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The Effect of Flash Flood on the Efficiency of Roads Networks in South Sinai, Egypt. Case Study (Nuweiba-Dahab Road)

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Abstract— Sinai Peninsula is located at a unique position, both geographically and politically (1). In the mountainous area of Sinai Peninsula in Egypt, the improvement of infrastructure networks require reliable and accurate information about natural hazards particularly flash flood. Flash flooding is the most dangerous hazard to focus on because it prone the life of people who lives in the rough topography areas. This paper presents the assessment of flash flood hazards in the Southern Sinai governorate especially the road between Nuweiba and Dahab. GIS was used to delineate the morphometric parameters extracted from Digital Elevation Model (DEM) to construct a hydrological model that, indeed, helps the decision makers to rapidly take the necessary procedures to avoid risks.

Index Terms— GIS, Flash floods, Hazard, South Sinai, Infrastructure, Nuweiba, Dahab.

1. Introduction

Natural disasters are inevitable and it is almost impossible to fully recover from the damage caused by such events (2).But, it is possible to minimize the potential risk by preparing and implementing plans to avoid such disasters, and to help in rehabilitation and disaster reduction. A Flash flood is one of the many natural processes. During the last three decades GIS has become increasingly important tool for improving the conventional methods of data collection and map production in geo-sciences.

Egypt is located in northern Africa, and is in both the eastern and northern hemispheres. The Tropic of Cancer runs through the bottom half of the country. Egypt is bordered by the countries of Israel, Libya, and Sudan, as well as the Aqaba Gulf, Red Sea and Mediterranean Sea. The Sinai Peninsula is a triangular-shaped peninsula, linking Africa with Asia, about 61,100 km^2. Similar to the desert, the peninsula contains mountains in its southern sector that are a geological extension of the Red Sea hills, the low range along the Red Sea coast that includes Catherine mountain, the country's highest Point at 2,642 m above sea-level. The southern side of the peninsula has a sharp escarpment that subsides after a narrow coastal shelf that slopes into the Red Sea and the Aqaba Gulf. The elevation of Sinai's southern rim is about 1,000 m, moving northward, the elevation of this limestone plateau decreases. The northern third of Sinai is a flat, sandy coastal plain, which extends from the Suez Canal into Gaza Strip. El-Salam canal project is planned to feed about 200,000 feddans in North Sinai using mixed drainage and fresh water. The Sinai is administratively divided into two governorates North Sinai and South Sinai.

The present work represents an endeavor of applying geographic information systems (GIS) in predicting the hazards which affects the infrastructure in Egypt (especially Sinai Peninsula). This paper analyzes the situation, trends, and effects of infrastructure in Egypt especially the study of the main natural disasters that threaten through the study area and to identify the positions of the threats to and find out how serious.

2. Definition of Study Area.

2.1 Study Area Location

The scope of the current study is the coastal zone of the Aqaba Gulf **(Dahab – Nuweiba road). Dahab**, is a tourist city located in South Sinai in Egypt. Its importance comes after Sharm el-Sheikh, where the number of tourists attending them. Dahab city was in the past a small village of fishermen and was became famous in the nineties after the Egyptian government has attached special attention. It maintained tourist hotels and villages in its Centre, and still resides where some Bedouin yet. **Dahab** is located on the Aqaba Gulf at the south-east of the Sinai Peninsula on Red Sea, about 100 km to the north of the famous resort of Sharm el-Sheikh, and lies about 140 kilometers from the Israeli city of Eilat. **It** includes two bays, there are Qurah which is located downtown, and El Gouna. **Dahab** was named that name relative to the golden color that characterizes the net sand beaches. **It** is bounded by a latitude 28^0 29\ 35\\ N and longitude 34^0 30\ 17\\ E.

The importance of the city in terms of tourism.

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Dahab is Famous due to golden beaches, spectacular and suitable locations for diving, that is one of the most prominent activities that Dahab visitors can exercise. Dahab characterized in that it cheaper than the tourist resorts where the sports are practiced in the rest of the Sinai, next safari and spas is practiced. As well as the sport of skydiving as that the water sport does not exist in Sharm El-Sheikh, a surfboard or a sailboat ride and Dahab is characterized in the sport due to the wind speed, wind is the fast because the mountain is surrounded by many of views.

Nuweiba, is an Egyptian port and city, and is located on the opposite bank of Jordanian port of Aqaba, and linked to it by nautical line across the Arab Bridge Maritime Company and therefore passes by pilgrims during the pilgrimage season. It is located between the towns of Dahab and Taba. And it includes prosecutors and courts of South Sinai Governorate, located 465 km from Cairo, and after an hour of Aqaba by speedboat or a three-hour by the boat.

Road that links between Dahab - Nuweiba for a distance of 68.00 kilometers is the subject of study, Fig. (1).

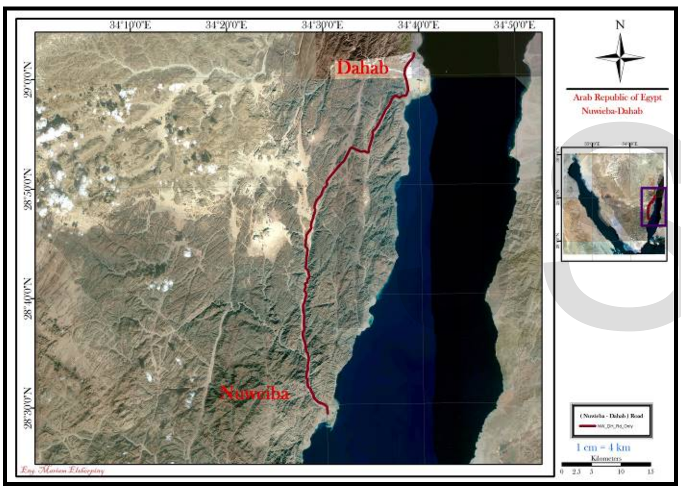

Fig. (1) Road between Nuweiba and Dahab, Aqaba Gulf, Southern Sinai. Arc Map (10.1).

2.2 Climate

Generally Sinai is classified as semi-arid area. Semi-arid is characterized by climate conditions dominated by long hot, rainless summers and mild winters. Most precipitation occurs as heavy showers of a short duration forming destructive flash flooding especially in the period from December to April resulting in damage of houses, industrial projects, infrastructure and stopping in tourist's activities. The semi-arid area is a deep and narrow cliff in the rain shallow of the abruptly rising, two meters high massifs to the west, in Sinai Peninsula Mountains. Records of maximum temperature may reach 45°C at the northern part of the Aqaba Gulf and 47°C at Sharm El-Sheikh.

However, the minimum temperature is as low as 4°C measured at Nuweiba area. Generally, the annual rainfall pattern is rather changeable and the rain fall is about 22 mm/y. Evaporation over the Aqaba Gulf is extremely high about 400 cm/y and the relative humidity in the shore localities of the Gulf average 30%– 55%. (Mohamed O. Arnous, 2010).

2.3 Geology of South Sinai.

The geologic of the South Sinai area is characterized by basements of Sedimentary rocks, Jurassic sedimentary rocks, Sedimentary rocks alhilosin Prateek and sabkha, Cretaceous sedimentary rocks and Fourth age sedimentary rocks of continental.

Mountainous basement terrain occupies most of the western coastal area and forms a horst block. This mountainous terrain is intensely dissected by a large number of wadis and drainage lines, the slopes gently eastward forming the Watieer and Dahab alluvial plain issuing from the topmost part of the mountain and trending eastwardly to the Aqaba Gulf. In addition, some types of basement rocks form steep fault scarps facing the Aqaba Gulf. Fig. (2)

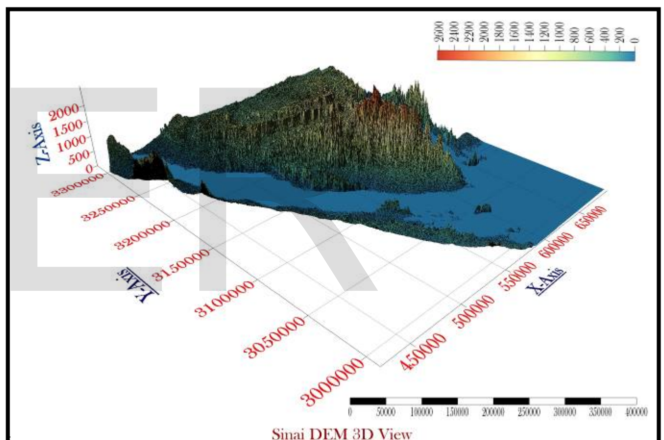

Fig. (2) Mountainous basement terrain (surfer 10).

Alluvial fans are primary landforms of the Aqaba Gulf, they are formed by tectonic movements that are modified and degraded by mass destruction, erosion and sedimentation. The dominance of run-off on the mountains slopes make a high rates of sediment transport and delivery in a depositional environment. The alluvial fans have a conical surface form with slopes radiating away from an apex at the point where the stream issues from the crest [(3)]. These fans show various shapes, ranging from pear to circular shape at Wadi Watier, Wadi Dahab and Wadi Kid.

The coastal plain is the result of structural control and occupies overlooking the coast areas. Overall, it's a limited scope and appears in the form of Delta cut downstream of the main channels. It includes some spots and small hills relief from a few meters in height or spread in very close to the beach. Sandy beaches are flat areas along the beach. Consisting at least partly of unconsolidated materials of sand, paving, rock or wooden board.

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2.4 Data Usage.

This study uses the GIS technique, the GIS and raster map analyses aim to integrate different morphometric data of South Sinai, which involve topographic analysis of raster, hazards. The data that has been used are (1) Digital Elevation Models (DEMs) from Shuttle Radar Topography Mission (SRTM) data, with 30 m spatial resolution; to evaluate the geo-hazards at the infrastructure in South Sinai, drawing the drainage network and identifying the geomorphological units. It is geo-referenced to the UTM coordinate system, zone 36 north based on 1:50,000 scale topographic map. (2) The Arc Hydro tool of ArcGIS 10.1 has been used to create a basis for extracting the drainage network of the drainage and watershed system in the studied area from DEM [4]. Terrain pre-processing has been used in the processing and creating the watershed basin of the study area Fig. (3)

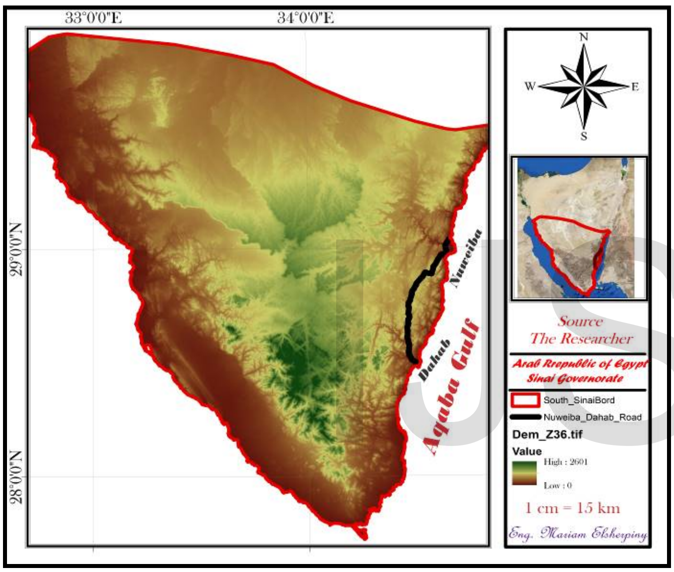

Fig. (3) DEM of South Sinai in general. (Arc Map 10.1)

3. Methodology and Morphometric analysis

The DEM of the study area with scale (1:1,500,000) was prepared from SRTM and used to construct slope, aspect, Hill shade, Drainage lines and catchments that are affects the efficiency of infrastructure in public study of South Sinai and focuses on the Nuweiba – Dahab road.

3.1 Terrain Processing

The following functions are sequenced in terrain pre-processing. (1) The **"Fill Sinks"** function filling dips and rises anomalous and unexpected in digital elevations layer data, the cells that contain the values of low-rise or high substantially from neighboring cells heights, the water is trapped in that cell and cannot flow, it removed and creates a new layer free of those dips or rises. (2) The **"Flow direction"** Tool to determine the direction that water will take place from cell to neighboring cells, by comparing high (level) cell with the levels of neighboring cells, and based tool direction of flow to give a value for each direction where water will flow, for example, if the water flow in the direction of the east would execute trend = 1, while the direction of the south-east will take direction = 8 and so on, until the conversion of free Digital Elevation file from depressions to grid file containing each cell by the value of the direction of flow. (3) **"Stream definition"** process represents the minimum limit of accuracy in extracting the drainage network of tracks that determined automatically while attached to the-direction of flow and aggregation. There is no fixed value for the referred stream definition, so much of the experimental attempts should be made to compare the results of this method with a reliable network streams to their authentic, as a network streams derived from large-Scale aerial photographs, so it is used to determine the level of detail to extract network drainage basin area. Stream definition value was taken 3000 in this study after more trial carried out by the researcher. (4) **"Stream segementation"** is the last step in the formulation of the final river network profiles spill-networking, and depend on the step followed in determining the feeding areas every tributary or each part separately. (5) **"Stream order"**, this step allows us to extract the stream order according to (Strahl, 1952) and (Shreve, 1967) classification. Due to the flexibility in the way (Strahl, 1952) rating has been reliable in the classification of the stream network in the catchment area, It identified the resulting image characteristics, the stream order of the catchment area up to the fifth grade, Fig.(4).

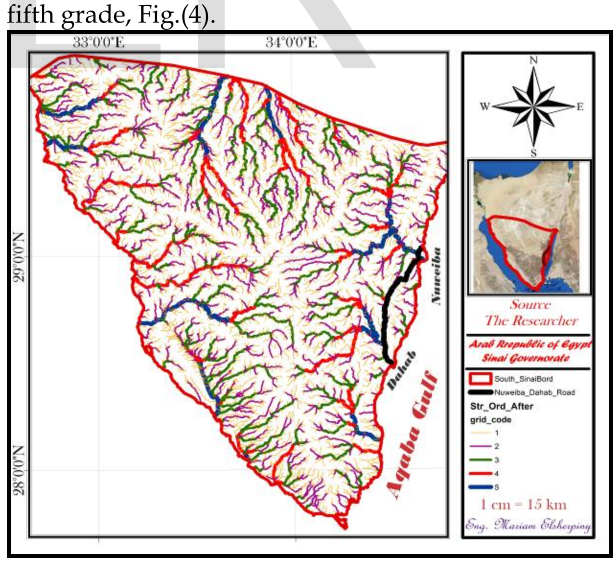

Fig. (4) Stream Order according to (Strahl, 1952) and (Shreve, 1967) classification.

(6) Once the direction of the flow out of each cell is resolved, it is possible, through the calculation of the flow accumulation grid, to delineate the drainage network of the study area. Flow accumulation was calculated from the flow direction grid. Each pixel was assigned a value equal to the

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number of pixels drained through a given pixel in the flow accumulation. (7) The Catchment Grid Delineation function creates a grid in which each cell carries a value called grid code indicating to which catchment the cell belongs, Fig. (5).

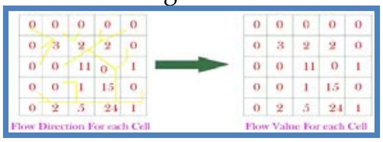

Fig. (5) Grid code indicating to which catchment the cell belongs.

The value corresponds to the value carried by the stream segment that drains that area, defined in the stream segment link grid. The Catchment Polygon Processing function converts the raster format of catchment delineation which extracted from the previous step to vector format to become polygons layer from which we get the lengths and area of the catchment through it**.** The adjacent cells in the grid that have the same grid code are combined into a single area, whose boundary is vectorized. (8) The Adjoin Catchment Processing function determining cumulative catchment so as to determine the area and perimeter of subbasins. (9) Stream links, where streams join together, were calculated. This is followed by the interactive selection of outlet cells, where main channels join the mainstream trunk. Outlet points were utilized in the derivation of the watershed of Feiran basin, and its associated main subwatersheds. The current research attempts to map the prone watersheds; Wadi Watieer and Wadi Dahab. It also provides the complete drainage map of the area, Fig. (6)

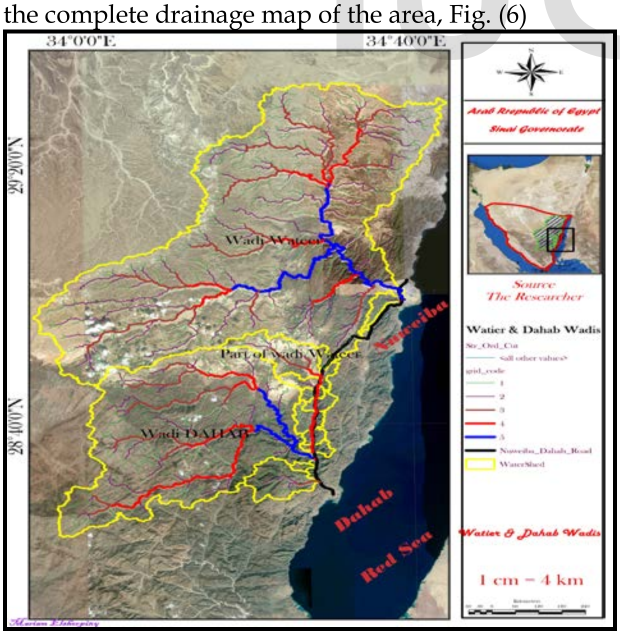

Fig. (6) Drainage basins of study area.

3.2 Slope of longest stream lines.

$$S = \frac{H}{Lb} \quad \text{.. Eq. (1)}$$

Where H: - is the difference of max. and min. elev. Of Wadi Lb: - is the length of the Wadi. Since the morphological factors that affect the occurrence of Flash Flood are:-

1. Drainage basin outline. 2. Length of the stream path
3. Drainage basin area. 4. Slope of Wadi. (S %) table (1)
5. Drainage basin shape. 6. Concentration time.

3.3 Basins Areas.

Wadis	Catche-ment name	Length (LB) Km	Max. Elev. (H1) m	Min. Elev. (H2) m	Slope (S) %
1	Wadi Watieer	123	1397	24	1.116
2	Wadi 2	25	1171	535	2.544
3	Wadi 3	84.5	1888	245	1.944
4	Wadi Da-	18.3	784	86	3.814

Table (1) Slope of longest path of wadis.

Watershed is the area covering all the land that contributes run-off water to a common point. There are four basins as shown in Fig. (6) attack the road, comparing the area of each basin we can conclude that, Wadi Watieer is the biggest area, whereas its area is 3510 km2 and the center of the basin is located at x=3223985 and Y=3223985 (UTM Zone36). The area of Wadi Watieer is 65.37% of total area of four basins while that the area of Wadi Dahab is 30.126% of total area of four basins.

3.4 Hazard points.

Any area under development that is subjected to flood hazards had to be protected against flood events [(5)], there is no doubt that the investigated road that mentioned previously has been attacked by four hazard points, two points of them have their outlet in main and vital cities, one in the city of Dahab, Wadi Dahab, and the other outlet in the city of Nuweiba, Wadi Watieer Fig. (7).

Hz1, is located in the city of Nuweiba, and is junction of Nuweiba – Dahab Road with Nuweiba - Taba through this point that is the outlet of Wadi Watieer, which flows into the city of Nuweiba. The longest path of Wadi Watieer is 123 km and Slopes by 1.116% depending on the eq. (1).

Hz2, Is located in a distance about 34.50 kilometers from the city of Dahab, from the profile of the road, we could find that the level of the road at this point is 535 m above sea level, that is lower level than the level of the oulet of Wadi Watieer (1171m), therefore protection works decision will be depend on the difference of the levels between stream line and the outlet point, so it will be either direction wall to direct the water so as not to cause erosion in the side of the road or a compilation of the water pipe on the side of the road and collect water flood in plantation and therefore can benefit from the water stream to serve the neighboring cities rather than wasted in the Red Sea.

Hz3, Is located in a distance about 10.00 kilometers from the city of Dahab, from the profile of the road, we could find that the level of the road at this point is 190 m above sea level.

Hz4, is located in the city of Dahab, and is junction of Nuweiba – Dahab Road with Dahab – Sharm El-Sheikh through this point that is the outlet of Wadi Dahab, which flows into the city of Dahab. The longest path of Wadi Dahab is 18.30 km and Slopes by 3.814%. So Wadi Dahab is the steepest wadi compared to the other three Wadis.

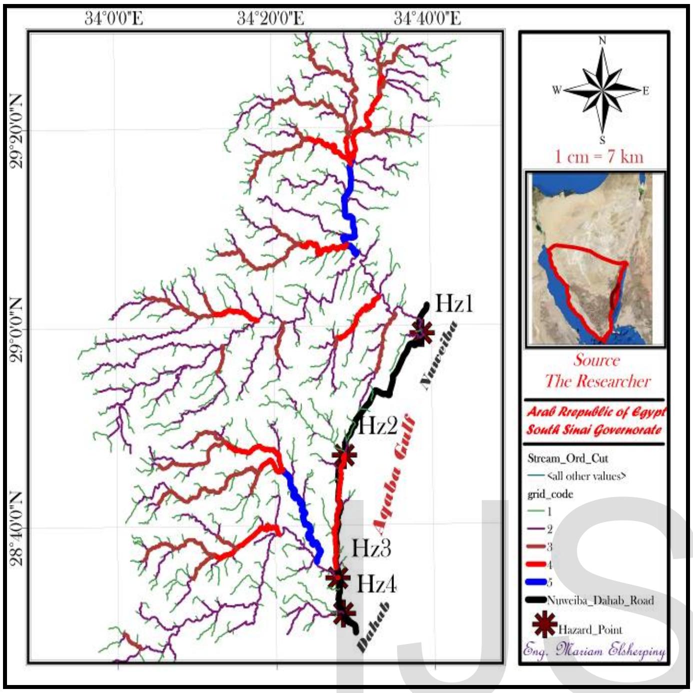

Fig. (7) Hazard points prone the investigated road.

4. Conclusion

This paper has demonstrated a generic approach to the systematic using of GIS analysis that can provide geo-environmental hazard zone maps. The main advantages to be gained are the capability to use raster DEM, database creation, and to analyze the available data to reach the hazards that threaten the road of study.

Flash flood prone wadis were delineated and assessed in ArcGIS especially the ArcHydro tool. As part of the research, this tool has been used to determine the hazard points that catch the investigated road which are of high risk. The final flood hazard map was produced with the conservative values of the slope of the longest path of drainage lines, whereas the velocity of the flashing water depends primarily on the slope of the drainage path in which the water has moving. Also the confluence points with the road has been delineated from the previously mentioned analysis. So the specialist must take the necessary protection procedures to maintain the road from collapse by constructing the appropriate protection works in those points.

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