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Hydrological Parameters Affecting Flash Floods: Case Study Wadi Al-Baroud El-Abiad, Safaga City, Red Sea Governorate

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Abstract:

Flash flood is one of the most important natural hazards all over the world. It is very dangerous because of its effect on people's lives and can lead to death. So we must be aware of the flash flood by studying the factors that affect it and predict it. In this paper, hydrological parameters that affect flash floods in arid or semi-arid areas are studied. The study area is Wadi Al-Baroud El-Abiad which is located to the northwest of Safaga city on the red sea coast that is frequently subjected to a severe flash flood. Parameters affecting floods are considered i.e. meteorological (climatic), morphological, and geological factors. Climatic data are analyzed to reach the design storm values for different return periods by knowing the annual rainfall values of the study area by using rainfall data from a rain gauge station near the area. In this research, the mean monthly rainfall values of Safaga meteorological station from 1994 to 2018 are used and the annual maximum values of rainfall rates are extracted from it. Digital elevation model (DEM) and digital terrain data of the catchment are obtained from the USGS EathExplorer website and inserted into WMS and ArcGIS software. To obtain the hydrological characteristics such as unit hydrograph, concentration-time, delay time, and storage coefficient, the land use and soil type in the study area must first be determined by the geomorphological and geological study. SCS and curve number methods are used in estimating the soil type and land use of the basin. Many software and tools are used in data analysis and watershed delineation among them, GIS, WMS, SURFER, HYFRAN, GOOGLE EARTH. From this study, watershed morphological characteristics, flood quantity, and flow hydrograph at Wadi Al-Baroud El-Abiad dam are estimated for different rainfall intensity, duration, and return periods. Moreover, the storage capacity of the dam reservoir at different rainfall intensity, duration and return periods is estimated and the time required for storage water to evaporate and infiltrate into the subsurface soil is identified. The results of this research can help the developer, planners, and decision-makers for flood management in arid areas.

Keywords: Flash flood, hydrological parameters, ArcGIS, WMS, Hydrograph curve, water budget.

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1- INTRODUCTION

We suffer from a lack of information on floods due to lack of accurate environmental data, the high variability of rainfall and complex inter-terrain relationships, the nature of the land cover and soil characteristics (Douvinet, 2012). This is why it is important to calculate the amount of water carried by the downpour in the selected basin and how to take advantage of this water and prevent it from damaging the city, property, and lives. There are many scientific researches that studied flash floods, the areas in which they occur, and the factors affecting them because of their great importance in our lives where they have an impact on the facilities and people together among of them (Elnazer et al. 2017; Cools et al. 2012).

The factors affecting the floods vary from one region to another, due to the different nature of the region in terms of the types of valleys, topography, weather factors surrounding the region and the amount of rainfall falling as well as the quality of soil in the valley, so each region is classified separately, although they are in the same country or even the province by examining all the influencing factors.

Egypt is an arid to semi-arid country, it is attacked by flash flood from period to period that affects the coastal and Nile wadi systems (Abdel-Fattah et al.2015).

Destro et al. (2018) and Ma et al. (2019) defined a Flash flood as a huge amount of rains fall in a small catchment with a small area less than 500 km^2 approximately during a short period and occurs suddenly.

There are many researches on the valleys along the red sea such as (Wadi El-Gemal and Wadi Umm El-Abas, Wadi Abu Ghuson …etc.). Abdalla et al. (2014) studied flash floods in these valleys and the hydrological and geomorphologic factors to quantify groundwater recharge. In this article, the researcher recommends the construction of multifunctional dams to take advantage of flash floods and mitigate their effects.

The city of Ras Ghareb is one of the cities of the Red Sea Governorate, which had a sudden flood in 2016, which caused a lot of devastation in the city. The research was carried out on this sudden flood and the intensity of unexpected rainfall and how the impact of hydrological, metrological, and geological factors on the flood. DEM (digital elevation model) and GIS (geographic information system) were used in the study of these factors, where an artificial channel was constructed along a kilometer to collect water and deliver it to the sea coast to protect the city from flooding in the future (Elnazer et al. 2017).

Youssef et al. (2009) studied the importance of geomorphological factors in assessing flood risks through the rules of the GIS program on the Red Sea coast, especially in the area between the cities of Safaga – Quseir. They explained the impact of the flood on the urban areas, tourist villages, and the road network to control the possibility of floods to deal with later.

2- STUDY AREA

The Red Sea Governorate is one of the coastal border governorates of the Arab Republic of Egypt. It has an area of about 118500 thousand km^2, which is equivalent to 1/8 of the area of Egypt. This area extended between latitudes 22^o and 29^o north of the equator. At the east, the Red Sea Governorate bordered by the Red Sea coast of about 1080 km, and is bordered on the west by the governorates (Beni Suef - Minya - Assiut - Sohag - Qena - Aswan) as shown in figure (1).

Many valleys that affect the city of Safaga such as Wadi Abu Jrov, Wadi Safaga, Wadi Gasoos, and Wadi El Baroud El Abiad as shown in Fig. (2). In this paper, we focus on the study of Wadi El Baroud El Abiad and the floods factors affecting it because Safaga city is located at the outlet of this valley.

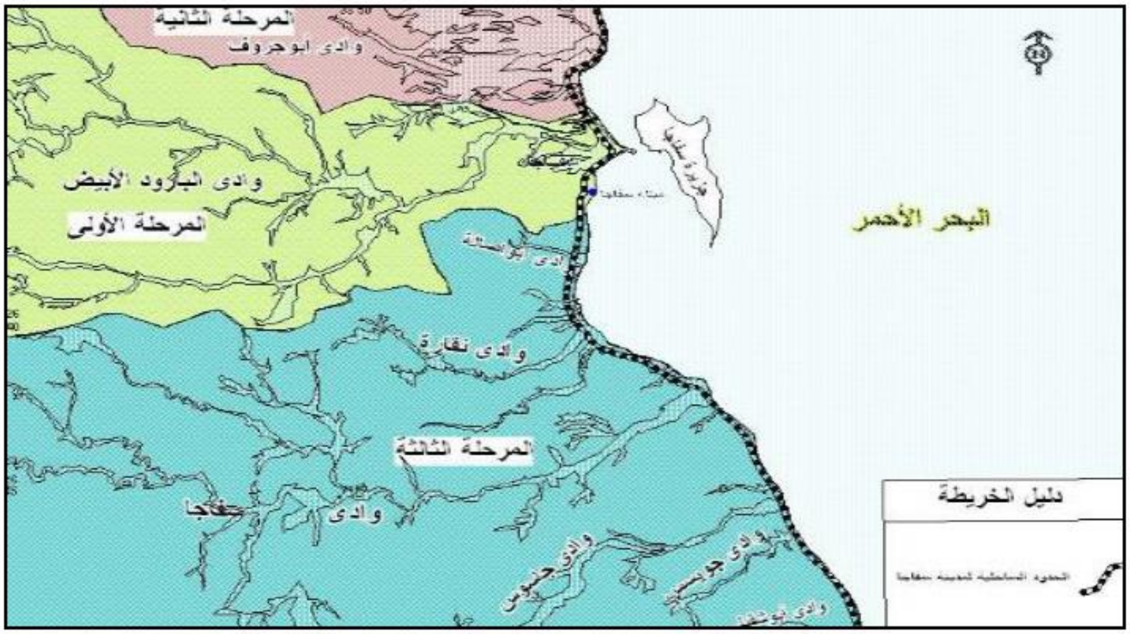

Fig. (1): General location of the study area.

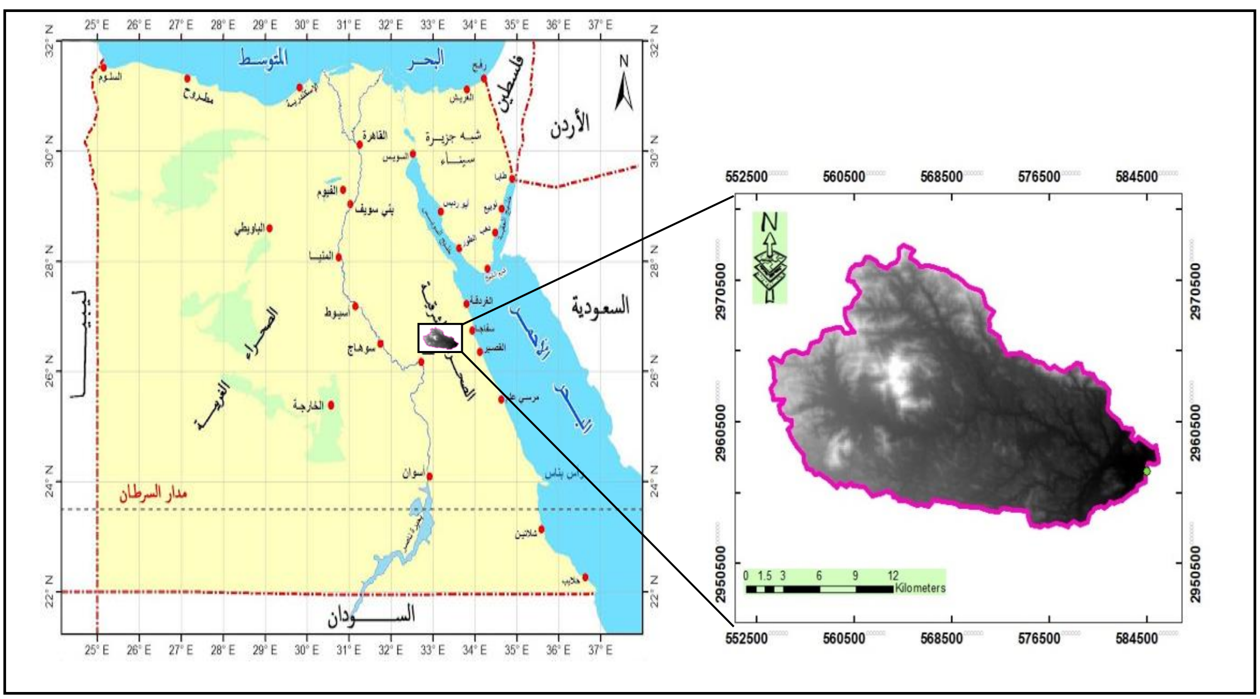

Fig. (2): Valleys affecting the city of Safaga.

Wadi El Baroud Al Abiad is one of the most influential valleys in the city of Safaga on the Red Sea coast. It is extended between latitudes (2950500 and 2980000 N') and longitudes (552500 and 585000 E’) and covers an area of about 500 km^2 and its outlet at 6.5 km west of the city of Safaga, Where there is EL Baroud Al-Abiad dam 1 and the EL Baroud Al-Abiad dam 2 at the end of the valley as shown in Fig. (3). Valley descends from the high mountains of the Red Sea, which reaches about 1000 meters above sea level.

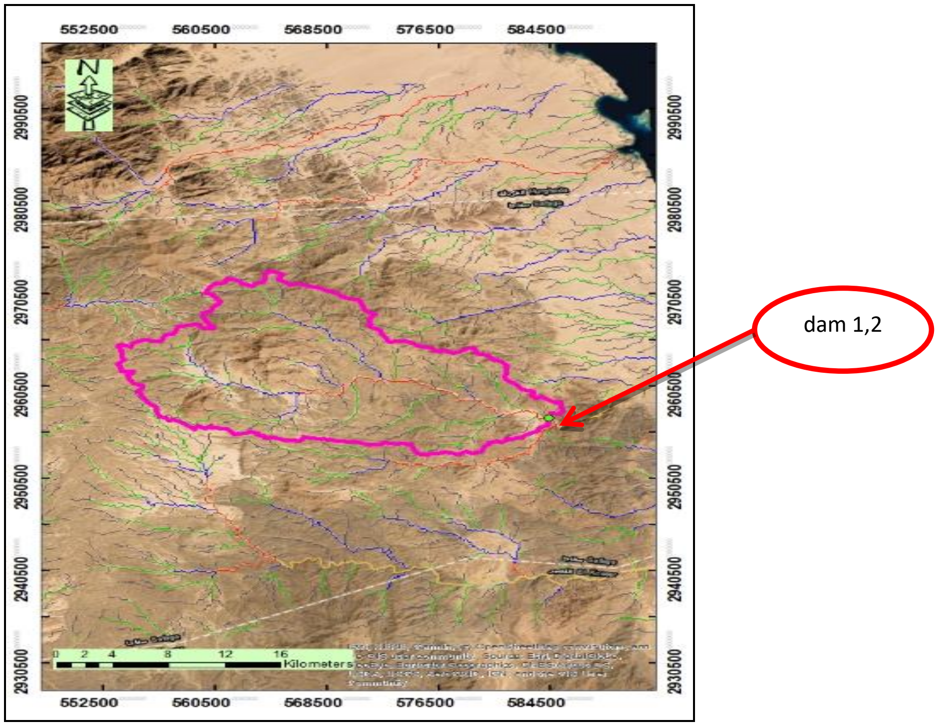

Fig. (3): El Baroud Al-Abiad drainage basin and dams 1 and 2.

3- METHODOLOGY

In recent years, valleys have been exposed to so-called morphological hazards as well as human intervention in the nature of the earth (Lazzari et al. 2006). Therefore, the factors affecting these valleys must be studied continuously and from these specialized studies, i.e. meteorological, morphological, geomorphological, and geological, valley characteristics can be obtained.

3.1 Meteorological observation:

Climatic data are analyzed to reach the design storm values for different return periods by knowing the annual rainfall values of the study area by using rainfall data from a rain gauge station near the area. Norbiato et al. (2007) mentioned that most of the flood-prone valleys do not have direct measurement stations but rely on modeling between nearby measurement stations and altitude difference between the region and their vicinity . Rain values are not only known by radar stations but are supported by data analysis methodology using various statistical analysis programs. Irina et al. (2014) used HYFRAN (hydrological frequency analysis) program to determine the probability of non-exceedance for maximum annual rainfall in 24,48,72 hours. Al Aboodi (2014) also used Hyfran for calculating the maximum monthly rainfall in Baghdad city for the period (1887-1958). In this research, Hyfran-plus program is used, which is a statistical analysis program to find the possible relationship between the potential daily rain values and different return periods.

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The maximum annual rain data is entered for the program and the equations for the application is chosen to get some analysis of the numbers such as the total number of data and the largest and smallest number and standard deviation and some variable factors. Moreover, the appropriate function is chosen from the set of different functions to achieve the greatest efficiency of the curve, and then the values of rain daily are obtained for different return time periods. Gamma (maximum likelihood) curve is used because it is the most convenient curve. In this research, we use the monthly rainfall values of Safaga meteorological station from 1994 to 2018 and the annual maximum values of rainfall rates are extracted from it as shown in Fig. (4).

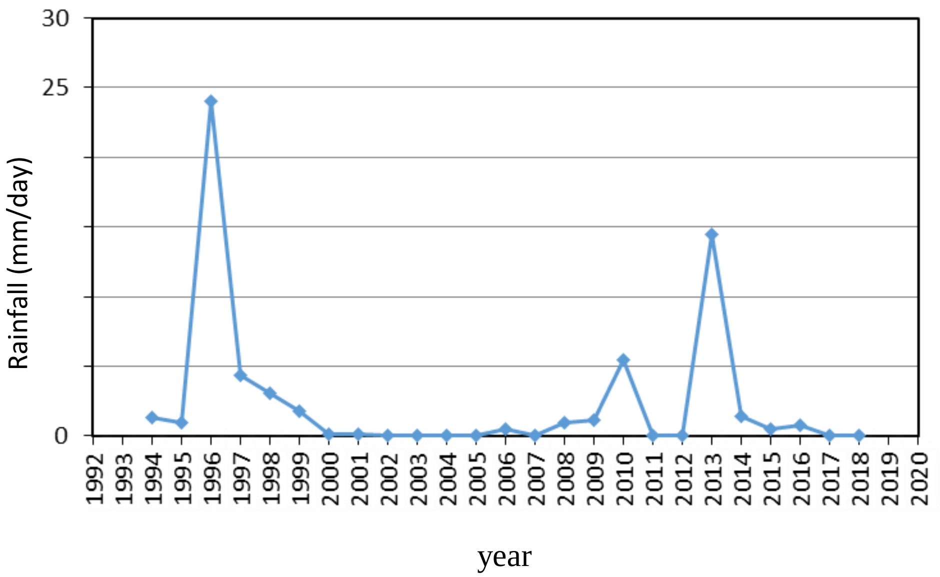

Fig. (4): annual maximum rainfall values at the period (1994-2018).

Evaporation Rate: -

To calculate the rate of evaporation in the region we must obtain the following meteorological parameters are considered i.e. Wind velocity (m/sec), Air temperature (°F), Relative humidity (%) to be applied in the evaporation equation, we use the meteorological data of Safaga city on weather world site as shown in Figs. (5), (6) and (7).

3.2 Watershed morphology:

Digital elevation model (DEM) and digital terrain data of the catchment are obtained from the USGS Earth Explorer website and inserted into WMS and ArcGIS software. Abdalla et al. (2014), and Youssef et al. (2009) used ArcGIS program and topographic maps of different scales to obtain the morphometric characterization and basins delineation along Red Sea coast. In the current study, WMS (Watershed Modeling System) software is used to determine the total drainage basin characteristics that affects the area by determining the direction of water flow from the "topaz model" after determining the output point to extract the morphological characteristics such as area, length, inclination, perimeter, ... etc.

It was found that the area of the catchment is 360 km^2, the length is 30 km, the basin slope is 0.1927 m/m and the perimeter is 100 km. Using the results of the characteristics of the basin, the other basin coefficients can be calculated such as circulation ratio and elongation ratio and the shape factor of the basin as shown in table (1), it is noted that the basin of the study area is characterized by elongation than in the roundness where there is a similarity between the shape of the basin and rectangle shape. ArcGis (geographic information system) software is used to divide the water basin in the area into three basins, each basin has a point of convergence of streams and the characteristics of each basin separately indicating the direction of water flow as shown in Fig (8).

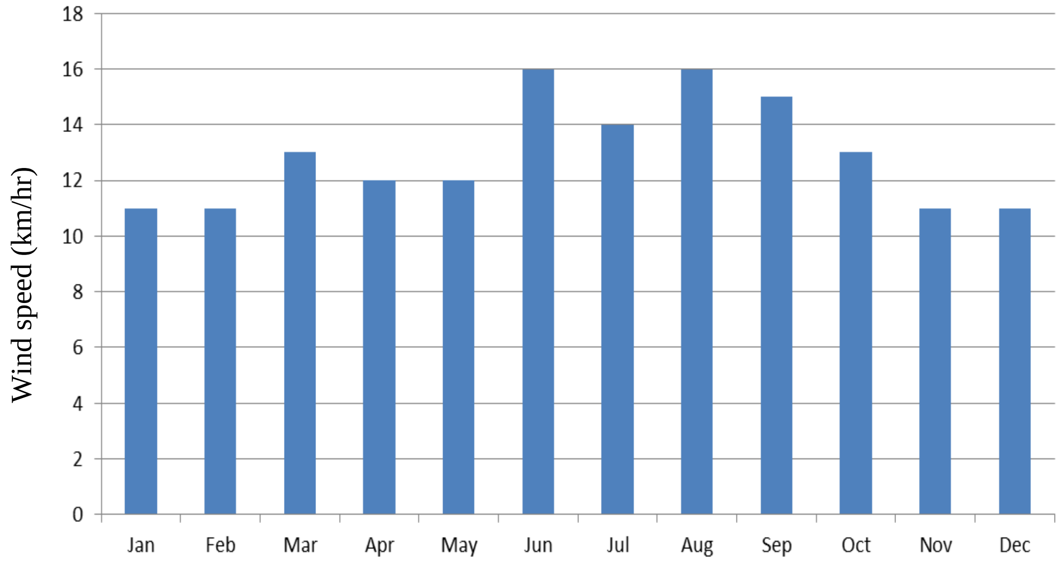

Fig. (5): Wind velocity of Safaga city.

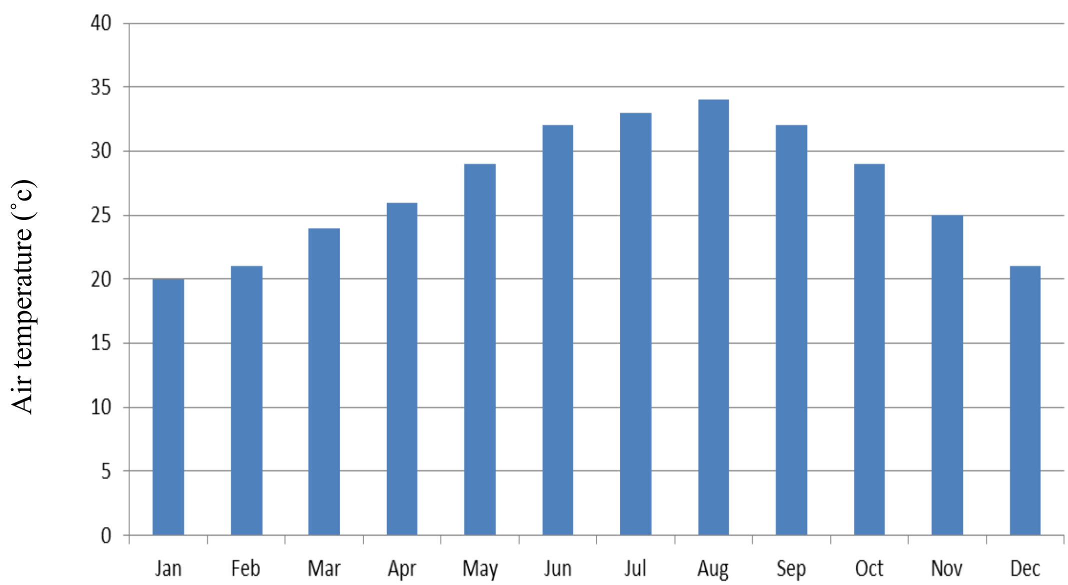

Fig. (6): Air temperature of Safaga city.

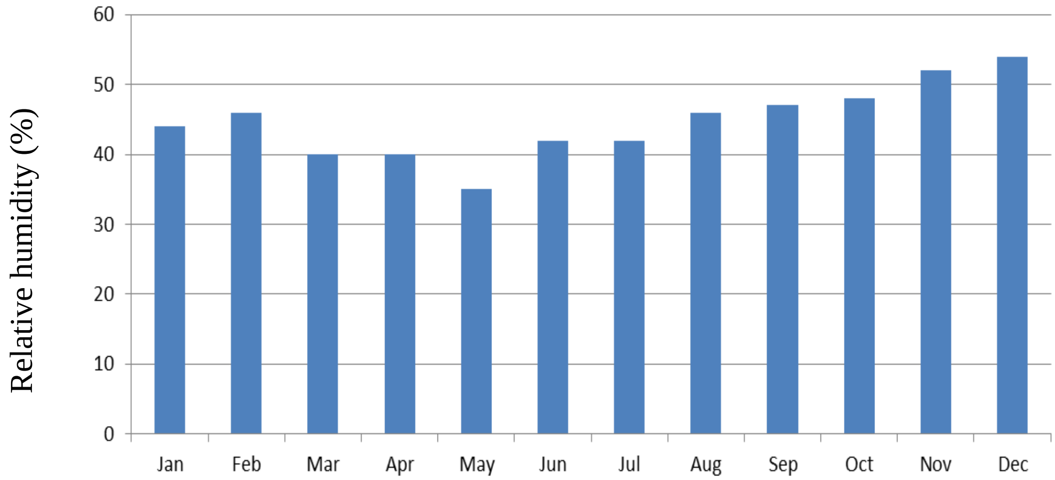

Fig. (7): Relative humidity of Safaga city.

Table (1): characteristics and coefficients of basin.

Area	360	km²
perimeter	100	km
length	30	km
basin slope	0.1927	m/m
Circulation ratio	0.47	km²/km
Elongation ratio	0.7	Km/km
shape factor	0.4	km²/km²

3.3 Watershed Soil type and land use:

In this part of the research, soil type and land use are estimated in this region by the so-called curve number. SCS "soil conservation society " method is used in classifying the soil type. The hydrological groups of the soil were divided into A, B, C, D according to this method as shown in table (2). By obtaining the digitized map of the area from the USGS website as shown in Fig (9), the relationship between the produced polygons and the hydrological soil groups resulting in the calculation of the related curve number.

Grid Leveling for the storage lake to wadi Al-Baroud El-Abiad dam (1) from the ground and Google Earth and TCX converter software were used to find out the dam site in 3D as shown in Fig (10).

4- RESULTS AND DISCUSSIONS

HYFRAN-PLUS software was used for estimating max daily rainfall (mm/day) values at different return periods for 5, 10, 25, 50, 100, and 200 years as shown in table (4) from the monthly rainfall values of Safaga meteorological station from 1994 to 2018 obtained in section (3.1) and Fig. (4).

Using DEM map which is deduced in the previous section, streams through the watershed are delineated using the GIS program as shown in Fig. (11). The streams of the water basin are classified for four consecutive ranks and the number of streams for each rank and the total lengths using Strahler method is shown in table (5).

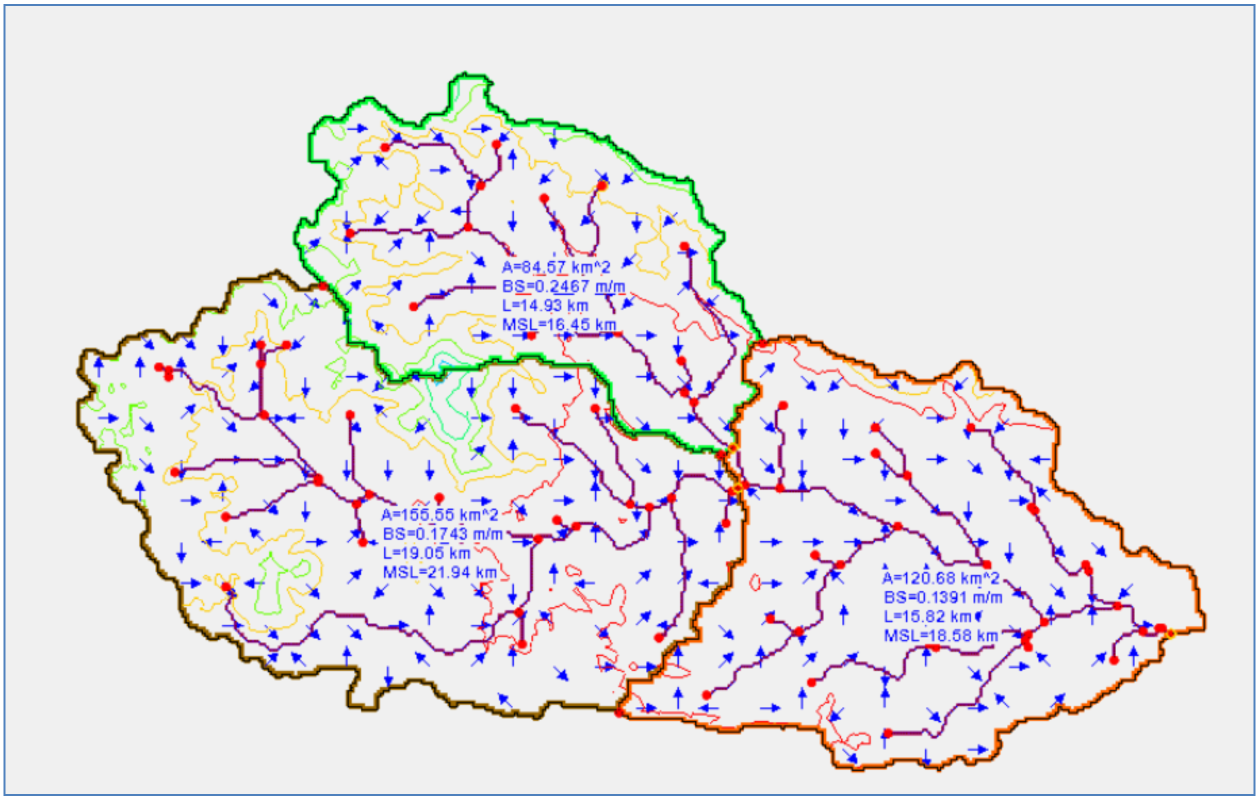

Fig. (8): Divided basin to 3 sub basin (indicating the direction of water flow).

Table (2): hydrological groups of the soil.

Land use ID	**CN**
soil type A	63
soil type B	77
soil type C	85
soil type D	88

Table (4): Maximum daily rainfall at different return periods.

Return periods (year)	**Max rainfall (mm/day)**
5	6.3
10	9.91
25	14.9
50	18.8
100	22.8
200	26.9

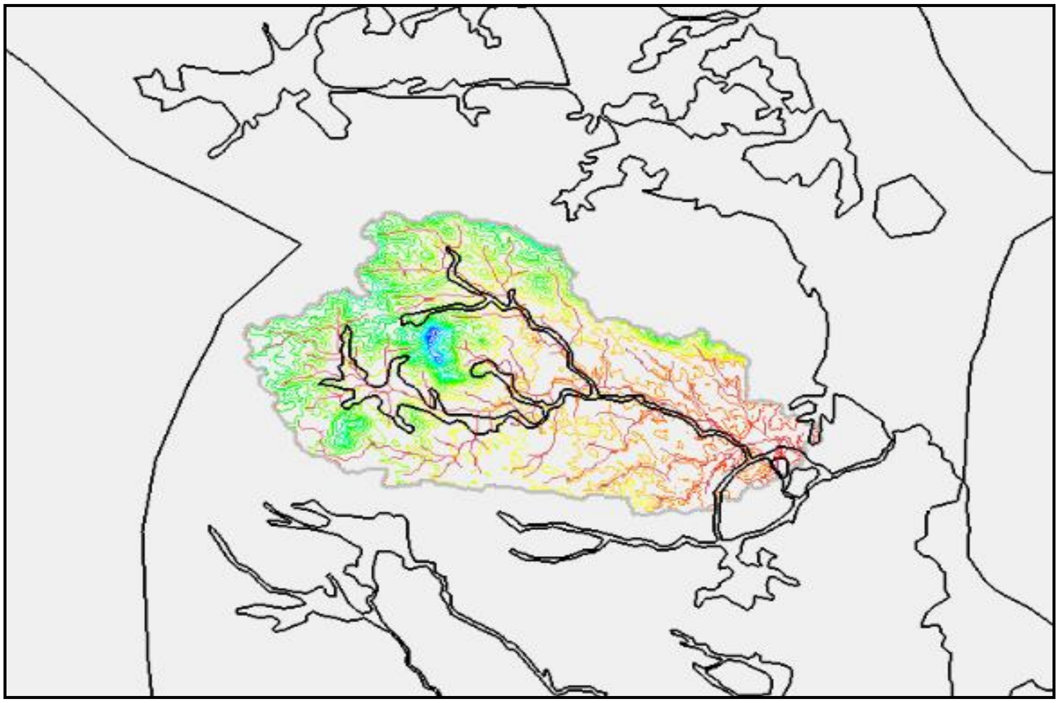

Fig. (9): topographic maps (soil type) of the area.

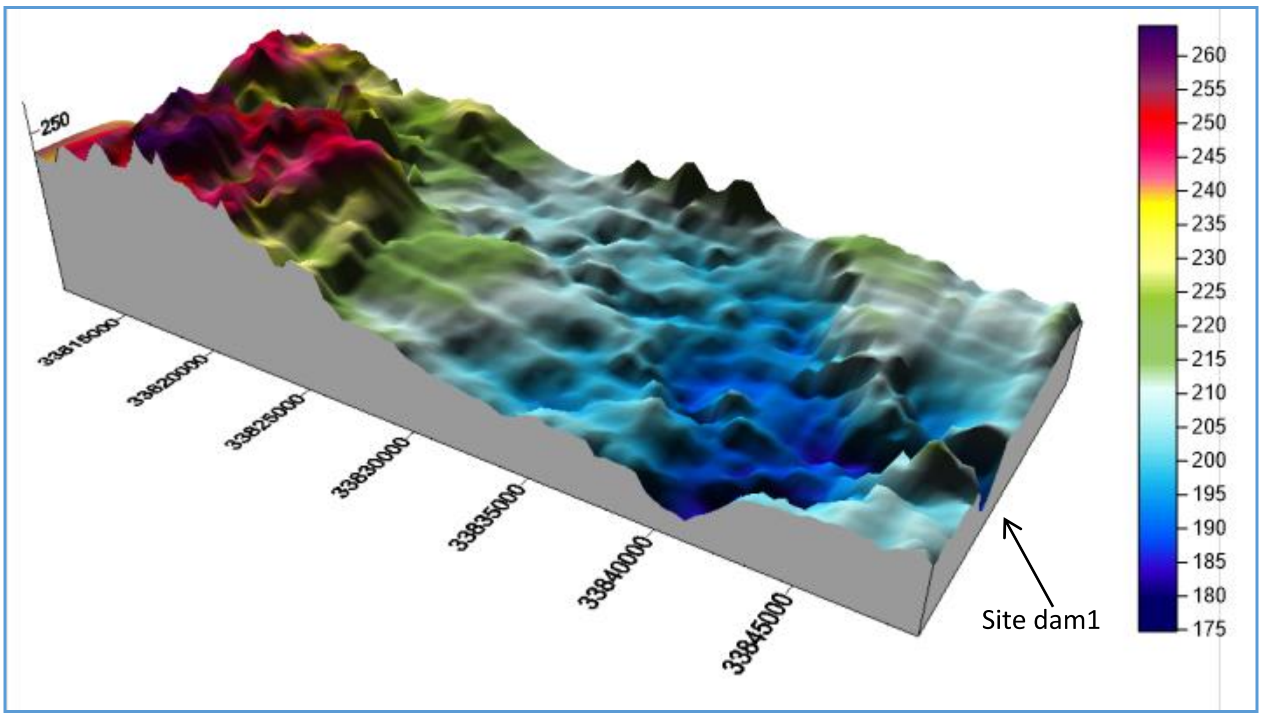

Fig. (10): Terrain (3D) of storage lake of Dam 1.

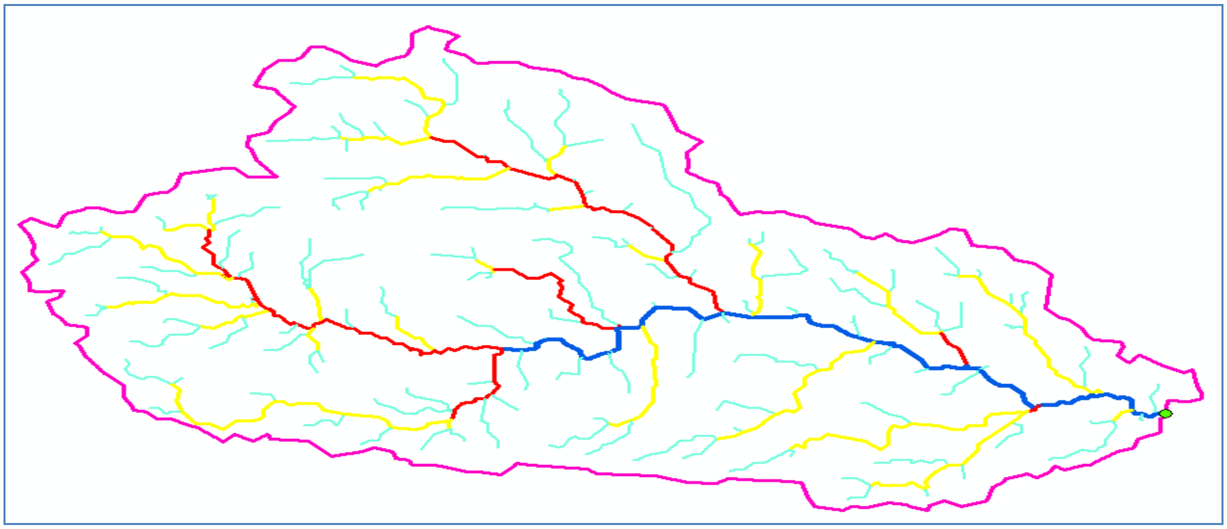

Fig. (11): Stream delineation of drainage basin.

Table (5): Stream ordering.

	Stream order	**N0. Of streams**	**Total length (km)**
(cyan)	1	160	158.72
(yellow)	2	76	86.93
(red)	3	51	36.47
(blue)	4	30	23.43

For this water basin, the soil is classified and it was found that it is similar to the type (C) from the hydrological group of curve number 85. All the previous data are incorporated into WMS to obtain the runoff hydrograph. Table (6) shows the hydrograph parameters, where it was found that the concentration- time is 7.616 hrs., the lag time is 4.569 hrs., and the storage coefficient is 0.6.

Table (6): runoff parameters for flood water.

hydrograph unit parameters	**Values**
concentration time	7.616 hrs.
lag time	4.569 hrs.
storage coefficient	0.6

The runoff hydrograph is computed at the outlet of the wadi for different return periods 5, 10, 25, 50, 100, and 200 years respectively. It was found that for the return period equal 5 years the rainfall intensity is less than the infiltration capacity, so there is no runoff at all. Figs. (12-16) show the runoff hydrograph for the return periods 10, 25, 50, 100, and 200 respectively. Table (7) shows the maximum discharge, time of peak discharge, and volume of water for different return periods. According to the geometric design of Wadi Al- Baroud El- Abiad dam 1, it can be concluded that the volume of the water on which the dam is designed is 1800000 m^3 at level 200 m above sea level is safe to accommodate the flood for 100 years return period. In comparison to the results obtained from this research, it can be found that the dam safe for up to 100 years, but for the time period of 200 years, precautions should be taken to increase the storage capacity of the dam by proposing an artificial lake in front of the dam.

Table (7): hydrograph parameters for different return periods.

Return periods	**Max discharge (m^3/s)**	**Time of peak discharge (minute)**	**Volume of water (m^3)**
5	0	0	0
10	.31	735	6964.20
25	10.58	690	247992.75
50	26.10	675	632816.10
100	46.8	660	1167339.15
200	71.88	600	1834121.25

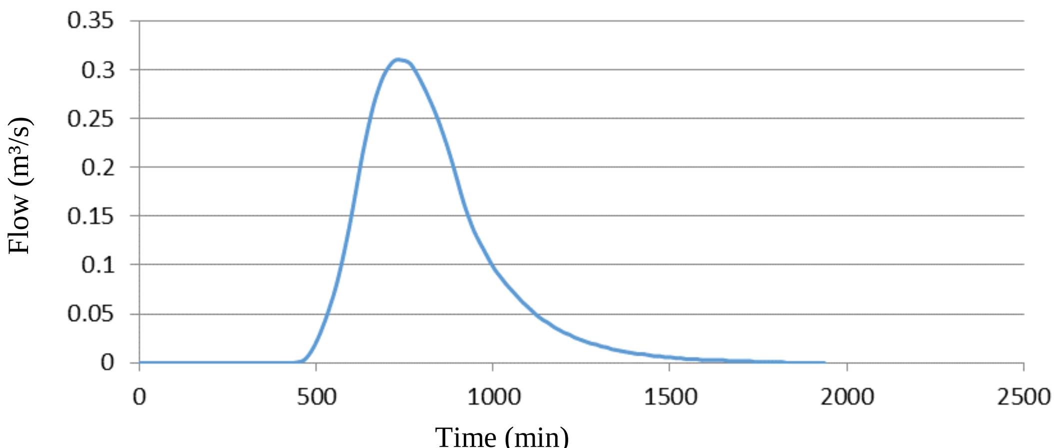

Fig. (12): Flood hydrograph for return period (10) years.

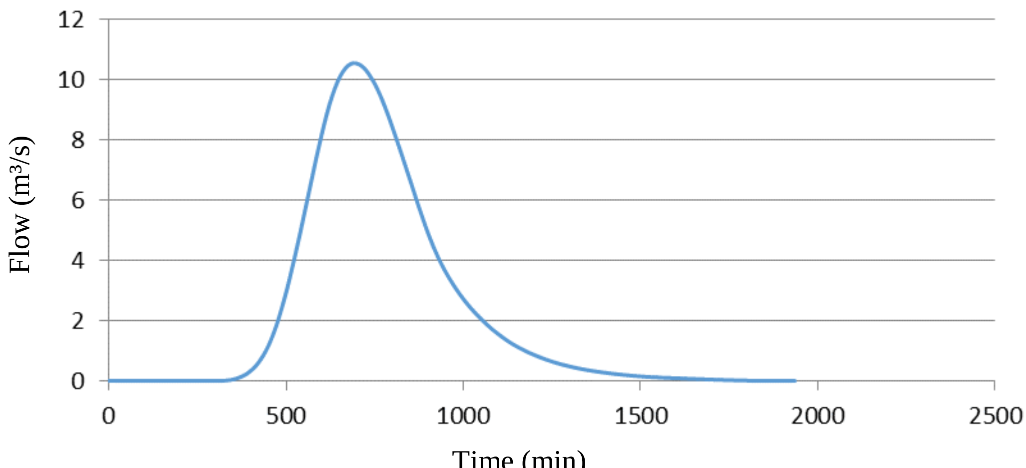

Fig. (13): Flood hydrograph for return period (25) years.

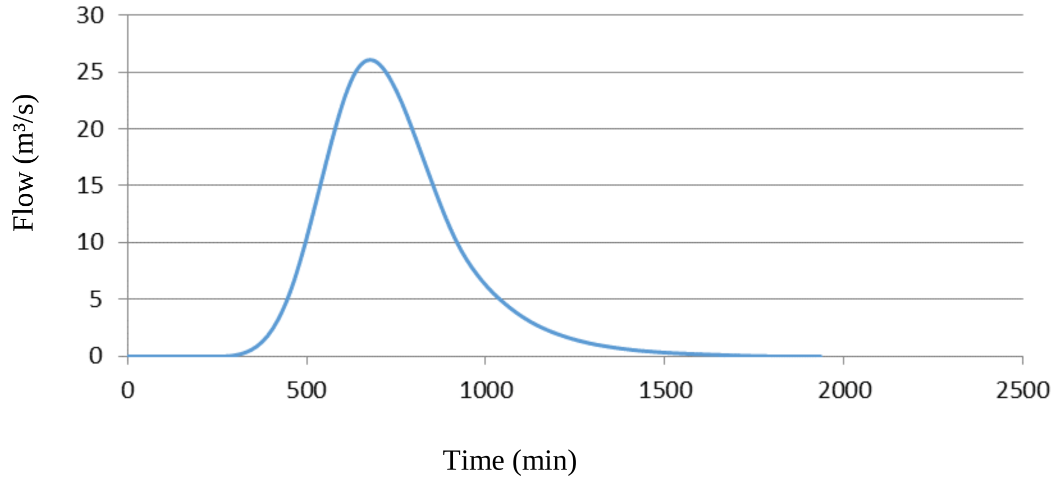

Fig. (14): Flood hydrograph for return period (50) years.

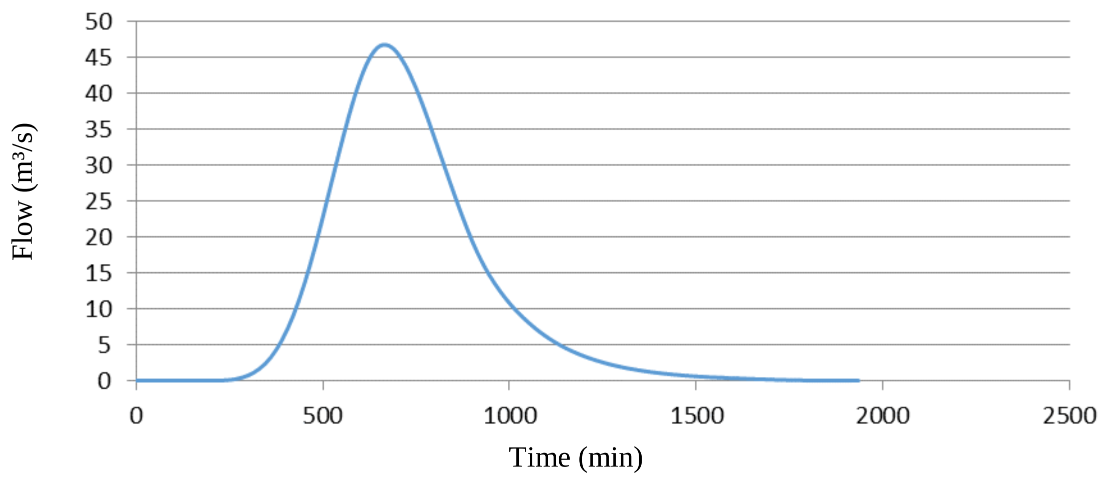

Fig. (15): Flood hydrograph for return period (100) years.

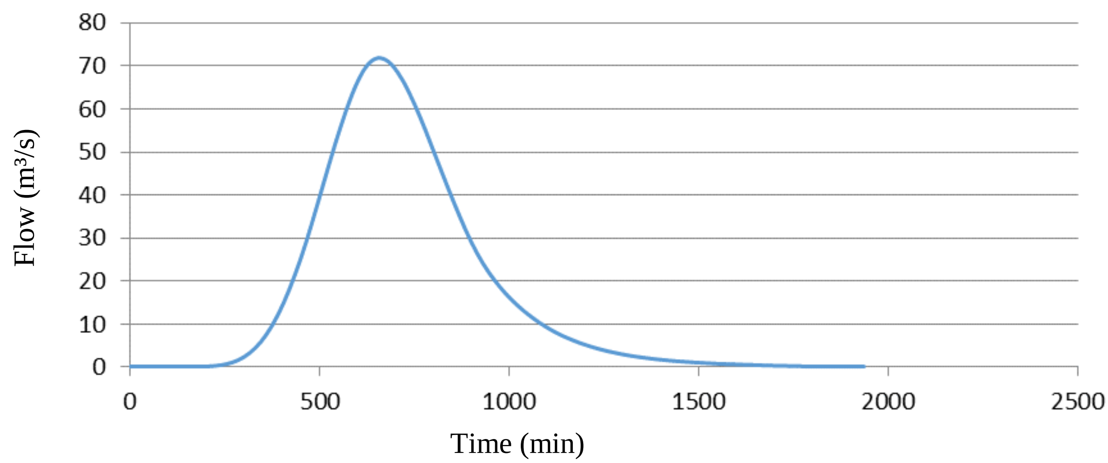

Fig. (16): Flood hydrograph for return period (200) years.

Water budget:

Water budget method is used for computing evaporation and infiltration from dam reservoir. This method is considered one of the most acceptable methods for calculating evaporation losses (Hamdan and Zaki, 2016). This method is used to estimate the time required for storage water to evaporate and infiltrate into the subsurface soil from the reservoir based on storage area elevation curve of dam shown in table (8).

Table (8): Elevation, area and storage volume of storage lake for dam 1.

Elevation (m)	Area (m^2)	Volume (m^3)
200	450000	1800000
199	300000	900000
198	200000	550000
197	100000	300000
196	75000	150000
195	50000	100000
194	25000	50000
193	0	0

By applying the water budget equation and considering that the amount of water upstream the dam represents the storage capacity of the dam which is obtained from the corresponding area of the storage lake according to the water level in front of the dam as shown in the table (8) and amount of evaporation and infiltration, the time required for water resection from the lake can be computed. The month of October is the rainiest month in the region every year so the value of evaporation is calculated according to the value of October month. Table (9) show the time required for storage water to evaporate and infiltrate into the subsurface soil according to change in water level, area and volume of the lake.

Table (9): Time required for drying the lake at different elevation.

Elevation m	Area m^2	Volume m^3	N	Evap mm/day	Evap m/day	Hw m	Infil m/day	Time day
200	450000	1800000	0.1518	18.69	0.0187	7	0.125	28
199	300000	900000	0.1549	19.08	0.0191	6	0.122	21
198	200000	550000	0.1581	19.47	0.0195	5	0.118	20
197	100000	300000	0.1636	20.15	0.0202	4	0.115	22
196	75000	150000	0.1660	20.44	0.0204	3	0.112	15
195	50000	100000	0.1694	20.86	0.0209	2	0.108	15
194	25000	50000	0.1754	21.60	0.0216	1	0.105	16
193	0	0	0.0000	00.00	0.0000	0	0.000	0

It can be noticed from table (9) that the lower the water level in front of the dam, the less the time period for the survival of the water with the difficulty of exploiting the water in this short period of time, where the maximum period of time for the survival of water is 28 days.

Conclusions:

In this study, hydrological parameters that affect flash floods in arid or semi-arid areas are studied. Three types of parameters affecting floods are considered i.e. meteorological (climatic), morphological, and geological factors. The study area is Wadi Al-Baroud El-Abiad which is located in the northwest of Safaga city on the red sea coast. Monthly rainfall values of Safaga meteorological station from 1994 to 2018 were used in this study. The annual maximum values of rainfall rates for different return periods for 5, 10, 25, 50, 100, and 200 years are computed using HYFRAN. WMS and ArcGIS software are used to determine the total drainage basin characteristics that affect the area and hydrograph unit parameters for flood water such as concentration-time, lag time, and storage coefficient. Topographic maps of the area and SCS method "soil conservation society " are used to estimate the curve number for this area (CN=85). After applying all these transactions, the unit hydrograph for different return periods is assessed to know maximum discharge, time of peak discharge, and volume of water in each period. Moreover, the calibration curve for Wadi Al-Baroud El-Abiad dam (1) and the meteorological parameters for area are used in water budget equation to determine the time required for storage water to evaporate and infiltrate into the subsurface soil, where the maximum period of time for the survival of water is 28 days.

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