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Studying and Assessing Surface Water Use of Shuwaija Marsh within Wasit Governorate-Iraq

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ABSTRACT

This study aims to study and evaluate the surface water use of Al-Shuwaija marsh by estimating the maximum value of water flow and the volume of water revenues through the hydrological analysis of the characteristics of these marsh basins in addition to the physical analysis of the characteristics of the selected design storm. The hydrological model was created for the watersheds of the Al-Shuwaija marsh. Sixty simulations were conducted to model the Shuwaija marsh for different return periods and rainstorms, where the model was calibrated and then validated to predict the flow and volume of water using the (WMS) program. The SCS method was used to calculate the value of the total curve number (CN) based on the land use and soil type of Al-Shuwaija marsh basins, where its value was 80.84. It has been shown via modelling that a discharge may be achieved into 8298 m^3/sec at a return period of 100 years and obtain a discharge of up to 1775 m^3/sec at a return period of 2 years. Based on the expected amount of precipitation that would fill the selected reservoir, three scenarios were assumed each scenario representing the area of the reservoir and the volume of incoming water.

Keywords: AL-Shuwaija marsh, SCS method, WMS, Curve number.

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دراسة وتقييم استخدام المياه السطحية لهور الشويجة ضمن محافظة واسط-العراق

سيف علي عبد الرضا*، باسم شبع عبد

قسم هندسة الموارد المائية، كلية الهندسة، جامعة بغداد، بغداد، العراق

الخلاصة

تهدف لدراسة الحالية إلى دراسة وتقييم استخدام المياه السطحية لهور الشويجة وذلك بتقدير القيمة العظمى لتدفق المياه وحجم الإيرادات المائية من خلال التحليل الهيدرولوجي لخصائص احواض هور الشويجة بالإضافة الى التحليل الفيزيائي لخصائص عاصفة التصميم المختارة. تم إنشاء النموذج الهيدرولوجي لمستجمعات المياه في هور الشويجة، حيث تم عمل ستين عملية محاكاة هيدرولوجية لهذا الهور لفترات عودة وعواصف مطرية مختلفة، حيث تم معايرة النموذج ومن ثم التحقق من صحته للتنبؤ بتدفق وحجم المياه باستخدام برنامج (WMS)، تم استخدام طريقة (SCS) لحساب قيمة رقم المنحني الكلي (CN) بالاعتماد على استخدام الأراضي ونوع التربة لأحواض هور الشويجة حيث بلغت قيمته 80.84. من خلال النمذجة الهيدرولوجية، تم إيجاد اقصى تصريف يصل الى 8298 م^3 / ثا خلال فترة عودة مدتها 100 عام والحصول اقصى تصريف بقيمة يساوي 1775 م^3 / ثا في فترة عودة مدتها سنتان، بناء على كمية الأمطار المتوقعة التي من شأنها أن تملأ الخزان المحدد، وتم افتراض ثلاثة سيناريوهات يمثل كل سيناريو مساحة الخزان وحجم المياه الواردة.

الكلمات المفتاحية: هور الشويجة، طريقة SCS، برنامج WMS، رقم المنحني.

1. INTRODUCTION

The major risk of the Iraqi marshes drought is still unless decisive action is taken, such as conducting a comprehensive study and planning for water resources by estimating the amount of water for various stages of the hydrological cycle and their return periods and studying the future of water resources **(Adamo et al., 2018)**. The lack of water sources during droughts, in addition to climate change, has a clear impact on the marshes. Therefore, it is necessary to evaluate hydraulic and hydrological behavior by estimating the amount of water revenue through rainfall (**Ali et al., 2023)**. Predicting floods requires an understanding of the likely quantities of precipitation to come **(Al-Mudaffar et al., 2016**). Observed precipitation may be converted into stream flow with the use of hydrological models **(AL-Heetimi et al., 2015)**. **(AL-Thamiry and Hassani, 2015)** found that the restoration of the entire marshes is not achievable under the current conditions due to the limited discharge of water from the feeders of the Iraqi marshes and the decline in nutrition from the Iranian side. **(Hilo and Saeed, 2019)** investigated the quality and amount of water in the streams that flow into Al-Shuwaija marsh, as well as improved water management. Different hydrological processes in watersheds are significantly impacted by climate change **(Luo et al., 2013).** Water resources management relies heavily on accurate estimates of surface runoff from rainfall in water basins **(Farhan and Abed, 2021)**. **(Rahi et al., 2019)** investigated the runoff of eight catchment regions (Mandali, Qazania, Tursaq, Mirzabad, Galal Badra, al-Chabbab, al-Teeb, and Dwaireeg) using regression models developed for the western and southern United States. The optimal investment in a region's natural water resources is one strategy to provide large quantities of water that may help mitigate the harmful effects of climate change**(García-Ruiz et al., 2011)**. In watershed research, it is crucial to conduct a thorough evaluation of the parts of any hydrological system **(Manhi and Al-Kubaisi, 2021)**. **(Abbas and Abdulameer, 2020**) used the Landsat series of images to identify flood waters in Al-Shuwija marsh from 1972 to 2019, as well as to track the geographical extent and spread of flooding. The effects of climate change, as well as the fact that these wetlands have no outlets during times of low flow. So, it is important to assess the hydraulic behaviour and quality of the marsh water and determine the optimal position of the output drains **(Al-rikabi and Abed, 2021)**. **(Hasan et al., 2021)** calculated the highest and lowest water levels in the Al-Shuwija marsh basin and provided quantitative information on the size of the flooded areas to use in future planning and research using Landsat pictures (1984-2019).

(Abed and Abduljabbar, 2022) analyzed the potential impact of upgrading the flooding of Al-Shuwija marshes using a geographic information system, and more specifically the QGIS tool.

Moreover, a digital elevation model was used to examine the wetlands, with 28 m spatial resolution, and applying the Watershed Modeling System (WMS), to estimate the surface runoff over the watershed was performed. The software ARC-GIS and the WMS, were frequently used to simulate terrain models and to extract watersheds runoff **(Kamal et al., 2018)**. An assessment of water budget and flow estimates was conducted using the results produced from meteorological models with control specifications with local meteorologic data that were used to conduct the simulation of the basin model's precipitation-runoff response **(Kazezyılmaz-Alhan et al., 2021)**.

The current study aims to develop a numerical model to simulate surface runoff in Al-Shuwaija Marshrivers using WMS software to forecast the amount of water that the marsh will receive from the basins of the local rivers Galal Badra and Tarsaq.

2. MATERIAL AND METHODS

2.1 Watershed Modeling System (WMS)

As it is well known to the specialists, the Watershed Modeling System (WMS) software provides a wide range of analyses of the hydrologic environment **(Erturk et al., 2006)**. The software was created by the Waterways Experiment Station which belongs to the U.S. Army Corps of Engineers by the Environmental Modeling Research Laboratory at Brigham Young University (ECG) **(Yannopoulos et al., 2005)**.While there is only one storm event per Watershed Modeling System (WMS), there are multiple modeling options.. T Using a DEM-based approach, watersheds have been defined by the WMS software, making it possible to identify numerous sub-basins inside each watershed (**Srinivas et al., 2018)**. The flow rate of each subbasin is established.. Following the WMS form's setup and completion of all required data entry, The program starts examining the basins' spatial data **(Deliman et al., 2002)**.

2.2 The Study Area

Al-Shuwaija Marsh is roughly six kilometers from Kut City's northern region, has coordinates (3611873.86–3631813.39) N and (590379.11–585830.23) E, as shown in **Fig. 1**. It is a naturally occurring, rectangular depression that the Tigris River flows alongside **(Al-Shamaa and Ali, 2011)**.

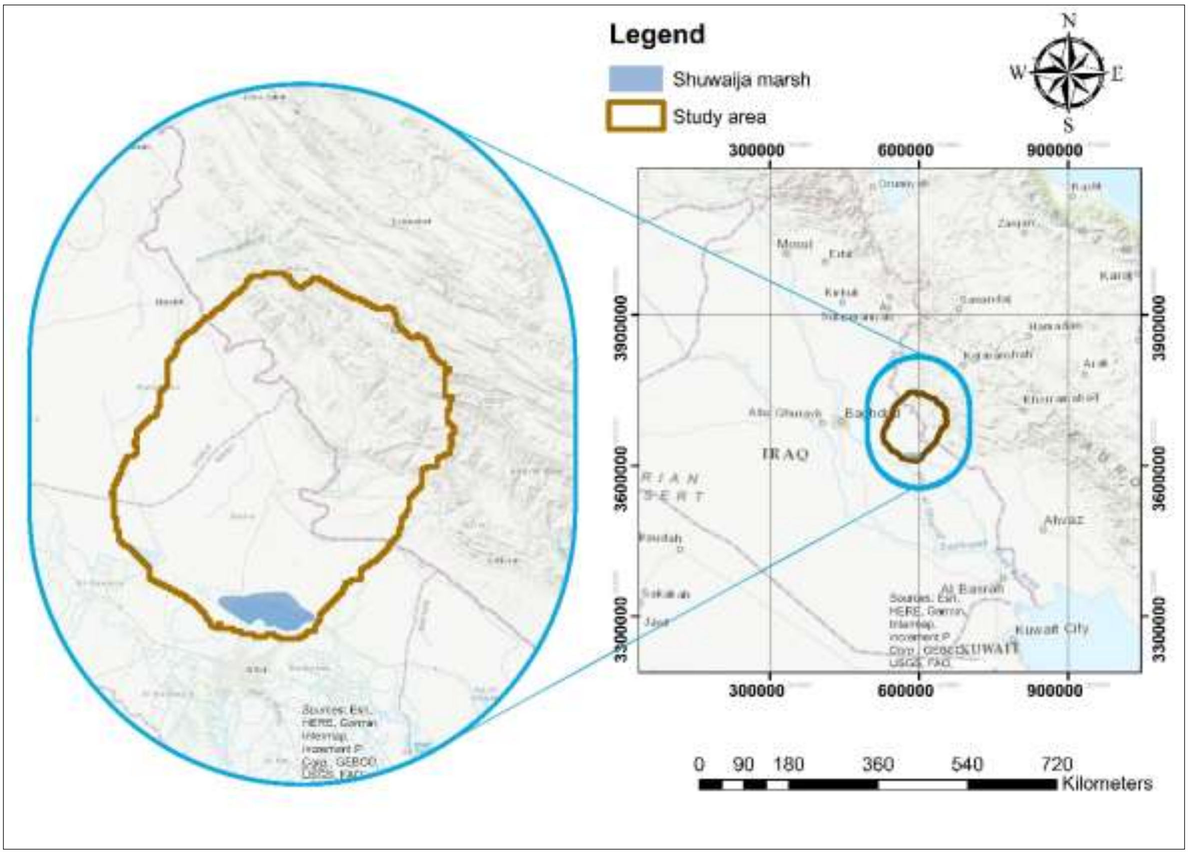

Figure 1. Site of the Study area (**ESRI World Street)**

2.3 The Input Data

In this research, the Digital Altitude Model (DEM), Land Cover/Usage Map, Soil Map, and Weather were used, in addition to calibrating and verifying the WMS mode using the curve number and the observed Galal Badra discharge as references.

2.3.1 The Digital Elevation Model (DEM) and the Triangulated Irregular Network (TIN)

The WMS model requires topography as a necessary input because it enables the analysis of land surface features and the process of determining flow directions and watersheds **(Fathy et al., 2019**). One technique developed to represent relief is the Digital Elevation Model (DEM) **(Jenson, 1991)**. The procedure of creating a model of the Earth's surface using previously gathered data is known as DEM building **(Hapep and Maythm, 2020)**. Furthermore, its effects extend to the velocity and direction of flow across the planet's surface. Thirty-meter resolution digital elevation models are available for download at https://earthexplorer.usgs.gov/. **Fig.s 2 and 3** display the study area's TIN and DEM maps.

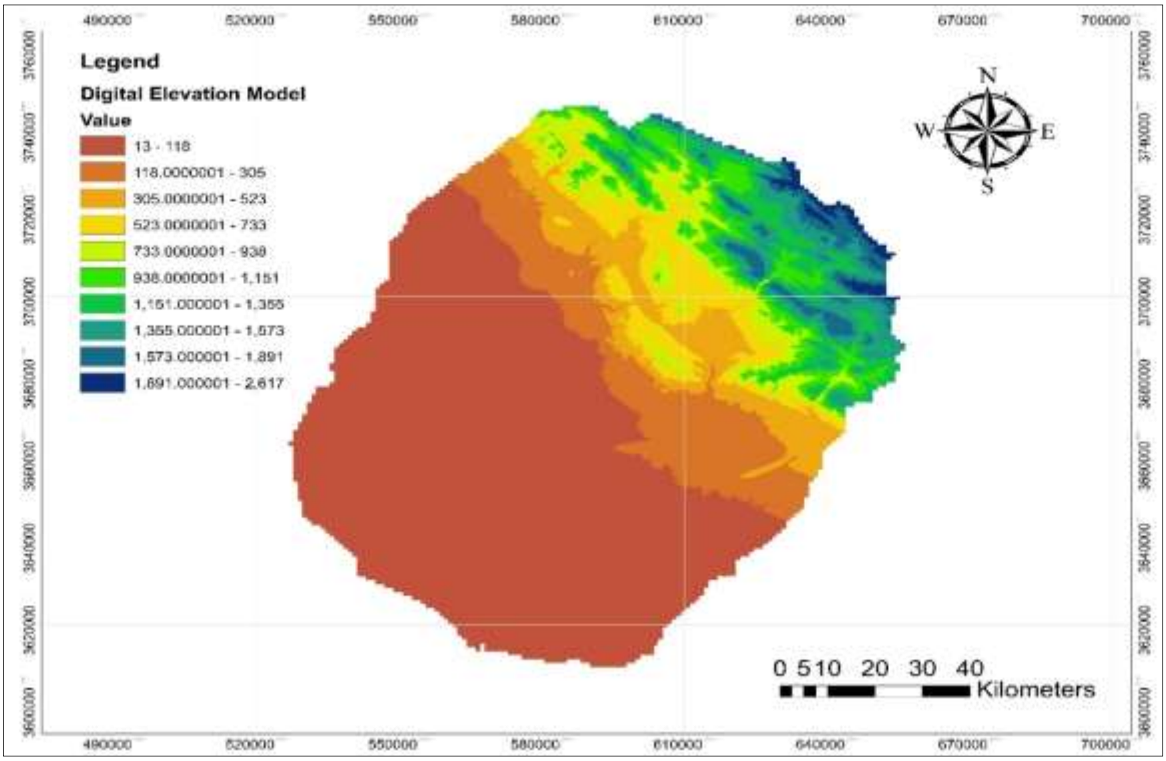

Figure 2. Digital elevation model (DEM) of Al-Shuwaija watersheds

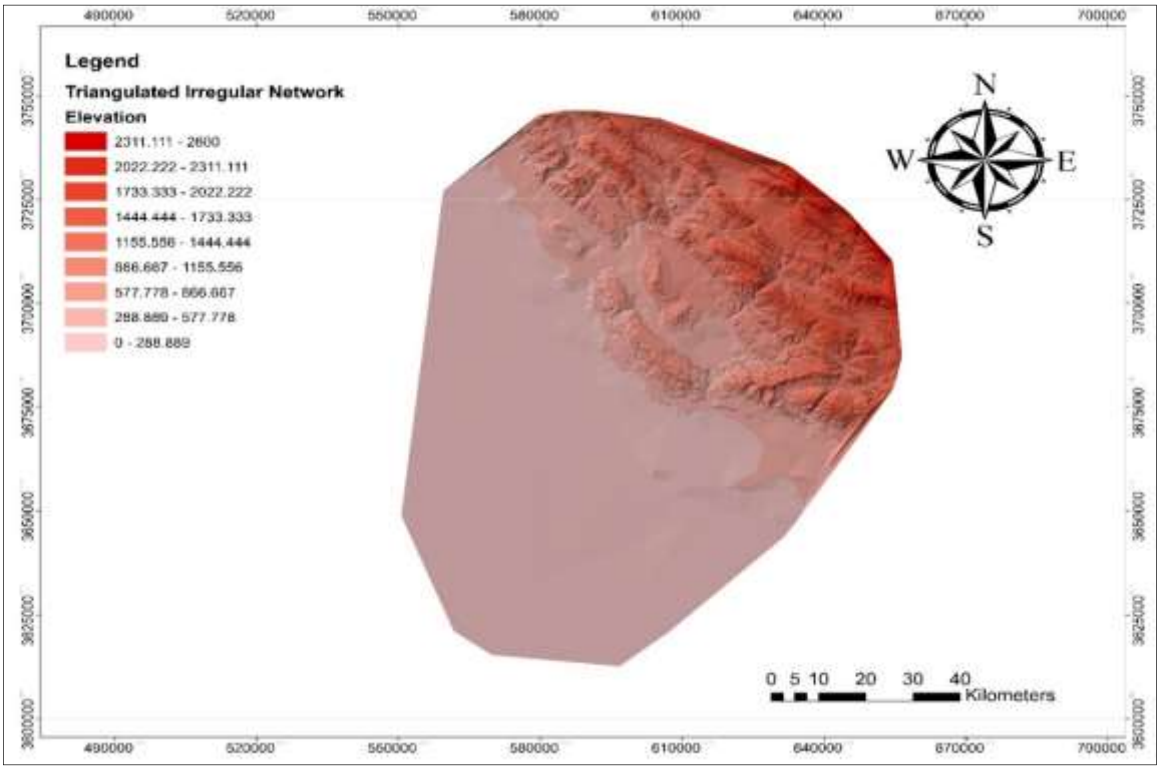

Figure 3. The Triangulated Irregular Network (TIN) of Al-Shuwaija watersheds

2.3.2 Existing Soil Types

The scale of the soil map utilized the obtained from the FAO's website https://www.fao.org/home/en/. The map is segmented into a great number of polygons. Each polygon represents a unique combination of soil characteristics from the surrounding research region. The U. S. Soil Conservation Service has classified around 4,000 distinct soil types into four hydrologic soil categories A, B, C, and D based on their respective runoff capacities **(Alzubaydi and Alamar, 2016).** Runoff volume and rate are strongly influenced by soil moisture, which is evident in the CN values that the SCS generated under three different situations, these three (Antecedent Moisture Condition) AMC classifications according to **(Silveira et al., 2000)** to features of soil groupings are presented in **Table 1.** Hydrological response units were established using this data, as shown in **Fig. 4.**

Table 1. Characteristics of Soils Assigned to Soil Groups

AMC Group		Total (5-day) antecedent rainfall (mm)	
		Dormant Season	Growing Season
I	dry, but above the wilting point	Less than 13	Less than 36
II	average (normal).	13 to 28	36 to 53
III	wet (saturated soil).	More than 28	More than 53

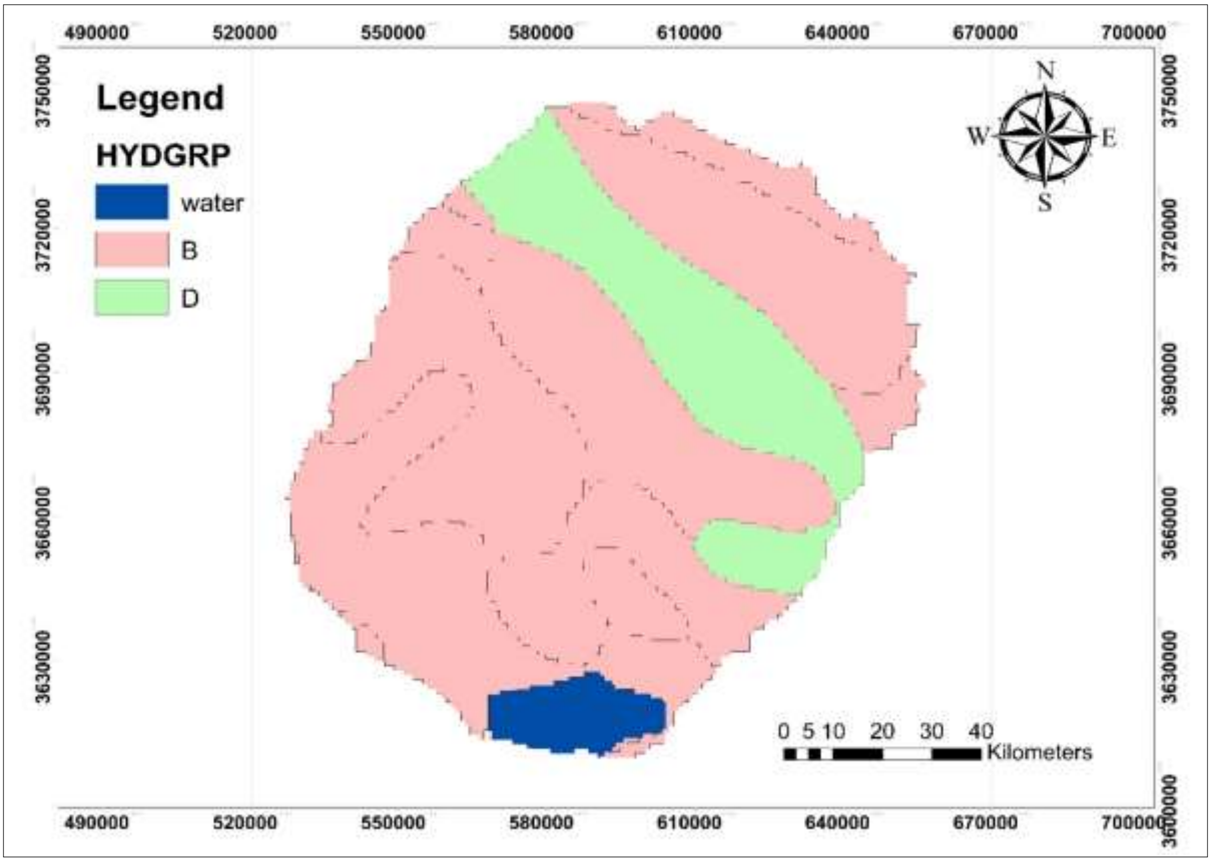

Figure 4. Soil groups map of the study watershed

2.3.3 Land Cover / Land Use

Land Use is the substance that covers the surface of the soil. Asphalt, grass, and clay, among others, have varying surface infiltration and storage rates **(Talukdar et al., 2020)**. Consequently, land cover influences runoff volume, runoff timing, and peak flood flow rates (**Myers and Pezzaniti, 2019**).
Global Land Survey (GLS**)** http://www.usgs.gov/landsat; this land cover is one of the best that is accessible, and it is offered at a resolution of 30 meters, as shown in **Fig. 5**. Each land parcel's Curve Number, which characterizes a catchment's reaction to a storm event, has been approximated using the LU layer and soil layer present within **(Shukur, 2017).**

2.3.4 Slope

The slope is the rate of height change per unit mile along the route of the main channel **(Begin et al., 1981)**. It is an essential component of the runoff's momentum, which has a bearing on the size of floods **(Najafi, 2003)**. The DEM is used to determine the slope. The variance in slope % throughout the research region is shown in **Fig. 6.**

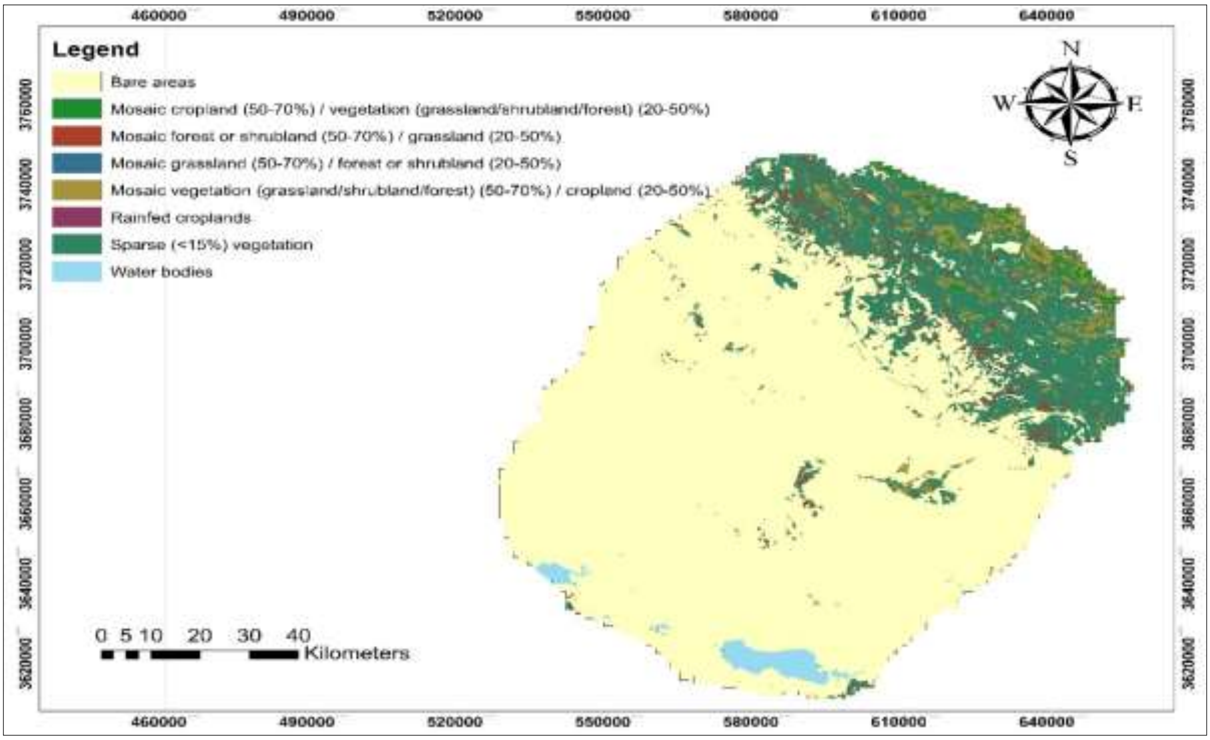

Figure 5. Land use in the study area

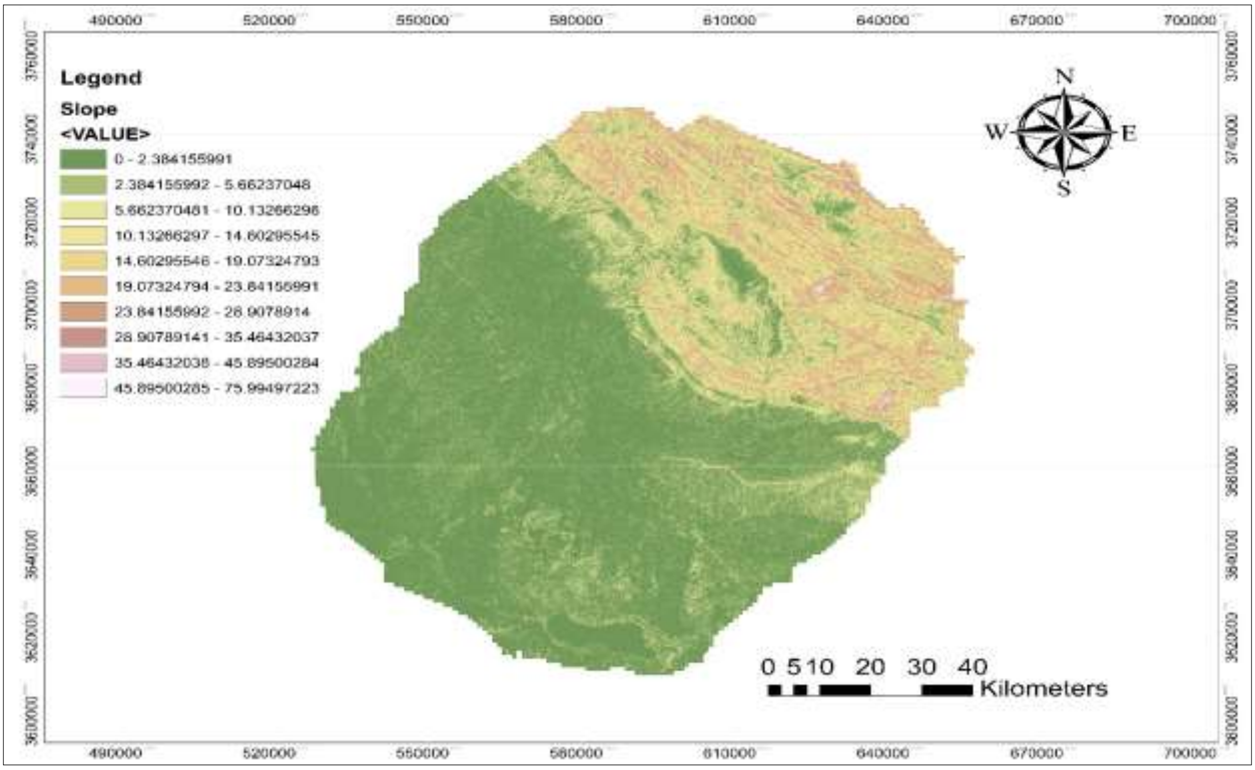

Figure 6. Slope percentage in the study area

2.3.4 Average Rainfall Interpolation

Precipitation data, often collected from rain gauges or weather stations, is essential for watershed management and hydrological modelling **(Ly et al., 2013).** It is necessary to evaluate hydraulic and hydrological behavior by estimating the amount of water revenue through rainfall **(Parvez and Inayathulla, 2019).** As a standard element of the modelling process, preliminary spatial interpolation is sometimes necessary for hydrological models **(Hassan et al., 2018**). To better understand the behaviour of the hydrological system, it is important to use accurate predictions of true mean precipitation over watershed gauge stations that are given relative importance based on the size of the watershed using the Thiessen polygon interpolation technique **(Kahaduwa and Rajapakse, 2019).** It is used by the Directorate of Water Resources in Wasit Governorate. **Table 2.** shows the characteristics of rainfall stations in the study area.

Table 2. Rainfall stations' characteristics

Station type	Station name	Coordinates		Elevation (m)	Average accumulated rainfall (mm) (2001-2020)
		North	East		
Rainfall	BADRH	3664983.36	587693.42	69	185
	MEHRAN	3664101.01	610096.86	150	195
	ILAM	3717575.69	629909.85	1337	223
	KUT	3600509.15	565728.99	14	175
	SUMAR	3748963.22	546238.97	297	207

3. RESULTS OF CALIBRATION AND VALIDATION

3.1 Watershed Analysis

The watershed analysis included using a DEM to draw flow lines and routes and determine watersheds. The WMS software has defined watersheds using the DEM-based technique, allowing for the identification of many sub-basins within each watershed. Each subbasin's flow rate is determined.

3.1.1 Drainage Area

The drainage area is the land area from which precipitation drains into creeks, streams, rivers, and lakes. It is a land feature that may be determined manually or automatically by drawing a line along the greatest elevation between two regions on a map. Calculating the amount of precipitation and establishing the watershed's curve number both need the drainage area, which is an essential component. Consequently, the drainage area is an input for the hydrological model used to predict peak flow and runoff volume. The drainage region encompasses 11937 km^2. **Fig. 7** shows the drainage system in the research area.

3.1.2 Watershed Length

A watershed's length is measured from its outlets along the main channel to its division point, and it increases as the watershed's surface area increases. It is essential to estimate the concentration time. The longest trail in the watershed of the study area is (140 km for Galal Badra and 235 km for the Tursaq River) as shown in **Fig. 8.**

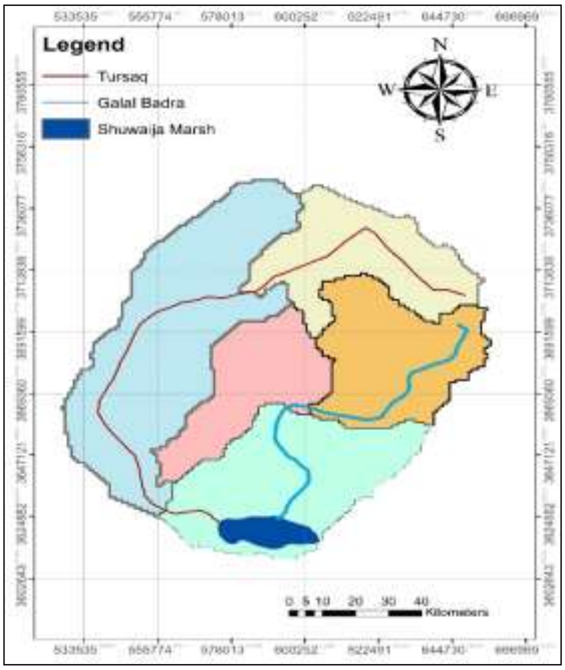

Figure 7. The drainage system at the watershed

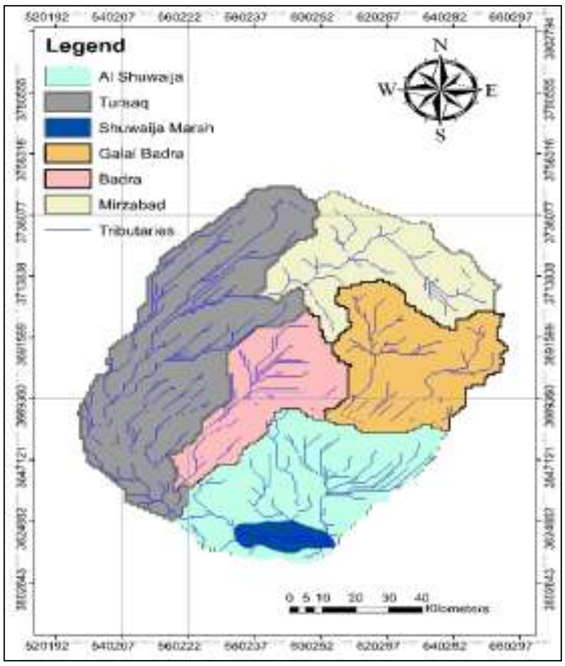

Figure 8. The watershed with the main channels

3.1.3 Curve Number

The curve number (CN) is an indicator for a hydrologic soil type and land use combination. It is computed in WMS once the watershed has been delineated. Importing the soil classes into ArcGIS and then converting them to shapefile format does this. After importing the shapefile and its CN characteristics into WMS, a new Land-use coverage is built to transform the CN shapefile into the land-use coverage. The CN characteristics translate to the land use identifier. **Table 3** shows the CN number that was derived for each of the identified sub-watersheds. The curve number (CN) value for the sub-watersheds in the research region varies from 85 to 78. The weighted curve number for the whole watershed.

Table 3. The CN curve number for all watersheds

Watershed Name	Area (km^2)	CN	CN × Area
Al Shuwaija	2642	78.04051	201126.7828
Badra	1507	80.0438	120670.4159
Mirzabad	1905	81.1689	154625.1311
Galal Badra	1996	85.53836	170767.9265
Tursaq	3887	80.476	965025.8
Weighted CN = 80.84324			

3.1.4 Time of Concentration (Tc) and Lag Time

Using WMS's (Compute Travel Time) function from the calculators' menu, the study's sub-watershed journey times were computed. After that, the appropriate input parameter for the chosen hydrologic model was given the calculated journey time. Result in the window for Tc computation in WMS. **Table 4** shows the Time of Concentration (TC) that was acquired for each of the defined sub-watersheds.

Table 4. Time of concentration value for all sub-watersheds

Watershed Name	Tc (hrs.)
Al- Shuwaija	28.805
Badra	14.216
Mirzabad	11.400
Galal Badra	10.817
Tursaq	33.623

Time of concentration (Tc) values for the sub-watersheds in the research region vary from 10.817 hours to 33.623 hours. As the longest route in the watershed has a Tc of 47.80 hours, that's the total Tc for the whole watershed.

3.1.5 Watershed Delineation

Based on the direction of flow accumulation, WMS automatically determines four sites as outflow points for a watershed. **Table 5** shows the watershed's characteristics.

Table 5. The watersheds characteristics

watershed name	Area (km^2)	mean Elevation (m)	Shape factor (m)	Premier (km)	Length (km)	Slope	Sinuosity Factor	Tc (SCS) (hr)
Al-Shuwaija	2643	48	1.10	287.4	54.2	0.01	1.21	28.805
Badra	1506.99	121.9	3.87	257.58	76.3	0.054	1.06	14.216
Mirzabad	1904.98	1121	2.88	324	74	0.15	1.37	11.400
Galal Badra	1996.39	755	2.05	266	63.95	0.11	1.23	10.817
Tursaq	3886.60	164.24	3.95	455	123.98	0.051	1.42	33.623

3.1.6 Generated Thiessen polygons

Using (WMS 11.1) software, the weighted ratio for each effective rainfall station is determined by applying the Thiessen polygons. Thiessen polygons for the three rainfall stations in the watershed of the study area are shown in **Fig. 9.** The contribution ratio of each rainfall station to the overall 11937 km^2 area, as well as the contribution area for each rainfall station.

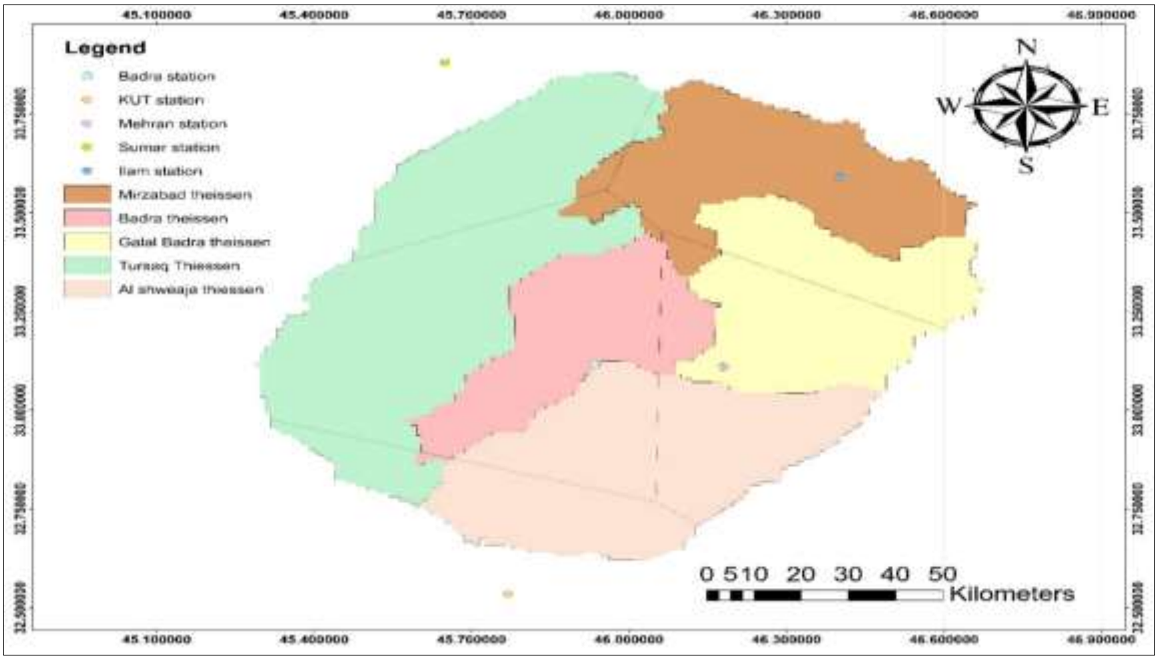

Figure 9. Generated Thiessen polygons for all rainfall station

3.1.7 Calibration and Validation

Both the calibration and validation of Galal Badra were carried out for the periods 2015–2018 for the calibration and 2019–2020 for the validation as shown in **Table 6**. The WMS Software's simulated peak discharge was used to calibrate and validate the observed estimated discharges as shown in **Fig. 10.**

Table 6. The observed and the simulated results at the calibration drainage for the Galal Badra watershed

Date	CN	Rainfall (mm)	Observed Peak flow (m^3/s)	Simulated Peak flow (m^3/s)
2015/10/30	93.13	118	1030	931.42
2016/3/29	85.50	20.3	180	230.79
2017/3/19	93.13	132	900	1086.99
2018/11/24	93.13	215	1500	2392.64
2019/4/1	93.13	85.7	950	854.81
2020/11/28	93.13	126	700	1008.84

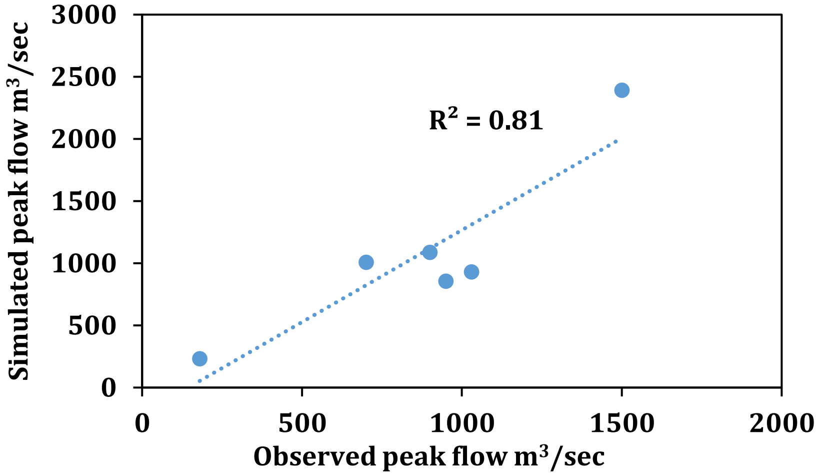

Figure 10. Peak discharges compared between simulations and estimates

3.1.8 Peak flow

The Watershed's discharge point is where the SCS hydrograph was collected. This result was produced using the HEC-1 model for a storm of varying intensity duration and return periods. The hydrograph is shown in **Table 7**.

Table 7. Peak flow (m^3/sec) for the study area.

Duration (min)	Peak flow (m^3/sec) for the retune period					
	2 years	5 years	10 years	25 years	50 years	100 years
5	0.0000	9.2000	37.1900	124.1000	197.5700	314.6400
10	8.04	65.64	171.6	346.92	524.23	727.51
20	16.39	147.07	314.64	562.58	815.29	1059.93
30	65.64	314.64	601.98	999.7	1398.75	1830.4
60	197.57	642.96	1047.49	1719.88	2287.06	2885.33
120	253.59	771.01	1295.6	2055.97	2703.05	3381.59
180	380.32	1144.97	1774.94	2404.49	3571.09	4475.52
360	642.96	1611.02	2404.49	3571.09	4607.04	5675..64
720	860.33	1999.04	3008.07	4409.96	5540.63	6905.81
1440	1775	2945	4214	5540	6906	82984

4. WATER VOLUME SCENARIOS FOR THE AL-SHUWEJA MARSH

To study the projections of water quantities for the Al-Shuwaija marsh under the influence of climate change, we will have three proposals the scenarios are listed below:

4.1 First Scenario (Depth of Precipitation of 95 mm)

The lake would be filled to a capacity of 342319565 m^3 with a surface area if it received 95 mm of precipitation (300 km^2). Scenario No. 1, lake filling within boundaries, is shown in **Fig. 11.**

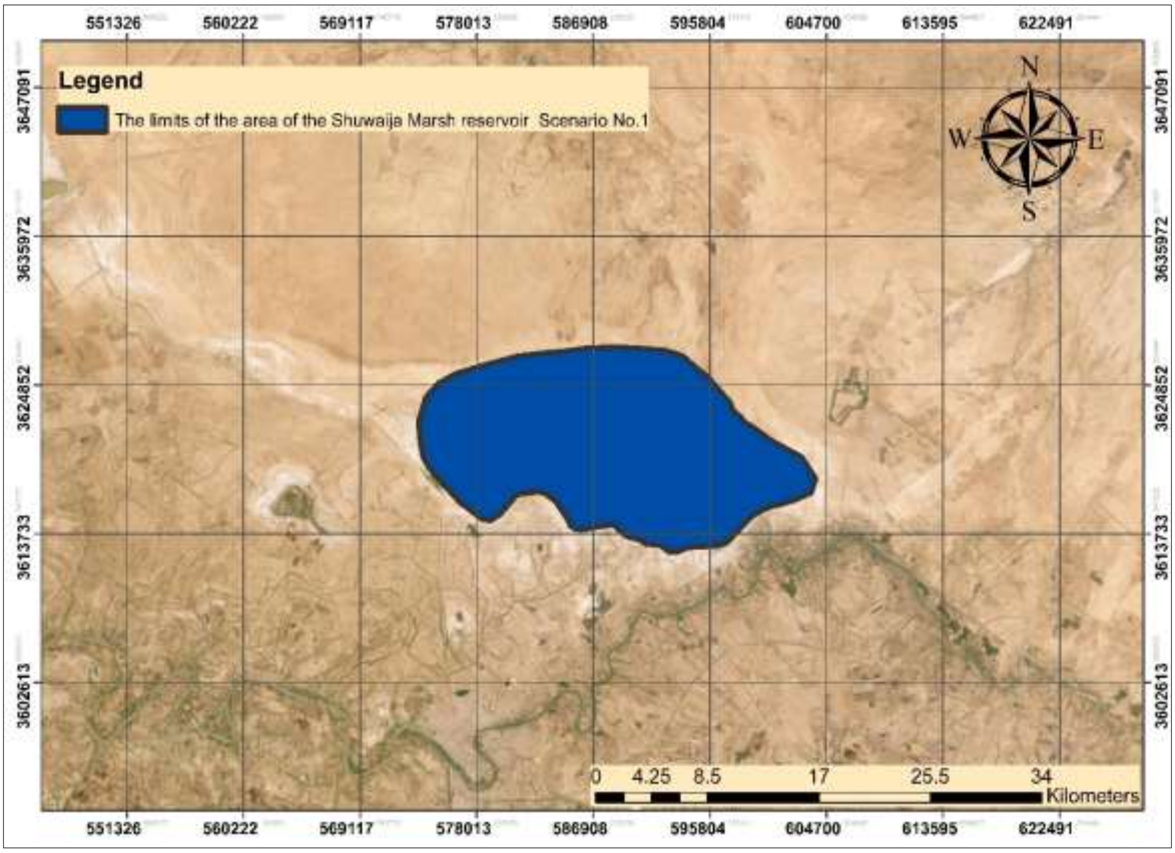

Figure 11. Scenario No.1, Filling of the bounded lake

4.2 Second Scenario (Depth of Precipitation of 130 mm)

With 130 mm of precipitation, the lake would reach its volume of (6153674140 m^3) and its surface area of (550 km^2). Lake filling within boundaries is shown in **Fig. 12.**

4.3 Third Scenario (Depth of Precipitation of 75 mm)

With 75 mm of precipitation, the lake would reach its volume of (184253485 m^3) and its surface area of (185 km^2). Lake filling within boundaries is shown in **Fig. 13.**

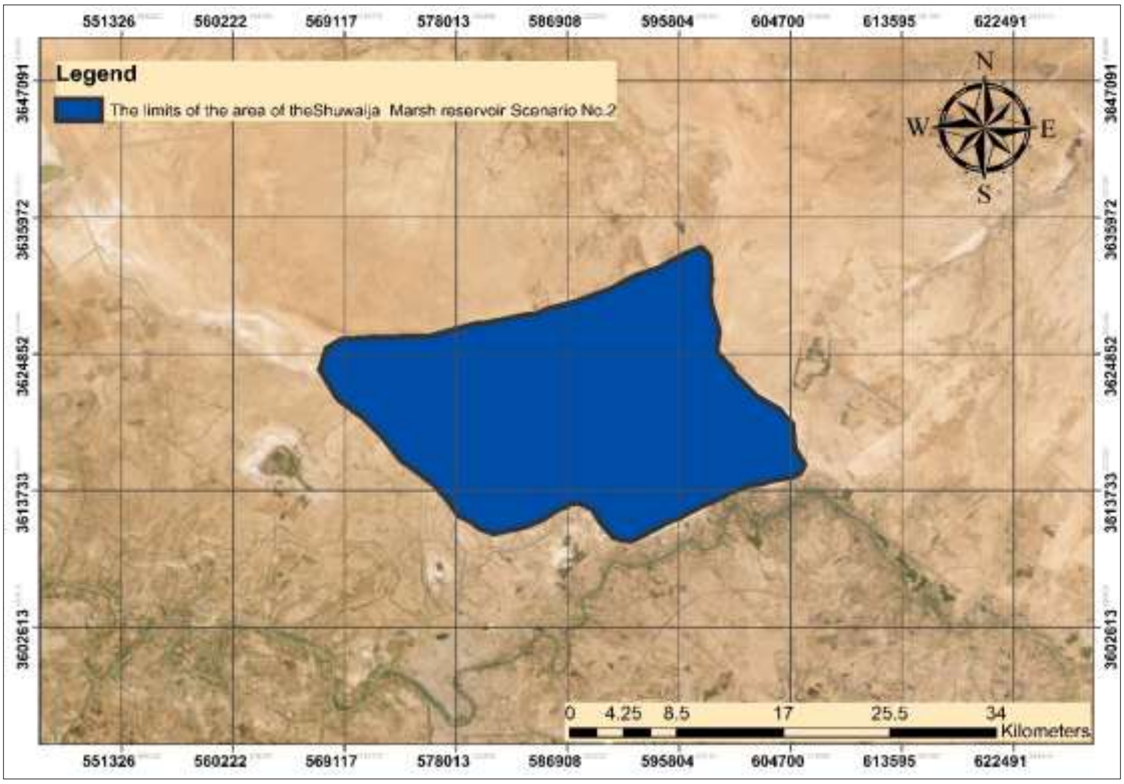

Figure 12. Scenario No.2, filling of the bounded lake

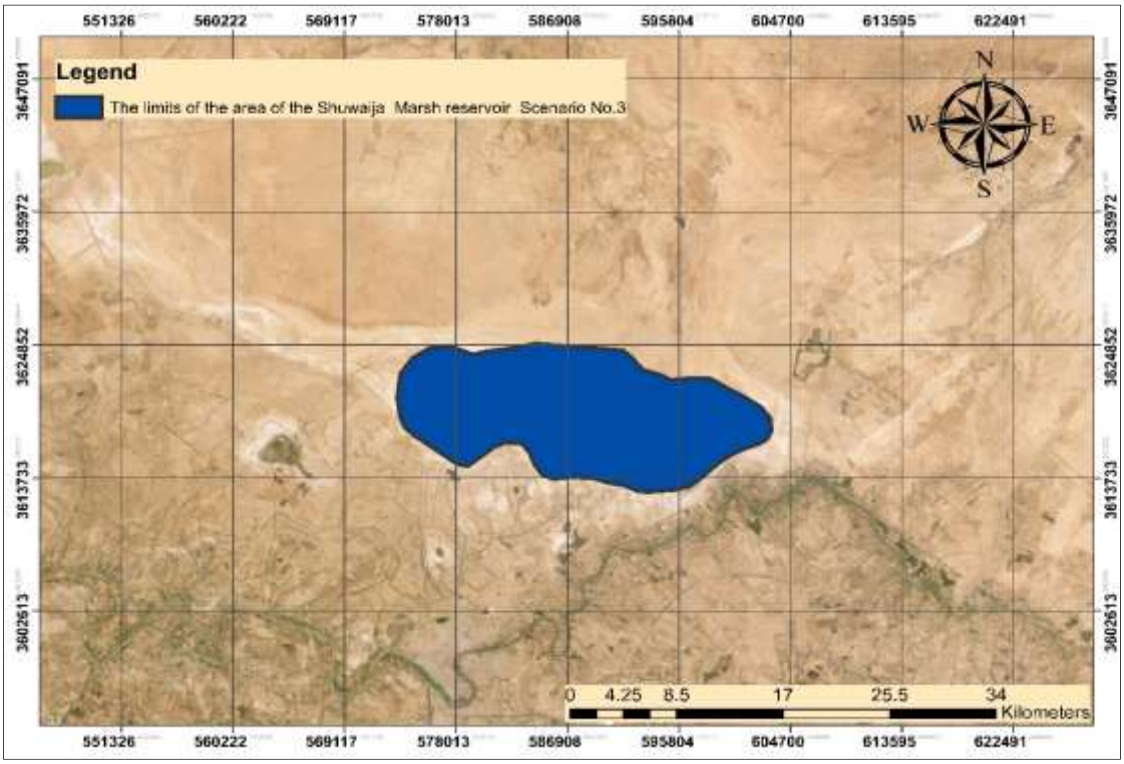

Figure 13. Scenario No.3, filling of the bounded lake

Table 8 shows all the information used in the scenarios to calculate the peak discharge and volume of water and surface area for the Shuwaija reservoir.

Table 8. Details of scenarios computation

Description of measurements	Observation	Increased rainfall scenario	Decreased rainfall scenario
Max. precipitation in 24 hrs. (mm)	95	130	75
Peak discharge in hrs. (m^3/sec)	2350	4212	1456
The volume of water (m^3)	342319565	6153674140	184253485
the surface area (km^2)	300	550	185

5. CONCLUSIONS

The main results of this study contributed to rain forecasts in estimating water quantities, the surface water quality during dry and inundation seasons, and the impact of the sewage treatment plant were evaluated through the following conclusions;

a) Loamy soil makes up the majority (78%) of the soil type in Al-Shuwaija marsh.
As the SCS method was used to estimate the peak discharge for each sub-basin, we now know that the peak discharge at the outflow of watershed Al-Shuwaija is 1775, 2945, 4214, 5540, 6906, and 82984 m^3/s for the 2, 5, 10, 25, 50, and 100-year return periods, respectively.
b) This research creates a footprint for Al-Shuwaija watersheds in the form of flow-duration-frequency (FDF) curves, which allow us to calculate the peak discharge for a given storm duration and return period.
c) To implement effective measures for the economic and social development of the Al-Shuwaija watersheds, the findings of this research are very significant for the local authorities. The research confirms that the amount and rate of water flow recorded may be captured and stored in Shuwaija Reservoir. Moreover, the model may be used to make storage predictions in light of precipitation data.
d) The model is calibrated by changing the CN of the watershed Al-Shuwaija since it contributes to the flow at the monitoring station in Badra city; the results of calibration were successful and logical, so the model is validated to predict flow discharge and volume at the watershed outlet across a range of time scales and return periods.
e) The water levels decreased significantly during July to reach 40 cm, in addition to the decrease in the flooded area of the marsh to reach half its area in March as a result of several factors, the most important is the evaporation of large quantities of water as a result of high temperatures, shallow depths of water and the extended areas of the marsh.

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