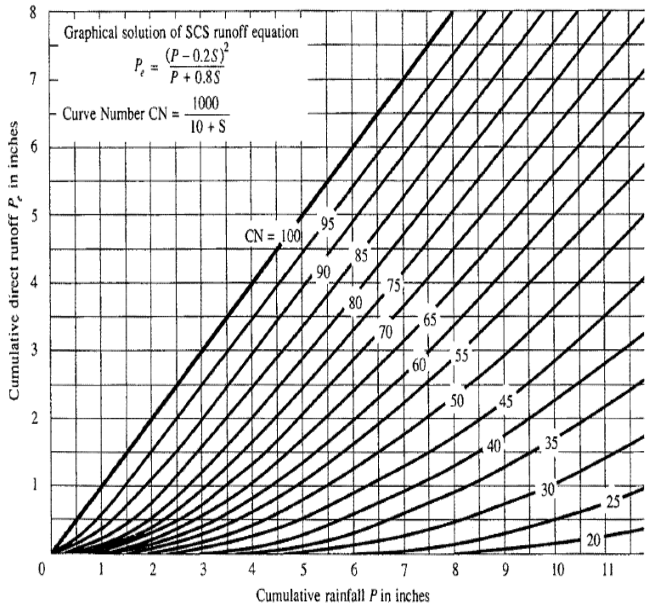

Fig -12: CN relationship with cumulative rainfall and runoff (Chow et al, 1988).

Applying curve number method requires defining the soil type and land use. Therefore soils could be classified into four groups A, B, C and D, depending on the infiltration rate and other properties. Here is a short description of the four hydrologic soil groups:

- Group A: this group is classified as Deep sand and aggregated silts. These soils have high infiltration rates.
- Group B: this group is classified as sandy loam. These soils have moderate infiltration rates.
- Group C: this group is classified as Clay loams. These soils have low infiltration rates.
- Group D: this group is classified as heavy plastic clays and rocks. These soils have low infiltration rates (Chow et al., 1988).

After that, it should define the condition of the soil according to the type of AMC (I, II, III); where AMC I represents dry condition and CN (I) can be calculated from equation (7); While AMC II represents normal condition and AMC III for wet condition which has highest runoff potential. CN (III) can be estimated from equation (8).

$$CN\,(I) = \frac{4.2CN(II)}{10-0.058CN\,(II)} \quad (7)$$

$$CN\,(III) = \frac{23CN\,(II)}{10+0.13CN\,(II)} \quad (8)$$

Where:

P: Areal Average Precipitation.

I_a: Initial abstraction.

P_e: Depth of excess rainfall or direct runoff.

S: potential maximum retention.

CN (I): Curve number for normal condition.

CN (II): Curve number for dry condition.

CN(III): Curve number for wet condition.

Finally, Curve numbers (CN) are based in this study, as shown in table 2.

Table -2 Calculated CN values for Wadi El-Melaha

storm	CN		Ia
	Type	Trial	
St1994	CN(II)	75,77,79, 80	0.2S
St2011	CN(III)	88,90,93,95	0.2S

3.5 Transform Method

One of several different methods of lag-time computation can be chosen when generating synthetic hydrographs according to the nature of the basin. The lag-time can be given as a function of some geometric, geological, and metrological parameters of the basin as given in the following :

For both storms (1994 and 2011) , the lag time was calculated using both of Denver methods, which recommended in a previous study for wadi Sudr in Sinai (Sonbol, et al., 2005. The equation for computing the lag time by the Denver method is given as follows:

$$TL = Ct * \left(L * \frac{Lca}{sqrt} (s)\right)^{m}$$

Where:
TL : lag-time (hrs.)
L : length of the lo ngest flow distance (m);
Lca : length to the centroid (m) ;
S : slope of the max flow distance (ft/m);
Ct and m are coefficients that depend on the method of calculations.

Ct = 0.163 , m = 0.48

These parameters are calculated automatically by the WMS program after delineating the basin.

For both storms (1994 and 2011), the lag time is also calculated using the SCS Lag-time method. The equation for computing the lag time using the SCS method is given as follows:

$$TL = \frac{(s+1)*0.7}{1900*sqrt(y)}$$

Where:
TL : lag-time (hrs.)

$$S = \frac{1000}{CN} - 10$$

S: potential maximum retention.

L: length to the centroid (ft)
Y: watershed slope in percent.

The summery of calculation results are shown in Table 3.

Table -3 Calculated Lag time values for Wadi El-Melaha

Storm	Method	TL(hr)
St 1994	Denver Method	2.71
St 2011	Denver Method	2.71
St 1994	SCS Method	2.70
St 2011	SCS Method	1.47

3.6 Run Off

Wadi El- Melaha has high-resolution rainfall and runoff measurements. The criteria of selecting storms for this study is based on isolating storm event with high rainfall and resulting in high peak flow rate. A storm event was considered to be over when it had a period of at least 6 hours without rainfall. HEC-HMS was applied on two real storms which took place in 1994 and 2011. Figure 13 shows stage hydrograph at Wadi El –Melha outlet for storm 11-3-1994.

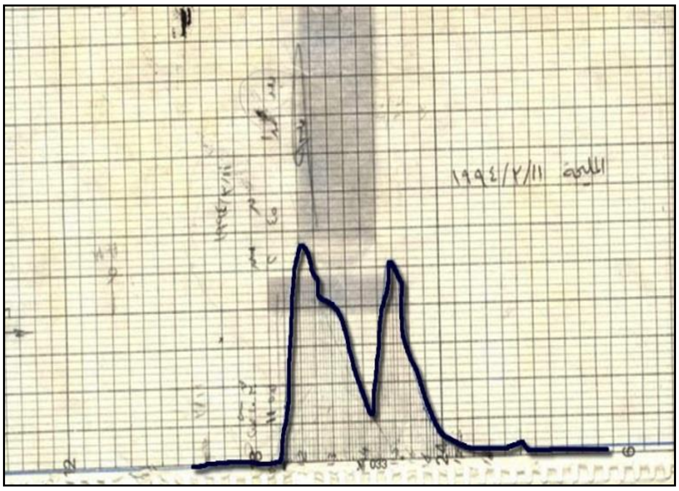

Fig -13 : Water level recorded at the watershed outlet during (11-3-1994) storm

4.RESULTS AND DISCUSSION

HEC-HMS model is applied to Wadi El- Melha using two real storms (1994 and 2011). The output hydrographs of HEC-HMS were compared to the observed flow hydrographs.

4.1 Calibration Process

The calibration process is to adjust the parameters which are used as inputs to the hydrological model such as SCS curve number and the SCS unit hydrograph parameter (lag time). Then these adjusted parameters are used to calculate the runoff values and peak discharge of flood for different storms 1994 and 2011.So the target of this study, is to investigate the applicability of hydrologic modeling to simulate (rainfall-runoff) to choose areal curve number and lag time.

Two real storms took place in Wadi El-Melaha were selected to perform the sensitivity analysis, storms of 11-3-1994 (Double peak) and 3-4-2011 (Single peak).

Model calibration process was used through fourteen methods (first lag autocorrelation, maximum absolute residual, main absolute residual, main squard residual, nash Sutcliffe, peak weighted RMS error, percent error peak, percent error volume, RMS error, RMS log error, sum absolute residuals, sum squared residuals, time weighted error and variance absolute residuals)

The base values that were used in this study are presented in table 4-a. Figures 14 and15 show the comparison between the simulated and observed hydrographs.

The showing of this model is estimated using the Peak Weighted RMS Error . This method gives the best results, which mean a great approval between the simulated and observed hydrographs.

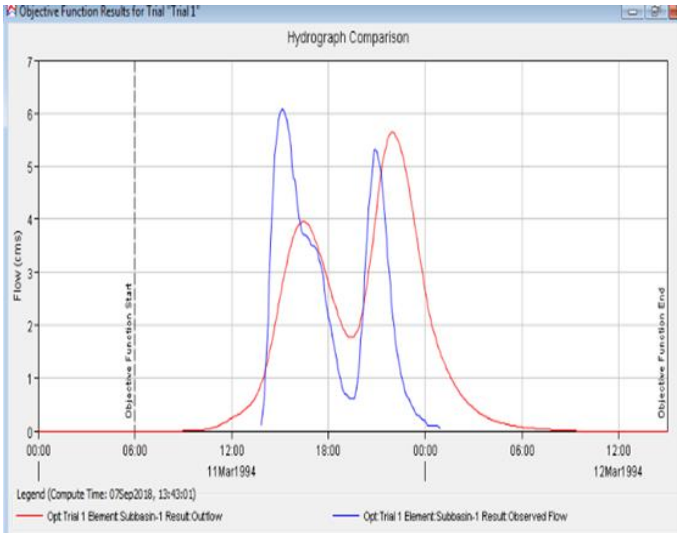

Fig -14-a :Hydrographs of storm (11-3-1994) peak-weighted RMS error methods.

Table -4-a Model parameter values used for sensitivity analysis storm (11-3-1994) peak-weighted RMS error method

`parameter	unit	Initial value	Optimized value	Objective function
Curve Number		77	68.35	-0.64
Lag Time	min	162.6	160.61	-0.89

For 1994 Storm, it was found that the difference between initial and optimized values of the lag time (Denver & SCS) were very close when using Peak Weighted RMS Error method. As forthe 2011 storm, it was found that the difference between initial and optimized values of the lag time were very close by using only the calculated value of lag time from SCS method, while this difference jumped a lot when Denver method was used. By analyzing these results, it can be noted that SCS Lag-time method gave that compatiabilty because its dependency on the Curve Number parameter.

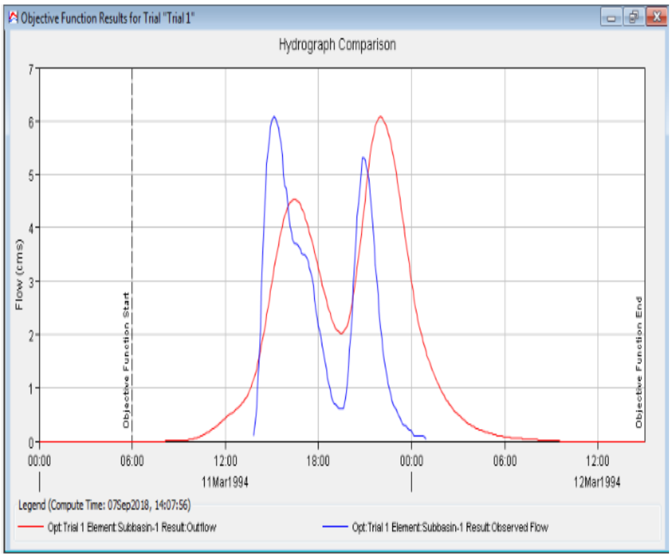

Fig -14-b :Hydrographs of storm (11-3-1994) percent error peak method.

Table -4-b Model parameter values used for sensitivity analysis storm (11-3-1994) percent error peak method.

parameter	unit	Initial value	Optimized value	Objective function
Curve Number		77	69.60	0.78
Lag Time	min	162.6	163.33	0.07

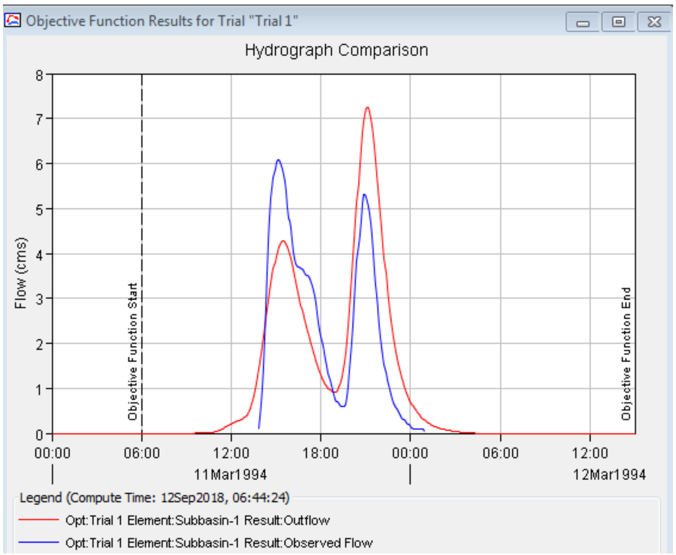

Fig -14-c :Hydrographs of storm (11-3-1994) Nash Sutclitte method.

Table -4-c Model parameter values used for sensitivity analysis storm (11-3-1994) Nash Sutclitte method.

parameter	unit	Initial value	Optimized value	Objective function
Curve Number		77	66.846	4.85
Lag Time	min	162.6	99.98	0.33

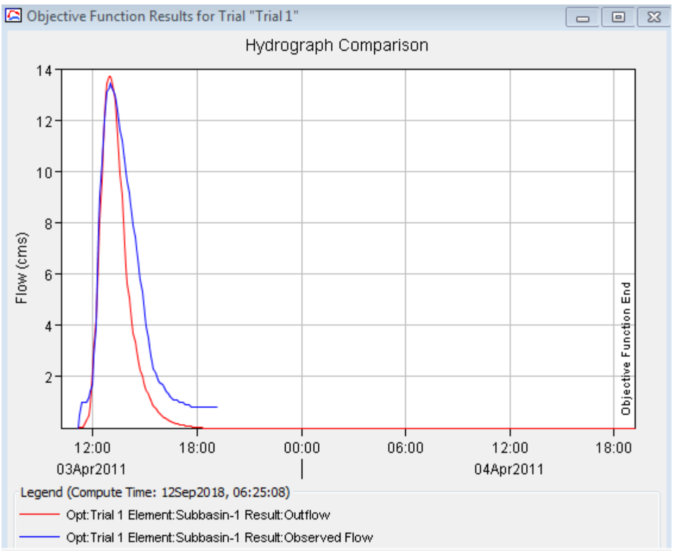

Fig -15-a :Hydrographs of storm (3-4-2011) peak-weighted RMS error methods.

Table -5-a Model parameter values used for sensitivity analysis storm (3-4-2011) peak-weighted RMS error method

parameter	unit	Initial value	Optimized value	Objective function
Curve Number	-	93	99	-23.34
Lag Time(Denver)	min	162.6	75.51	-2.29
Lag Time (SCS)	min	88.2	83.01	-0.14

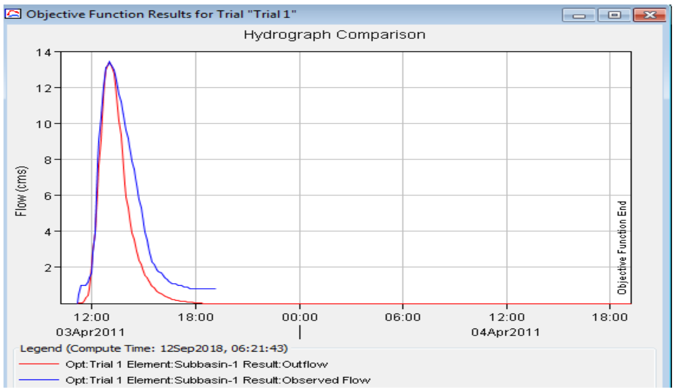

Fig -15-b :Hydrographs of storm (3-4-2011) percent error peak method.

Table -5-b Model parameter values used for sensitivity analysis storm (3-4-2011) percent error peak method.

parameter	unit	Initial value	Optimized value	Objective function
Curve Number		93	99	99.18
Lag Time	min	162.6	75.45	79.98

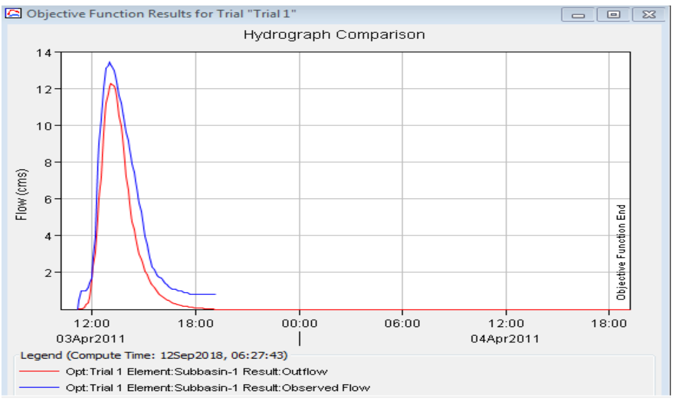

Fig -15-c :Hydrographs of storm (3-4-2011) Nash Sutclitte method.

Table -5-c Model parameter values used for sensitivity analysis storm (3-4-2011) Nash Sutclitte method.

parameter	unit	Initial value	Optimized value	Objective function
Curve Number		93	99	-48.13
Lag Time	min	162.6	85.063	-0.24

5. Conclusions

In this study, HEC-HMS model was used to simulate runoff hydrograph for Wadi El- Melaha outlet. Two real storms had been used to develop and validate the results of runoff hydrograph storms which occurred in 1994 and 2011. In addition to that, DEM data of 30 m resolution was used for this Wadi delineation. Geological, soil type and land use data were used to well-understand the nature of the basin. Moreover, the method of Soil Conservation Services curve number losses was used to determine the study area's hydrologic losses and the method of SCS unit hydrograph which were used for effective rainfall transformation.

The HEC-HMS model was selected because it can investigate the applicability of hydrologic modeling in arid and semi-arid regions, in order to simulate rainfall-runoff through the employing of HEC-HMS model using Soil Conservation Services, Curve Number and SCS Unit Hydrograph.

This model produced good results compared to the observed hydrograph and sensitivity analysis, for the methods of Lag-time (TL) computation and Curve Number were carried out, as shown in Table 6.

Table -6 : Final results for Lag time and curve number

Storm	Lag time(hr)		CN	
	Method	Value	Type	Value
1994	Denver & SCS	2.71	CN (II)	77
2011	SCS	1.47	CN (III)	93

It is recommended to use more rainfall and runoff data in order to apply all the different methods of the unit hydrographs such as (Clark UH – Kinematic Wave – Snyder UH, etc.) to obtain more accurate results.

Finally, the results suggest the possibility of conducting this model on the ungauged basins in arid and semi-arid regions. For future work, it's recommended to work on more verification before generalizing these results on the similar region.

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