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HYDROLOGICAL MODELING BY USING ARCGIS-SWAT A CASE STUDY KIRKUK-KHASSA CHAI DAM

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Abstract
Runoff estimation is a critical part of watershed management and is an issue that has a direct impact on dam performance because of its effects on dam efficiency and operating schedule. The Soil and Water Assessment Tool (SWAT) ,which is part of the ArcGIS program, was used to estimated the runoff volume for the Khassa Chai dam watershed in Kirkuk, Iraq. Its goal is to predict unavailable daily-monthly runoff volume for the dam during the period (2002–2021) and use this data to predict changes in study area to aid management in planning and managing this significant reservoir. The land use map, soil map, and digital elevation model (DEM) were used throughout the research. The model was calibrated from 1999 to 2000 years and validated using 1992 year. R^2, IOA and NSE were used to confirm the results. The statistical values for the calibration and validation of runoff results show that observed and predicted values are in excellent agreement. The results of calibration,IOA, NSE, and R^2 reached 0.95, 0.85, and 0.91, respectively.Whereas the outcomes of validation IOA, NSE, and R^2 became 0.92, 0.75, and 0.90, respectively.For reservoir management, this form of runoff simulation is critical. Furthermore, this method has the ability to be used as a tool for khassa chai dam water resource management.

Keywords: SWAT ,Khassa Chai Dam , Runoff volume , Calibration and validation, R^2.

1. Introduction

All living beings are dependent upon water for their survival,it is essential for agricultural and industrial expansion and economic development and is especially important in quicklyrising urbanization and population[1]. A lot of areas suffer from a lack of freshwater or are polluted. As a result, water resources' availability and long-term utilization have become central to these areas' municipal and national plans and politics[2].Therefore, many aspects of hydrologic processes occurring must be evaluated and quantified to tackle water management issues within the study region[3].Also, the industrial revolution has had a significant impact on the natural environment, causing a change in the volume and distribution of precipitation due to the significant increase in global temperature. The effect is measured in atmospheric evaporation (change in potential evaporation), changes in precipitation, changes in vegetation composition and interception, changes in stream flow characteristics, and recharge processes at the catchment level[4].For improved livelihoods, the watershed is a starting point for addressing concerns about sustainable rainwater management. As mentioned earlier, aspects of hydrologic processes must be evaluated to tackle water management issues within the study region [5].Because all of these activities occur throughout watersheds, this study must obviously be done at a watershed level. Only after gaining a thorough grasp of the hydrologic components' geographical and temporal fluctuations, as well as their interactions, can they be effectively managed[6].According to the review, SWAT is capable of modeling hydrological processes with good precision and can be used to model a large stream flow basin[7].The SWAT model with an ARCGIS interface was chosen for the current study to assess the model's capacity in calculating the runoff of the watershed[8].The major goal of this research is to use a geospatial database to extract the parameters needed for runoff modeling and to predict the runoff in the Khassa Chai basin.

2. Study area

The Khassa Chai watershed was chosen as a case study. The Khassa Chai Dam Watershed is located on the Khassa Chai River in northeast Iraq, 10 kilometers northeast of Kirkuk City, as shown in Figure (1). The research region is located between (39.52964–39.28476 East) and (45.1807–48.3362 North) shown in table (1), and it flows into the Adhaim Dam reservoir [9].The length of the dam is 2250 meters, the storage capacity is 101 million cubic meters and the elevation ranges from 441–906 m above sea level , the height of the dam is 62 meters, it is considered as a large size dam according to the Robinson classification as shown in the Table (2) [10] .

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Table (1) the coordinates and elevation of Khassa Chai dam abutment.

Abutment	Elevation	Coordinates	
		E	N
Left	497.10	44°24′41″	35°27′54″
Right	496.80	44°20′41″	35 24′06″

Table (2)Robinson Size Classification of Dams.

Category	Storage m^3	Height(m)
Small Dam	<1234000 ≥ 61600	< 12.5 and ≥ 7.5
Intermediate Dam	≥1234000 and <61675000	≥12.5 and < 30.5
Large Dam	≥6165000	≥ 30.5

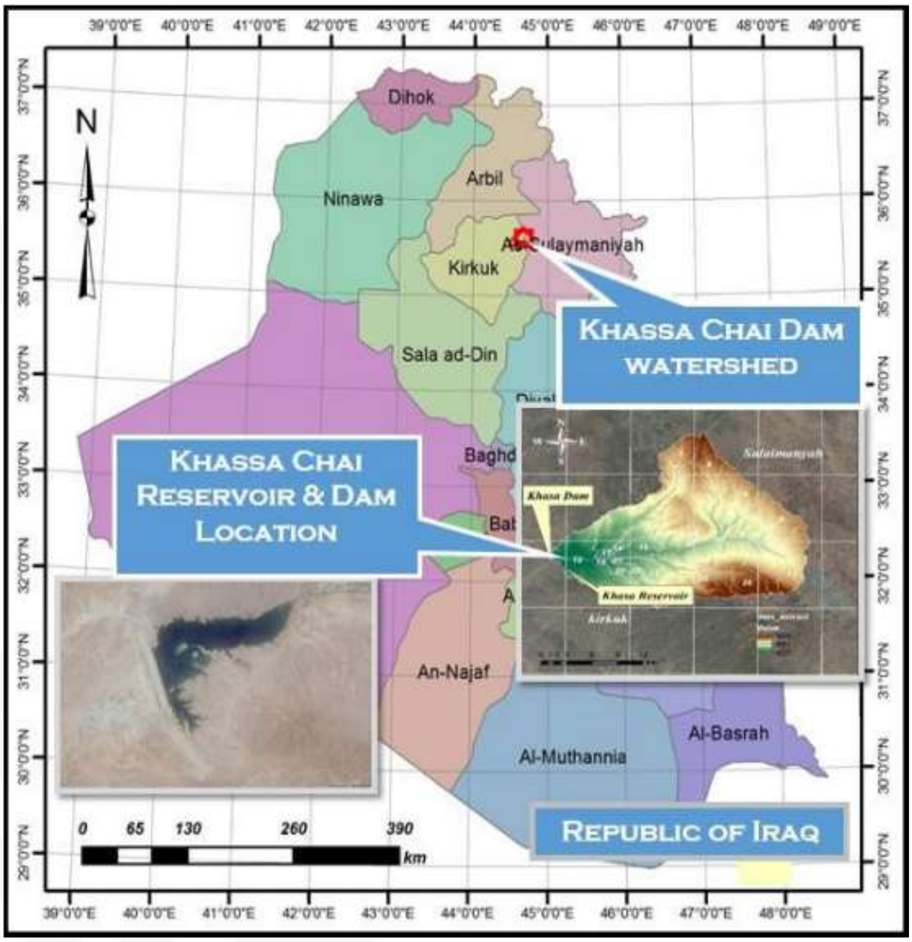
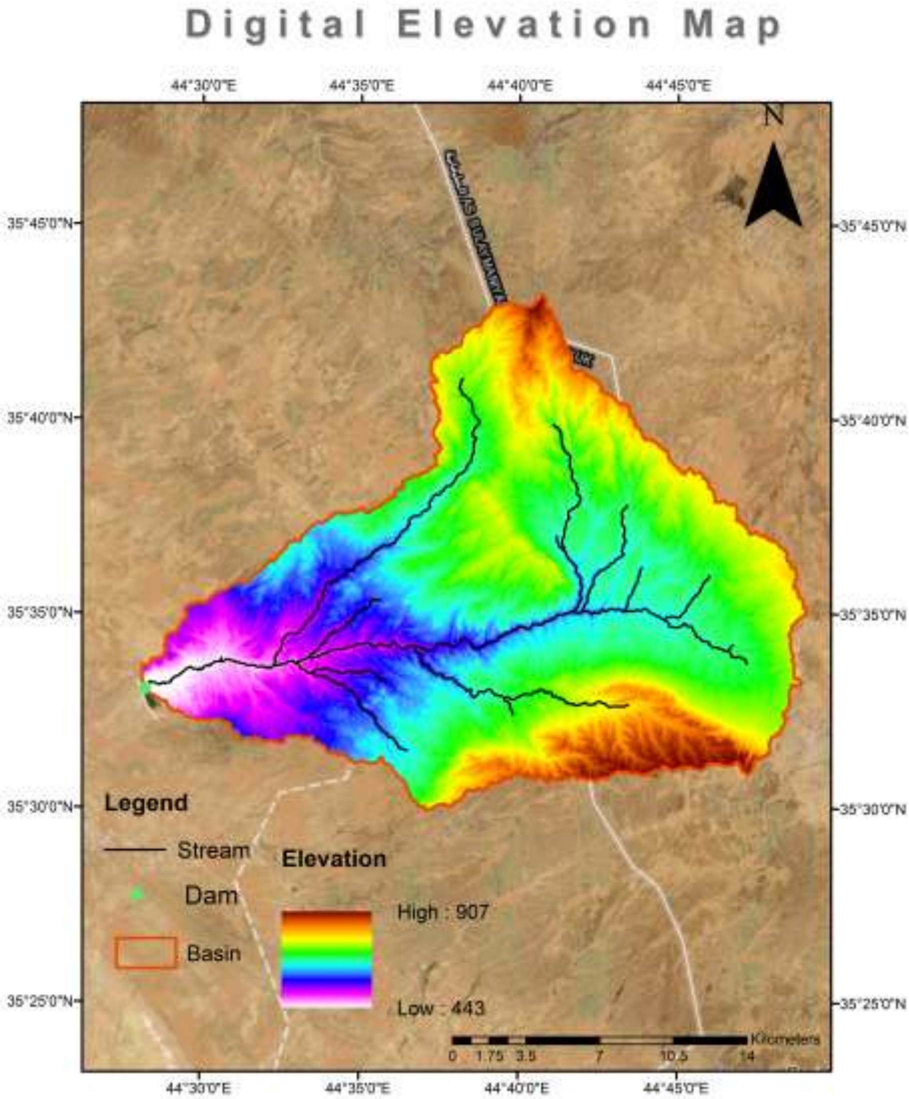


Figure (1) Location of Khassa Chai Dam.

3. Satellite Data

3.1 Digital Elevation Model (DEM)

Numerical, it is a value of the average height for each pixel on the earth's surface. Furthermore, the DEM is the kind of data that SRTM Shuttle Radar Topography Mission A network Raster Grid [11] . As depicted in Figure (2), digital release (30 m) is extracted for the study basin.The flow direction, flow accumulation, stream network creation, watershed and sub-basin delineation were all extracted from the DEM.



Figure(2) DEM For Study Area.

3.2 Land use map:

The global land use map has been adopted (Globcover2009-L4-V2.3). It is submitted by(Université catholique de Louvain, UCL) and (European Space Agency, ESA) to determine the study's land use [12] . The map consists of a digital code used to obtain land-use type for each cell. A file was created to be input into a model (SWAT). To specify the code in the land use database on the map (Globcover2009-L4-V2.3). Figure (3) shows a map of land use (3.V2_L4_Globcover2009) for the study area. The map can be downloaded from (http://due.esrin.esa.int/page_globcover.php).

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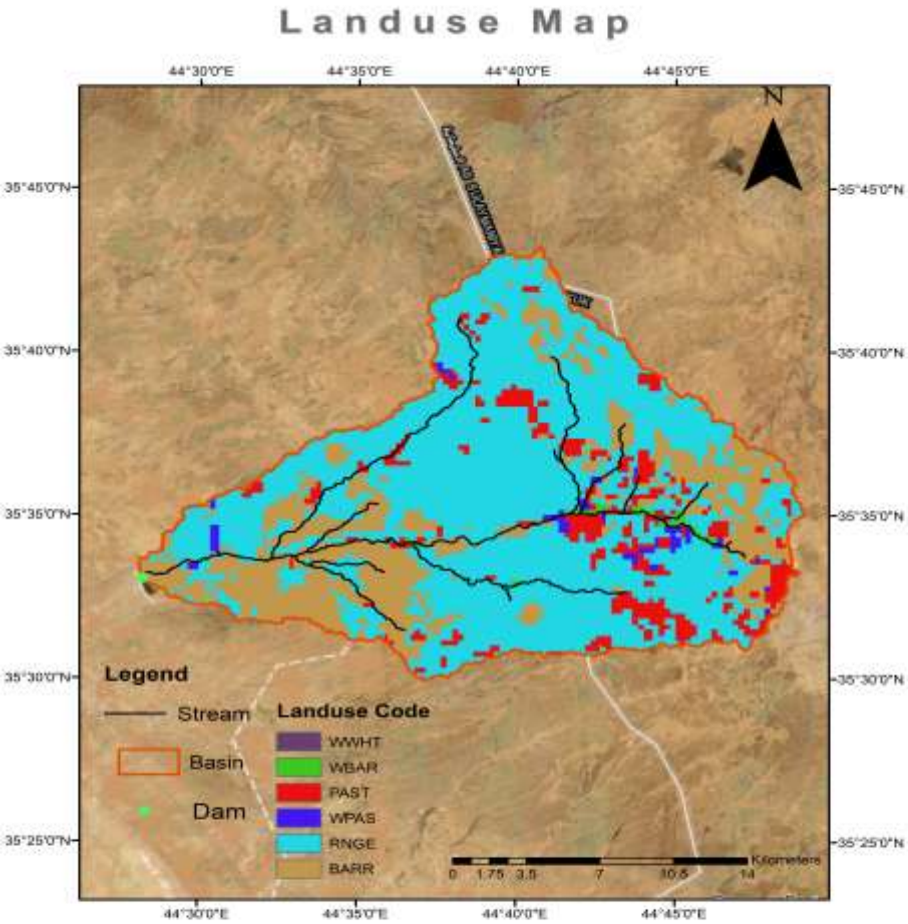

Figure (3) Land Use For Study Area.

Table(3) The land-use code in SWAT database (Globcover 2009-L4-V2.3).

Code	Global land-use code describe	Land use SWAT code	Describe of land use SWAT code	Colour
14	Rainfed croplands	WWHT	Winter Wheat	
20	Mosaic Cropland (50-70)% - Vegetation (grassland, shrubland, forsest) (20-50)%	WBAR	Winter Barly	
30	Mosaic Vegetation (grassland, shrubland, forsest) (50-70)% - Cropland (20-50)%	PAST	Pasture	
110	Mosaic Forest/Shrubland (50-70)% - Grassland (20-50)%	WPAS	Winter Pasture	
120	Mosaic Grassland (50-70)% - Forest/Shrubland (20-50)%	RNGE	Range Grasses	
130	Closed to open (15%) - Shrubland (5%)	PAST	Pasture	
150	Sparse (15%) vegetation (woody vegetation, shrubs, grassland)	RNGE	Range Grasses	
200	Bare areas	BARR	Barren	
210	Water bodies	WATER	Water	

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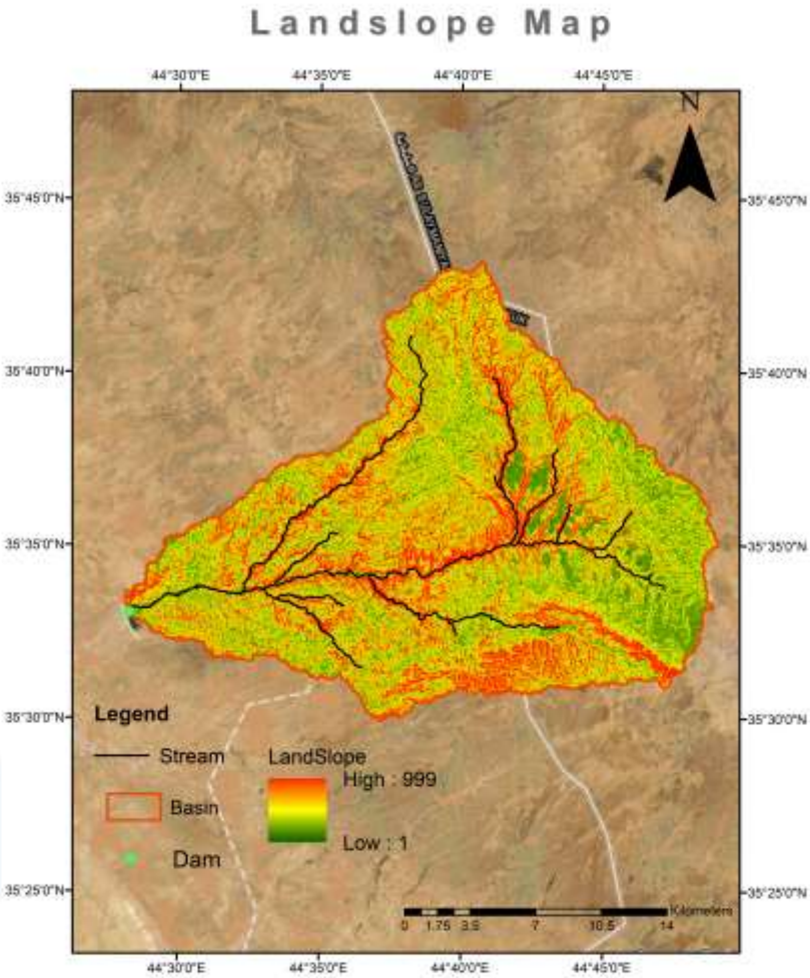

Figure (4) Land slope.

3.3 Soil map:

To determine the soil types and data for an area, the Global Harmonized Soil Database Map was adopted by the following [13]:

1. Joint Research Centre of the Commission, JRC.
2. Institute of Soil Science-Chinese Academy of Sciences, ISSCAS.
3. SRIC-World Soil Information.
4. International Institute for Applied Systems Analysis, IIASA.
5. Food and Agriculture Organization of the United Nations (FAO).

The study maps contain a database rich in all the necessary information that has been included in the SWAT model for the purpose of simulation, as shown in Figure (5).For more details, the map is available at the following link: (https://webarchive.iiasa.ac.at/Research/LUC/External-World-soil-database/HTML/).

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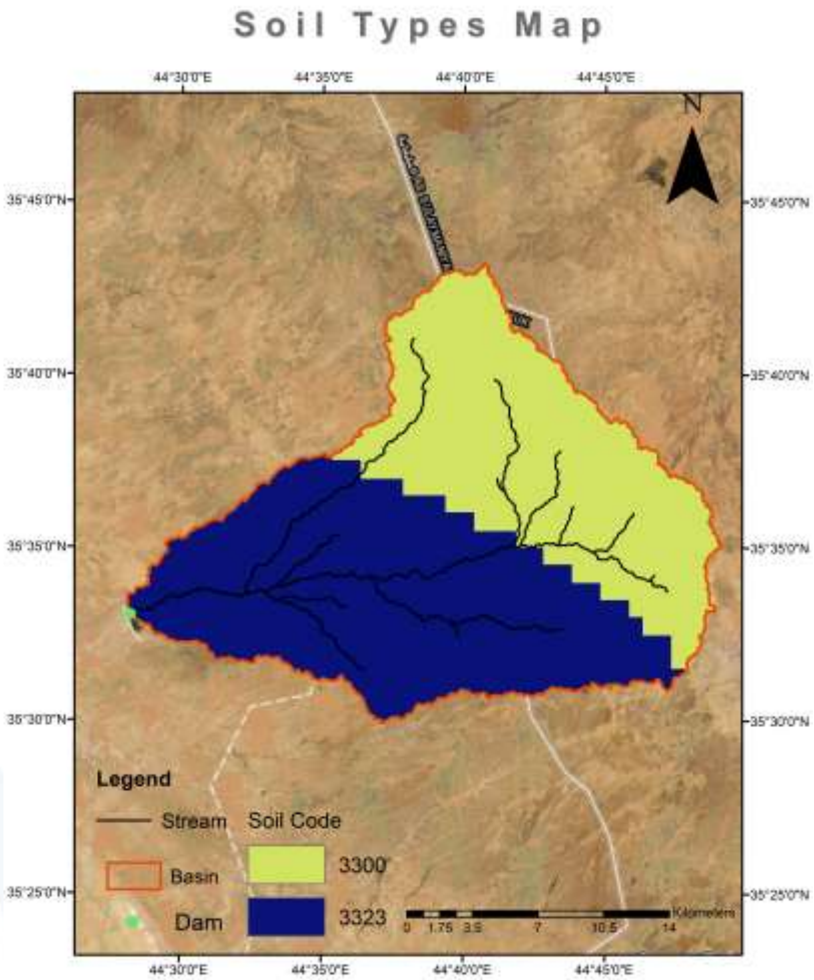

Figure (5) Soil Map For Study Area.

Table(4)Database soil type of the Khassa Chai SWAT model.

Mu_global(soil code)	Hydraulic soil group	Soil type	Soil layer depth (cm)	Bulk density	Available water content	K mm/hr	Gravel content	Clay content	Sand content	Silt content	Clay content	Organic content
3300	D	Clay loam	10	1.3	0.069	64.4	5.52	33.1	32.6	34.3	33.1	0.70
3300	D	Clay loam	30	1.3	0.075	62.3	3.55	32.0	33.7	34.3	32.0	0.62
3300	D	Clay loam	100	1.3	0.075	34.3	3.78	29.7	37.0	33.3	29.7	0.37
3323	B	Loam	10	1.4	0.121	76.8	10.00	36.8	26.5	36.7	36.8	0.71
3323	B	Loam	30	1.4	0.147	74.7	6.74	35.2	27.6	37.2	35.2	0.55
3323	D	Clay Loam	100	1.3	0.147	49.5	6.45	33.1	30.8	36.1	33.1	0.33

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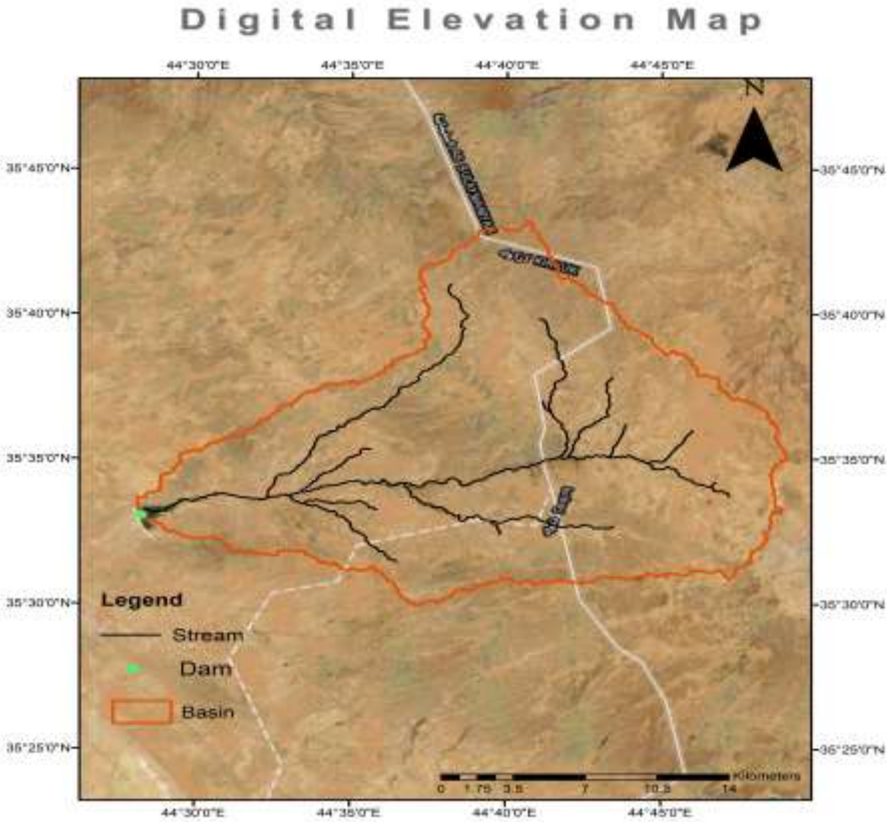
3.4 Topography map:

For the Khassa Chai watershed, the description and analysis of a basic topographic are obtained by using the Google Earth Pro version utility tool. Figures (6).



Figure(6) Topographic of the catchment area of Khassa Chai dam.

4. Meteorological Data:

SWAT requires daily values for precipitation, maximum and minimum temperatures, solar radiation, relative humidity, and wind speed. Weather data was received from the Iraqi Meteorological Organization. A long-term climate database should represent the observed daily data for more accurate and realistic findings. Therefore, from 1990–2021years ,Kirkuk, Sulaymaniyah, and Chamchamal meteorological stations were chosen to gather daily climate data records.

4.1 Precipitation Data :

It varies between 1600 mm and 800 in mountainous places. In the catchment area, it fluctuates between 500 mm and 400 m in the lower parts. The season of rain starts from October to May.The highest and lowest monthly precipitation rates are recorded in December (69.3 mm) and August (0 mm), respectively.

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4.2Wind speed :

Wind speed and direction in the project area, as measured between northeast and west. Highest monthly wind speed recorded in January was (9.4 m/sec) , and the lowest monthly wind speed recorded was (0 m/sec) .

4.3Relative humidity:

The relative humidity in the winter period reaches (70%) ,while it drops to (25%) in the summer period. The relative humidity for the period (1990–2021) was recorded.

4.4Temperature :

The temperature records cover the period (1990–2021). Considerably, the temperatures fluctuate in summer/winter and day/night. The maximum and minimum monthly temperatures at the project area are recorded in July (47 °C) and in January and February (-5.6 °C).

4.5 Solar Radiation:

The average daily solar radiation for the period (1990-2021) was recorded.

5. Estimation of runoff:

SWAT model utilizes two methods to estimate the surface runoff depth due to catchment area precipitation [14]:

1. (Green and Ampt, 1911): The Green-Ampt method predicted infiltration first in SWAT, with the remaining precipitation becoming surface runoff. This approach necessitates a great deal of information on the soil in the research area andrainfall depths dataover time, such as specifics of rain strength and depth per hour. These can't be accessed at the meteorological stations in the research location.
2. Soil Conservation Service, SCS, 1972 (the curve number technique) is the most extensively used method for predicting the surface runoff depth . It was recently renamed Natural Resource Conservation Service (NRCS). The soil qualities, land use, and hydrological conditions are used in this procedure [1]. From the (NRCS), the SWAT uses curve number values. In the beginning, runoff depth is estimated by The curve number model in SWAT. Then, it is assumed that the remaining precipitation may penetrate.To determine the surface runoff depth from rainfall, the empirical method widely utilized by using curve number equation [15] as follows:

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$$Q_{surf} = \frac{(R_{day}-I_a)^2}{(R_{day}-I_a+S)} \quad \text{.......(1)}$$

Where:

Q_{surf}denotes the daily surface runoff or excess rainfall (L), $I_a$refers to the initial abstraction,which consists of infiltration before the runoff, interception, and surface storage (L). R_{day}defines the daily rainfall depth (L), and S = Retention parameter (L), representing the potential maximum soil moisture retention after the starting of runoff.

The retention parameteralters into two kinds: Firstly, temporally due to changes in soil water content. Secondly, spatially due to changes in slope, management, land use, and soils. In the US units, the retention parameter can be calculated as follows:

$$S = \frac{(25400-254\times CN)}{CN} \quad \text{.......(2)}$$

The equivalent curve number is known as (CN1, CN3), CN1, and CN3 refer to dry and wet (saturated) soil, respectively.They can be determined by the following formulas [1]:

$$CN1 = \left(\frac{20(100-CN2)}{100-CN2+e^{(2.533-0.0636(100-CN2))}}\right) \quad \text{.......(3)}$$

$$CN3 = CN2 * e^{(0.00673-(100-cn2))}$$

Peak runoff rate is the maximum rate of runoff flow is that exists with a particular rainfall event. For the design of stormwater management systems channels and ditches,the rational technique is still perhaps the most extensively utilized method .

$$q_{peak} = \frac{C.i.Area}{3.6} \quad \text{.......(4)}$$

Where:q_{peak}denotes the peak runoff rate (m^3/s), and Area refers to the sub-basin area (km^2). Additionally, the rainfall intensity (mm/hr) is defined by I, and C is the runoff coefficient.

6. Setup of the model:

The USDA Agricultural Research Service's soil and water assessment tool (SWAT) is a continuous simulation model. Arc SWAT version 10.2.2 was used to do hydrological modeling of the dam watershed.

Step 1:Based on the DEM map, a watershed outline (of the study area) is created by the ArcSWAT user. After dividing the basin into many cells, the user draws stream outlet and flow direction. This includes obtaining the sub-basins boundary.Alternatively, the user can usea mouse to click on the watershed outlet.
Step 2: The watershed created in Step 1 is intersected with soil and land cover data, slope definitions, and parameters necessary for the hydrologic model runs. The next is the Hydrologic Response Units (HRUs) creation, which is the model's smallest spatial unit .
Step 3: The climate data input file is built at this stage.Dependingupon the geographic location files . The files have been created for distributed (i. e., multiple gauges) and uniform (single gauge).
Step 4: Here, this step prepares all the demanded input data as follows:

1. The watershed was subdivided into model elements.
2. For each element, Hydrologic parameters were determined.
3. Climate files were created.

Then the model can be run to simulate the daily-monthly flow for Khassa Chai dam.
Step 5: Manual calibration and validation of the SWAT model was conducted by altering the parameters that impact surface runoff, such as channel flow, Manning coefficient of roughness for surface runoff, and curve number. Additionally, the soil's hydraulic conductivity is within accepted limits until the best outcomes of the SWAT simulation flow series are obtained. The results are determined by comparing with flow data records to improve the model efficiency for forecasting the daily/monthly flow at Khassa Chai stations [14].

7. SWAT calibration and validation:

SWAT input parameters are dependent on a procedure and must be kept within a reasonable range of uncertainty. The selection of the most sensitive parameters for a specific watershed is the first stage in SWAT's calibration and validation procedure. Based on sensitivity analysis and expert judgment, the user decides which variables to alter. The process of determining the rate of change in model output in response to changes in model inputs is known as "sensitivity analysis." It's important to figure out what the main parameters are and how precise they need to be for calibration and validation . Good model calibration and validation should involve:

1. Observed data from dry, average, and wet years.
2. Multiple evaluation.
3. Calibration of all constituents.
4. Verification that other important model outputs are reasonable.

Graphical and statistical approaches with some type of objective statistical criteria are applied when the model has been calibrated and validated. The calibration andvalidation can be done manually or via SWAT or SWAT-CUP auto-calibration tools [16].

8. Evaluation of Model Performance:

Different methods have been applied for calibration and validation. The traditional approach was employed in this investigation. An interface's principal purpose is to connect a calibration and validation program's input and output to the model . The coefficient of determination is the most commonly used criterion for evaluating model performance.

$$R^2 = \frac{[\Sigma(Q_{sim\,i}-Q_{asim\,i})(Q_{obs\,i}-Q_{aobs\,i})]^2}{\Sigma(Q_{sim\,i}-Q_{asim\,i})^2\,\Sigma(Q_{obs\,i}-Q_{aobs\,i})^2} \quad \ldots\ldots(5)$$

where R^2represents determination coefficient. At time step i, $Q_{sim\,i}$ and $Q_{obs\,i}$ define the simulated value and observed value, respectively. Similarly, $Q_{asim\,i}$ and $Q_{aobs\,i}$ refer to average simulated value and observed value, respectively.

Following a best fit line is an effective way to indicate consistency between observed and simulated data. It has a range of zero to one[17].

Table(5) Performance rating for calibration and validation of SWAT model.

Performance rating	R^2
Very Good	$R^2 > 0.70$
Good	$0.60 < R^2 \leq 0.70$
Satisfactory	$0.50 < R^2 \leq 0.60$
Unsatisfactory	$R^2 < 0.50$

The second method for calibration and validation is the Index of Agreement (IOA). Established the Index of Agreement as a standardized measure of model prediction error that ranges from 0 to 1. A number of 1 shows complete agreement, while a value of 0 indicates no agreement at all[18] .

$$IOA = 1 - \frac{\sum_{i=1}^{n}(Q_{obs\,i}-Q_{sim\,i})^2}{\left(\sum_{i=1}^{n}|Q_{obs\,i}-Q_{aobs\,i}|-|Q_{sim\,i}-Q_{aobs\,i}|\right)^2} \quad \ldots\ldots(6)$$

And another method is The Nash–Sutcliffe efficiency index (NSE) the Nash–Sutcliffe efficiency (NSE) coefficient is used to determine model efficiency, integrated existing results and divided NSE into four levels to evaluate the model's simulation results[19]:

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1. Very good (0.75 < NSE < 1).
2. Good (0.65 < NSE < 0.75).
3. Satisfactory (0.5 < NSE < 0.65).
4. Unsatisfactory (NSE < 0.5).

$$NSE = 1 - \frac{\sum_{i=1}^{n}(Q_{obs\,i} - Q_{sim\,i})^2}{\sum_{i=1}^{n}(Q_{obs\,i} - Q_{aobs\,i})^2} \quad \text{...}(7)$$

9. Results and Discussion:

Changes to the factors that impact surface runoff, such as curve number, Manning coefficient of roughness for surface runoff, and channel flow, can using to manually calibrate the SWAT model . The values of (R^2, IOA and NSE) were evaluated in assessing the degree of efficiency. This is done to minimize the level of uncertainty in the model's predictions. The daily-measured runoff data at the flow of the Khassa Chai watershed and forcasted from SWAT model were used to calibrate for the years 1999 to 2000. The R^2, IOA and NSE for daily and monthly values were 0.91, 0.95, and 0.85, respectively.

Table (6) shows the values of (R^2) ,IOA and NSE before and after calibration of the SWAT models.

	Value before calibration	values after calibration	Change limit of CN
R^2	0.9	0.91	+5%
IOA	0.91	0.95	+5%
NSE	0.76	0.85	+5%

Only CN was calibrated in this study; this calibration entails experimenting with increasing or decreasing CN values derived from SWAT models in order to get the best values that reflect the best-generated daily-monthly flow series.

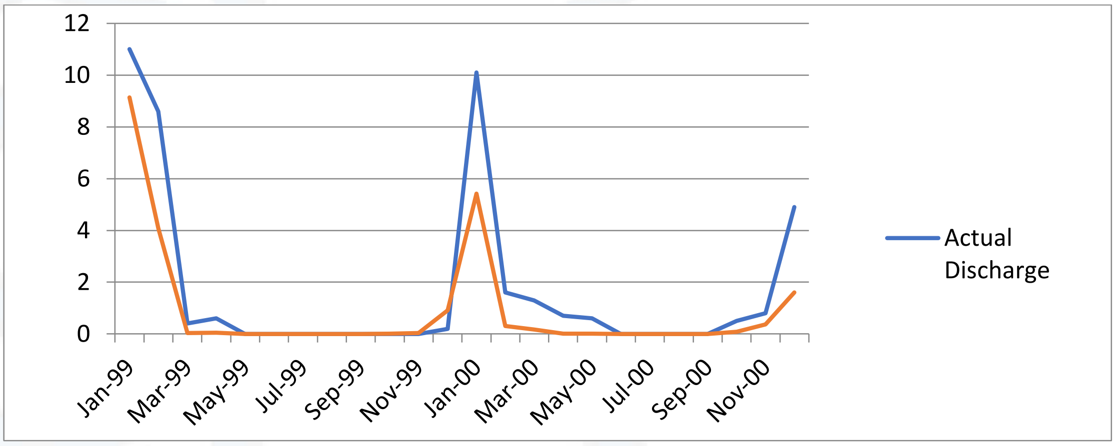

Figure (7) Measured and modelled flow before calibration.

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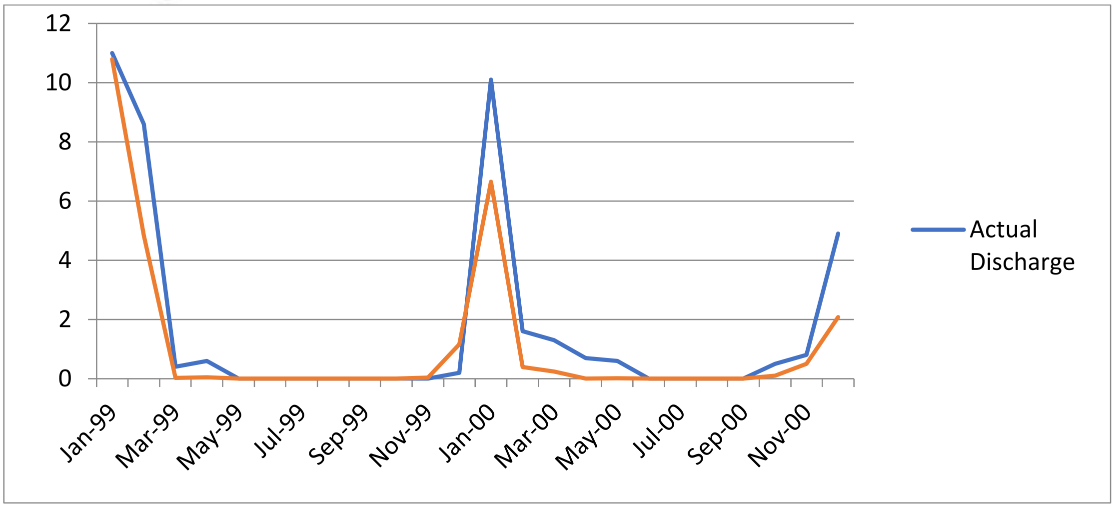
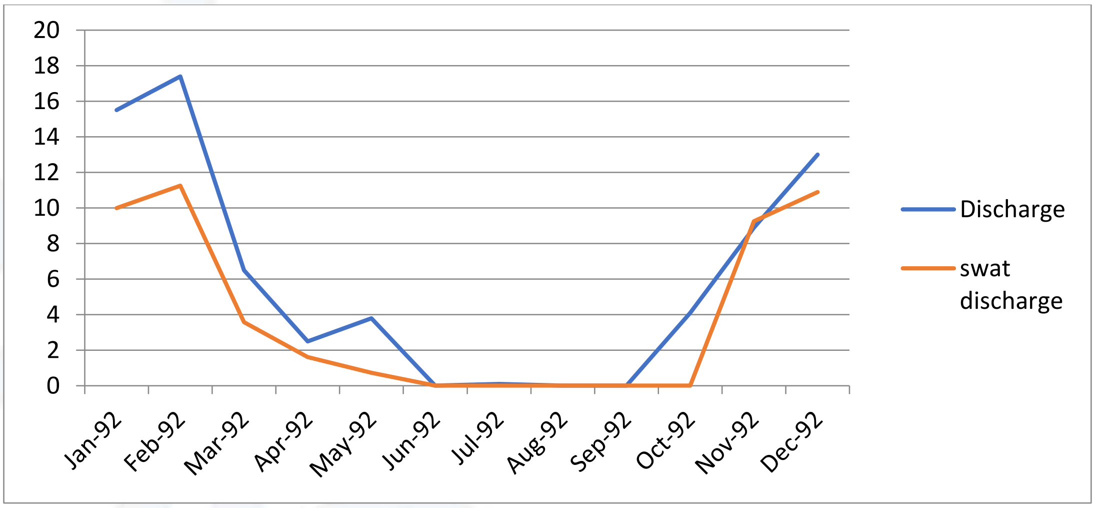


Figure(8) Measured and modelled flow after calibration.

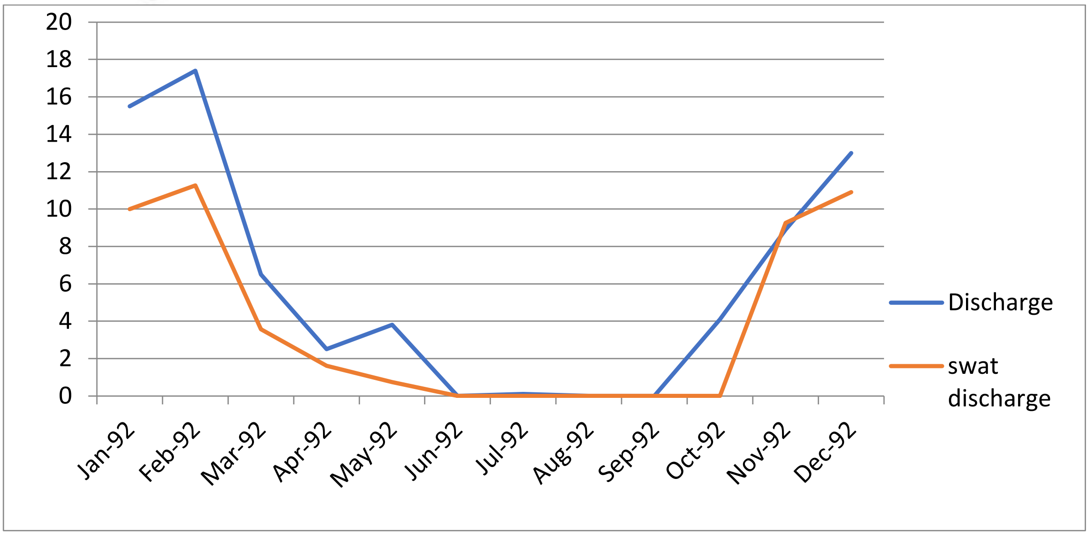
As a validation stage, after obtaining the best calibration of the SWAT model, the model has been validated for year (1992).

Table (7) Values of (R^2),IOA and NSE before and after validation of the SWAT models.

	Value before calibration	values after calibration	Change limit of CN
R^2	0.536	0.90	+5%
IOA	0.74	0.92	+5%
NSE	0.315	0.75	+5%



Figure(9)Measured and modelled flow beforevalidation.



Figure(10)Measured and modelled flow after validation.

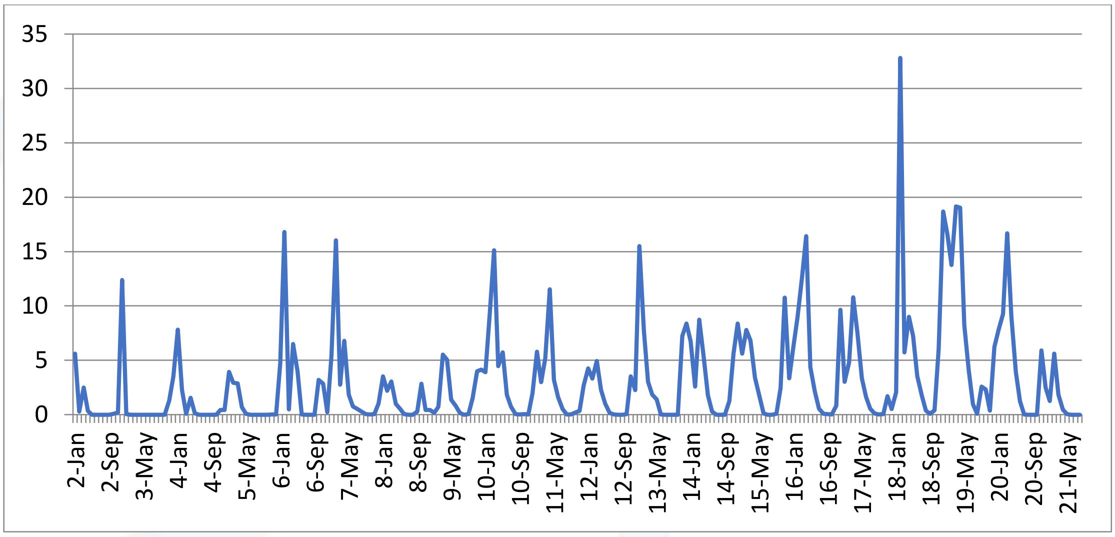


Figure (11) The simulated monthly flow (m3 /day) from 2002 to 2021-July.

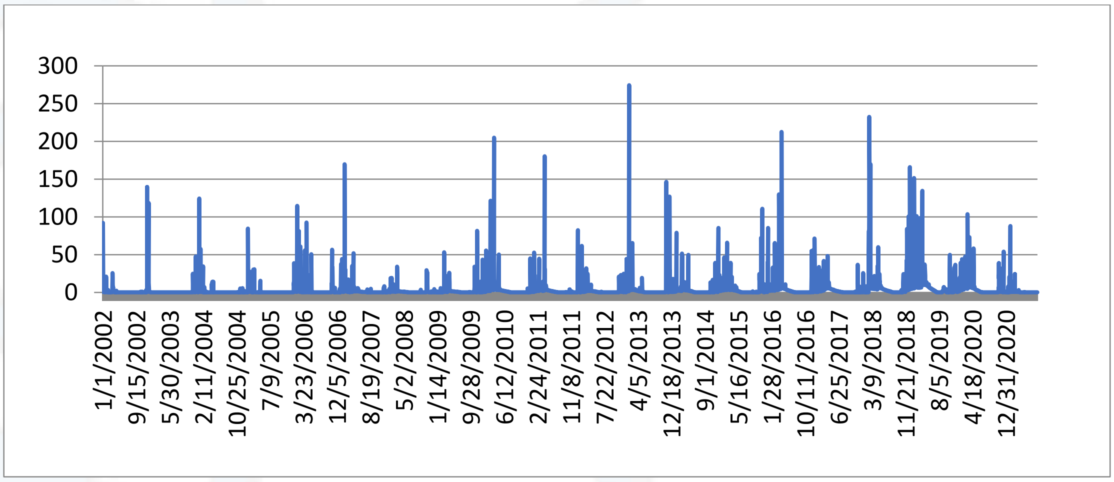


Figure (12) The simulated daily flow (m3 /day) from 2002 to 2021-July.

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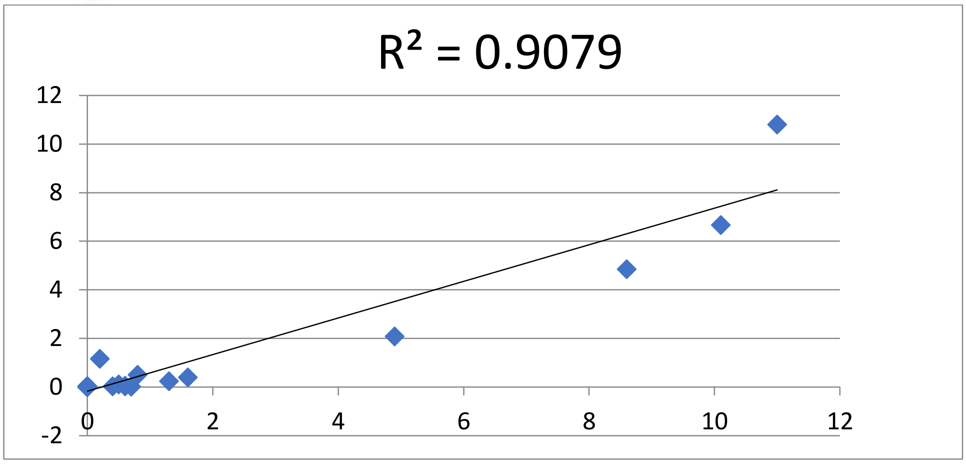


Figure (13) Determination coefficients (R^2) for calibration .

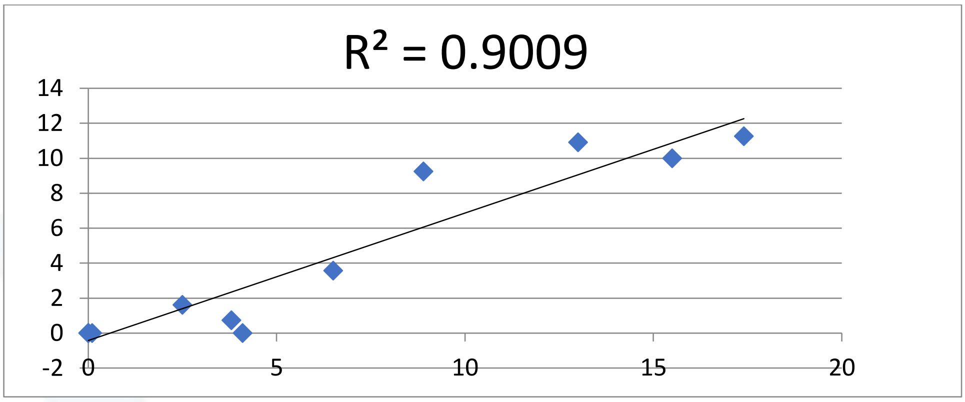
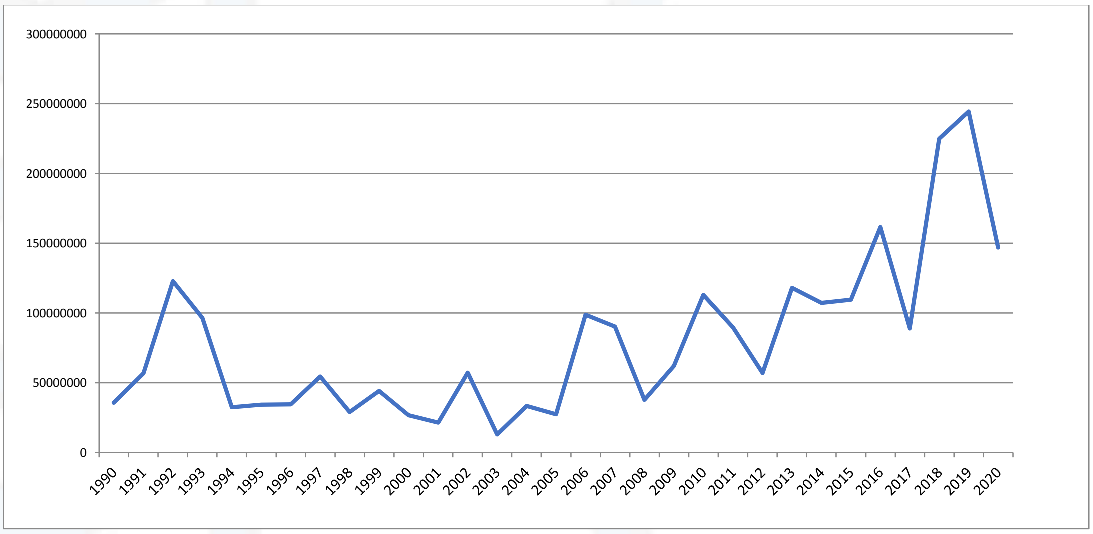


Figure (14) Determination coefficients (R^2) for validation .

Using the curve number technique, a continuous daily-monthly simulation was run during the study period to determine the resulting surface runoff. The maximum runoff volume is between (224932032 and 244343520) m3 for the years (2017–2018), while the lowest amounts of water were (12772512 and 27333504) m3 for the years (2003, 2005).The total runoff over the study period reached (2468131776) m3.



Figure(15) annual runoff volume for khassa chai dam.

Table (8) Monthly flow for Khassa chai dam.

Data	Flow	Data	Flow	Data	Flow	Data	Flow	Data	Flow	Data	Flow
2-Jan	5.6	5-Aug	0	9-Mar	5.53	12-Oct	0.05	16-May	4.38	19-Dec	6.24
2-Feb	0.29	5-Sep	0	9-Apr	5.04	12-Nov	3.53	16-Jun	2.13	20-Jan	7.78
2-Mar	2.48	5-Oct	0	9-May	1.37	12-Dec	2.25	16-Jul	0.06	20-Feb	9.25
2-Apr	0.33	5-Nov	0.01	9-Jun	0.03	13-Jan	15.5	16-Aug	0	20-Mar	16.69
2-May	0	5-Dec	0.01	9-Jul	0	13-Feb	7.74	16-Sep	0	20-Apr	9.05
2-Jun	0	6-Jan	4.72	9-Aug	0	13-Mar	3.03	16-Oct	0.02	20-May	3.92
2-Jul	0	6-Feb	16.7	9-Sep	0.05	13-Apr	1.85	16-Nov	0.81	20-Jun	1.21
2-Aug	0	6-Mar	0.49	9-Oct	1.53	13-May	1.39	16-Dec	9.65	20-Jul	0.01
2-Sep	0	6-Apr	6.5	9-Nov	4	13-Jun	0.01	17-Jan	3.01	20-Aug	0.02
2-Oct	0.07	6-May	4	9-Dec	4.15	13-Jul	0	17-Feb	4.78	20-Sep	0.08
2-Nov	0.19	6-Jun	0.01	10-Jan	3.89	13-Aug	0	17-Mar	10.78	20-Oct	0.1
2-Dec	12.39	6-Jul	0	10-Feb	9.5	13-Sep	0	17-Apr	7.56	20-Nov	5.9
3-Jan	0.05	6-Aug	0	10-Mar	15.1	13-Oct	0	17-May	3.35	20-Dec	2.48
3-Feb	0	6-Sep	0	10-Apr	4.47	13-Nov	7.23	17-Jun	1.64	21-Jan	1.26
3-Mar	0	6-Oct	3.2	10-May	5.72	13-Dec	8.37	17-Jul	0.54	21-Feb	5.61
3-Apr	0	6-Nov	2.85	10-Jun	0.8	14-Jan	6.76	17-Aug	0.11	21-Mar	1.85
3-May	0	6-Dec	0.21	10-Jul	0	14-Feb	2.59	17-Sep	0.02		
3-Jun	0	7-Jan	5.44	10-Aug	0	14-Mar	8.73	17-Oct	0.03		
3-Jul	0	7-Feb	16.02	10-Sep	0.02	14-Apr	5.26	17-Nov	1.69		
3-Aug	0	7-Mar	2.75	10-Oct	0.03	14-May	1.78	17-Dec	0.51		
3-Sep	0	7-Apr	6.8	10-Nov	0.01	14-Jun	0.27	18-Jan	2.06		
3-Oct	0	7-May	1.83	10-Dec	1.95	14-Jul	0	18-Feb	32.83		
3-Nov	1.28	7-Jun	0.07	11-Jan	5.8	14-Aug	0	18-Mar	5.73		
3-Dec	3.48	7-Jul	0	11-Feb	3	14-Sep	0	18-Apr	9		
4-Jan	7.81	7-Aug	0	11-Mar	5.19	14-Oct	1.26	18-May	7.23		
4-Feb	2.29	7-Sep	0.03	11-Apr	11.5	14-Nov	5.6	18-Jun	3.54		
4-Mar	0.07	7-Oct	0.01	11-May	3.2	14-Dec	8.38	18-Jul	1.77		
4-Apr	1.54	7-Nov	0.05	11-Jun	0.53	15-Jan	5.6	18-Aug	0.36		
4-May	0.12	7-Dec	1.02	11-Jul	0.00	15-Feb	7.8	18-Sep	0.06		
4-Jun	0	8-Jan	3.53	11-Aug	0.00	15-Mar	6.81	18-Oct	0.4		
4-Jul	0	8-Feb	2.18	11-Sep	0.01	15-Apr	3.41	18-Nov	6.09		
4-Aug	0	8-Mar	3.05	11-Oct	0.2	15-May	1.8	18-Dec	18.69		
4-Sep	0	8-Apr	1	11-Nov	0.34	15-Jun	0.09	19-Jan	16.63		
4-Oct	0	8-May	0.55	11-Dec	2.7	15-Jul	0	19-Feb	13.77		
4-Nov	0.44	8-Jun	0.05	12-Jan	4.25	15-Aug	0	19-Mar	19.15		
4-Dec	0.42	8-Jul	0	12-Feb	3.32	15-Sep	0.06	19-Apr	19.04		
5-Jan	3.94	8-Aug	0	12-Mar	4.94	15-Oct	2.42	19-May	8.22		
5-Feb	2.92	8-Sep	0.27	12-Apr	2.29	15-Nov	10.7	19-Jun	4.06		
5-Mar	2.87	8-Oct	2.85	12-May	1.01	15-Dec	3.33	19-Jul	0.97		
5-Apr	0.68	8-Nov	0.44	12-Jun	0.16	16-Jan	6.22	19-Aug	0.06		
5-May	0.08	8-Dec	0.44	12-Jul	0	16-Feb	8.96	19-Sep	2.58		
5-Jun	0	9-Jan	0.17	12-Aug	0	16-Mar	12.6	19-Oct	2.32		
5-Jul	0	9-Feb	0.71	12-Sep	0	16-Apr	16.41	19-Nov	0.36		

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10. Conclusions:

The most essential part of water resource management to construct a good model for a river basin is hydrological process.The SWAT hydrological model was used to estimate runoff in the Khassa Chai watershed. The SWAT model's performance and applicability were effectively assessed through model calibration and validation . The R^2, IOA and NSE are 0.91, 0.95, and 0.85, respectively , in calibration , and 0.9 ,0.92 and 0.75 , respectively , in validation. According to the results,it was estimated that there was a large rise in runoff volume in the previous years (2017 , 2018, 2019 and 2020), especially during the summer, indicating that the region's properties had changed as a result of climatic changes. As a result, this model may be used as a possible tool for khassa chai watershed water resource management.

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