

Analysis of Hydro-Morphometric of Flash Flood Hazard Map of Wadi Gharandal Basin, Southwestern Sinai Area, Egypt, Using GIS and RS

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ABSTRACT

The main object of the present study is to assess and produce flash flood hazard map to Wadi Gharandal based on the morphometric analysis with the aid of the techniques Remote sensing (RS) and geographic information system (GIS) ASTER DEM data are used to extract the stream network to assess the morphometric parametric and to make risk zone map of the study area. (GIS) and (RS) have been utilized for the morphometric analysis of wadi Gharandal basin southwestern Sinai, Egypt. Several morphometric parameters have been computed and analyzed, such as, circularity ratio, elongation ratio, form factor ratio, stream frequency and bifurcation ratio. Impacts of morphometric parameters on flash flood characteristics have been also investigated. Wadi Gharandal is divided into eighteen relatively large sub-basin, nine of them have high susceptibility for flooding, six have medium susceptibility and about three have low susceptibility for flooding. [Bul. Soc. Géog. d'Égypte, 2018, 91: 67-87]

Key Words: GIS, RS, ASTER, DEM, Hydro-Morphometric parameters.

Introduction

One of the main objects of the present study is using the powerful of a GIS tool to produce a map showing the pre-development flood risk potential of the Wadi Gharandal basin. The drainage basin analysis is important in any hydrological investigation like assessment of groundwater potential and management. The morphometric analysis of drainage basin carried out by Horton, (1945) Strahler (1952) and others is based on the fact that for the given conditions of lithology, climate, rainfall and other relevant parameters of the basin the river network, the slope and the surface relief tend to reach a steady state in which the morphology is adjusted to transmit the sediments and excess flow produced.

The present paper describes the drainage characteristics of Wadi Gharandal basin obtained through RS and GIS techniques as abasis of morphometric analysis. It is felt that the study will be useful to understand hydrological behavior of the basin. The remotely sensed data is geometrically rectified with respect to the studied Egyptian civil survey Authority topographical maps at scale 1:50000 using ENVI 7.4 software.

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Study Area

The study area is located in the southwestern Sinai Egypt. It is bounded from the West by the Gulf of Suez and from the East by Wadi Al-Arish and Wadi Wardan, from the north by Wadi Wardan watershed and from the south by wadi al Hamr watershed (Figure 1). Wadi Gharandal basin is elongated and covers an area of about 1261.1 km², and drains to the Gulf of Suez at about 24 km to the north of Abu zanima Town.

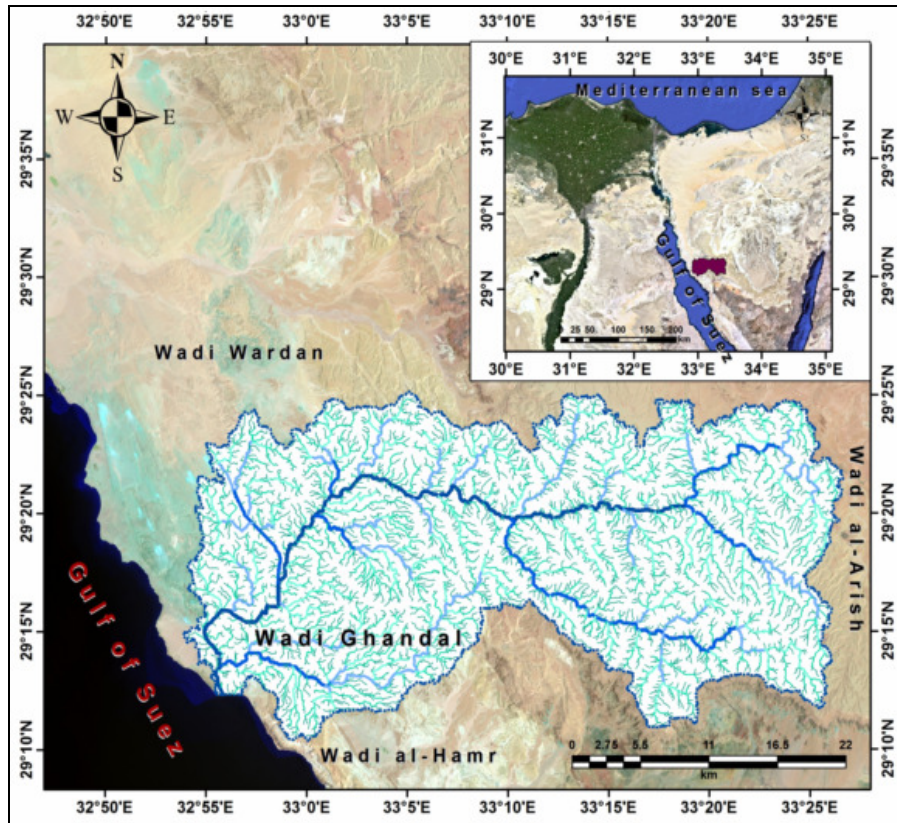


Figure 1. The Study area.

Methodology

The present study is based on four types of data set, which are as follows. (i) topographic map (scale 1:50,000) (ii) Geological maps (scale: 1:100,000). (iii) Aerial-photos (scale: 1:33,000). (iv) Satellite images (Landsat 7 ETM, 2000) (scale: 1:400,000). All primary data were imported in a Geographical Information System in environment to produce different GIS overlays and to compute the different areal and liner morph-hydrologic

parameters the drainage basin and network. There are 3 meteorological stations in and around the study area. Their climatic data recorded from 1934 up to 2016.

Physical Characteristics of The study Area

Geological Study Area:

Wadi Gharandal basin is covered by basement rocks. It consists of igneous and metamorphic rocks, forming high areas which are deeply dissected by numerous narrow and long wadies bounded by steep cliffs forming high mountains with extended flat topped plateaus and steep slopes. The different rock units are highly affected by several faults and joints with different trends and densities (Figure 2).

The cretaceous sequence is classified into: The Wata Formation which deposited above the Raha Formation. The Matulla Formation, which overlies the Wata formation. Plate (1) consists mainly of limestones, marbles commonly alternating with shales, sandstones, shaley limestones and siliceous limestones. This Upper Cretaceous sequence is topped by the Sudr Formation that is composed mainly of chalk, partly changing to marls or argillaceous to crystalline limestone. The Upper Cretaceous sequence is unconformably overlain by calcareous Eocene sediments (limestone, chert, marl and shale) (Anwar, 2009, p. 84). The Miocene sequence exposed at the study area is classified into three main groups: (upper Miocene) South charib Formation and the Middle Miocene Hammah firawn Formation, Balaim Formation, Karim Formation (Egyptian General Petroleum Corporation, EGPC, 1964; Gawad et al., 1986) and the lower Rudays Nuknl Formations with extrusive basaltic rocks. The Eocene sequence is classified into five formations; the Minya Formation and the wasit (Lower Eocene), Samalut Formation (Lower-Middle Eocene) and the Tankah Formation, atyaban Formation (Upper Eocene). The Quaternary deposits are cover by the stream courses and flood plainarea (Plate 2).

Climatic Conditions

The climatic conditions of the Sinai Peninsula are similar to those, which characterize desert areas in other parts of the world. They include extreme aridity, long hot and rainless summer months and a mild winter. During the winter months, some areas of Sinai experience brief but intensive rainfall that makes wadi beds overflow and sometimes cause severe flash floods damaging the roadways and, sometimes, human lives (JICA, 1999, p. 65). The climatic data from 1980 to 2016 of three meteorological stations around the study area are available.

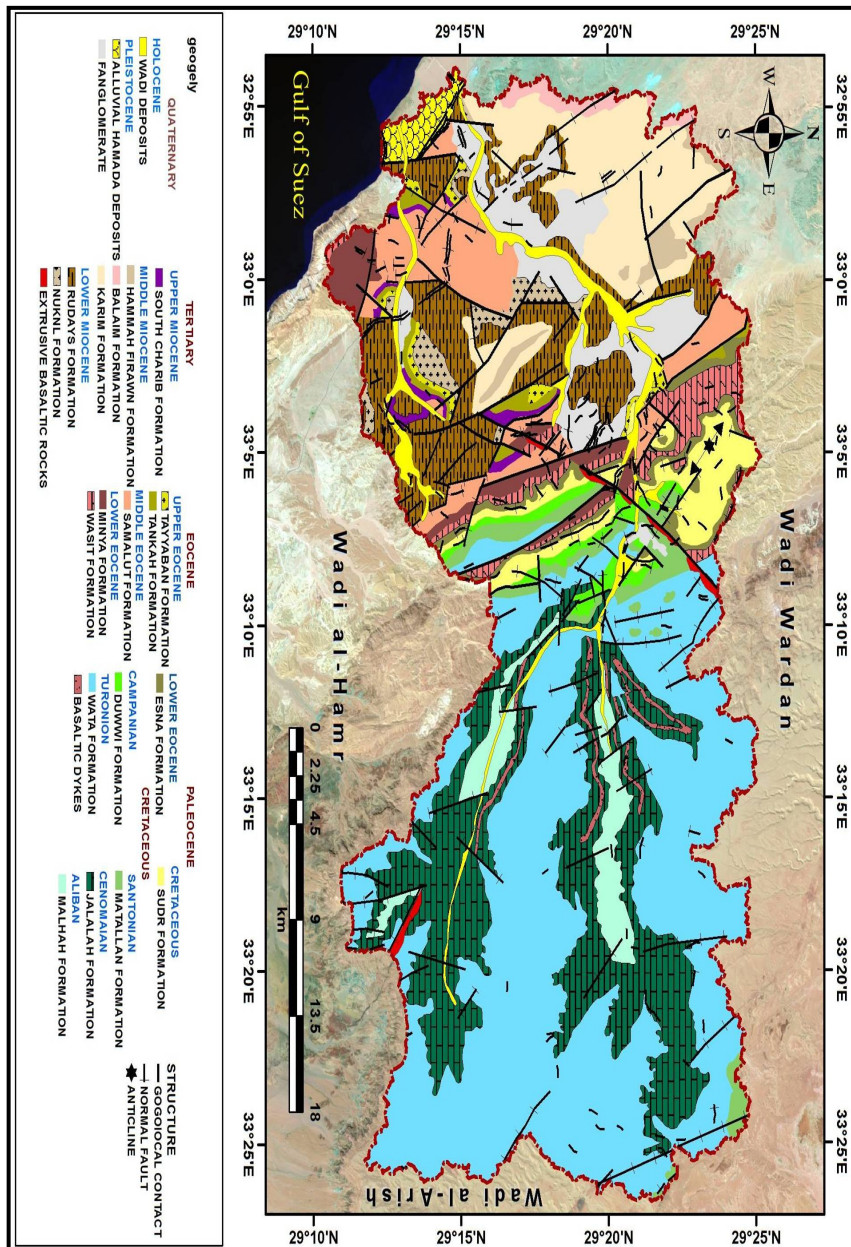


Figure 2. Geologic map of the study area modified from Conoco, 1987.



Plate 1. Wata Formation above the Raha Formation in Wadi Gharandal basin.



Plate 2. The Quaternary deposits are covered by the stream courses and flood plain areas in Wadi Gharandal basin.

Table 1. Climatic Data of Three Meteorological Stations from 1980 up to 2016 for The study Area.

Station	Saint Catherine	EL-Tur	Ras Sudr
Max T (C)	24.3	28.3	28.7
Min T (C)	8.9	17.5	17.6
Annual Rainfall	63	10.4	15.4
Annual Rainfall in one day (mm/in2)	10.5	6.2	3.4
Average evaporation (mm)	11.6	9.9	8.8
Average Humidity (%)	29	59	58

Source: The Egyptian meteorological authority from 1980 to 2016.

The minimum and maximum temperatures of the EL-Tur Station are 17.5-28.3 °C and for St. Catherine 8.9-24.3 °C and for Ras Sudr. 17.7-28.7 °C. Flood resulting from convective rains has been observed during all seasons, the mean annual rainfall ranges between 10.4 mm/year at El Tur and 15.4 mm/year at Ras Sudr and 63 mm/year at St. Catherine and these amounts indicate that the rain increases toward the east of Sinai. The hydrographical basins of the study area which have high surface water potentialities due to the fact that the eastern branches of their steep sloping channels drain the high lands of south and central Sinai where high rates of rainfall prevail (Gad, 1996, P. 25).

However, chances for infiltration are limited due to the steep rocky slopes of their Wadis. Average rainfall is relatively low with a mean of about 3.4 mm/year at Ras Sudr Station, 6.2 mm/year El-Tur Station and relative humidity varies between 29 and 59% at St. Catherine and El-Tur respectively. Evaporation in the study area is very important because it is much higher than precipitation; the values of evaporation depend on some factors such as temperature, relative humidity, wind speed, the plant cover and solar radiation and average evaporation varies between 8.8 mm Ras Sudr Station and 11.6 mm in St. Catherine.

Generally, the prevailing climatic conditions in the south Sinai include low rainfall, high temperatures, strong wind, high evaporation and low relative humidity.

Morphometric Analysis of The studied Basin Using Satellite Image and GIS

Combining the remote sensing data in terms of satellite images with topographic maps of smaller scale would noticeably enhance the accuracy of maps outputs. Overlaying the automated networks on satellite images is considered as a good routine to enhance the accuracy of output networks and

minimize the errors in the basin calculations. Another advantage of using the satellite images is getting high resolution and updated view of the drainage pattern (El-Behiry, 2005, p. 21). In the present study, the ASTER DEM data which corrected by topographic maps of scale 1:50,000 use the extract of the drainage networks of the study area. These work steps are indicated as follows:

- In the first step, a current of the stream network from the Digital Elevation Model (DEM). As shown in Figure (3), the stream network map of the Gharandal basin was extracted from this step. The extraction of the stream network was compared with parameters of a georeferenced topographic map (1:50,000), the Gharandal basin is of the sixth order according to ordering system of Strahler.
- The water divide line was drawn through the highlands between the sub-basins and matched with the topographic maps and then pour points were identified and digitized was used to ensure the accuracy of the work using the watershed tool.
- Morphometric parameters for each part of the sub-basin were extracted in the GIS environment.

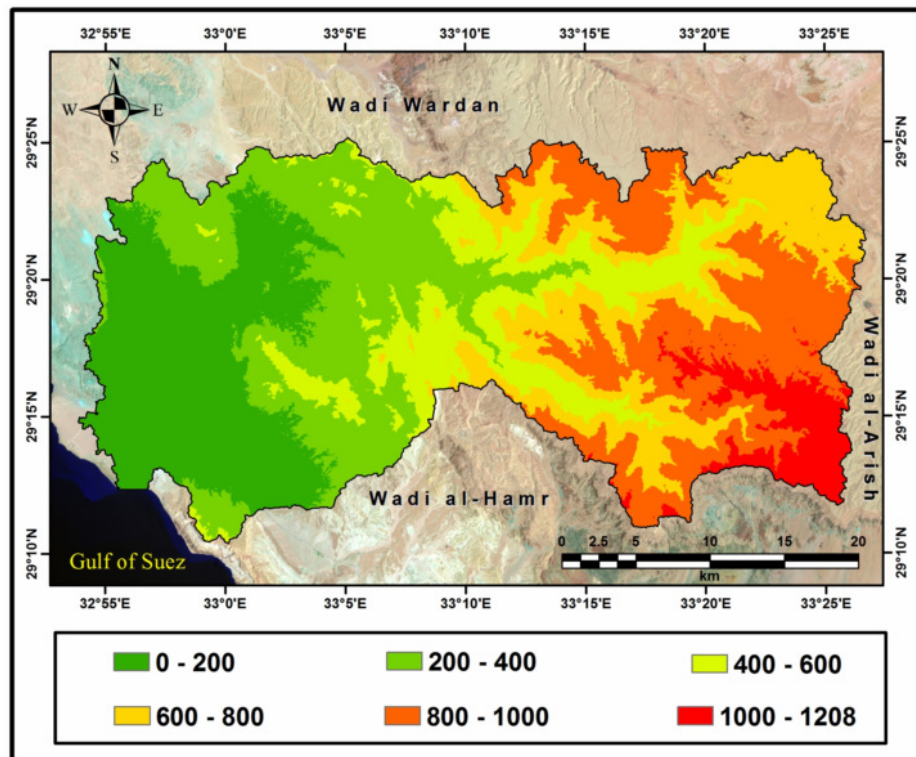


Figure 3. The digital elevation model (DEM) of the study area.

The hydrographic Gharandal basin map that is delineated and divided into 18 sub-basins. Morphometric parameters of the drainage network were also computed using interactivity Arc GIS. The morphometric parameters with respect to the stream order (U), bifurcation ratio (RB), stream frequency (F), stream density (SD), and other morphometric parametric in (Table 2). The watersheds of the Wadi Gharandal basin are classified according to their area and the geomorphology characteristics for each watershed are used. The characteristics for each basin are summarized as the following:

Wadi Gharandal covers an area of about 1261.1 k m² of which 74.6 km in length, the basin perimeter is about 223.5 km, bifurcation ratio is 8.8, frequency is 6.2. Wadi Gharandal has six order trunks that reflects the wide areal extent of the basin (Table 3), Wadi Gharandal is divided into eighteen relatively large sub-basin (Figure 4 and Table 2).

Morphometric analysis of Hydrographic Gharandal Basins

The hydrographic Gharandal basin that is delineated and divided into 18 sub-basins.

Drainage Frequency (F):

The high value of stream frequency is more than 0.5 and tend to give more possibilities for the collection of runoff. Drainage frequency in Wadi Gharandal basin, ranges between 3 in w (B6-5) sub-basin and 14.4 w (B7-5) sub-basins.

Overland Flow (OLF):

Overland flow in wadi Gharandal ranges between 0.19 in w (B9-4) sub-basin and 0.24 in w (B5-5) sub-basin. Generally, the basins of long overland flow make highly infiltration rate and also a low risk of flash floods.

Drainage Density (CD):

The drainage density is connected to rock strength erosion, to the climatic conditions and soil permeability. In geomorphology, the term density of fragmentation is utilised and is given by the report between the length of the valleys and the investigated surface, evaluated in the same measurement units (Filip, 2008). The basins of high values are a high flash flood and favored in regions of weak or impermeable surface material, Drainage density in Wadi Gharandal basin ranges between 1.6 in w (B12-4) sub-basin and 5.4 in w (B7-5) sub-basin (Table 2).

Table 2. Morphometric parameters of the drainage basins of the Gharandal basin.

Name	A Km ²	U	Nu	Lu (Km)	Rb	Rbw	F	CD	MD	OLF	P km	Basin shape		H (m)	MG	RF	
												Re	ML km				
B1-5	132.8	5	816	312.2	4.9	4.11	6.1	1.3	198	0.23	98.2	15.6	0.36	0.66	187	10.9	0.54
B2-5	65.3	5	385	144.3	2.5	5.1	5.8	2.2	45.2	0.23	19.2	14.6	0.35	0.71	19	10.2	0.30
B3-5	165.8	5	1139	406.8	3.7	4.36	6.8	2.4	269	0.22	65	41.6	0.38	0.69	135	6.5	0.09
B4-5	151	5	964	372.6	2.4	4.8	6.3	2.5	90.3	0.21	39.5	36.4	0.60	0.42	159	19.2	0.11
B5-5	56.15	5	362	144.5	2.2	4.8	6.4	2.6	185.1	0.24	68.5	16.8	0.34	0.64	169	9.5	0.19
B6-5	64.4	5	194	181.5	2.8	3.2	3	2.8	86.2	0.23	44.2	9.9	0.49	0.55	83	8.66	0.65
B7-5	30	5	431	163.5	2.5	3.9	14.4	5.4	59.1	0.21	97	6.2	0.66	0.34	91	14.6	0.78
B8-6	370.7	6	2428	905.5	6.5	4.6	2.4	2.4	1523	0.22	221	39.8	0.25	0.56	87	4.4	0.23
B9-4	26.3	4	106	42.9	4.6	5.21	4	1.6	19.8	0.19	19.6	6.9	0.29	0.75	58	7.8	0.55
B10-4	9.5	4	41	16.5	3.7	3.5	4.3	1.7	87.1	0.23	45.2	6.2	0.49	0.54	67	7.5	0.24
B11-4	17.6	4	78	31.1	4.4	4.2	4.4	1.8	17.6	0.23	19.2	7.2	0.55	0.35	94	15.6	0.33
B12-4	30.6	4	123	49.1	4.6	3.2	4	1.6	88.2	0.23	36.5	8.5	0.47	0.58	85	8.55	0.42
B13-4	16.1	4	70	29.3	3.8	3.9	4.3	1.8	41.2	0.21	25.3	7.8	0.36	0.54	89	9.2	0.26
B14-4	22.1	4	92	37.5	4.6	3.5	4.2	1.7	88.8	0.23	36.2	9.9	0.47	0.61	89	8.4	0.22
B15-4	16.4	4	70	29.1	3.8	4.2	4.3	1.8	19.6	0.23	50.1	10.2	0.4	0.58	91	6.6	0.15
B16-4	23.6	4	101	41.8	4.2	3.1	4.3	1.8	66.7	0.21	29.2	8.2	0.42	0.61	51	6.2	0.35
B17-4	13.3	4	74	61.3	4.9	3.9	5.6	4.6	15.4	0.15	9.5	1.9	0.55	0.41	49	7.9	0.91
B18-4	26	4	105	44.4	4.5	5.1	4	1.7	26.9	0.23	57	6.4	0.57	0.48	90.2	11.2	0.63
W Gharandal	1241.1	6	7672	3021.5	8.8	4.9	6.2	2.4	2784	0.23	223.5	59.6	0.29	0.71	390	7.6	0.34

U = Number of order, *Nu* = Number of stream segment, *Lu* = Total length of stream, *Rb* = Bifurcation ratio, *Rbw* = Weight mean *Rb*,
H = Difference in elevation in meter, *F* = Frequency, *CD* = Calculated density, *MD* = measured density, *OLF* = Overland flow, *P* = Perimeter in km,
ML = Max .Length in km, *Re* =Circularity ratio, *Re* = Elongation ratio, *A* = Area in km², *Rf* = Form factor,

Table 3. The adopted Morphometric Parameter used in the present study.

Parameter	Formula	References
Area of basin (km ²) A	measured by Arc GIS 9.3	
Perimeter of basin (km) P	measured by Arc GIS 9.3	
Circularity ratio	$Rc=4\pi A/P^2$ A = Area of the basin (km ²) P = Perimeter of basin	Miller (1953)
Bifurcation Ratio: Rb	Rb = Number of streams of an order / number of streams of the next order	Schumm (1956)
Form factor ratio	$Rf = A / Lb.$	
Elongation ratio (Re)	$Re = \sqrt{4A} / \pi / Lb.$ A = Area of the basin (km ²) Lb = Basin length	Schumm (1956)
frequency (F)	$F = N / A$ N = Total no. of streams of all orders A = Area of the basin (km ²)	Horton (1932)
Nu	Nu = Total number of streams of all orders	Strahler (1964)
Lu	Lu = Total stream length of all orders,	Horton (1945)

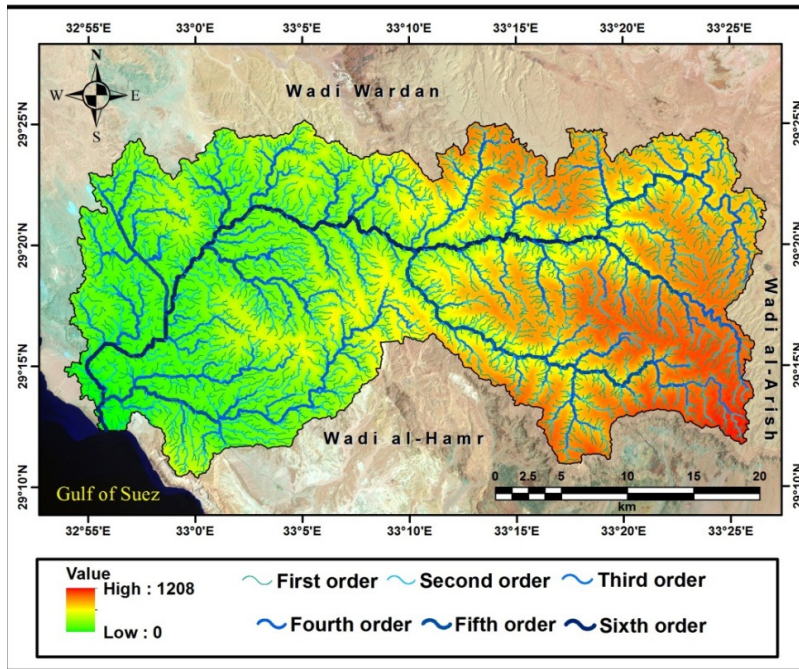


Figure 4. The drainage network Wadi Gharandal overlaid of (DEM).

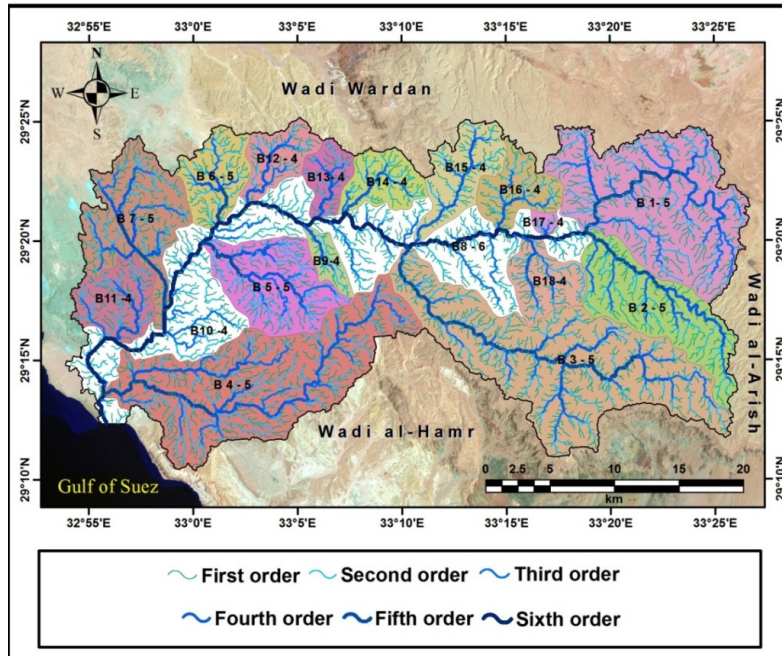


Figure 5. Wadi Gharandal basin and its sub basins.

Circularity Ratio (Rc):

Circularity ratio near one is typical of regions of nearly circular basins with low relief and high-risk flash flood. In Wadi Gharandal basin, whereas the more values of circularity decrease the more a basin is far from regular shape the more circularity values increase, the more a basin is near of the regular shape. In the study area, w (B7-5) sub-basin is the nearest basin to regular shape while its values are considered the largest values reaching to 0.66.

Elongation Ratio (Re):

The ratio between the diameter of circle with the same area of the basin (D) and the basin length (L). This ratio runs between 0.6 and 1.0 over a wide variety of climatic and geologic types. Values near to 1.0 are typical of regions of very low relief, whereas values in the range 0.6 to 0.8 are generally associated with high relief and steep slopes (Strahler, 1964). Elongation ratio in Wadi Gharandal basin ranges between 0.71 in w (B2-5) sub-basin and 0.34 in (B7-5) sub-basin.

Form Factor (RF):

Factor as the ratio of the area of the basin and square of the basin length (Horton, 1932). Form factor in Wadi Gharandal basin 0.34, and ranges from 0.09 in w (B3-5) sub-basin to 0.91 in (B17-4) sub-basin.

Mean Gradient (MG):

A result to the slope of the basin affects mostly the quantity of infiltration that takes place and the rate of overland flow, the basins with time for infiltration and the recharge of groundwater is minimized (Arnous et al., 2011). Mean gradient in Wadi Gharandal basin ranges between 6.2 in w (B16-4) sub-basin and 19.2 in w (B3-5) sub-basin.

In the present study, ranking of streams has been carried out based on the method proposed by (Strahler, 1964). The stream orders are classified up to six orders in the Wadi Gharandal basin.

Stream Number (Nu):

The number of streams of different orders in a given drainage basin tends closely to approximate as inverse geometric series of which the first term is unity and the ratio is the bifurcation ratio (Horton, 1945). The total Stream number is 7655 stream lines including Wadi Gharandal basin is recognized in the whole basin, out of them 54.1% (4147) is 1st order, 22.9% (1753) 2nd order, 10.8% (831) 3rd order, 6.3% (304) 4th order, 0.18% (24) 5th order, 6th order stream (1).

Table 4. Morphometric parameters of the drainage basins of the Gharandal basin.

Name	total Stream number	1 st		2 nd		3 rd		4 th		5 th		6 th	
		Nu	Lu	Nu	Lu	Nu	Lu	Nu	Lu	Nu	Lu	Nu	Lu
B1-5	816	416	166.4	189	72.6	2.2	48.4	1.5	24.3	8	1	0.5	8
B2-5	385	195	78	81	32.4	2.4	17.2	1.8	15.9	2.9	1	0.8	2.9
B3-5	1139	577	230	273	109.2	2.1	45.6	2.3	21.3	5.1	1	0.7	5.1
B4-5	964	488	195.2	245	98	1.9	39.6	2.3	39.2	2.7	1	0.6	2.7
B5-5	362	184	73.6	89	32.6	2	21.9	2.2	15.6	2.9	1	0.8	2.9
B6-5	194	98	39.2	57	22.8	1.7	10.1	2.8	1.9	3.3	1	0.5	3.3
B7-5	431	221	88.4	99	39.6	2.2	22.3	1.8	12.8	2.9	1	0.4	2.9
B8-6	2428	1231	492.4	568	227.2	2.1	114.8	2.0	65.6	4.3	17	4.3	9.6
B9-4	106	88	35.2	14	5.6	6.2	3	1.2	0.9	3			
B10-4	41	33	13.2	5	2.1	6.6	2	0.6	0.6	2			
B11-4	78	63	25.2	12	4.8	5.2	2	0.3	0.8	2			
B12-4	123	95	38	22	8.8	4.3	5	1.5	0.8	5			
B13-4	70	53	21.2	12	4.9	4.4	4	2.3	0.9	4			
B14-4	92	72	28.8	13	5	5.5	6	2.9	0.8	6			
B15-4	70	54	21.6	12	4.8	4.5	3	1.8	0.9	3			
B16-4	101	77	30.8	19	8.2	4	4	2.1	0.7	4			
B17-4	74	49	47.2	19	10.2	2.6	5	3.1	0.8	5			
B18-4	105	84	33.6	17	7.9	4.9	3	2.3	0.6	3			
W Grandell	7655	4147	1685	1753	696.7	2.4	338	2.1	404.4	2.7	24	8.6	12.6
											1	1.2	24

after: researcher

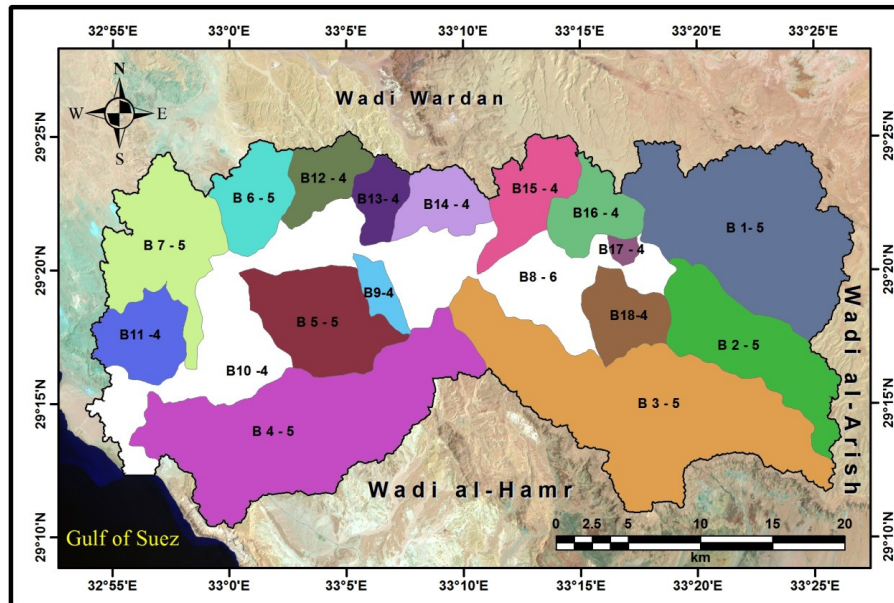


Figure 6. Grandell basin and its sub-basins in the study area.

Stream Length (Lu):

Stream lengths delineating the total lengths of stream segment of each of the successive orders in a basin tend to approximate a direct geometric series in which the first term is the average length of the stream of the first order. Horton (1945) identified that the cumulative stream length is higher in first-order streams and decreases as the stream order increases. The highest stream order (6th). Total stream length of all orders is 3133 km line of Wadi Gharandal basin is recognized in the whole basin, out of them 53.71% (1685) km is 1st order, 22.2% (696.7) km 2nd order, 10.7% (338) km 3rd order, 12.9% (404.4) km 4th order, 0.27 % (8.6) km 5th order, 0.03% (1.2) km 6th order.

Shamy's Model:

According to Shamy's Model, the area was divided into three areas: The first zone (A) is characterized by high possibility for flash floods and low possibility for the groundwater aquifer recharging, the second zone (B) is characterized by moderate possibility for flash floods and moderate possibility for recharging the groundwater aquifer, and the third zone (C) is characterized by less possibility for flash floods and high possibility for recharging the groundwater aquifer (Fouad, 2012) (Figure 7).

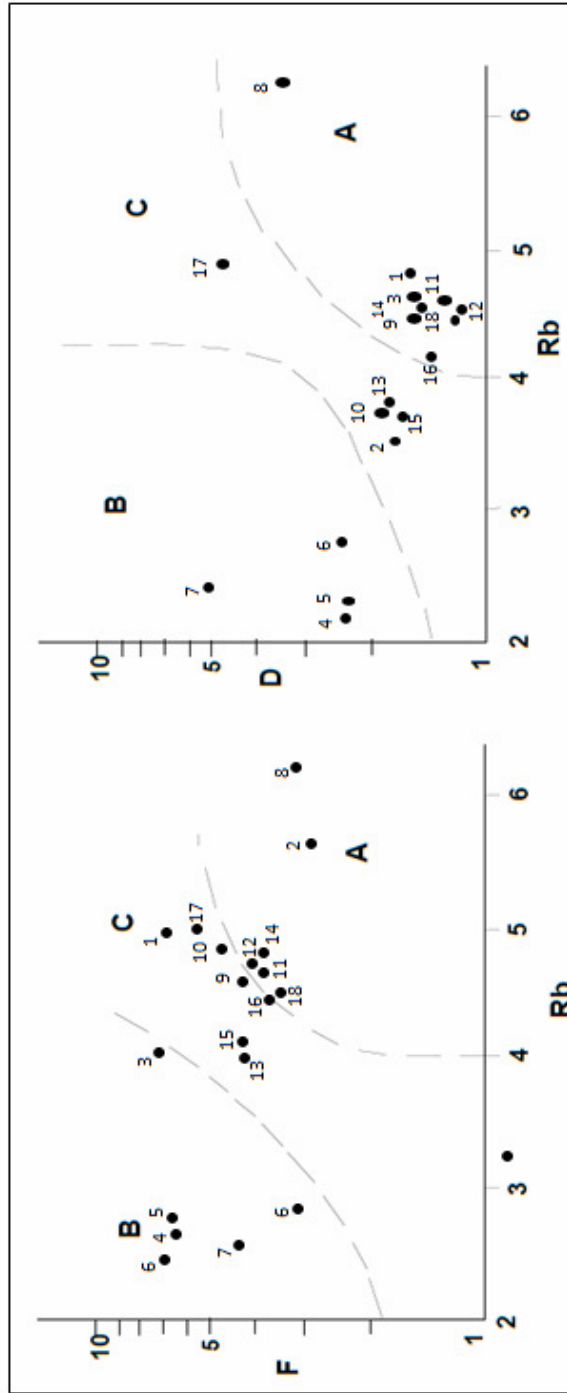


Figure 7. Hazard degree according to drainage density vs. bifurcation ratio following El-Shamy's and drainage frequency vs. bifurcation ratio following El-Shamy's (1992) approach.

Table 5. Hazard degree analysis following El-Shamy's (1992) approach.

Name	HD1	HD2	FHD
B1-5	M	H	H
B2-5	H	L	M
B3-5	L	H	H
B4-5	M	M	M
B5-5	M	M	M
B6-5	M	M	M
B7-5	M	M	M
B9-4	L	H	M
B10-4	L	H	M
B11-4	H	L	M
B12-4	H	H	H
B13-4	L	L	L
B14-4	H	H	H
B15-4	L	L	L
B16-4	H	H	H
B17-4	L	L	L
B18-4	H	H	H

HD1 = hazard degree Br vs. F, HD2 = hazard degree BR vs. D, and FHD = Final hazard degree from HD1 and HD2. L: low hazard (low possibility for flash floods); M: moderate hazard (moderate possibility for flash floods); and H: high hazard (high possibility for flash floods). (after: researcher based on Figure 7)

1) Flash Flood Hazard Map

According to the overlaying of all maps and calculation, the flash flood hazard map area defined is shown in (Figure 6). The overall hazard degree was added to the GIS database to assist in constructing the drainage basin hazard map for the most hazardous basins. The assessment is based on the computed weight and mean values of the important morphometric parameters in Tables (6 and 7) consequently the study basin can be classified in accordance with the weighting process into three Categories: high, medium and low susceptibility for flooding shown in Table (7).

Finally, the Flash flood hazard map of Wadi Grandell basin is considered as a first attempt to assess the hazardous zone in the whole basin and its sub-basin (Figure 8), and the results were identical with El-Shamy's Model of six basins and deferred of three basins (Plate 3).

The for ementioned assessment basically based on the morphometric parameters, therefor some field cheek and rainfall –runoff statistics are needed.

Table 6. The weighting ranges of the morphometric parameters.

Flash flood scores based on	Measurer of drgrees hazard		
	1	2	3
Area of basin (km ²) A	≤ 50	50 - 100	≥ 100
Calculated density CD	≥ 3	2 - 3	≤ 2
Frequency F	≥ 6	6 - 4	≤ 4
Circularity ratio Rc	≥ 0.3	0.3 - 0.5	≥ 0.5
Overiand flow OLF	≥ 0.23	0.2 - 0.23	≤ 0.20
MG	≤ 10	10 - 20	≥ 20
Form factor RF	≤ 0.3	0.3 - 0.5	≥ 0.5

Table 7. Flash flood hazard weight numbers for Gharandal sub-basins and total hazard socere for each one.

Name	Sub-basin name	Flash flood scores based on							Total hazard score
		A	CD	F	Rc	OLF	MG	RF	
B1-5	w. Abu Zerub	3	3	3	1	1	2	3	16
B2-5	w. Al-Muqar	2	2	2	1	1	2	2	12
B3-5	w. Abu Shuyukh	3	2	3	1	2	1	1	13
B4-5	w. Jaref	2	2	3	3	2	2	1	15
B5-5	w. Akhul	2	2	3	1	1	1	1	11
B6-5	w. Am Kathira	2	2	1	2	1	1	3	12
B7-5	w. Al'abyad	1	1	3	3	2	2	3	15
B9-4	w. Abu Nodah	1	2	1	1	3	1	3	12
B10-4	w. Am Kashem	1	3	2	1	1	1	1	10
B11-4	w. Alsulafa	1	3	2	2	1	2	2	13
B12-4	w. Abo Azzaz	1	3	2	3	1	1	2	13
B13-4	w. Laughed	1	3	2	2	2	1	1	12
B14-4	w. Al-Jabalah	1	3	2	1	1	1	1	10
B15-4	w. Hadib	1	3	2	2	1	1	1	11
B16-4	w. Abu Aalajah	1	3	2	2	2	1	2	13
B17-4	w. Azzaz	1	1	2	3	3	1	3	14
B18-4	w. Al-Asbaa	1	2	2	3	1	2	3	14

after: researcher based on Table (6).

Table 8. Flash floods and ground water possibility of wadi Gharandal sub-basins using some hydro-morphometric parameters.

high susceptibility of flooding and low water ground recharge probability ≤ 13	medium susceptibility of flooding and medium water ground recharge probability (11-13)	low susceptibility of flooding and high water ground recharge probability $10 \leq$
B1-5	B2-5	B10-4
B3-5	B5-5	B14-4
B4-5	B6-5	
B7-5	B9-4	
B11-4	B13-4	
B12-4	B15-4	
B16-4		
B17-4		
B18-4		

after: researcher based on Table (7).

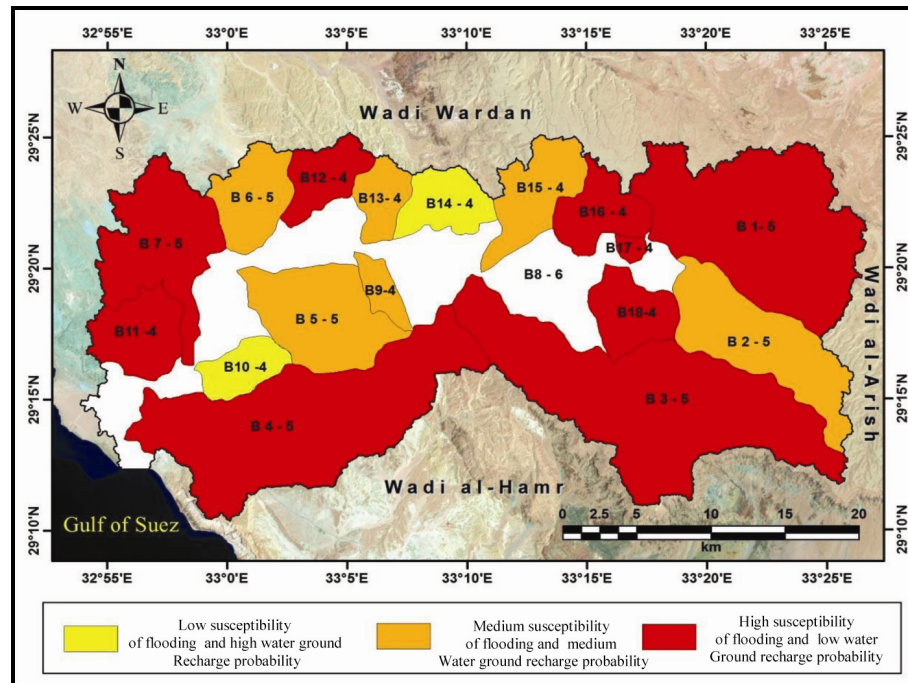


Figure 8. Flash flood hazard map of Wadi Gharandal basin sub-basins in the study area (based on the morphometric parameters).



Plate 3. Cover of plant by flood waters wadi Gharandal basin.



Plate 4. Flood waters wadi Gharandal basin.

Conclusion

A new framework which integrates the Geographic Information System (GIS) with the stallites images data for flood modeling developed. It also interconnects the terrain models and the GIS software.

The hydrographic basin of wadi Gharandal is divided into 18 delineated sub-basins. The morphometric parameters of wadi Gharandal are calculated. The flash hazard map of the area are caused mainly by soil and geological characteristic and morphometric parameters of the drainage basins. The flood hazard risk map of Wadi Gharandal basin shows that 53% of the total sub-basins in the Wadi Gharandal basin have a high flooding risk (Plate 4), and low water ground recharge probability. About 35.3% of all sub-basins have medium flooding risk and medium water ground recharge probability, which includes the Gharandal sub-basin and 11.7% of the sub-basins have a low and high water ground recharge probability. These results can be used as basic data to assist flood mitigation and landuse planning of the flood plain of Wadi Gharandal area.

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