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# Watershed Delineation and Runoff Estimation of Wadi Tayyibah, South Sinai Using Arc-GIS And HEC-HMS Model.

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## ABSTRACT

Sinai is a rigid region and one of the most important strategic areas in Egypt for its historical importance, its location, Its touristic importance, and its natural resources. the lack of water sources in Sinai is the most important reason for the lack of development in it.so the study aims to estimate the runoff in wadi Tayyibah which located in south Sinai to benefit from it in different uses and avoid the hazards which occurred due to the floods through design protection structures that depend on the amount of run off. The present study aims to evaluate the runoff, morphometric properties and delineate the watersheds in Wadi Tayyibah relying on The Soil Conservation Service Curve Number (SCS-CN) method besides Hydrologic Engineering Center-Hydrologic Modeling System (HEC-HMS) model which is a hydrological model that be used to estimate the runoff and produce the hydrographs for storms with different return period5,10,25,50and100 years, that model also be used in watershed delineation for the study area. The Arc-GIS is used in hydrological and topographical analysis and used to represent the characteristics of the case study in maps. The rainfall data which be used was for Abou Redus rainfall station in monthly data from1976 year to2018 year. The frequency analysis has been done using Microsoft Excel which produce storms with depths20.6,29.2,40.7,49.3,58mm of return periods5,10,25,50and100years, respectively. The runoff as a volume 0.18, 0.911, 2.53,3.89 and 5.89 Mm3 and as depth 0.5, 2.56, 7.10, 10.93 and16.54 mm of return periods respectively

**Keywords**: Runoff, SCS-CN, Arc-GIS, HEC-HMS, Wadi Tayyibah, Sinai.

## 1. INTRODUCTION

Shortage is a worldwide problem in varied countries around the world but developing countries are the most affected [1]. The problem has become more critical in case of arid and semi-arid regions (ASARs). Excessive usage of water resources makes the problem worse in terms of quality and quantity of water [2]. Water scarcity is also affecting soil characteristics such as soil erosion [3]. the problem of water shortages of traditional source can be addressed by finding non-traditional, suitable, and sustainable water resource such as Runoff Water Harvesting (RWH) [4]

Sinai is arid region that suffer from a lack of water resources, and it is one of the most important causes of lack of population in Sinai. It is also one of the most important strategic areas in Egypt for its historical importance, distinctive geographical location, availability of tourist locations and as well as its natural resources. Hence, management of water resources in this part of Egypt is very necessary. So, the government is trying to reconstruction Sinai providing sources of water out there and from those projects El-Salam canal which use to transport the water of River Nile to Sinai, but that project covers the northern part only [5] Therefore, developing unconventional water resources are important to overcome the shortage of traditional water resources. (RWH) can play very important role to benefit from the excessive surface water which is often lost [6]. RWH is a technique depends on collecting and storage of run-off water for any useful usage [7], that definition is general so, RWH could be defined as collecting water from surface run-off for crops and recharging the soil with water [8]

RWH has become spread in many of (ASARs), such as Western Asia, North African countries and the Middel East, each State applies RWH using global or own unique methods of collecting and storing water. [9]. The main required steps have been needed to choose the suitable locations for RWH techniques including the choice of influential factors on it, collecting the data related to each factor, evaluating, and analyzing all of them and consequently, the suitable sites can be selected. This study aims to determine the volume of runoff in Wadi Tayyibah and make watershed delineation Using GIS depending on ARC-GIS 10.3 software besides using hydrological model called HEC-HMS under WMS 10.1 software.

GIS are one of the technologies based on Using the computer, which can display geographical information in its various images, the implementation of statistical operations, as well as its potential for building databases and, they have become an active tool in Planning and decision-making.

WMS is an integrated system to solve complex hydrological issues by dealing with watersheds and hydrological characteristics digitally. it could be used to get the surface runoff depending on SCS-CN method.

Research [10]– [15] used SCS-CN method in calculations of Runoff depending on Remote Sensing (RS) besides GIS. Research [16] converge ARSAs in Australia to select the suitable location of RWH and that research indicated the importance of the average annual rainfall parameter and use SCS-CN to get the runoff.

The determination of surface runoff using SCS-CN method depend on many factors such as precipitation characteristics, land use and soil properties. All previous factors make the selection very difficult plus it takes time, so GIS technology and WMS have used to simplify the determination of runoff volume in wadi Tayyibah which located in Abou Zenima which represent 17.2% of south Sinai but the populated area only represents 4% of all areas of Abou Zenima due to the lack of water resource so, the study aims to estimate the runoff in wadi Tayyibah which located in south Sinai in traying to benefit from it in different uses and in addition to avoid the hazards which occurred due to the flood trough design protection structures which depend on the amount of run off using HEC-HMS model depending on SCS-CN method and ARC-GIS software

## 2. STUDY AREA

Wadi Tayyibah is in Abou Zenima between longitudes 33° 5’ E and 33° 24' 0 E and latitudes 29° 4' N and 29° 15' N (figure 1) with area about 356 km2 and perimeter about 125 Km as indicate in table1.Abou Zenima is located on the Gulf of Suez, south Sinai, Egypt, between longitudes 32° 27' 22" E and 33° 44' 12" E and latitudes 28° 56' 50" N and 29° 25' 16" N with a total area of about 5371 km2, which represents 17.2% of South Sinai, where the area of governorate is about 31272 km2.the populated area in Abou Zenima is about 4%.

**Table 1: Properties of Wadi Tayyibah**

| **Area (km2)** | 356 |
|---|---|
| **perimeter (Km)** | 125 |
| **Length (km)** | 33 |
| **Width (Km)** | 10.8 |
| **Max elevation (m)** | 1133 |
| **Min elevation (m)** | 1 |

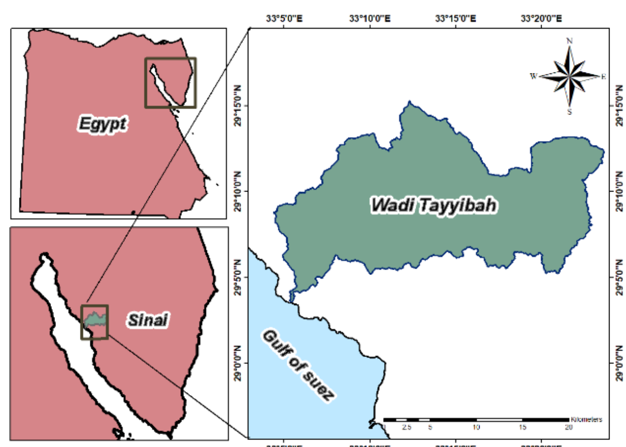


**Figure 1: Location map of the study area**

## 3. DATA COLLECTION

In this study, the datasets are used to build the database of the case study are topographical data such as Digital Elevation Model (DEM) and topographical maps, geological maps, climatic data, and satellite images ArcGIS 10.3 software is involved to collect and analyze data.

### 3.1. Topographical Data

DEM is a digital description of the surface terrain. The DEM of wadi Tayyibah from Shuttle Radar Topography Mission (STRM) data downloaded with 30 m of resolution (1-arc second) from the website of United States Geological Survey (USGS). The DEM is important to get the topographic properties such as slop of basins, length of streams and the boundary of sub-catchment in addition to its importance in making hydrological analysis for the study area. Figure 2 indicate the elevations of wadi Tayyibah in meters after correction of DEM defects and making geo-referencing to UTM WGS84 Zone 36 N using ARC GIS 10.3 Software, that elevation ranges from 1m to about 1133m.

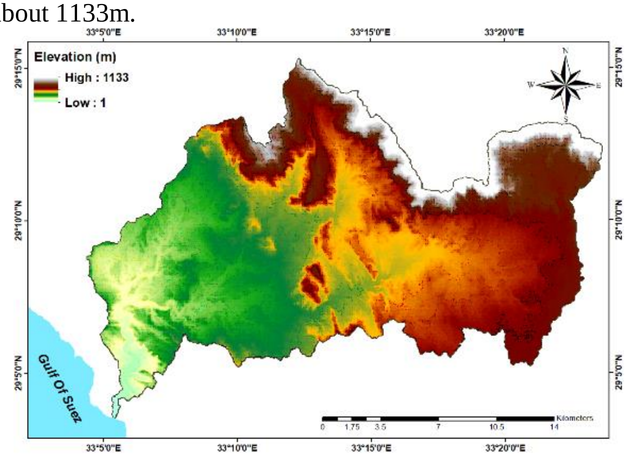


**Figure 2: DEM of Wadi Tayyibah**

### 3.2. Land Use/Land Cover

The land use is influential element in the method of SCS-CN which used to get the value of curve number to estimate the runoff. Curve Numbers (CNs) are numbers between (0 – 100), that its values depend on, land use and hydrological soil groups (HSG). The land uses of wadi Tayyibah has been extracted Cover as shown in figure 3. the percentage of Scrub area and Bare ground almost cover all the area of wadi Tayyibah as shown in table2

**Table 2: The description of HSG**

| Land use | Scrub/Shrub (Km$^2$) | Build Area (Km$^2$) | Bare Ground (Km$^2$) |
|---|---|---|---|
| Area (Km2) | 119.79 | 0.22 | 235.93 |
| percentage (%) | 33.65 | 0.06 | 66.28 |

### 3.3. HYDROLOGICAL SOIL GROUPS (HSGS)

One of requirement of SCS-CN method is classification all type of soil of the study area into group A, B, C and D. Table 3 refers to the description of each group. Geological information of the study area is got from geological maps which be available in digital format with scale 1:250,000. the maps were available in the Egyptian Geological Survey and Mining Authority (EGSMA), and it be got from

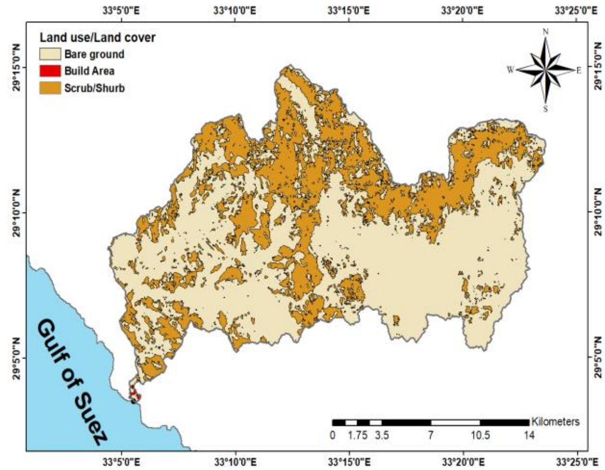


**Figure 3: Land cover of Wadi Tayyibah**

National Authority for Remote Sensing and Space Sciences (NARSS). The map was exported to ArcGIS 10.3 software and was georeferenced to WGS 1984 -UTM -Zone 36 and with shapefile of wadi Tayyibah, the extraction of geological information it was done as shown in figure 4 and table 4 .it was be difficult to convert the geological map to HSG so, [17] created HSG`s map of Sinai. This map was clipped and exported to Arcgis10.3 software to extract HSG`s map of Wadi Tayyibah as shown in figure 5. the area of each group in Wadi Tayyiba indicated in table 5.

**Table 3: HSG `S description**

| Hydrological soil groups (HSG) | Descriptions |
|---|---|
| Group(A) | Lowest Runoff potential |
| Group(B) | Moderately Low Runoff |
| Group(C) | Moderately high Runoff |
| Group(D) | Highest Runoff potential |

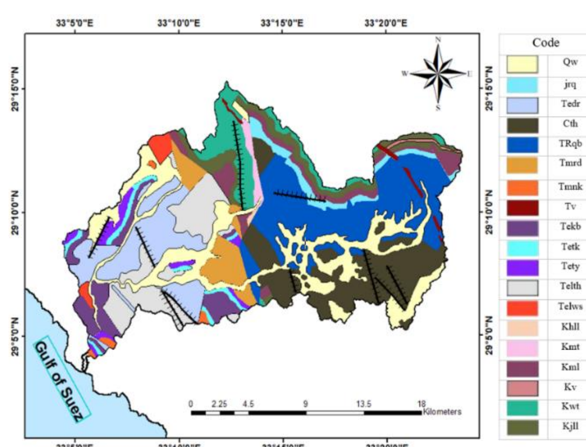


**Figure 4 Geological map of wadi Tayyibah Which extracted from geological map of Sinai**

**Table 4: Geological map `S description**

| Code | | Geological age | Description |
|---|---|---|---|
| | Qw | Holocene | Wadi deposits |
| | jrq | Mesozoic (Jurassic) | Sandstone |
| | Tedr | Middle Eocene | Limestone with gypsiferous marl and clay |
| | Cth | Lower Carboniferous | Sandstone with carbonaceous clay |
| | TRqb | Triassic | Sandstone and mudstone |
| | Tmrd | Lower Miocene | Marl and sandstone with fossiliferous carbonates |
| | Tmnk | Lower Miocene | Conglomerate and sandstone |
| | Tv | Lower Miocene | Extrusive basaltic rocks |
| | Tekb | Middle Eocene | Limestone with gypsiferous marl and clay |
| | Tetk | Upper Eocene | Yellowish white limestone with brown marl |
| | Tety | Upper Eocene | Beds of limestone, red silt, and clay |
| | Telth | Lower Eocene | grey to white compact Nummulitic limestone |
| | Telws | Lower Eocene | White hard limestone |
| | Khll | Cretaceous (Cenomanian) | Beds of dolomitic limestone, marl, and clay |
| | Kmt | Cretaceous (Santonian-Cenomanian) | Argillaceous limestone, marl, and shale |
| | Kml | Cretaceous (Albian-Aptian) | Sandstone With Kaolinitic pockets |
| | Kv | Cretaceous | Basaltic dykes |
| | Kwt | Cretaceous (Turonian) | Limestone with shale interoaltions |
| | Kjll | Cretaceous (Cenomanian) | Marl capped with limestone |

**Figure 5: HSGs of wadi Tayyibah**

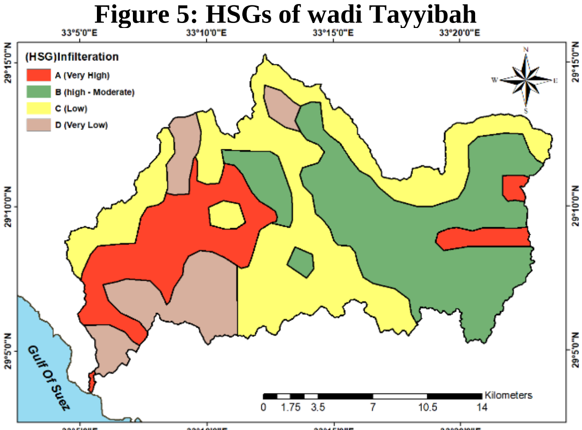


**Table 5: HSGs areas of Wadi Tayyibah**

| HSG | A | B | C | D |
|---|---|---|---|---|
| Area (Km2) | 78.82 | 119.092 | 105.86 | 52.18 |

## 3.4. Rainfall Data

Precipitation data were collected from Abou-Rudes station which located at intersection of longitude 33° 11' 41.69" E with latitude 28°54'35.19"N as indicate in table 6 at distance 27.5 km from center of wadi Tayyibah as shown in figure 6. the Thiessen polygons indicate the Abou Rudes station only effect on the study area as shown in figure 7. the data were monthly rainfall data from year 1976 to year 1989 and from year 2000 to year 2018 in depth with millimeters. the data be had from The Water Resources Research Institute (WRRI) as shown in figure 8.

**Table 6: Characteristics of Abou Rudes rainfall station**

| Name | Geographical Coordinates (Datum 1984) | | | Records |
|---|---|---|---|---|
| | Long. | Lat. | elevation | |
| Abo Rudes | 33° 11' 41.69" E | 28°54'35.19"N | 13 m | 1976 - 1989 & 2000 - 2018 |

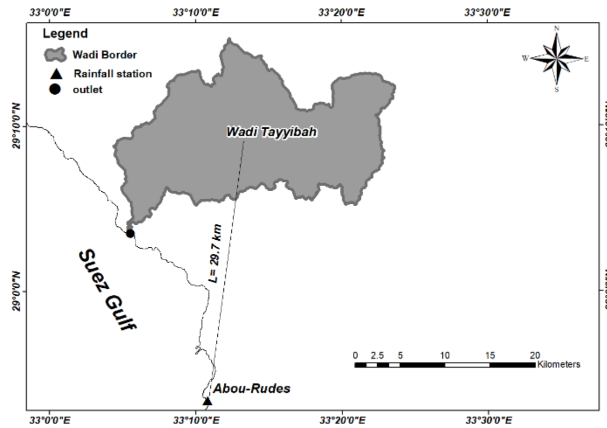


**Figure 6: Location of Abou Rudes station and its distance from wadi Tayyibah.**

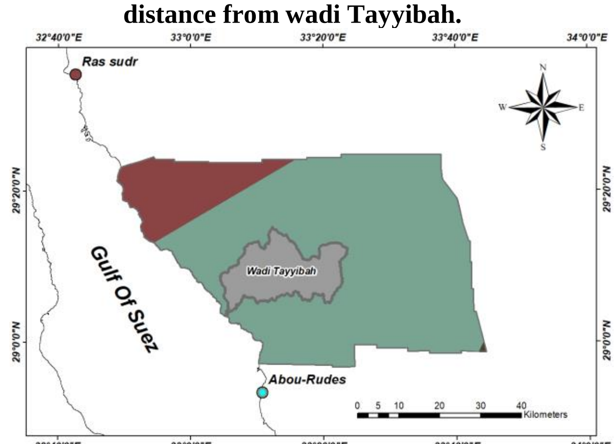


**Figure 7: Thiessen polygons between the rainfall stations.**

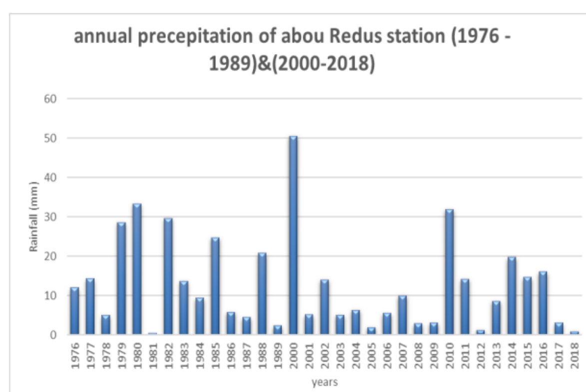


**Figure 8: annual rainfall data of Abou Redus station.**

## 4. METHODS

### 4.1.Rainfall Data Screening

Rain fall data screening must be made for verification of outliers and data homogeneity.[18], assigned the outlier that the value is not consistent with other values in the data set. While ,[19], defined the outlier as disperses a lot of other records to increase doubts recorded by different mechanisms. The outlier's records were screened for Abou Rudes station using the Equations of Charles as follow.

$$Y_{high} = Y_{ave.} + K_n\,\sigma_y \qquad (1)$$

$$Y_{low} = Y_{ave.} - K_n\,\sigma_y \qquad (2)$$

$$K_n = 1.055 + 0.981\log(n) \qquad (3)$$

Where: (n) is number of records, $(\sigma_y)$ is standard deviation of the data., $(Y_{high})$ represents the high outlier in log units, and $(Y_{low})$ is the low outlier in log units, $(K_n)$is coefficient of outlier depend on the number of records. The results pointed that no outliers` readings in the collected data of Abou Redus rainfall station as shown in table 7.

**Table 7: Screening of outliers` records**

| Station name | Abo Redis |
|---|---|
| available records | 1976 - 1989 & 2000 -2018 |
| Number of records | 33 |
| Kn | 2.545 |
| high outlier | 2.14 |
| Low outlier | -0.356 |
| Max predicted Rainfall | 138.177 |
| Min predicted Rainfall | 0.44 |
| Result | No outliers |

### 4.2.Frequency Analysis

Frequency analysis is a simple method used to predict the depth of storm or probability with regard to its return period depending on historical records of precipitation data. There are many equations and software to make the frequency analysis[7],prompted equation 4 to get the probability of the precipitation.it is suitable for records range from 10 to 100 records. Microsoft Excel software was used to get the best fitting curve of which represent Abou Redus station `s data. As shown in figure 9, the best fitting curve is logogrammatic. The table 8 indicate the rainfall depth corresponding to different return period

$$P_{(\%)} = \frac{m - 0.375}{n + 0.25} x100 \qquad (4)$$

$$RP = \frac{1}{P_{(\%)}} \qquad (5)$$

Where: (P) is the probability of record with rank m, (m)is the rank of records. (n)represents the total number of records, and (RP)is the return period in years.

**Table 8: the rainfall depth corresponding to different return period**

| Return period (years) | rainfall depth (mm) |
|---|---|
| 5 | 20.59 |
| 10 | 29.24 |
| 25 | 40.67 |
| 50 | 49.32 |
| 100 | 57.96 |

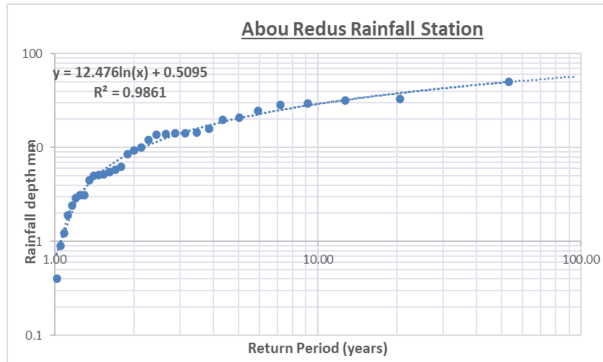


**Figure 9: Best fit distribution graph for Abou Redus Station.**

### 4.3.Scs-Cn Method

SCS-CN is one of the most popular methods that be used to estimate the runoff. This method was originated 1954 by the United States Department of Agriculture (USDA) and was developed to serve the regions of the United States. There are regions there similar in its nature of Sinai. The estimate of runoff depth has been calculated from the following equations in the SCS-CN method Which is one of most common methods to extract the surface runoff from rainfall storm [20]

$$\mathrm{DOR} = \frac{(\mathrm{P} - \mathrm{I_a})^2}{(\mathrm{P} - \mathrm{I_a}) + \mathrm{S}} \qquad (6)$$

Where DOR depth of Runoff (mm), P depth of Rainfall(mm), Ia initial abstraction (mm) that involves all of losses prior the start of runoff, evaporation, infiltration, and objection of water through vegetation $(I_a = 0.2\,S_r)$. Sr potential maximum retention with the start of runoff

So, we can replace $(I_a = 0.2\,S_r)$ in equation 6.

$$\mathrm{DOR} = \frac{(\mathrm{P} - 0.2\,\mathrm{S_r})^2}{(\mathrm{P} + 0.8\,\mathrm{S_r})} \qquad (7)$$

Sr Can be given depend on CN Values which related with the land use and the type of soil:

$$S_r = Y\left[\frac{100}{CN} - 1\right] \qquad (8)$$

Y= 10 in English units, or 254 in metric units. In equation 4 (Sr) can be replaced by its value from equation 8 to get equation of surface runoff with only two parameters as following:

$$DOR = \frac{\left[P - 0.2\,Y\,(\frac{100}{CN} - 1)\right]^2}{\left[P + 0.8\,Y\,(\frac{100}{CN} - 1)\right]} \qquad (9)$$

## 4.4.Curve Number (Cn) Estimation

CN is one of the main parameters that required to estimate the surface runoff in SCS-CN method. [21].CNs are numbers between (0 – 100), its value depends on land use, HSG and Antecedent Soil Moisture Conditions (AMC). referring to the map of land use and HSG of wadi Tayyibah in figure3 and figure 5 respectively and depending on the value of CN of (ASARs)in [22],CNs of HSG of wadi Tayyibah for group A, B, C and D are 63, 77, 85 and 88 respectively as shown in figure10. The area of each group be calculated using Arcgis10.3 software with values 78.82 ,119.09, 105.86 and 52.18 Km2 respectively. The equivalent CN of wadi Tayyibah in case of normal soil conditions was estimated with value 78 depending on the equation 10

$$\mathrm{CN} = \frac{\sum A_c CN_c}{\sum A_c} \qquad (10)$$

Where CNc is the CN that represent on the part of basin of area Ac

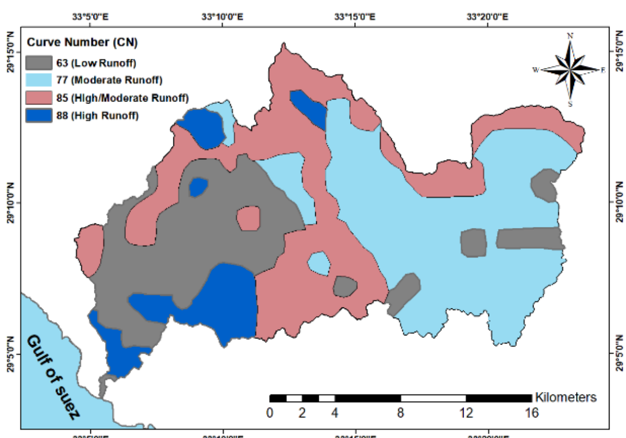


**Figure 10: Values of CNs of Wadi Tayyibah.**

## 4.5.Watershed Delineation

Watershed delineation has been done by some of steps as shown in figure11. DEM of Wadi Tayyibah was downloaded from USGS website with accuracy 30 m as shown in figure2.

DEM is effective input in watershed analysis which consist of cells, each cell contains the value of its elevation. Pure DEM that downloaded containing depression, so the first step is removing the depressions in it, then making geo-referencing to UTM WGS84 Zone 36N using ArcGIS10.3 Software. Flow direction is the following step of fill sinks and through the directions of flow have been indicated as shown in figure 12.

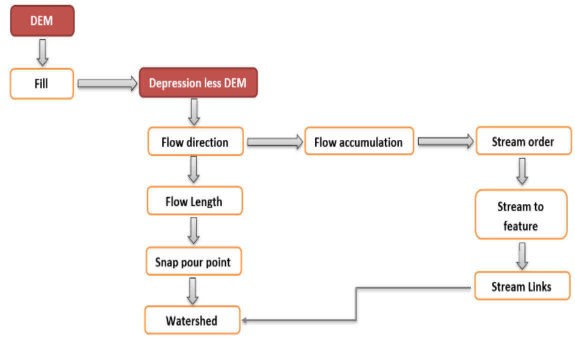


**Figure 11 steps of Watershed delineation.**

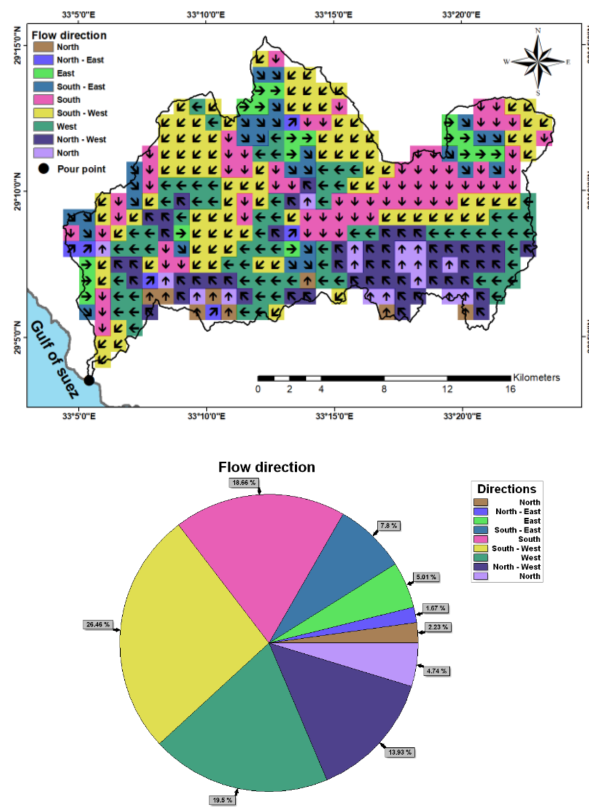


**Figure 12 Flow directions of wadi Tayyibah.**

in this step, the direction of flow for each cell was determined with respect to the neighboring cells by comparing the elevations of the cells. the following step is called flow accumulation, while the number of cells that pour into each cell is determined. the output of flow accumulation is a raster contains the number of cells pour into each cell and from that, the mainstream can be indicated as shown in figure 13. then the stream orders definition is the main step in the watershed analysis process. Sorting of streams has been done depending on the method of [23]. through this method, the streams that no other streams reached are Known as first stream order and when two streams of 1st order meet, there will produce stream of 2nd order and so on the stream order of wadi Tayyibah is indicated in figure 14

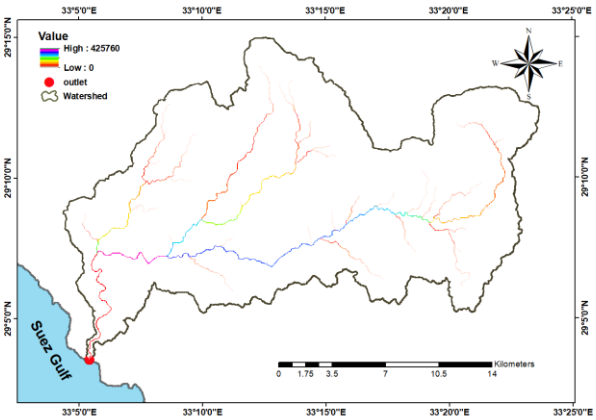

**Figure 13 Flow accumulation of wadi Tayyibah**

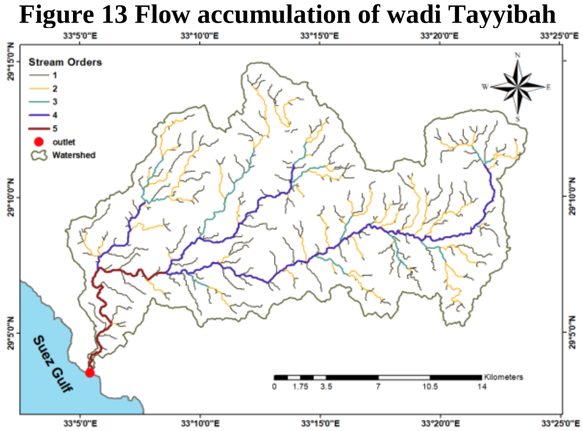

**Figure 14 Stream orders of wadi Tayyibah.**

## 5. RESULTS AND DISCUSSION

### 5.1.Estimation Of Runoff

The results of SCS-CN model of Wadi Tayyibah which produced by HEC-HMS indicate that the volumes of runoff equal 0.18, 0.911, 2.53, 3.89 and 5.89 Mm3 for return period 5,10,25,50 and 100 years respectively, also pointed the runoff depth 0.5, 2.56, 7.10, 10.93 and 16.54 mm respectively as indicated in table 9. The hydrographs which be produced by Microsoft Excel depending on the extracted date from HEC-HMS indicate the values of the peck of discharge and the time of peak for storms of different return periods as shown in figure 15 and table 9.

**Table 9 Rainfall depth, Runoff volume and depth, peck of discharge and its time of wadi Tayyibah**

| Return period (years) | 5.00 | 10 | 25 | 50 | 100 |
|---|---|---|---|---|---|
| Rainfall depth (mm) | 20.60 | 29.2 | 40.7 | 49.3 | 58 |
| Runoff volume (Mm3) | 0.18 | 0.91 | 2.53 | 3.89 | 5.89 |
| Runoff Depth (mm) | 0.50 | 2.56 | 7.1 | 10.93 | 16.54 |
| Peak of discharge (m3/s) | 3.80 | 20 | 60.4 | 96.1 | 150 |
| Time of Peck(min) | 1425.0 | 1215 | 1155 | 1125 | 1110 |

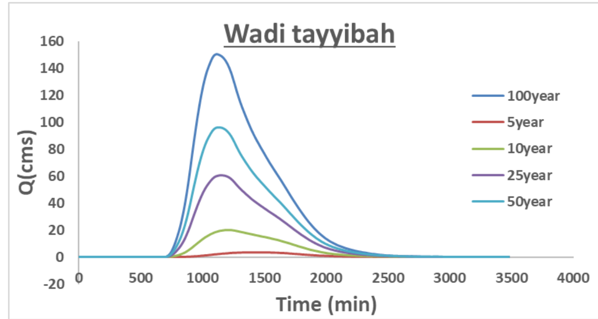


**Figure15 hygrographs of different return periods of wadi Tayyibah**

### 5.2.Morphometric Analysis of Wadi Tayyibah

The expression of morphometric analysis is used to indicate the measurements and the characteristics of the earth surface and its effects on the streams. These measurements could be classified as Basin geometry measurements which related with the dimensions of the basin as length, width, area, and perimeter in addition to Circularity ratio and Form factor ratio. Measurement related with the Drainage Network such as stream orders, stream number stream length, Bifurcation ratio and drainage density. Measurement related with terrain properties as elevations, relief ratio, Ruggedness number, Hypsometric internal and slops. The morphometric properties of this study were calculated with ArcGIS 10.3 software. The results show that wadi Tayyibah (area 355.9 Km2 and perimeter 125 Km) has five stream orders. The properties of the network of the streams are very influential in the basin study so ArcGIS 10.3 software and HEC-HMS model besides to Microsoft Excell are integrated in this study to determine most of morphometric properties as shown table 10

#### *5.2.1.Drainage Density (DD)*

The drainage density is very effective property for hydrologists in determining the runoff potential [24] .DD has a very important relationship with climatic conditions especially the precipitation on the one hand ,and lithology from other hand, besides its relation with land slop[25],where the areas with high rainfall , rocks with low permeability and surface with steep slop ,all that produce high drainage density. the drainage density is defined with the result of dividing total length of streams and area of basin so DD of Wadi Tayyibah equal 1.23 Km/ Km2 where the total length of streams equal 442.8 Km and the area equal 355.9 Km2 as shown in table 10. Also, Drainage density map has been produced by ArcMap software as shown in figure16. The more moderate Drainage density that lead to moderate permeability.[26].

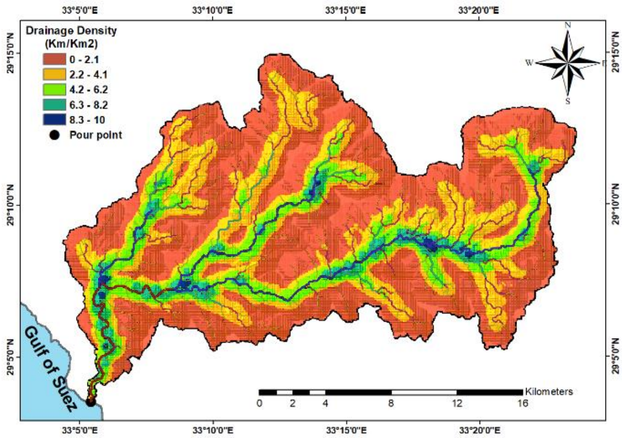


**Figure 16 Drainage density map of wadi Tayyibah**

*5.2.2.Stream Frequency (F)*

The stream frequency illustrated by [27] is defined with the result of dividing the total number of streams and the basin area .SO stream frequency of wadi Tayyibah equal 1.011 stream/ Km2, where the total number of streams equal 360 stream and the wadi area equal 355.9 Km2. This mean that wadi Tayyibah is in the young stage where there is about one stream for every one square kilometer as shown in table10. The Drainage density and stream frequency are the most effective parameters in Morphometric classification of the basins that control the runoff and a lot of hydrological characteristics[25].

*5.2.3.Bifurcation ratio (Rb)*

The bifurcation ratio was defined by [27]as follow ,it represents the relation between the streams number of any stream order and the following order to it according to[23] . the bifurcation ratio of wadi Tayyibah ranging from 3 to 5.33 as indicated in table10.There is important relationship between the bifurcation ratio and the runoff where it decreases with the increasing of the bifurcation ratio.

*5.2.4.Infiltration Number (IF)*

infiltration number is calculated depending on the drainage density and stream frequency which is equal the stream frequency multiplying by the drainage density. So, the infiltration Number of Wadi Tayyibah equal 1.26 stream/Km. the relationship between the infiltration number and runoff is direct relationship where the increasing of infiltration number indicates the decreasing in infiltration and runoff increasing.

*5.2.5.Stream Length Ratio (RL)*

Length Ratio is expressed as the ratio between the length of main stream of any order and the following main stream length of the next order [28].the value of RL of wadi Tayyibah are ranging from 0.299 to 1.473 as indicated in table 10. RL has an effective relationship on the surface flow discharge.

*5.2.6.Elongation Ratio (Re)*

Elongation ratio describes the extension of basin according to the rectangular shape The values of Re increase in case of longitudinal basins but decrease in basins which have clear difference between the length and the width. Elongational ratio could be defined by the ratio of circular `s diameter with the same area of the basin and the length of the basin [29]. Elongation ratio of wadi Tayyibah is evaluated with 0.64.

*5.2.7.Circularity Ratio (Re)*

Circularity Ratio indicate the ratio between the basin area and basin area in circular shape have the same perimeter of the basin [23].the circularity ratio of wadi Tayyibah equal to 0.29 as indicate in table 10

*5.2.8.Form Factor Ratio (FFR)*

Form factor ratio is known by the ratio between the area of the basin and the length of the basin. The area of wadi Tayyibah equal 355.9 km2 with length 33 km so the form factor ratio of wadi Tayyibah equal to 0.33 as shown in table 10.[30] suggested this ratio to predict the intensity of flow of the basin with known area.

**Table 9 Some of Morphometric properties of Wadi Tayyibah**

| **Wadi name** | | Tayyibah |
|---|---|---|
| **Bifurcation ratio (Rb)** | **1st/2nd** | 3.65 |
| | **2nd/3rd** | 4.56 |
| | **3rd/4th** | 5.33 |
| | **4th/5th** | 3 |
| **Basin Area A(Km2)** | | 355.9 |
| **Perimeter (km)** | | 125 |
| **Max. Elevation(m)** | | 1133 |
| **Min. Elevation(m)** | | 3 |
| **Relief(m)** | | 1130 |

| **Wadi name** | | Tayyibah |
|---|---|---|
| **Strems order (Su)** | | 5 |
| **Stream Numbers (Nu)** | **1st** | 267 |
| | **2nd** | 73 |
| | **3rd** | 16 |
| | **4th** | 3 |
| | **5th** | 1 |
| **Stream Length (Lu) (Km)** | **1st** | 227.05 |
| | **2nd** | 108.86 |
| | **3rd** | 36.71 |
| | **4th** | 54.08 |
| | **5th** | 16.16 |

| **Wadi name** | | Tayyibah |
|---|---|---|
| **Mean Stream Length (Lsm)** | **1st** | 0.85 |
| | **2nd** | 1.491 |
| | **3rd** | 2.294 |
| | **4th** | 18.02 |
| | **5th** | 16.16 |
| **Stream Length ratio (RL)** | **2nd/1st** | 0.479 |
| | **3rd/2nd** | 0.337 |
| | **4th/3rd** | 1.473 |

| | 5th/4th | 0.299 |
|---|---|---|

| Wadi name | Tayyibah |
|---|---|
| Drainage Density (DD)(Km/Km2) | 1.23 |
| Stream Frequency (F) (Stream/Km2) | 1.01 |
| Form factor ratio (FFR) | 0.33 |
| Length of overland flow (Lo) | 0.40 |
| Circularity ratio (Rc) | 0.29 |
| Elongation ratio (Re) | 0.64 |

## 6. CONCLUSION

The main purpose of this study is evaluation the runoff and delineation the watersheds in wadi Tayyibah which located in south Sinai Egypt relying on (SCS-CN) method using Hydrologic Engineering Center-Hydrologic Modelling System (HEC-HMS) and ArcGIS software in traying to benefit from it in different uses and in addition to avoid the hazards which occurred due to the floods trough design protection structures which depend on the amount of run off. The conclusions can be summarized as following:-

- The delineation of wadi Tayyibah indicate that its area is 356 $km^{2,}$ perimeter equal 125 Km, Width 10.8 km and length equal 33 km
- The elevation of wadi Tayyibah range ranges from 1 m to 1133 m above the sea level
- The land uses of wadi Tayyibah are scrub/shrub with area 119.79 $km^2$, buildings with area 0.22 $km^2$ and Bare ground with 235.93 $km^2$
- The Curve Number of wadi Tayyibah is 78
- The runoff as a volume in wadi Tayyibah of return periods 5,10,25,50, and 100 years are 0.18, 0.911, 2.53, 3.89 and 5.89 $Mm^3$ respectively.
- The runoff as a depth in wadi Tayyibah of return periods 5,10,25,50, and 100 years are 0.5, 2.56, 7.10, 10.93 and 16.54 mm of return periods, respectively

The Morphometric properties of wadi Tayyibah can be summarizes as following

- Drainage Density (DD) of Wadi Tayyibah equal 1.23 Km/ $Km^2$
- Stream Frequency (F) of wadi Tayyibah equal 1.011 stream/ $Km^2$
- Bifurcation ratio (Rb) of wadi Tayyibah ranging from 3 to 5.33
- infiltration Number (IF) of Wadi Tayyibah equal 1.26 stream/Km
- Stream Length Ratio (RL) of wadi Tayyibah are ranging from 0.299 to 1.473
- Elongation Ratio (Re) of wadi Tayyibah is evaluated with 0.64.
- Circularity Ratio (Re) of wadi Tayyibah equal to 0.29
- Form Factor Ratio (FFR) of wadi Tayyibah equal to 0.33

## 7. RECOMMENDATION

The recommendation can be summarizes as following: -

- We prompt using the data of runoff which be estimated in this study the suitable uses.
- We recommend building Integrated database for wadi Tayyibah on ArcGIS.
- We prompt using Geographic Information systems (GIS) and one of Multi-Criteria Decision Making (MCDM) as Analytical Hierarchy Process (AHP) to choose the best location to construct water harvesting structure in wadi Tayyibah.
- We motivate studying the hazards of floods which may effect on the railways and buildings in the wadi Tayyibah.

**Credit Authorship Contribution Statement**

Mahmoud Maher: Collecting data, Methodology preparation Writing

Tarek H. Nasrallah: Reviewing, Editing

Mostafa Rabah: Reviewing, Editing, Supervision, Fahmy S Abdelhaleem: Generating the idea, Validation, Reviewing, Supervision

**Declaration of Competing Interest**

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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