DOI: 10.24996/ijs.2022.63.9.39

ISSN: 0067-2904

Utilization of Geographic Information System for hydrological analyses: A case study of Karbala province, Iraq

Habeeb Ghdhaib Maarez[1], Hussein Sabah Jaber[1], Muntadher Aidi Shareef*[2]

[1]College of engineering, university of Baghdad

[2]Department of Surveying Engineering Techniques, Technical College of Kirkuk, Northern Technical University, Baghdad Road, 36001 Kirkuk, Iraq

Received: 6/8/2021 Accepted: 31/1/2022 Published: 30/9/2022

Abstract

Analyses are the power point of GIS because GIS can process and analyze different spatial and attribute data, leading to new results for supporting decision makers. The research aims to study advanced hydrologic analyses for the western part of Karbala province, Iraq. The hydrologic analysis is done based on where that DEM creates from the field survey method. This analysis gives digital maps and tables showing the region's main and minor hydrological properties, such as flow direction, flow accumulation, stream order, stream to feature, basin, and watershed maps. Also, it can be calculated as area, perimeter, lengths of streams, and numbers of stream orders for the main watersheds that are effective in the study area. These analyses are very important for making decisions in studying the hydrologic properties of any region in Iraq, and the GIS technique saves time, cost, and effort.

Keywords: GIS, DEM, Hydrological analyses.

استخدام نظم المعلومات الجغرافية الجغرافية في التحليل الهيدولوجي: دراسة حالة لمدينة كربلاء , العراق

حبيب غضيب معارز[1] , حسين صباح جابر[1] , منتظر عيدي شريف*[2]

[1]كلية الهندسة , جامعة بغداد, قسم هندسة المساحة

[2]الجامعة التقنية الشمالية, الكلية التقنية كركوك, قسم هندسة تقنيات المساحة[2]

الخلاصة

التحليل هي نقطة القوة في نظم المعلومات الجغرافية لأن نظم المعلومات الجغرافية لديها القدرة في معالجة وتحليل البيانات المختلفة مثل البيانات المكانية والسمات التي تؤدي إلى الحصول على نتائج جديدة لدعم صانعي القرار .يهدف البحث إلى دراسة التحليل الهيدرولوجي المتقدم للجزء الغربي من كربلاء في العراق باستخدام نظم المعلومات الجغرافية .يتم إجراء التحليل الهيدرولوجي بناءً على المكان الذي تنشئه DEM من طريقة المسح الميداني .يعطي هذا التحليل خرائط وجداول رقمية توضح الخصائص الهيدرولوجية الرئيسية والثانوية للمنطقة مثل اتجاه التدفق ، وتراكم التدفق ، وترتيب التدفق ، والتيار إلى المعلم ، والحوض ، وخرائط مستجمعات المياه .أيضا ، يمكن حساب المساحة ، المحيط ، أطوال المجاري المائية وأعداد المجاري المائية لمستجمعات المياه الرئيسية التي تؤثر على منطقة الدراسة .يعتبر هذا التحليل مهم للغاية لاتخاذ القرارات في

* Email: muntadher.a.shareef@ntu.edu.iq

دراسة الخصائص الهيدرولوجية لأي منطقة في العراق وتوفر تقنية نظم المعلومات الجغرافية توفير الوقت والتكلفة والجهود.

1. Introduction

Iraq is considered one of the water-rich countries due to the presence of two rivers (Tigris and Euphrates). Building dams on Tigris and Euphrates and their tributaries by countries that originate or pass from them, such as Turkey and Syria, and global climate change and mismanagement of these resources are all reasons leading to scarcity of water in Iraq by the year 2040 [1, 2, 3]. Geographic information systems (GIS) are used to classify and analyze information and store it in databases [3]. The methods of obtaining data using GIS allowed geographers, engineers, and those interested in accessing any part of the world, even those difficult to reach using traditional methods [4, 5]. The digital elevation model (DEM) is a three-dimensional representation of the earth's surface and one of the most accessible digital representations of the earth's surface topography [6, 7]. Digital elevation models can be used to determine many hydrological studies, for example, fill, flow direction, flow accumulation, stream order, basins, and watersheds [8]. There are many ways to create a digital elevation model that differ in terms of accuracy, time, and cost, such as satellite images, aerial photos, laser scanning, and field surveys [9, 10]. The western part of Karbala is a part of Iraq's western plateau, where there is no surface water [11]. In recent years, the advancement of digital technology, such as geographic information systems and digital three-dimensional modeling, encouraged many researchers to study the hydrological characteristics of such lands, which in turn helped many decision-makers to manage and secure water resources to encourage local people to use water at scientifically correct ways [12]. Hence ,this research aims to study the hydrologic properties of western part of Karbala province, Iraq using GIS technology to support decision makers with these analyses due to GIS properties, low cost ,save the efforts and time [13].

2. Materials and Data used

2.1 Study area

Karbala governorate is located between latitudes 31.75° and 33.5° north, and longitudes 43.2° and 44.5° east, in the center of Iraq with borders occupied by Babylon governorate from the east and northeast, Anbar governorate from the west and northwest, and Najaf governorate from the south [14], Figure 1. The study area is located in the southern part of the northern temperate zone, at the end of the eastern end of the land area connected to the west with the desert climate. The high temperature in summer reaches 50 Cº, but in the winter, the temperature drops to below zero degrees Celsius. The topographic surface includes some sandy hills, valleys, and water bodies containing rainwater [15].

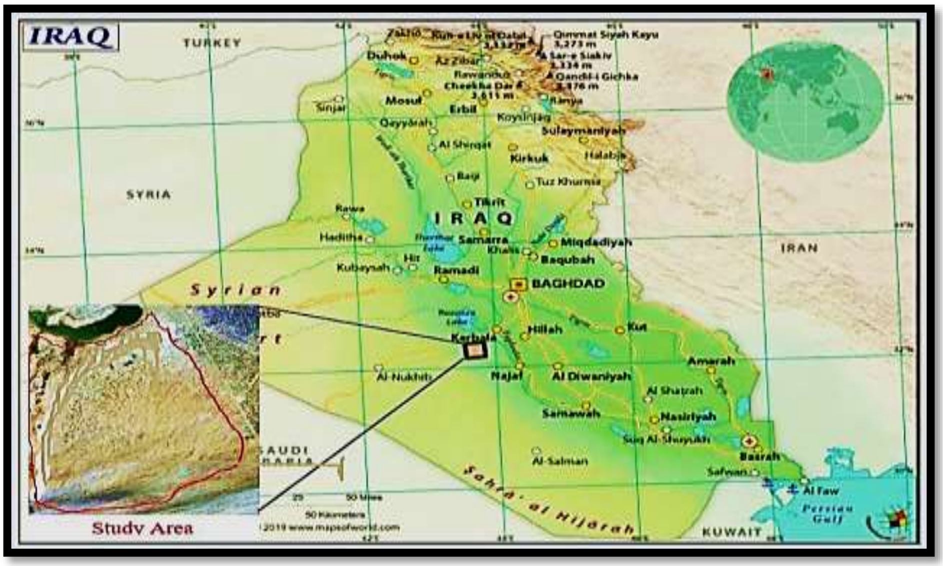

Figure 1-The map of the study area [16].

2.2 Data collection

The data were collected from the Ministry of water resources, Iraq, observed in the field; the total number of 350 points DGPS with technique static were collected using a DGPS device. The device accuracy for horizontal is (±≤5 cm), and vertical is (±≤10cm) [16, 17]. Table (1) shows some of the data for the study area.

Table 1-Some data from field surveys for the study area (Ministry of water resources, Iraq).

point	Lat. (degree)	Lon. (degree)	Elv. (m)		point	Lat. (degree)	Lon. (degree)	Elv. (m)
1	32.55095	43.79501	28.43		21	32.52217	43.63991	40.21
2	32.57090	43.76342	28.66		22	32.45618	43.65368	63.38
3	32.54097	43.75677	29.21		23	32.47945	43.63539	60.87
4	32.56255	43.73682	28.75		24	32.49774	43.61876	39.65
5	32.57922	43.72684	28.63		25	32.42292	43.65202	52.08
6	32..58919	43.74513	28.72		26	32.44786	43.63206	58.17
7	32.59917	43.70855	28.86		27	32.45784	43.61377	70.65
8	32.51147	43.74913	35.11		28	32.41627	43.63040	57.09
9	32.53432	43.73016	36.32		29	32.43456	43.61377	64.11
10	32.55095	43.71520	32.41		30	32.40962	43.60878	64.34
11	32.56425	43.69358	29.78		31	32.36140	43.60712	64.76
12	32.57922	43.67197	43.92		32	32.32316	43.63040	65.83
13	32.50107	43.72351	41.11		33	32.31817	43.60546	80.71
14	32.51271	43.70689	40.83		34	32.28990	43.60047	95.33
15	32.53599	43.68693	29.63		35	32.28159	43.62541	86.45
16	32.55428	43.66698	37.72		36	32.29323	43.65035	71.79
17	32.56592	43.64536	51.81		37	32.26496	43.60380	97.33
18	32.47114	43.65525	47.77		38	32.25665	43.63373	91.12
19	32.49103	43.68527	47.77		39	32.26330	43.66199	79.31
20	32.51603	43.67520	46.89		40	32.27660	43.68693	67.79

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3. Methodology

Figure 2 shows the schematic of the research methodology.

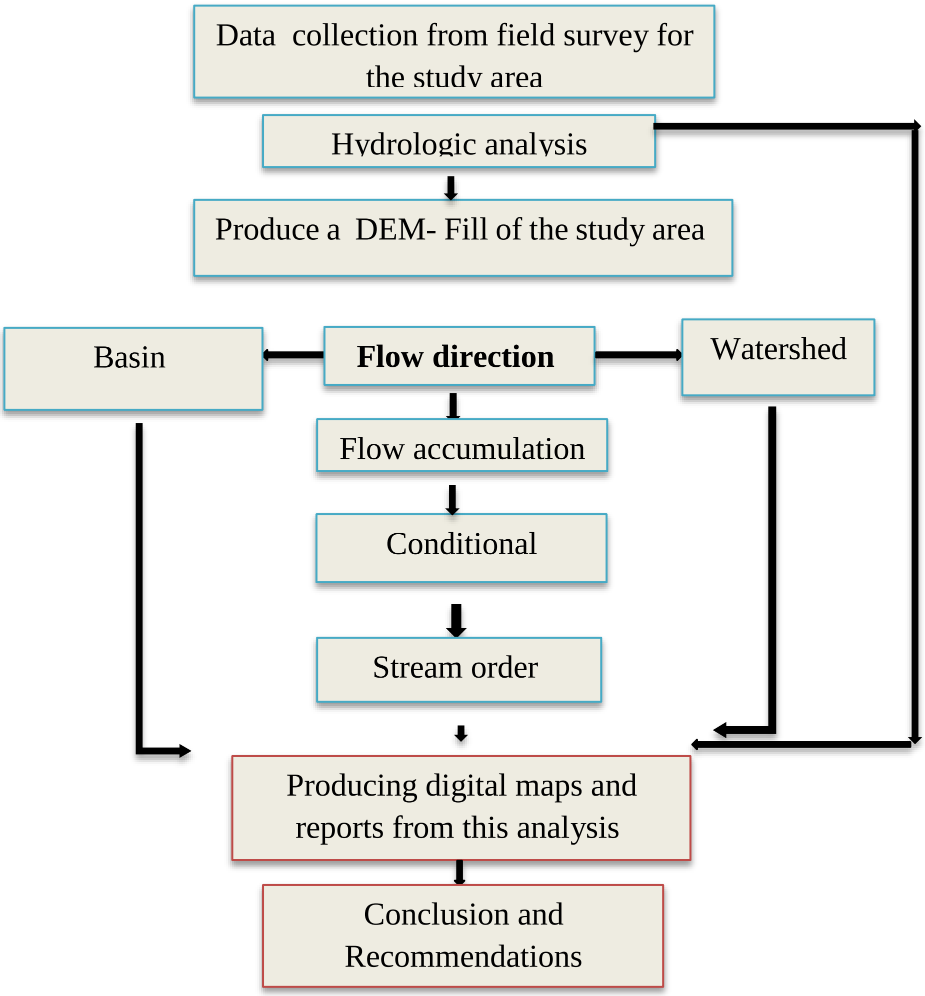

Figure 2-Schematic of the research methodology

The digital elevation model of the study area was created using ArcGIS software 10.8 and from the data collected using the field survey, as shown in table (1). The points were condensed using the spatial interpolation method to obtain a DEM close to the actual surface, where the Inverse distance weighted (IDW) method depends on the distance between known and unknown points [18]. The DEM's accuracy is less than (10 cm), which is more accurate than the free DEM resolution available from satellites; the field survey gives more visualization of the study area [19, 20, 21, 22]. Figure 3 shows the produced DEM for the study area. The field survey method focuses on creating DEM for the study area and the work of all the required analyses and representing the hydrological properties of the study area.

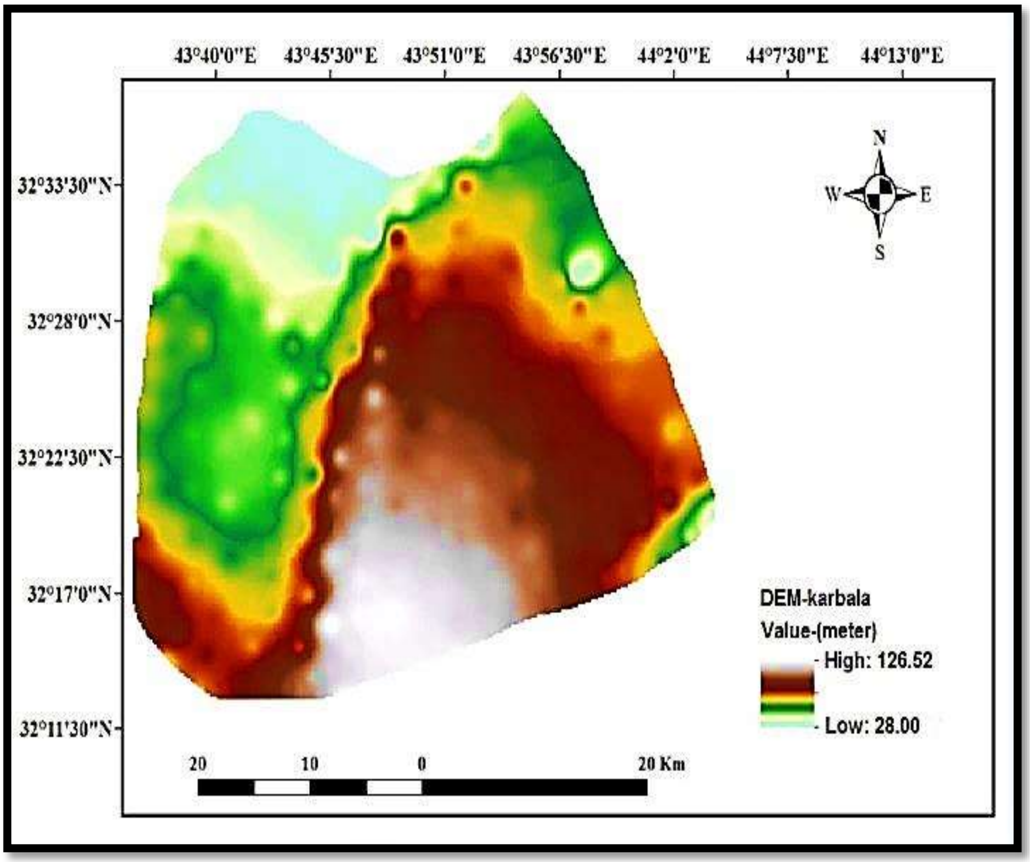

Figure 2-DEM of the study area.

4. Results and discussion

Based on the DEM produced for the study area, the hydrologic analysis was done using Arc GIS as follows:

4.1 Fill map

To treat outliers, for example, the irregular highs and lows of the digital elevation model for the study area, a filling process was used, where a digital elevation model is produced free from irregular values, as shown in Figure 4.

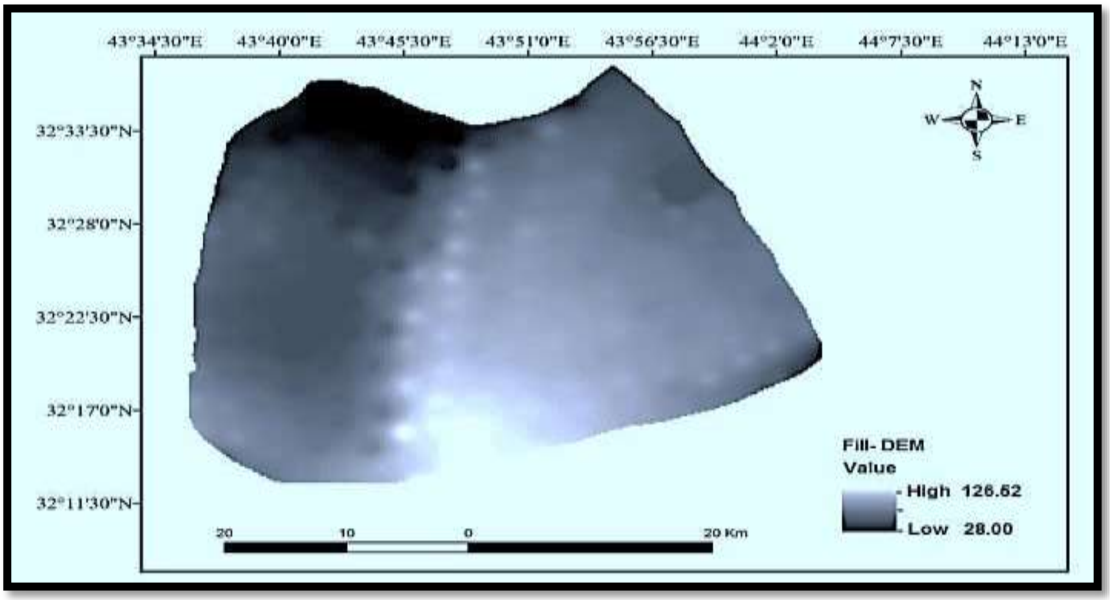

Figure 4-Fill-DEM map of the study area.

Flow direction map 4.2

A flow direction map was made from the digital elevation model after handling the outliers (highs or lows) through a process called (Fill) [21]. In Arc GIS software 10.8, the keys to the flow direction (direction coding) can be illustrated with the directions, so they were numbered as 1: East, 2: Southeast, 4: South, 8: Southwest, 16: West,32: Northwest, 64: North, and 128: Northwest as shown in Figure 5.

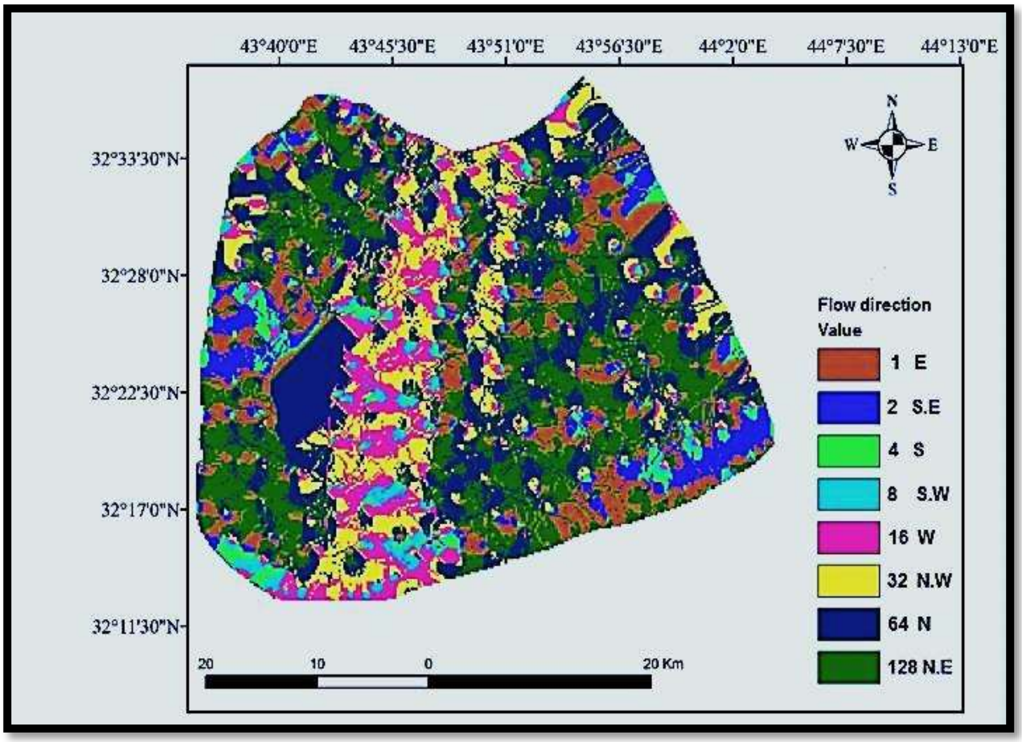

Figure 5-Flow direction map of the study area

Flow accumulation (conditional) map 4.3

The flow direction layer produced a flow accumulation layer using ArcGIS software 10.8. This layer is used to improve the flow accumulation layer through the conditional process. The conditional process depended on the value of sensitivity, where the value was > 100, and the stream feature treatment raster-layer was represented as a vector layer, as shown in Figure 6. The purpose of producing the condition map is to produce a stream order map.

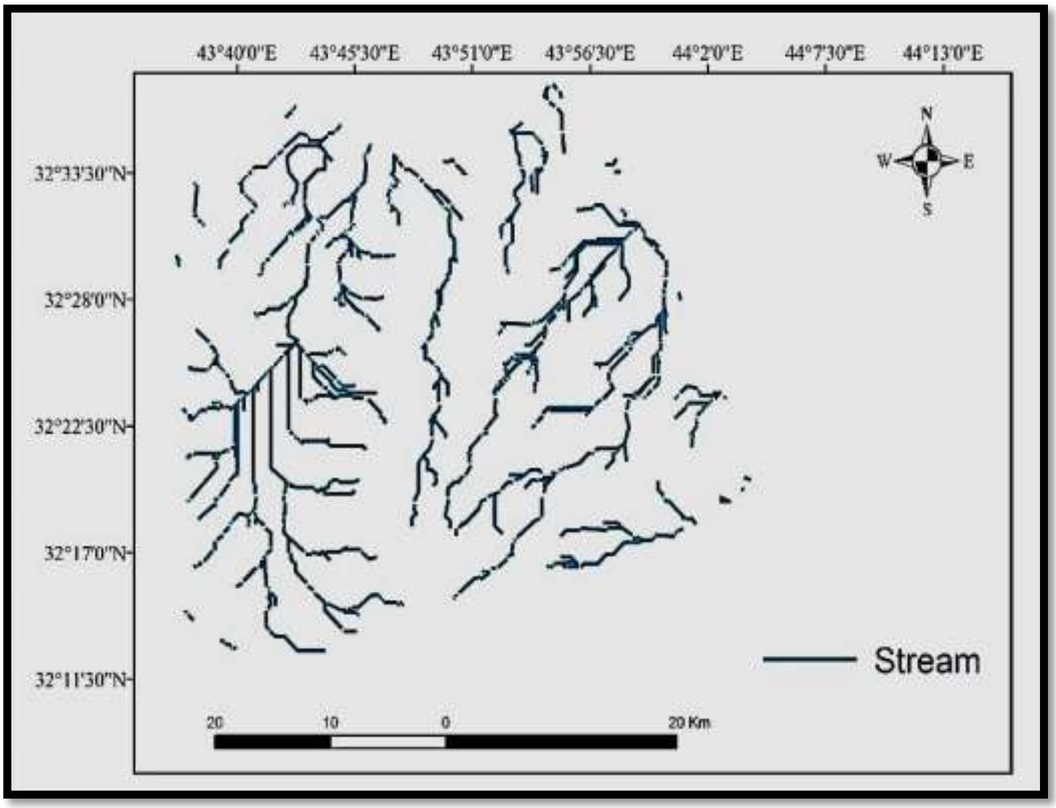

Figure 6 -Flow accumulation (conditional) map of the study area

Stream order map 4.4

The study area's stream order map was produced using ArcGIS software 10.8 by the Strahler method [22], as shown in Figure 7. The map indicated that the stream order is classified into four orders from 1 to 4. The map aims to classify the sinks into order in terms of capacity, where small sinks take order (1) and then meet with each other to be as order (2) with the largest size of capacity; and soon to the last order is (4) for the study area.

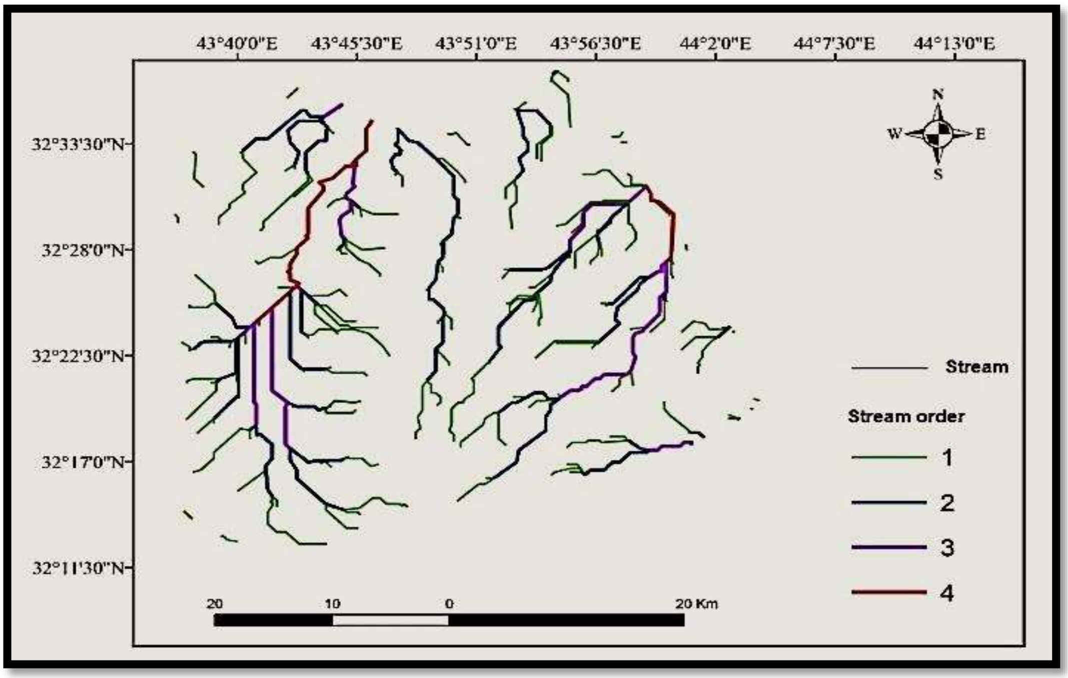

Figure 7-Stream order map of the study area

Basin map 4.5

The ArcGIS software defined the basins of the whole study area and the other basins from the adjacent areas, as shown in Figure 8. Therefore, determining the main basins depends on the large basins and neglects the basins with a small area. The basins map shows the 37 basins, but it can be possible to determine the main basins where the four basins start from. The main basins of the study area were determined using ArcGIS software, and from the flow accumulation layer and the flow direction layer, and this map, the morphometric properties of each basin in the study area can be studied. A map of the basin was produced from one parameter, DEM, to determine the efficiency of this DEM in hydrological analysis.

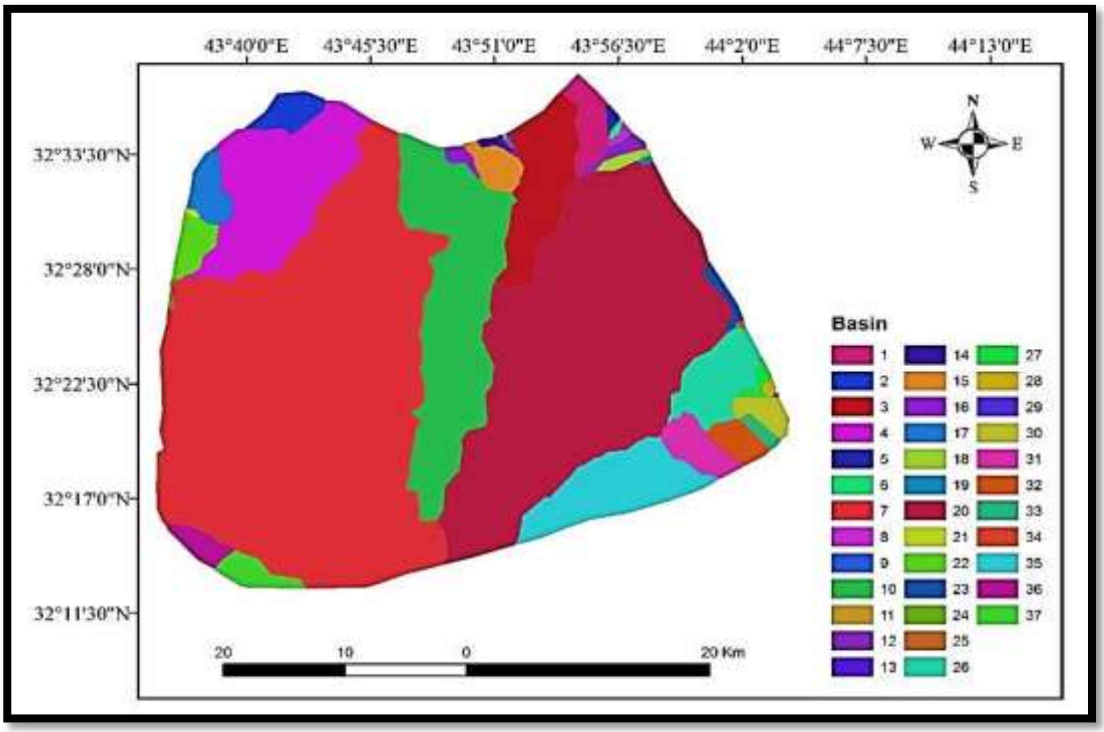

Figure 8-Basin map of the study area

Watershed map 4.6

A watershed map was produced for four main watersheds that affect the study area using the ArcGIS software 10.8, and the flow direction layer of the study area was produced after defining the four downstream points. Figures from (9 - 12) respectively showed that the largest basins were watersheds (1), which contain streams of all orders beginning with the smallest of order (1) and the most significant order (4). Moreover, watershed (2) was smaller than watershed (1); also, it contains streams of all orders beginning from order (1) to order (4). Watershed (3) was smaller than watershed (1) and watershed (2); also, it contains streams order (1, 2, and 3) only. The Watershed (4) was smaller than the watersheds (1, 2, and 3); also, it contains stream order (1, 2, and 3).

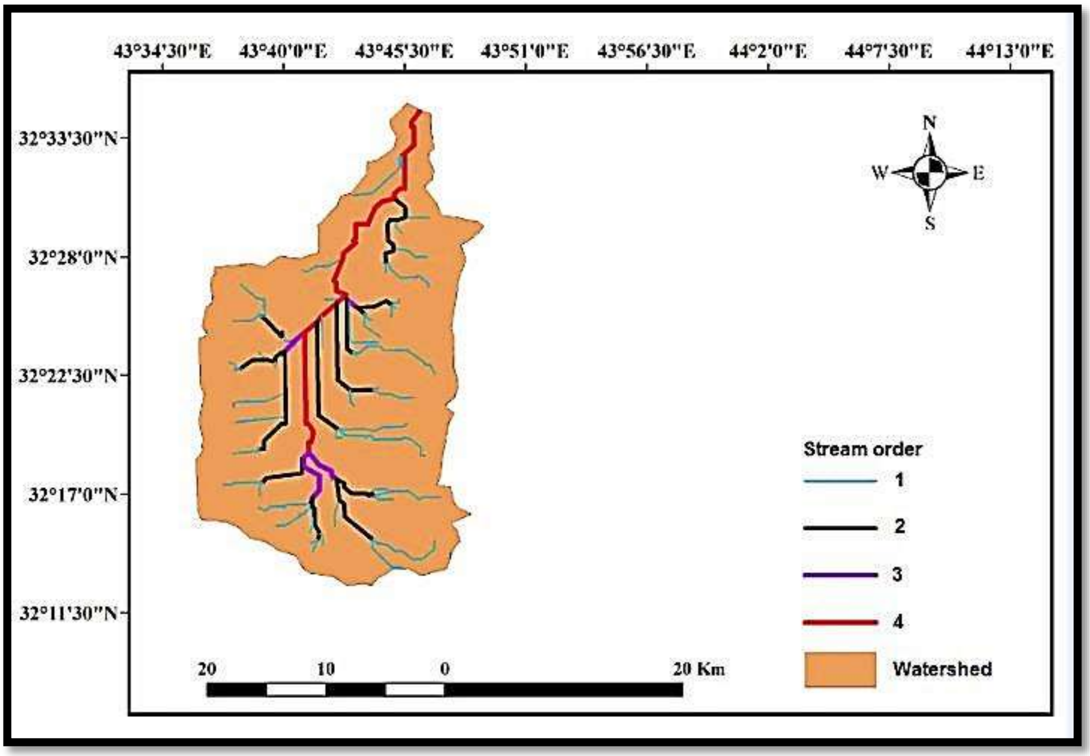

Figure 9-Watershed (1) map of the study area

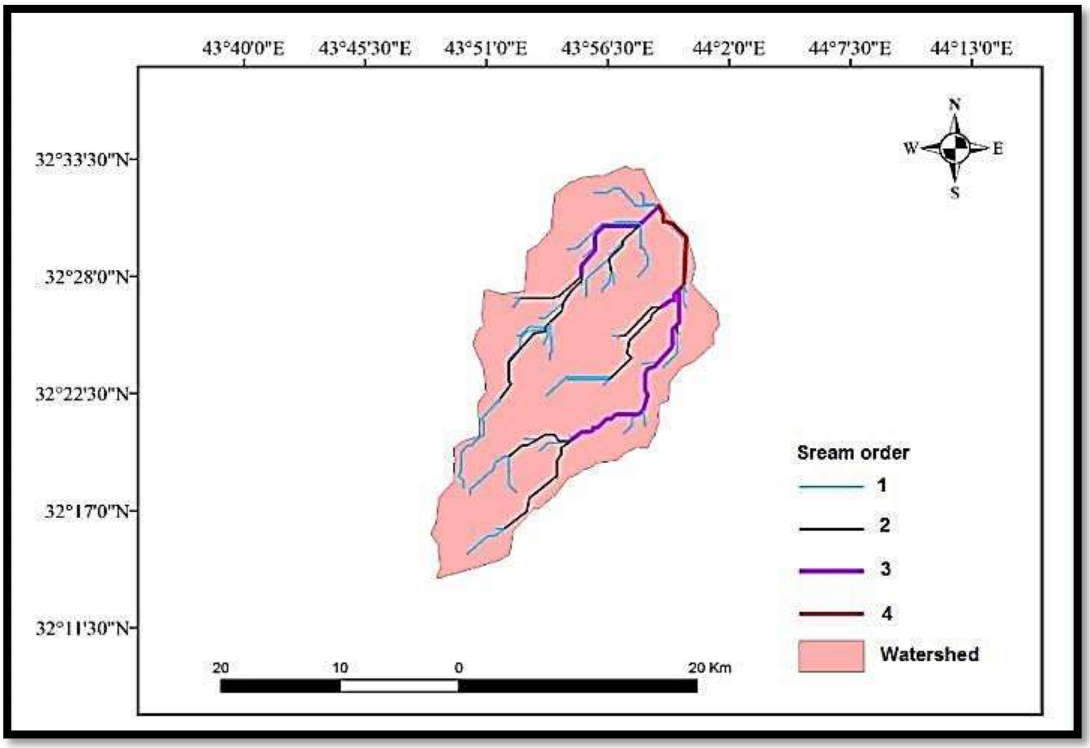

Figure 10-Watershed (2) map of the study area

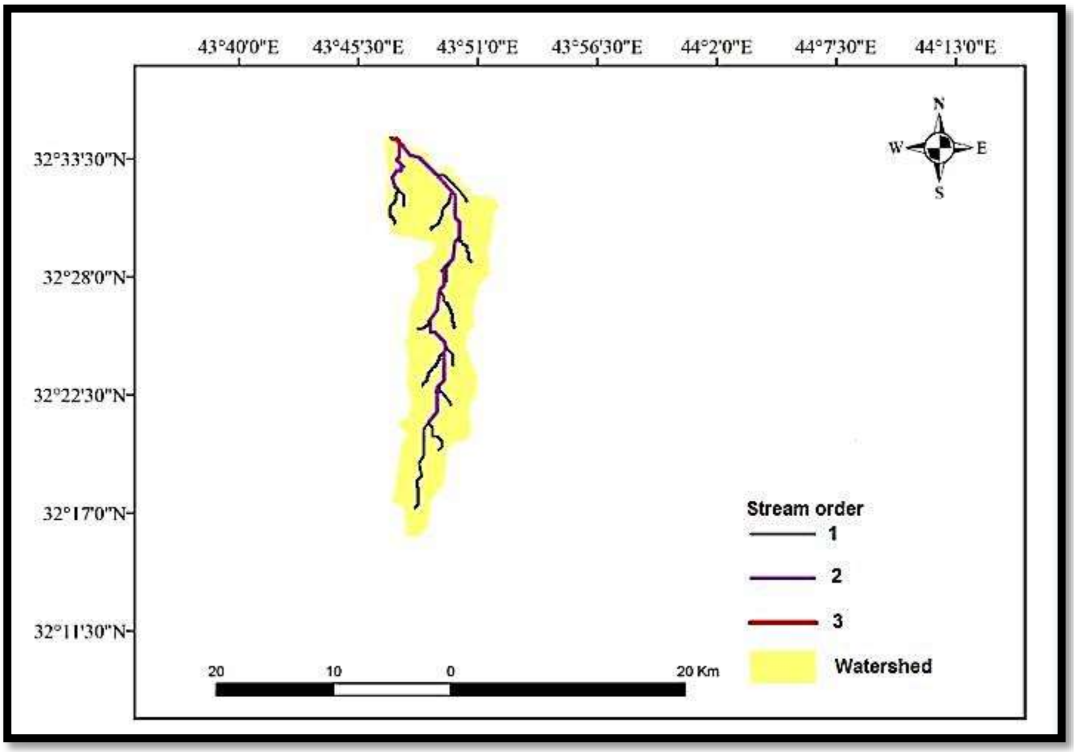

Figure 11-Watershed (3) map of the study area.

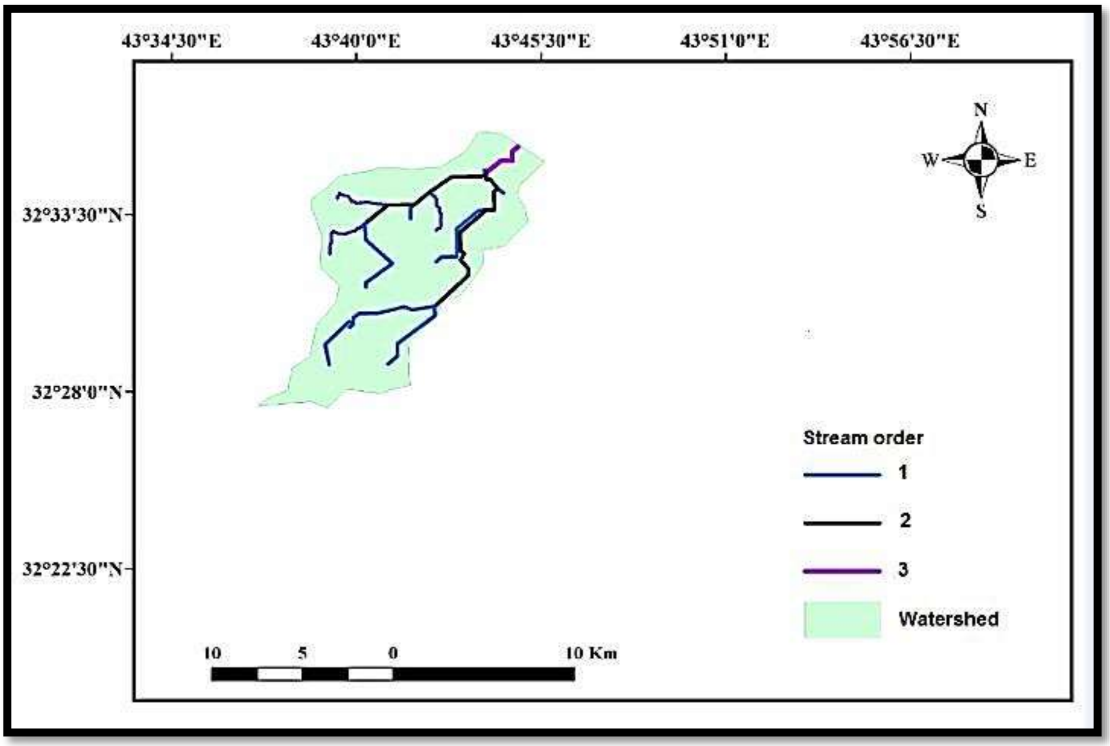

Figure 12-Watershed (4) map of the study area.

From the attribute table of each watershed and stream, the area, perimeter, stream length, and stream number of each four watersheds can be calculated according to stream order using Arc GIS software, as shown in Table 2.

Table 2-Values of area, perimeter, length stream, and number stream of four study area watersheds.

Watershed	Area km²)(	Perimeter Km)(	Length stream order-1 km)(	No. stream order-1	Length stream order-2 (km)	No. stream order-2	Length stream order-3 km) (	No. stream order-3	Length stream order-4 (km)	No. stream order-4
Watershed (1)	540.07	115.64	72.08	34	48.21	21	10.38	5	17.18	9
Watershed (2)	374.34	93.46	68.72	34	25.85	12	20.07	9	6.5	6
Watershed (3)	147.16	84.25	6.7	12	28.72	11	5.75	5	----	----
Watershed (4)	97.78	50.70	23.07	12	16.60	6	2.5	2	----	----

Conclusions

The field survey process for DEM production gives the most perception of the study area, as it simulates the reality of the study area hydrology in terms of identifying natural and artificial features. The flow direction of the streams within the study area took more directions northwest, northeast, and east. The study area contains four main basins and contains four main watersheds that affect the study area, which consists of rain and wells water areas of each watershed (540.07 km²,374.34 km², 147.16km², and 97.78 km²) respectively, with a perimeter of each watershed (115.64 km,93.46 km, 84.25 km, and 50.70 km). The largest watershed is located on the western side of the study area. The study area contains many streams that differ in length and capacity, from the smallest order to the largest order (1, 2, 3, and 4). This research can study its hydrological characteristics in Iraq's desert areas.

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