RISK MITIGATION AND OPTIMIZATION USE OF RUNOFF WATER IN WADI Al- ASSUITY, EASTERN DESERT OF EGYPT

[3]

Abo El-Nasr, M. M.(1); Saqr, S. A.(2); Ismail, Y. L.(3); Abotaleb, H. A.(1) and Hamdy, M. M.

1) Mechanical Power Engineering Dep., Faculty of Engineering, Ain Shams University. 2) Groundwater Sector, Ministry of Water Resource and Irrigation. 3) Hydrology Department, Desert Research Center.

ABSTRACT

Egypt is currently suffering from water shortages. This shortage is expected to increase significantly, as a result of increased population growth, agricultural and industrial activities, and development demands. So it was important to research the storage and the optimal use of any possible water resources that could contribute to the provision of any amount of water no matter how small or large the quantity. As the Eastern Desert of Egypt is full of wadis, which are subject to sudden rainfall, huge amount of runoff water is wasted. Water flows over the ground to dry either by evaporation or by the amount of water that leaks through the soil. Moreover, over the years, these floods have caused disasters, threats and destruction to villages and towns.

Since Egypt needs every drop of water, floodwaters may cover part of these needs. This paper contributes to the mitigation of the dangers of flood waters in Wadi Al- Assuity in the Eastern Desert of Egypt, finding practical solutions for storing them, protecting villages from their disasters and using their water to achieve sustainable development in the surrounding environment.

The results of this research are summarized in the assessment of the Wadi Al- Assuity in terms of: determination of geomorphological characteristics, estimation and evaluation of the size of the annual precipitation and the size of the floods that threaten the urban communities located on the basin's ports, mitigate the risks and threats of this basin by taking advantage of the flood waters and taking them as a source of water.

Methods of storage and use of flood water through the construction of check dams and protection dams, cisterns (reservoirs), collection ponds, or others.

Keywords: Runoff, Water Harvesting, Geomorphology.

Location and Climate

adi Al- Assiuty is located at the western side of the Eastern Desert and drains its surface runoff toward the Nile River. It covers a catchment area around 6049.35 km^2; the area is enclosed by latitudes 25° 50' 00" and 26° 15' 00" North and longitudes 33° 45' 00" and 34° 11' 00" East. Figure 1 shows the location of Wadi Al- Assuity Basin. The maximum temperature during the year reaches 38° C in January, while the minimum temperature recorded is 7.0° C in June; the average daily relative humidity ranges from 28 % in spring and summer, and increases to around 52 % in winter and fall (Sulaiman; Abdel Aziz, 2001). According to EMA, the evaporation rate increases southward; the maximum mean of evaporation varies from 3.2 mm/month in January and up to 12.1 mm/month in June, the annual rainfall is about 0.2 mm/month during the period from 1981 to 2010, and the total Radiation varies from 13.88 MJ/m^2 in January to 28.84 MJ/m^2 in June. Rainfall varies from season to another. Even though, rainfall events are rare, many flash floods are reported in the Eastern Desert. Table 1 shows the monthly averages of the meteorological data of Wadi Al-Assuity according to Assuit Station in the period from 1981 to 2010. Figure 2 shows the relation of total rainfall vs. months, figure 3 shows the relation of evaporation quantity vs. months, and figure 4 shows the relation of total Emission vs. Months of Wadi Al- Assuity.

General Geology & Geomorphology of Wadi Al-Assuity:

Wadi Al- Assuity sedimentary basin rocks are characterized by homogeneous geological deposits. The rock formations in Wadi Al- Assuity basin belong to Tertiary and Quaternary deposits. The Eocene rocks are considered the oldest most prevalent surface rocks in the basin, covering more than 91% of its total area of the Wadi, while, less than 1 % of the area is formed during the Era of Pliocene Rocks, and 8 % of the total area of the basin is formed of the deposits which represent the Quaternary age. The Eocene Formations are represented in both formations: Drunka and Serri (Early Eocene: Menia Formation, and Middle Eocene), while Pliocene Formations is represented in Qena and Armant Formation. Figure 5 shows geological map of Wadi Al- Assuity.

The Quaternary deposits are represented in floodplains' terraces, alluvial fans, wadi padding deposits, and sand formations, scattered on the slopes of the wadis. Main and secondary cracks effect the directions of waterways, and the distribution of the major landforms in the basin.

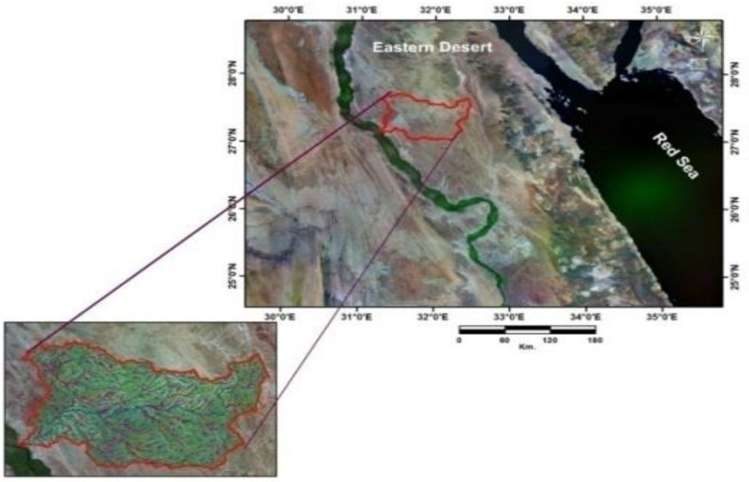


Figure 1 Location of Wadi Al- Assuity.

Source: Egyptian Geological Survey (EGS) – The Egyptian Mineral Resources Authority (EMRA).

Table 1: Monthly Averages of the Meteorological Data of Wadi Al- Assuity According to Assuit Station in the Period from 1981 to 2010.

Month	Total Rainfall (mm/month)	Largest Quantity (mm/Month)	Date of Occurrence (D/M/Year)	Period of Rainfall (Min.)	Evaporation Quantity (mm/Month)	Total Emission (MJ/m^2)
January	0.170	04.00	01 / 01 / 1994	52	3.20	13.88
February	0.090	00.09	07 / 02 / 2000	25	4.30	17.41
March	0.450	10.70	19 / 03 / 1995	120	5.90	21.63
April	0.050	01.10	03 / 04 / 2001	40	8.5	24.86
May	0.060	01.80	08 / 05 / 1990	45	10.60	26.61
June	0.000	00.00	-	-	12.10	28.84
July	0.000	00.00	-	-	11.30	28.01
August	0.000	00.00	-	-	12.10	26.17
September	0.000	00.00	-	-	08.50	23.16
October	0.002	00.10	10 / 10 /1994	18	6.90	18.94
November	1.250	24.00	01 / 11 / 1994	60	4.60	14.98
December	0.110	02.00	29 / 12 / 2010	30	3.20	12.84

Source: Egyptian Meteorological Authority (EMA).

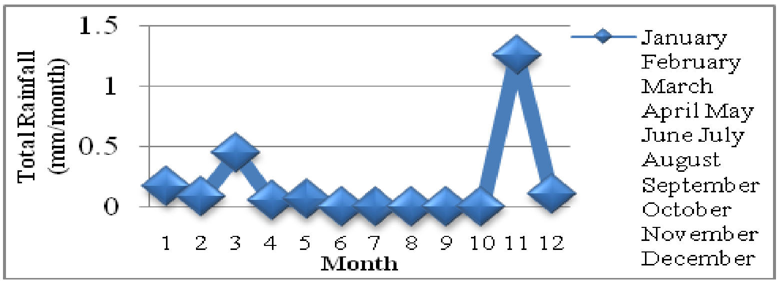


Figure 2 Wadi Al- Assuity, Total Volume Rainfall vs. Months.

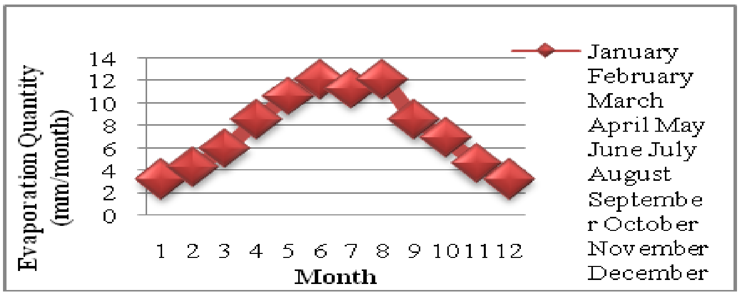


Figure 3 Wadi Al- Assuity, Evaporation vs. Months

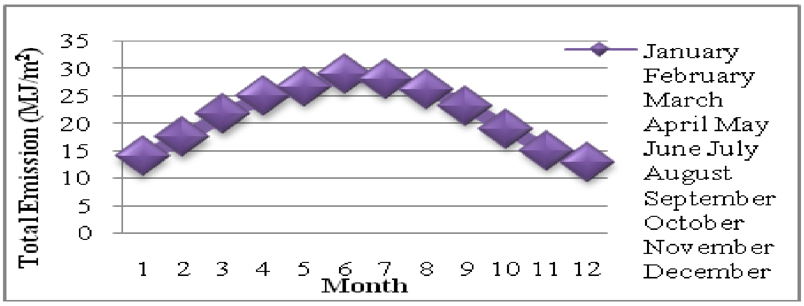


Figure 4 Wadi Al- Assuity, Total Emission vs. Months

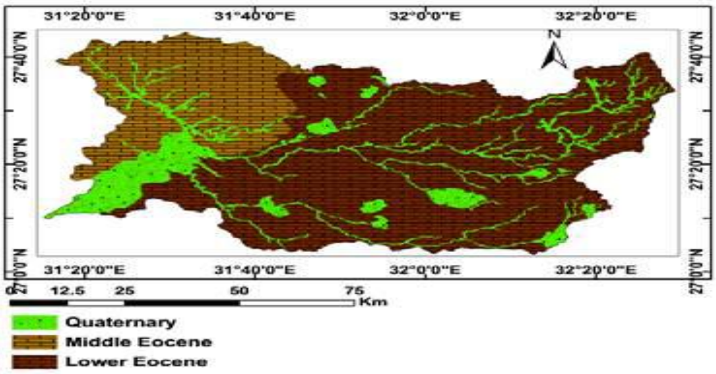


Figure 5 Geological Map of Wadi Al- Assuity (Milad, 2013).

Morphometric Analysis of Wadi Al-Assuity:

A. Linear Aspects:

A-1 Stream Order (N_u): Stream order represents the hierarchical ranking of the streams (Strahler, 1964). Horton's law shows that there is an inverse relation between the order of the streams and their numbers; the less the number of streams, the greater the order of the stream, forming reverse geometric sequence (Horton, 1945). Stream orders of Wadi Al- Assuity are as follows: N_1=2804, N_2=611, N_3=136, N_4=30, N_5=6, N_6=1; figure 6 shows basin stream orders of Wadi Al- Assuity. The total number of streams is 3588. The 1st order occupies 78.15%, 2nd order occupies 17.03%, 3rd order occupies 3.79%, 4th order occupies 0.84%, 5th order occupies 0.17%, 6th order occupies 0.02% from the total stream orders.

A-2 Stream Length (L_u): Stream length represents the length of the total lengths of all stream lengths in the basin (Horton, 1945). The Stream lengths are as follows: L_1= 3090656 m= 3090.656 km, L_2= 1497159 m=1497.159 km, L_3=764337 m=764.337 km, L_4=499625 m=499.625 km, L_5=235239 m=235.239 km, L_6=143314 m=143.314 km. The total stream lengths' is 6230.330 km. The 1st order lengths occupy 49.61%, 2nd order lengths occupy 24.03%, 3rd order lengths occupy 12.27%, 4th order lengths occupy 8.02%, 5th order lengths occupy 3.78%, 6th order lengths occupy 2.30% from the total stream lengths.

A-3 Mean Stream Length (L_{sm}): Mean stream length is a dimensional property which reveals the characteristic size of the drainage network components and its contribution to watershed surfaces. Mostly, it is observed that the mean stream length of any given order is greater than that of the lower order but less than that of the next higher order. In Wadi Al- Assuity mean stream lengths: L_{sm}= L_u/N_u (Strahler, 1964), L_{sm1}= 3090.656/2804=1.102 km, L_{sm2}=1497.159/611=2.450 km, L_{sm3}= 764.337/136= 5.620 km, L_{sm4}= 499.625/30 = 16.654 km, L_{sm5}= 235.239/6= 39.207 km, L_{sm6}= 143.314/1= 143.314 km. Mean stream length varies between 1.102 km (lowest value, 1st order), and 143.314 km (highest value, 6th order).

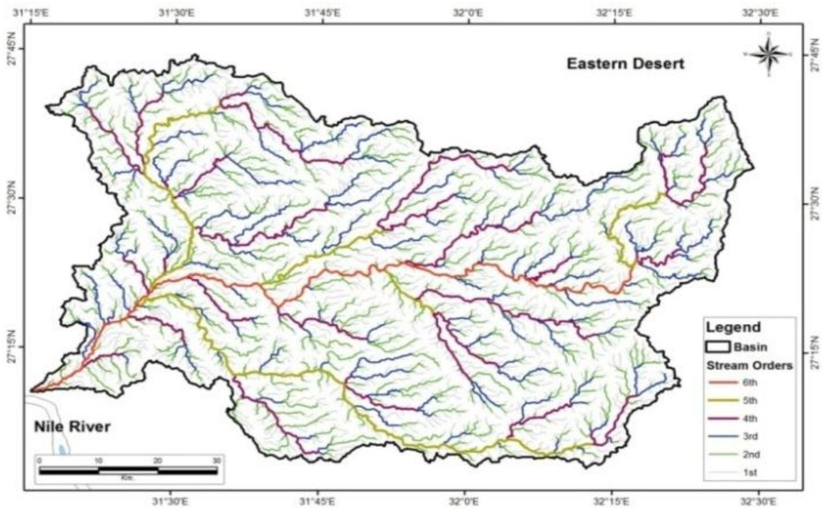


Figure 6 Basin Stream Orders of Wadi Al- Assuity**.**

Source: Egyptian Geological Survey (EGS) – The Egyptian Mineral Resources Authority (EMRA).

A-4 Stream Length Ratio (R_L): R_L between successive stream orders of the sub-watershed vary according to differences in slope and topographic conditions. In Wadi Al- Assuity: $R_L = L_{sm}/L_{sm-1}$ (Horton, 1945), R_{L1}=2.223, R_{L2}=2.294, R_{L3}=2.963, R_{L4}=2.354, R_{L5}=3.655. The values of the mean R_L varies from 2.223 to 3.655; this variation between orders is due to the difference in slope and topographic conditions.

A-5 Bifurcation Ratio (R_b): Bifurcation ratio expresses a relation with the geometric shape of the basin which affects the rate of discharge and time of concentration. In Wadi Al- Assuity: $\mathbf{R_b = N_u/N_{u+1}}$ (Schumm, 1956), R_{b1}=4.589, R_{b2}=4.493, R_{b3}=4.533, R_{b4}= 5, R_{b5}=6.

A-6 Mean Bifurcatio Ratio (R_{bm}): Mean Bifurcation Ratio (R_{bm})=Average of bifurcation ratio of all orders (Strahler, 1964). $R_b=R_{bm}=4.923 \rightarrow R_b$ for the whole basin=4.923. The lower the proportion of bifurcation ratio, the faster surface water is produced giving the opportunity to increase the probability of flooding in the area, and vice versa. In Wadi Al- Assuity, bifurcation ratio reached 4.923.

A-7 Weighted Mean Bifurcation Ratio (WMR_b): Weighted Mean Bifurcation Ratio is the product of multiplying the bifurcation ratio for each successive pair of order by the total number of stream involved in the ratio and taken the mean of the sum of these values.

$WMR_b = \sum\{ [R_{b(u)} / R_{b(u+1)}] \times (N_u + N_{u+1})] \} / \sum N$ (Strahler, 1953) =1.229

A-8 RHO Coefficient (RHO): According to Horton, RHO is considered as an important parameter as it determines the relationship between the drainage density and the physiographic development of the basin and allows the evaluation of the storage capacity of the drainage network. In Wadi Al- Assuity: $RHO=R_l/R_b$ (Horton, 1945), RHO_1=0.495, RHO_2=0.506, RHO_3=0.593, RHO_4=0.392.

B. Areal Aspects

The definition of areal aspects of a watershed of given order is the total area projected upon a horizontal plane, contributing overland flow to the channel segment of the given order including all tributaries of lower order.

B-1 Basin Area (A_b): Basin area of Wadi Al- Assuity drainage basin is measured by using the program ArcGIS version 10.5. The basin area of Wadi Al- Assuity is: A_b= 6049350000 m^2=6049.350000 km^2.

B-2 Perimeter (P_b): The basin perimeter (P) describes the circularity of the basin. Basin perimeter is defined as the length of the curve that defines the surface divide of the drainage basin (Horton, 1945). Basin perimeter of Wadi Al- Assuity drainage basin is measured by using the program ArcGIS version 10.5. The perimeter of Wadi Al- Assuity is: P_b=524758 m=524.758 km.

B-3 Basin Length (L_b): The basin length (L_b) is the shortest line dividing the basin into two halves running from the mouth to the source. Wadi Al- Assuity basin length is: L_b=127250 m=127.250 km.

B-4 Drainage Density (D_d): Drainage density is the total length of streams of different orders $\sum L_u$ per unit of area A. The drainage density of Wadi Al- Assuity is: $D_d=\sum L_u/A_b=1.030$ (Horton, 1932). The low value of D_d shows that the region is very rough.

B-5 Stream Frequency: Stream Frequency is the ratio of the total number of stream segments of all orders within a given basin to the total area of the basin. According to Zakrzenska (Zakrzenska, 1967), the results of this equation are:

- If F_s less than 4, then the topographic texture is rough.
- If F_s ranged (4 - 10), then the topographic texture is medium roughness.
- If F_s more than 10, then the topographic texture is fine.

$$F_s = \sum N_u/A_b \ \ km^{-2}=0.593\ km^{-2} \quad \text{(Horton, 1932)}$$

The stream frequency value of Wadi Al- Assuity is 0.5931 km^{-2} which is less than 4; this reflects the rough coarse texture topography of the area.

B-6 Length of Overland Flow (L_o): Horton defined the length of overland flow as the length of flow path which is projected to a horizontal plane of the rain flow from a point on the drainage divide to a point on the adjacent stream channel. The shorter the length of overland flow, the quicker the surface runoff from the streams (Kumar; Jayappab; Deepika, 2011). In Wadi Al-Assuity L_o is: $L_o=½D_d= 0.515$ (Horton, 1945).

B-7 Drainage Texture Ratio (D_t): Drainage texture is the ratio of the total number of basin segments to its perimeter. $D_t=\sum N_u/P_b$ Km^{-1} (Horton, 1945). Smith categorized the texture ratio of basins into three categories: (Fine> 16 km^{-1}, Moderate 6.4 to 16 km^{-1}, Coarse< 6.4 km^{-1}) (Smith, K.G. 1950)

While Morisawa (Morisawa, 1985) divided the relation between texture ratio and drainage density into four categories as follows; Table 2:

Table 2 Morisawa's Categorization.

Texture Ratio	Drainage Density	Conditions
Rough	**< 8**	**Resistant or permeable rocks + good natural plant**
Medium	**8 - 20**	**Resistant or permeable rocks + considerable precipitation + good natural plant**
Fine	**20 - 200**	**Non-permeable surface + severe precipitation + lack of plant natural**
Very Fine	**> 200**	**Non-permeable surface + heavy precipitation + weak rocks + natural plant scarcity**

$$\mathbf{D_t=\sum N_u /P_b\ km^{-1}=6.837\ km^{-1}}$$

According to Smith categorized the texture ratio of basins, Wadi Al-Assuity is located in the moderate range (between 6.4 to 16 km^{-1}). According to Morisawa, this value of drainage texture ratio which is 6.837, this indicates that the basin consists of permeable rocks, heavy rain, and good natural plants.

B-8 Basin Shape: Basin shape is determined through four equations:

- ***Circularity Ratio (R_c):*** The value of circulation ratio ranges between zero and one. The greater the value of circulation ratio is the more circular the shape of the basin. While the less the value of circularity ratio, means the irregularity of the water distribution lines surrounding the basin. The circularity ratio (R_c) of Wadi Al- Assuity is: $R_c=4\pi A_b/P_b^2=0.276$ (Miller, 1953). Circularity ratio value in Wadi Al- Assuity is 0.275918, which is considered as a low value; i.e. less circular. This indicates that the water distribution lines of the basin of the study area are skewed.
- ***Elongation Ratio (R_e):*** Elongation ratio value ranges between zero and one. If the elongation ratio approaches zero that means that the basin shape is similar to the shape of the rectangle. If the elongation ratio approaches one, then the basin shape is circular. The elongation ratio of Wadi Al-Assuity is: $R_e=2(A_b/\pi)^{0.5}/L_b=0.690$ (Schumm, 1956). The value of elongation ratio is 0.690 which is considered as a medium value. That means that stones contain many rifts and cracks as a result of the impact of the cracking processes that accompanied the formation of the Red Sea groove, which helped to develop the drainage network and the extension of the streams, which in turn, is reflected on the shape of the basin. Therefore, the basin is characterized by a regular slope along the sector of its main streams.

- ***Shape Index (I_{sh}):*** Whenever the value of shape index get closer to value one, then the shape of the basin is more regular and homogeneous, while the lower values of shape index means that the shape of the basin is irregular, then the basin shape form looks like a triangle where its head is heading towards downstream. The value of I_{sh} in Wadi Al- Assuity is: $I_{sh}=A_b/L_b^2=0.374$ (Hagget, 1956) which is considered a medium value. This indicates a medium consistency and harmony. The shape of the basin is less triangular shape that heads towards downstream.
- ***Infiltration Number (If):*** Infiltration number of a drainage basin is the product of drainage density and stream frequency. The higher the infiltration number, the lower will be the infiltration and higher will be the run-off (K. Rao; Rehman; and Yusuf 2011). I_f of Wadi Al- Assuity is: $I_f=D_d x F_s=0.611$ (Zavoiance, 1985).

C. **Relief Aspects:** Relief characteristics are determined through four equations:

C-1 Basin Relief (R): Basin relief is the difference in elevation between the remotest point in the water divide line and the discharge point is obtained from the available DEM. Basin relief of Wadi Al- Assuity is: R=H-h=0.820 (Hadley; Schumm, 1961). Figure 7 shows digital elevation model DEM of Wadi Al- Assuity.

C-2 Relief Ratio (R_f): According to Schumn, R_f is the ratio of maximum watershed relief to the horizontal distance along the longest dimension of the watershed parallel to the principal drainage line. The value of relief ration ranges from zero to one. The relief ratio of Wadi Al- Assuity is: $R_h = R / L_b = 0.006$ (Schumm, 1956).

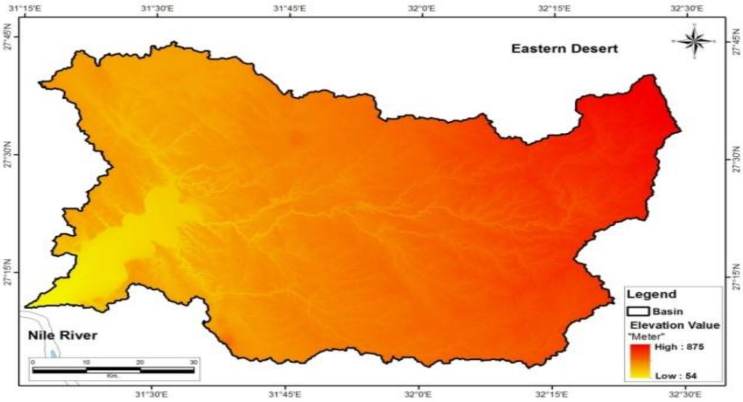


Figure 7 Digital Elevation Model DEM of Wadi Al- Assuity.

Source: Egyptian Geological Survey (EGS) –The Egyptian Mineral Resources Authority (EMRA).

C-3 Basin Slope (S_b): The slope value of Wadi Al- Assuity is: S_b = H–h/L_b^2 = 0.00005 (Mesa, 2006).

C-4 Ruggedness Number (R_n): The degree of ruggedness indicates how much the surface of the pelvis is cut by wadis. High values of the R_n in the watershed are because both the variables like relief and drainage density are enlarged. High value of ruggedness number occurs for a high relief region with high stream density. The ruggedness number of Wadi Al- Assuity is: $R_n = D_d \times R = 0.845$ (Melton, 1958).

Table 4 shows the main morphometric parameters of Wadi Al- Assuity. Table 5 shows the summary of geomorphologic parameters.

	Item	Value
	Basin Area (A_b) (m^2)	6049350000
	Basin Area (A_b) (km^2)	6049.350
	Basin Perimeter (P_b) (m)	524758
	Basin Perimeter (P_b) (km)	524.758
	Basin Length (L_b) (m)	127250
	Basin Length (L_b) (km)	127.250
Areal	Basin Width (m)	82144
	Basin Width (km)	82.144
Aspects	Drainage Density (D_d)	1.030
	Stream Frequency (F_s) (km^{-2})	0.593
	Length of Over Land Flow (L_o)	0.515
	Drainage Texture Ratio (D_t) (km^{-1})	6.837
	Circularity Ratio (R_c)	0.276
	Elongation Ratio (R_e)	0.690
	Shape Index (I_{sh})	0.374
	Infiltration Number (I_f)	0.611
	Basin Relief (R) (km)	0.820
Relief	Relief Ratio (R_f)	0.006
Aspects	Basin Slope (S_b)	0.00005
	Ruggedness Number (R_n)	0.845

Table 5 Summary of Geomorphologic Parameters of Wadi Al- Assuity.

Order	1	2	3	4	5	6	Total
Number of Streams	2804	611	136	30	6	1	3588
Percentage of Stream Order (%)	78.15	17.03	3.79	0.84	0.17	0.02	100
Length (m)	3090656	1497159	764337	499625	235239	143314	62303300
Length (km)	3090.656	1497.159	764.337	499.625	235.239	143.314	6230.330
Percentage of Length (%)	49.61	24.03	12.27	8.02	3.78	2.30	100
Mean Stream Length (Lsm) (m)	1102.23	2450.34	5620.13	16654.17	39206.5	143314	
Mean Stream Length (Lsm) (km)	1.1023	2.45034	5.62013	16.6541	39.207	143.314	
Stream Length Ratio (RL)		2.223	2.294	2.963	2.354	3.655	
Bifurcation Ratio (Rb)	4.589	4.493	4.533	5	6		
Mean Bifurcation Ratio (Rbm)							4.923
Weighted Mean Bifurcation Ratio (WMRb)							1.229
RHO Coefficient (RHO)		0.495	0.506	0.593	0.392		

RESULTS AND CALCULATIONS

In order to analyze the data of the study Wadi, three computer software packages were used: SMADA version 6, AQTESOLV version 4, and GWW version 3.

1. **Use SMADA Program** and input data of Wadi Al- Assuity shown in Table 6 to get watershed hydrograph, and rainfall hydrograph of Wadi Al- Assuity shown in Figures 8, and 9.

Table 6 Input Data of Wadi Al- Assuity.

Catchment Area (km^2)	**6049.350**
Duration of Peak Storm	60
Time Interval (minutes)	5
Infiltration Rate	
Low Infiltration Rate (m/day)	0.5
High Infiltration Rate (m/day)	1.7
Slope of Mini Channel (Dimensionless)	0.006

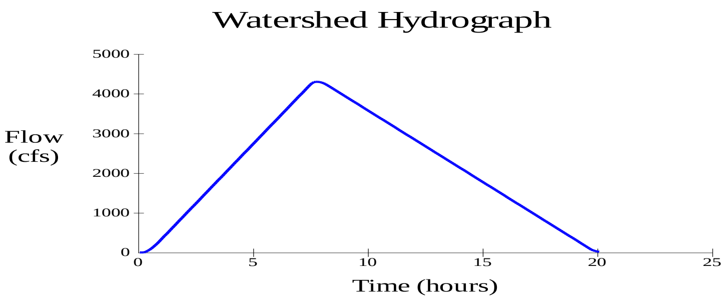


Figure 8 Hydrograph of Wadi Al- Assiuty.

Output Data:
Total Volume Runoff = 4,354,242.664 m^3
Time to Peak = 8 hrs = 480 min
Base Time = 20 hrs = 1200 min
Peak of Discharge = 4300 ft^3 / sec = 121.69 m^3 / sec

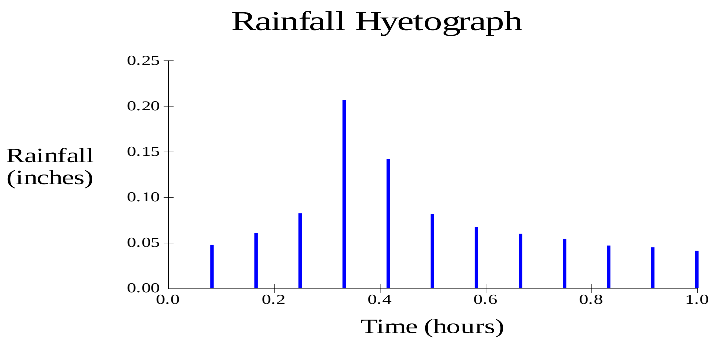


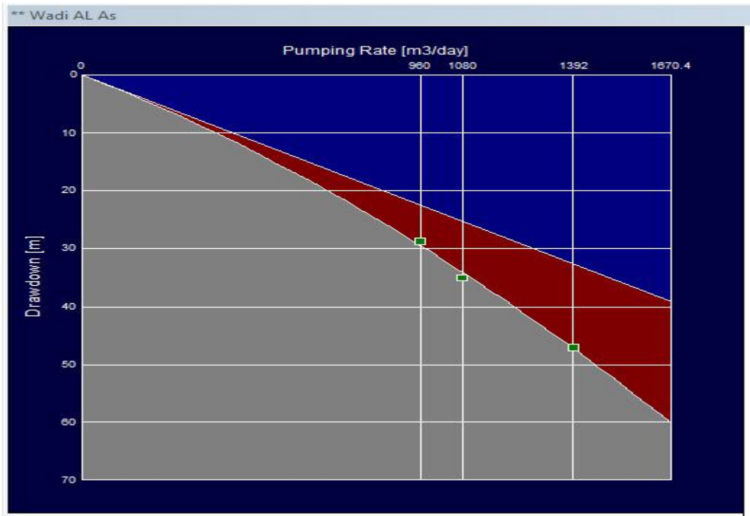
Figure 9 Rainfall Hyetograph of Wadi Al- Assiuty.

2. Well Efficiency and Productivity of the Productive Wells

By using GWW Program, and input data of Wadi Al- Assuity shown in Table 7 to get the analysis of step-drawdown test data of the Well: Al- Assuity; Figure 10. The output data is shown in Table 8.

Table 7 Results of Step – Drawdown Tests.

Steps	First	Second	Third
Drawdown (m)	28.7	35	47
Discharge (m^3/hr)	40	45	58



Drawdown	28.7	35	47	60.12
Pumping Rate	960	1080	1392	1670.4
Aquifer Loss	22.53	25.34	32.66	39.2
Well Loss	6.91	8.75	14.53	20.92
Efficiency [%]	78.5	72.4	69.5	65.2

Figure 10 Analysis of Step-Drawdown Test Data of the Well: Al- Assuity.

Table 8: Results of the Analysis of Step-Drawdown Test Data of the Well: Al-Assuity.

Drawdown (m)	28.7	35	47	60.12
Pumping Rate	960	1080	1392	1670.4
Aquifer Loss	22.53	25.34	32.66	39.2
Well Loss	6.91	8.75	14.53	20.92
Efficiency (%)	78.5	72.4	69.5	65.2

Probability of Accidence : By applying the formula G(x)=1/T (Ponce, 1989), that describes the relationship between the probability of accidence G(x), and return period T formula T=(N+1)/m (Brook, 1986), and based on the rainfall records of Assuit meteorological station during the period (1981–2010), the return period and the probability of accidence are tabulated in Table 9. The relation between the return period and the annual rainfall depth was plotted using a semi log paper; Figure 11.

Table 9 Wadi Al- Assuity Monthly Average Rainfall Depth in the Period from 1981 to 2010 Based on Assuit Meteorological Station.

Month	**Largest Quantity (mm/Month)**	**Largest Quantity Rainfall (mm) (Descending)**	**Ran k (m)**	**Return Period (T) (Year)**	**Probability of Accidence (G (x)) (%)**
January	04.00	24.00	1	13	7.69
February	00.09	10.70	2	6.50	15.38
March	10.70	4.00	3	4.33	23.09
April	01.10	2.00	4	3.25	30.77
May	01.80	1.80	5	2.60	38.46
June	00.00	1.10	6	2.17	46.08
July	00.00	0.09	7	1.86	53.76
August	00.00	0.10	8	1.63	61.35
September	00.00	0.00	9	1.44	69.44
October	00.10	0.00	10	1.30	76.92
November	24.00	0.00	11	1.18	84.75
December	02.00	0.00	12	1.08	92.59

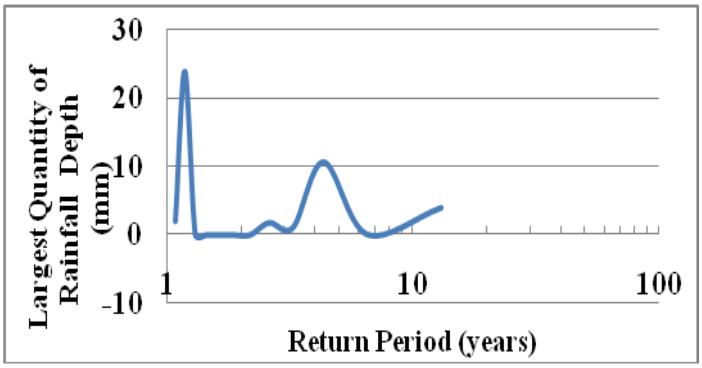


Figure 11 Relationship between the Return Period (Years) (X- Axis) and the Largest Quantity Rainfall Depth (mm) (Y- Axis) of Wadi Al- Assuity.

The relation between the largest quantity (mm/month) and the return period is inversely proportional annual, i.e. the rainfall increases; the return period becomes longer and vise versa; i.e. the annual rainfall of 24 mm is expected to occur each 13 years which a probability of 7.69 %; while the annual rainfall of 0.10 mm can occur every 1.63 years with a probability of accidence equal to 61.35 %.

Suggested Solution for Water Harvesting in Wadi Al- Assuity: Wadi Al-Assuity investigation of the specific chosen storm, shows that the total amount of runoff is 4,354,242.664 m^3 over a basin area of 6,049,350,000 m^2, (6049.350 km^2). The suggested solution is as follows:

* It will not be possible to do any artificial works that can hold water in 1st and 2nd order streams due to the high velocity and intensity of rainfall.
* It is suggested that before flood time, officials are to order labors to prepare the sight for runoff water harvesting through establishing distant rock check dams through 3rd order streams as much as possible. Those dams are

made of small stones covered with larger ones, and have a lower slope to the side of water slope.

* It is suggested to construct flood spreading bunds on the both sides of the stream over 4th, 5th, and 6th order streams. Officials are to order farmers to place appropriate seeds in pits and surround the side lands, by using small rocks to retain water inside them, so when the runoff stops the water remains in the soil for plant germination, and participate in nourishment of the underground aquifer.
* Small cisterns are to be distributed over 4th, 5th, and 6th order streams. Small cisterns will be side and bottom lined with permeable stone and located in places which are featured with low infiltration rate; they will be equipped with hand pumps for watering animals and irrigation. It is suggested to be placed in places near to villages, Bedouin communities, and mining locations.
* Large cisterns with concrete bodies and gravel permeable stone bottoms and equipped with pumps are to be built in specific locations after checking the infiltration rate of each location. If any of those locations is featured with high infiltration rate then it must be relocated, otherwise the soil will intake all water and no water will remain in the cistern. The larger the number of cisterns, the more water stock to be used in drought time. In addition, a lined pond connected with two large cisterns is to be constructed.
* Nine large lined collection ponds connected to two large cisterns are to be constructed on ^{4th} and ^{5th}, and ^{6th} order streams Ponds and cisterns are to develop, serve, and irrigate the surrounding areas.

* Two small dams and one large dam to be constructed on 6th order stream.

* There are two mining locations in Wadi Al- Assuity: alabaster, and limestone locations as shown in the Figure 12. This location was taken into consideration in the previous solution.

* Large cisterns may be replaced by injection wells if the nature of the area allows for this; it is necessary to make sure that the underground layers contain caves and fractures to facilitate water percolation into aquifer. Figure 13 shows the distribution of rock check dams, flood spreading bunds, small cisterns, large cisterns, and large collection ponds connected to two large cisterns, two small dams, and one large dam.

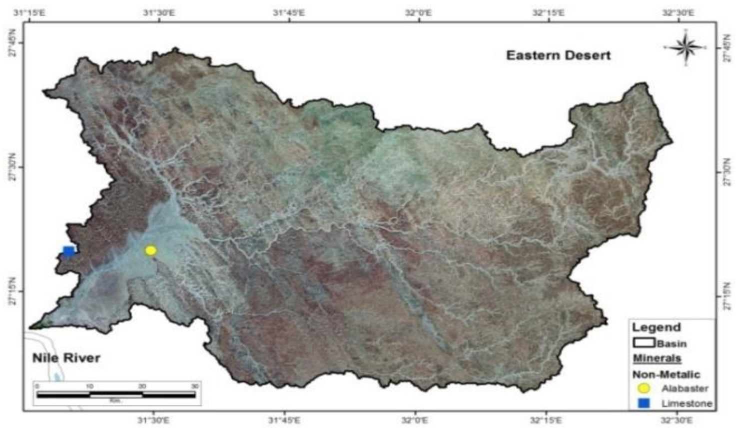


Figure 12 Mining Locations in Wadi Al- Assuity.

Source: Egyptian Geological Survey (EGS) – The Egyptian Mineral Resources Authority (EMRA).

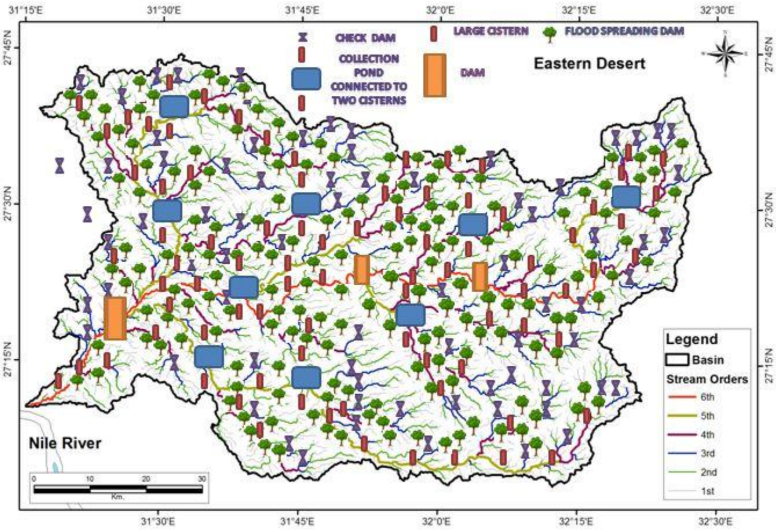


Figure 13 Suggested Water Harvesting Solution in Wadi Al- Assuity.

CONCLUSION

First: The geomorphological characteristics of Wadi Al- Assuity Basin was studied, evaluated and determined; Tables 4, 5.

Second: Climate conditions of the study area were evaluated and volume of rainfall and runoff water, which threatens the civil compounds located on the outlets of Wadi Al- Assuity basin, was estimated.

Third: The volume of floods directed to the Nile River or Red Sea, were estimated and evaluated. Maximum total volume runoff of Wadi Al- Assuity = 4,354,242.664 m^3.

Fourth: The risks and threats of Wadi Al- Assuity basin through making use of the floods of water as access water source were mitigated.

Fifth: Storing of flooding water through constructing water harvesting facilities such as: check dams, flood spreading bunds, cisterns, collection ponds, storage dams, and others, were optimized. The stored water will be used in irrigation, animal husbandry, keeping the surrounding areas from drought, development of the surrounding areas, and keeping on the sustainable development.

Sixth: The relation between the monthly rainfall depth and the return period is inversely proportional, i.e. if the rainfall increases, the return period become longer and vise versa.

In Wadi Al- Assuity, the monthly rainfall of 24 mm is expected to occur each 13 years which a probability of 7.69 %; while the monthly rainfall of 0.10 mm can occur every 1.63 years with a probability of accidence equal to 61.35%; Table 9.

Seventh: Suggested engineering solutions of water harvesting means were proposed to be applied; Figure 13.

Eighth: The environmental impacts of water storage means (projects) were studied and assisted and the mitigation of those impacts were proposed. The classification of the water harvesting means according to Egyptian Environmental Affairs Agency *(EEAA);* Table 10.

Table 10 Suggested Engineering Solutions of Water Harvesting in Wadi Al-Assuity, and the Classification of Water Harvesting Means in the Study Area according to Egyptian Environmental Affairs Agency *(EEAA)*.

Name of the Wadi	Water Harvesting Means	Stream Order	Project Classification
Wadi Al- Assuity	• **Check Dams** • **Flood Spreading Bunds** • **Small Cisterns** • **Large Cisterns** • **Nine Large Collection Ponds Connected to Two Large Cisterns** • **Two Small Dams** • **One Large Dam**	**3rd** **4th, 5th, 6th** **4th, 5th, 6th** **4th, 5th, 6th** **4th, 5th, 6th** **6th** **6th**	**A** **A** **A** **A** **A** **C** **C**

REFERENCES

Brook, R. J. (1986), 'The Fascination of Statistics', CRC Press, New York.

El-Shamy, I. Z. (1992), 'New Approach for Hydrological Assessment of Hydrographic Basins of Recent Recharge and Flooding Possibilities', 10th Symp. Quaternary and Development, Mansoura University, Egypt, P.P. 15.

Hadley, R.F. and Schumm, S.A. (1961), 'Sediment Sources and Drainage Basin Characteristics in Upper Cheyenne River Basin', United States Geological Survey, Water Supply Paper 1531, Part B, 137-96.

Hagget, P. (1956), Locational Analysis in Human Geography, Edward Arnold Ltd., London.

Horton, R.E. (1932), 'Drainage Basin Characteristics', *Trans. Am. Geophys. Union*, 13 350–361.

Horton, R.E. (1945), 'Erosional Development of Stream and their Drainage Age Basins: Hydro Physical Approach to Quantitative Morphology', Geol. Soc. Amer. Bull. 56: 275–370.

Kumar, A. B., Jayappab, K.S. and Deepika, B. (2011), 'Prioritization of Sub-Basins Based on Geomorphology and Morphometric Analysis Using Remote Sensing and Geographic Information System (GIS) Techniques', Geocarto International, 26, 7:569–592.

Melton M.A, (1958), 'Correlations Structure of Morphometric Properties of drainage Systems and their Controlling Agents', Journal of Geology, 66, 442–460.

Mesa, L. M. (2006), 'Morphometric Analysis of a Subtropical Andean Basin (Tucumam, Argentina)', Environmental Geology, Vol. 50 (8), PP. 1235-1242.

Milad, H. Masoud (2013), 'The Possible Impact of the Prevailing Physiographic Features of Selected Catchments Upon their Hydrological Characteristics, Egypt (Comparative Study)', Aust. J. Basic & Appl. Sci.,7(14): 324-347.

Miller, V.C. (1953), 'A Quantitative Geomorphic Study of Drainage Basin Characteristics in the Clinch Mountain Area', Technical Report - 3, Columbia University, Department of Geology, New York, P.P. 389-402.

Morisawa, M.E. (1985), Rivers Forms and Process, Longman, London, P.P. 140.

Ponce, V. M. (1989), 'Engineering Hydrology Principle and Practices', Prentice Hall, New Jersey, P.P. 260-261.

Rao Liaqat A., K., Rehman, Ansari Ziaur and, and Alia, Yusuf (2011), 'Morphometric Analysis of Drainage Basin Using Remote Sensing and GIS Techniques: A Case Study of Etmadpur Tehsil, Agra district, U.P.' International Journal of Research in Chemistry and Environment, 1(2):36-45.

Schumm, S. A. (1956), 'Evolution of Drainage Systems and Slopes in Badlands at Perth Anboy, New Jersey', Bulletin of the Geological Society of America, 67: 597-646.

Smith, K.G. (1950), 'Standards for Grading Texture of Erosional Topography', Amer. Jour. Sci., 248:655-668.

Strahler, A. N. (1953), 'Hypsometric Analysis of Erosional Topography', Bull. Geol. Soc. Am. 63:1117–1142.

Strahler, A. N., (1964). Quantitative Geomorphology of Drainage Basins and Channel Networks. In Chow, V.T. (ed.) Handbook of Applied Hydrology, McGraw-Hill, New York. pp 439-476.

Sulaiman, M. F. Abdel Aziz (2001), 'Wadi Al- Assuity Basin: Geomorphological Study', MSc. Thesis, Ain Shams University. Viewed on 5 August 2016 http://drepository.asu.edu.eg/xmlui/handle/123456789/57981

Zakrzenska, B. (1967), 'Trends in Methods in Land Forms Geography: A Review Article', Annals of the Association of American. Geographers, 57, 1:121.

Zavoiance, I. (1985), 'Morphometry of Drainage Basins: (Developments in Water Science)', Elsevier Science, New York, USA, 20:104-105.

الوقاية من السيول في وادي الأسيوطي في الصحراء الشرقية وتعظيم الاستفادة منها

[٣]

محمود محمد أبو النصر(١)– سامح عطية محمد صقر(٢)– يحيي لطفي اسماعيل(٣)
حمدي أحمد أبو طالب(١)– منى محمد حمدي

١) قسم هندسة القوى الميكانيكية، كلية هندسة، جامعة عين شمس ٢) قطاع المياه الجوفية، وزارة الموارد المائية والري ٣) قسم الهيدرولوجيا، مركز بحوث الصحراء

المستخلص

تعاني مصر حاليا من نقص في المياه، ومن المتوقع أن يزداد هذا النقص بشكل كبير كنتيجة لزيادة معدل نمو السكان، والأنشطة الزراعية، والصناعية، ومطالب التنمية. لذا كان من المهم أن يتم البحث في تخزين واستخدام أي موارد مائية ممكنة يمكن أن تسهم في توفير أي كمية من المياه مهما كانت الكمية صغيرة أو كبيرة. وبما أن الصحراء الشرقية في مصر مليئة بالأودية التي تتعرض لأمطار مفاجئة تشكل سيول هائلة تذهب مياهها سدى بدون أن تستغل، حيث تتدفق المياه على الأرض حتى تجف اما عن طريق التبخر، أو عن طريق كميات المياه التي تتسرب من خلال التربة.

وعلاوة على ذلك، فقد تسببت هذه السيول على مر السنين، في حدوث كوارث وتهديدات وتدمير للقرى والمدن.

وبما أن مصر تحتاج إلى كل قطرة من الماء، فإن مياه السيول قد تغطي جزءا من هذه الاحتياجات. هذه الورقة البحثية هي المساهمة في التخفيف من أخطار مياه السيول في وادي الأسيوطي في الصحراء الشرقية في مصر، وإيجاد حلول عملية لتخزينها، وحماية القرى من كوارثها، واستخدام مياهها في تحقيق التنمية المستدامة في البيئة المحيطة.

وتتلخص خطوات هذا البحث في تقييم وادي الأسيوطي من حيث: تحديد الخصائص الجيومورفولوجية، تقدير وتقييم حجم الهطول السنوي المهدر وحجم السيول التي تهدد المجتمعات العمرانية الموجودة على منافذ الحوض، التخفيف من مخاطر وتهديدات هذا الحوض عن طريق الاستفادة من مياه السيول فيها واتخاذها كمصدر للمياه، اقتراح طرق تخزين واستخدام مياه السيول من خلال بناء سدود الاعاقة وسدود الحماية، والصهاريج (الخزانات)، وبحيرات التجميع، أو غيرها.