Estimating the Volume of Surface Runoff for Water Harvesting Purposes and the Possibility of Investing it in Abu Dalayah Valley Basin Using Modern Statistical Methods

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Abstract:

This research aims to estimate the volume of surface runoff for the basin of Abu Delayah Valley, which is considered one of the seasonal valleys where water is available in the rainy season and is absent in other seasons. The valley basin includes three secondary basins that are similar in their hydrological characteristics. In order to obtain accurate scientific results, integration was used between several important data sources, such as remote sensing (RS), climate, and geomorphological data for the study area and its region. whereas all of the research outputs, such as maps and figures, were obtained using geographic information systems (GIS), which were used to categorize the study area surface into four land covers and four hydrological soil varieties. For the purposes of water harvesting, the statistical model (SCS-CN) was adopted to estimate the volume of surface runoff. The results showed that the study area is characterized by high runoff based on the values of CN, which ranged between 81 and 91, due to soil type C, which is considered a non-permeable soil. The hourly data for the season (2018-2019) showed that the amounts of rain were large, ranging between 652 and 761 mm, which is an economic amount of water that must be preserved, and therefore four sites were chosen to establish earthen dams in the region as well. The results of those proposed dams for water harvesting proved that the quantities of water storage in them vary, but they are very large and sufficient for various types of future investments.

Keywords: Water Harvesting \ Abu Dalayah Basin\ Surface Runoff \ Statistical Analysis

الملخص:

يهدف البحث الى تقدير حجم الجريان السطحي لحوض وادي ابو دلاية والذي يعد من الأودية موسمية الجريان حيث تتوفر المياه في موسم سقوط الامطار وتنعدم في المواسم الاخرى، يتضمن الحوض ٣ احواض ثانويه متشابهة في خصائصها الهيدرولوجية ، وللحصول على نتائج علميه دقيقه تم استخدام التكامل بين عدة بيانات اهمها بيانات الاستشعار عن بعد (RS) والبيانات المناخية والارضية لمنطقة الدراسة واقليمها .حيث تم الحصول على كافة مخرجات البحث من خرائط واشكال باستخدام نظم المعلومات الجغرافية(GIS). والتي من خلالها تم تصنيف سطح الحوض الى (٤) غطاءات ارضيه و(٤) اصناف من الترب الهيدرولوجية .ولأغراض الحصاد المائي تم اعتماد النموذج الاحصائي (SCS-CN) . واوضحت النتائج ان منطقة الدراسة تتصف بجريان عالي من خلال قيم ال CN

التي تراوحت بين (٨١-٩١) وذلك بسبب وجود التربة من النوع (C)التي تتصف بعدم تسريبها للمياه الى داخل التربة ، وقد اظهرت البيانات الساعية للموسم(٢٠١٨-٢٠١٩) ، ان كميات الامطار كانت كبيرة تراوحت بين(٦٥٢-٧٦١ ملم) ، وبذلك يجب الحفاظ على هذه الكمية الاقتصادية من المياه ولذلك تم اختيار (4) مواقع لإقامة السدود الترابية في المنطقة، فضلا عن ان نتائج تلك السدود المقترحة لحصاد المياه اثبتت ان كميات التخزين المائي فيها متفاوتة ولكنها كبيره جدا وكافيه لقيام شتى انواع الاستثمارات المستقبلية.

الكلمات المفتاحية: (حصاد المياه، ابو دلاية، الجريان السطحي، التحليل الاحصائي).

<u>Introduction</u>:

What is meant by "water harvesting"? It is the process of collecting the falling rainwater and benefiting from it, either directly by enabling the soil to store the largest possible amount of rainwater, which is intended to check the speed of surface runoff, or indirectly by collecting surface runoff water in a drainage and storage area that is not subject to erosion. (Al-Dulaimi, 2015).

During a drought, this water is used to grow crops, water animals, prepare food for human consumption, or replenish groundwater.The basin of Abu Dalayah Valley (which represents the study area) is considered one of the seasonal flowing valleys, where water is available in the rainy season and is not available in other seasons. Similar studies discussed by the two researchers included, but were not limited to: (Al-Adhari, 2005)

The hydrogeomorphology of the valleys west of the Euphrates and north of Iraq's western plateau was studied, and the study's most important finding is that the valleys follow the general direction of the plateau north-east towards the Euphrates River. (Al-Marawi, 2012) The study dealt with groundwater in the Al-Jazeera region, Al-Anbar Governorate, using geographic information systems, the possibility of investing in it for drinking, agriculture, and industry purposes, and future directions for the development of groundwater. As for the study (Al-Fahdawi, 2018), the study aimed to analyze the natural, morphometric, and hydrological characteristics and to study the water situation and the types of water resources in the Hauran Basin in order to identify suitable sites for establishing water harvesting projects in the region.

While Al-Hadithi (2020) studied the analysis of the natural characteristics and their relationship to the hydromorphology of the region, the researcher also used the best methods for harvesting water by knowing the amount of runoff in the region and working to preserve that water through the construction of dams in some basins. While Farhan (2012) studied the geological formations and geomorphological aspects related to water harvesting in the region and its rain characteristics, as well as choosing the appropriate location for the dam in the region. The study (Al-Jubouri, 2014) aimed at analyzing the geographical factors that contribute to choosing promising places for water harvesting, developing the agricultural and economic aspects, and working to increase population settlement in order to prevent population migration.

Also studied (Bilal, Abd al-Baqi, and al-Shukraji, 2019) was estimating the volume of surface runoff based on individual rainstorm values, as well as determining the hydrophobic characteristics of the al-Murr Valley basin, where the researcher was able to select the best sites for the construction of proposed dams to store rainwater.

- **Study problem:**

Is the Abu Dalayah Valley basin suitable for water harvesting? Is the SCS-CN model one of the appropriate statistical methods for water harvesting in the valleys of the Western Desert?

- **Study Hypotheses**:

1. The basin of Abu Dalayah Valley is suitable for water harvesting.

2. Is the SCS-CN model one of the appropriate statistical methods for water harvesting in the western desert valleys?

- **Objectives of the study:**

1. Investing the wasted water in the Delayah Valley Basin in order to make some future investments by knowing the natural characteristics and carrying out some research and scientific studies in order to achieve the greatest benefits without harming the ecosystem.

2. Using the best methods for harvesting water by knowing the amount of surface runoff in the area and working to preserve that water in order to use it better to reduce the demand for river water.

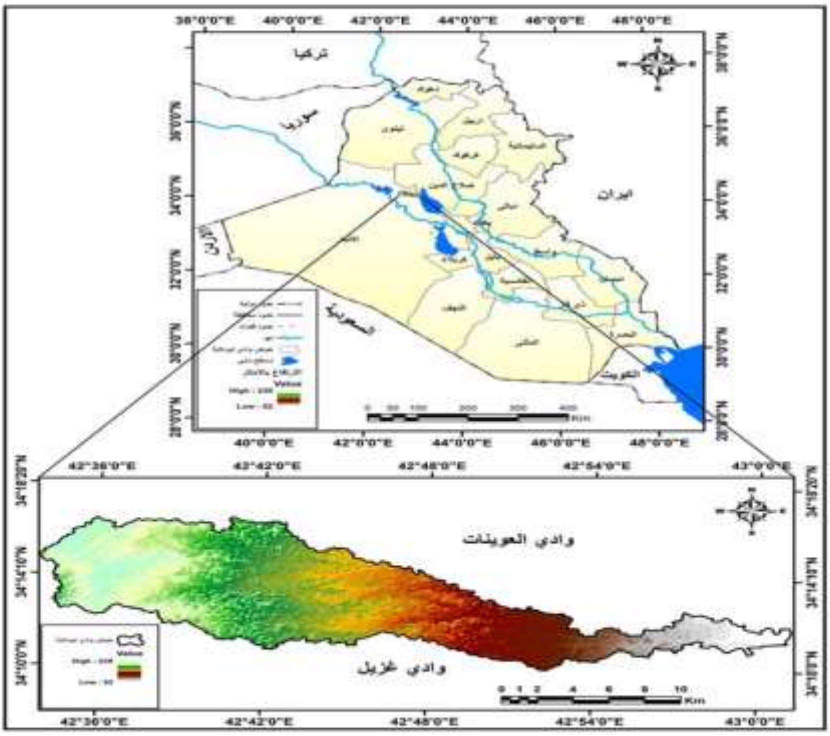
- **The importance of studying**

The study relied on the inductive approach in studying natural characteristics and the analytical approach in analyzing data related to those characteristics through the use of modern geographical techniques in drawing maps and figures and in choosing the best suitable areas for establishing water harvesting projects in the study area and benefiting from water.

Study Area Coordinates :

The Abu Dalayah Valley Basin is located in western Iraq, within the Anbar Governorate, in the northeastern part of the Western Desert, and runs northwest to southeast towards the Tharthar Depression. It is bordered on the north by the Owainat Valley, from the south by the Ghazil Valley, from the east by the Zaghil Valley, and from the west by the Duleeb Valley. As for the astronomical location of the valley, it is located between longitudes (42-38-46) east and two latitudes (34-18-53) north, and its total area is 227 km2 (note map 1).

Map (1) the location of the study area from Iraq



Source: Based on the digital elevation model (DEM) with a discriminatory resolution (30×30), and the output of the program, Arc Map 10.4.1.

Chapter one: Natural Characteristics of the study area

1.1: the geological formations of the study area:

The exposed geological formations vary within the basin area of Abu Dalayah Valley and range in age from the middle Miocene era to recent sediments from the Quaternary era. The following is an accurate description of these formations according to their chronological order, from the oldest to the most recent, as shown in Table 1 (Sixian and Hafez, 1993).

Table 1: Geological formations in the study area

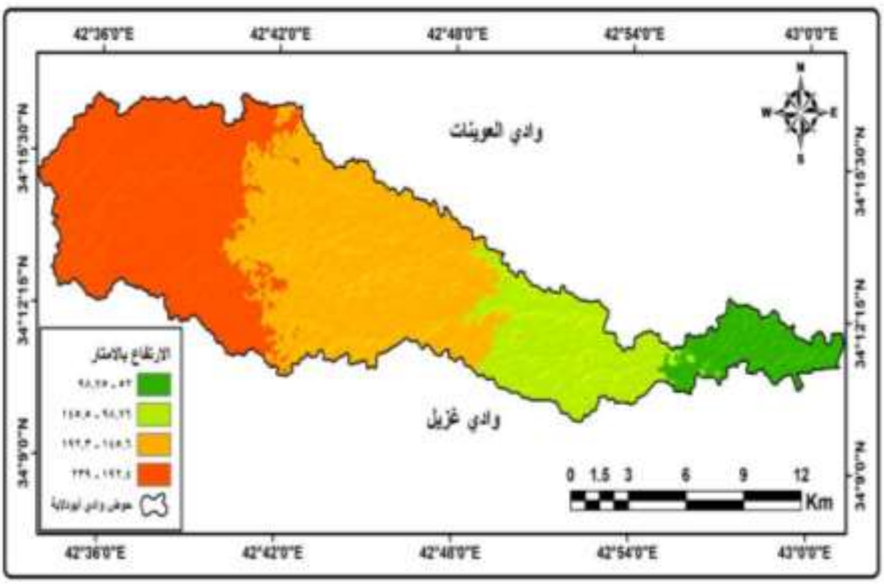
Percentage	Area is km²	Configuration type
٣,٥	٨	Soil filled valleys
٤١,٤	٩٤	remaining soil
٥٥,١	١٢٥	Aperture configuration
100%	٢٢٧	Total

Source: The two researchers based on the digital elevation model (DEM) with a resolution of (30X30) and the Arc map program, 10.4.1.

1.2: The Surface Characteristics:

The basin of Abu Dalayah Valley is characterized by the fact that its land has a slight slope (light) in a direction from northwest to southwest towards Tharthar Depression, and its height ranges between 52 and 239) above sea level, and that the study area is part of the island region, which is distinguished by its location between the Tigris and Euphrates rivers, so it is called the island. And that the topography is diverse and varies according to the terrain structure, which leads to the difficulty of assembling this diversity in a framework that facilitates its study, as evident by analyzing the height of the study area according to data extracted from the digital elevation model (DEM) (Said and Hadi, 2010), which is between 52 and 239 meters above sea level using (25)as contour line period.

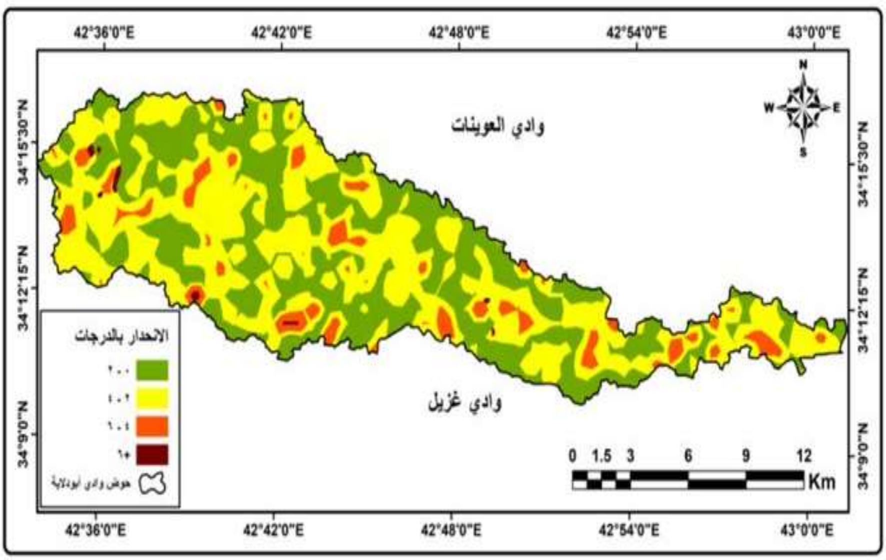
Map (2): Equal elevations in the Abu Dalayah basin



Source: Based on the Digital Elevation Model (DEM) with a resolution of (30 x 30), and the output of Arc Map 10.4.

As for the slopes, they are of great importance in geological and hydrological studies. From the hydrological point of view, they affect the surface runoff of water. As for the geomorphological point of view, the establishment of any project depends on the nature and severity of the slope., (Altom, 2004). One of these projects is to invest, preserve and benefit from water resources (the water harvesting project). The slopes are named according to the degree of slope, as shown in the map (3).

Map (3) Degrees of gradient in the Abu Dalayah basi



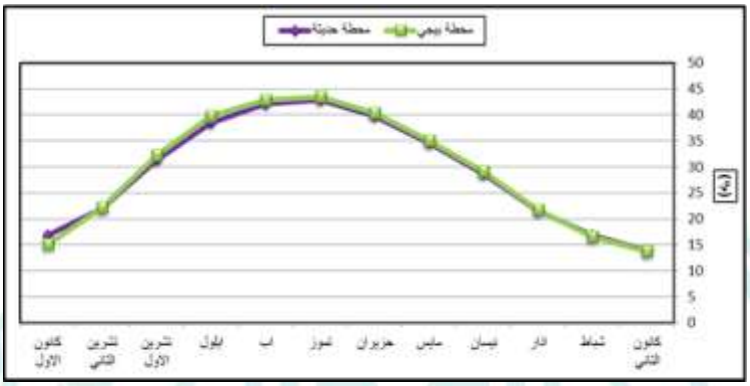
Source: Based on digital elevation models (DEM) with a discriminant resolution (30 x 30), and the output of Arc MAP 10.4.1

1.3: The climate

One of the important geomorphological studies that aims to understand the conditions of sedimentary environments for geomorphological formations within the periods of the energy column of the earth's crust rocks ([1]) is the study of the Earth's surface climate since its inception and the development of its crust.as high temperatures affect the amount of evaporation through the evaporation of surface runoff water and nearby groundwater from the surface and the amount of water in the wells, and this negatively affects water harvesting projects. It is clear from Figure (1) that the maximum temperatures begin to rise during the summer months (May, June, July, August, and September), as the month of July recorded the highest monthly averages in the station (Haditha

- Baiji). It reached (42.8 - 43.5) m, respectively. The Abu Dalayah Valley, which is located within the Jazira region, is distinguished, like the rest of the dry land, by fluctuating and irregular rainfall (Al-Samarrai and Al-Rawi, 1990).

Figure (1) The maximum temperatures (°C) of the study area stations for the period (1980-2014)

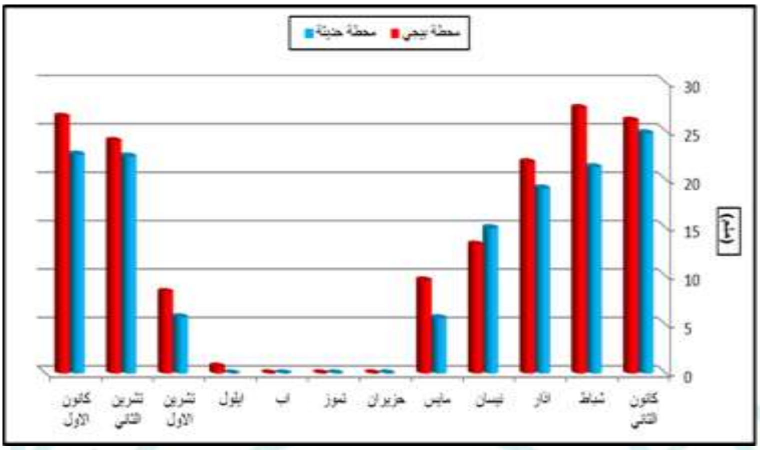


Source: The two researchers rely on climatic data issued by the Iraqi meteorological system.

As for the rain in the study area, it was shown through the analysis of Figure (2) that it is clear that the rain starts from October at Haditha station and starts from September at Baiji station, but at intermittent intervals, and that it does not rain in the summer months (June, July, and August). As the rainfall reaches its peak in Haditha station in January with an average of 24.8 mm, the maximum rainfall in Baiji station was in December with an average of 26.5 mm. While the lowest rate of rainfall was at Haditha station in the month of May, the rate was 5.7 mm. In Baiji station, the lowest rate of rainfall was in the month of September, where the rate was 0.7 mm. The annual total rates of precipitation were 136.7 mm at Haditha station and 157.8 mm at Baiji station, and this indicates that the annual total rainfall at Baiji station is higher than that at Haditha station. (Waheed and Abboud, 2016).

We can conclude from this study that there is a seasonal difference in rainfall, which is caused by the passage of depressions from the Atlantic Ocean across the Mediterranean Sea and through Iraq, and that the fluctuation of rain in the two stations during the months of the year has negative and positive effects on the Abu Delayah Valley, as the rain falls in large quantities, increasing the amount of surface runoff.(Al-Awaid, 2012).

Figure 2: Monthly and annual rainfall totals (mm) at (Haditha and Baiji) stations for the period (1980-2014)



Source: The two researchers rely on climatic data from the Iraqi meteorological station

Chapter Tow: building the (SCS-CN) model for water harvesting and land cover classification:

The (SCS-CN) method is one of the most important and accurate mathematical methods for calculating surface runoff, and it was prepared by the US Soil Conservation Service (SCS) of the US Department of Agriculture. (CN) is meant as a code of values and is used to distinguish the characteristics of rainfall for a specific type of soil or land cover (Al-Dulaimi, 2015). The values of CN range between 0 and 100; whenever the value approaches zero, this indicates the permeability of surfaces to water and the surface runoff is low; if the value approaches 100, this indicates the inability of water to penetrate the surfaces and there is surface runoff. Shortly after the start of the rainstorm (Al-Adhari, 2005), the value of CN depends on the land cover, the hydrological group of the soil, and the pre-moisture of the soil (Al-Marawi, 2012).The mathematical relationship of the (SCS - CN) method is expressed by the following equation[١]

$$\mathbf{Q} = \frac{(\boldsymbol{P} - \boldsymbol{la})^2}{\boldsymbol{P} - \boldsymbol{la} + \boldsymbol{s}} \dots\dots\dots\dots(\mathbf{1})$$

whereas: -

Q = runoff depth (in inches)

P = amount of rain falling (in inches)

La = initial interception before the start of surface runoff represented by evaporation, leakage and vegetation.

S = surface pool after start of runoff (in stock)

Since (La) is equal to one-fifth (S), (La) becomes as follows:

La = Q.2S ………………… (2)

As for the calculation of the value of (S), it is based on the following mathematical relationship:

$$S=\frac{1000}{cn}-10 \ldots\ldots\ldots(3)$$

Since all inputs are measured in inches, inches are changed to millimeters to comply with metric measurements by multiplying the numbers of the equation by the number (25,4), so the equation becomes as follows:

$$S=\frac{25400}{cn}-25,4 \ldots\ldots\ldots(4)$$

To calculate the surface runoff volume through the following mathematical equation:

QV = (Q*A / 10000) ………. (5)

2.1- The ground cover of the Abu Dalayah basin:

"Land Cover" means the real features or phenomena that exist on the earth's surface. (Bilal, Abdel-Baqi, and Al-Shukraji, 2019) The land cover includes four main types: barren lands, green lands, water, and urban lands. The classification of the land cover is one of the basic steps in studying the ways, management, and development of various natural resources.

To analyze and classify the land cover of the study area, it is done by relying on LandSAT-8 (7/2/2020) and using supervised classification, which is the process of classifying each unit of the image on the basis of its reports and its conformity with the training samples in terms of response. spectrum and some statistical calculations (Al-Dulaimi, 2015), in addition to what was seen through the field visit and viewing the land in terms of flatness and erosion. The study area was divided into four categories, as shown in the map (2), table (1), and figure (1).

2.1.1Rocky areas covered with coarse sediments:

This type of land is found in small areas in the northwestern and southeastern parts of the study area.which means it takes up the least amount of space in terms of space capacity.

2.1.2. Barren lands

Its area is 78 km2, accounting for 34.4% of the basin's total area, and it is the highest use of land, represented by the yellow color, and these lands are devoid of vegetation throughout the year due to a lack of water and the inability of the soil to germinate. The lack of obstacles in this type of land also leads to an increase in the speed of surface runoff, resulting in water not leaking into the ground or evaporating into the atmosphere.

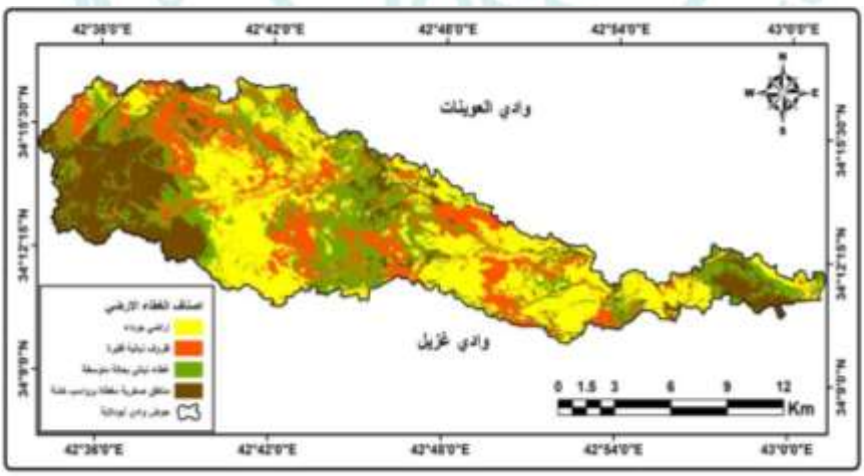
2.1.3 Lands with medium-density cover:

It is formed in the central parts of the study area and the northwestern and southeastern parts of the limited areas. It occupies an area of 57 km2 and constitutes an estimated percentage of 25.1% of the study area. surface runoff, which leads to water leakage into the soil and its evaporation into the atmosphere, thus decreasing the amount of running water, which negatively affects the second harvest in the region.

2.1.4 Low density vegetation cover lands:

This type of land spreads in a scattered manner in all parts of the valley basin, and these lands are characterized by the lack of natural vegetation in them due to climatic conditions or soil quality. It comes in the third rank in terms of area ratio, and it is indicated in red. Look at the map (4)

Map (4): Categories of land uses in the Abu Dalayah Valley Basin



Source: From the work of the two researchers, relying on the visuals, using the Erdas program, 9.2, and the Arc map program, 10.8.

Table (2): Categories of land uses in the study area

Percentage	Area is km²	Ground cover classes	NO.
١٨،٩	٤٣	Rocky areas covered with coarse sediments	١
٣٤،٤	٧٨	Barren lands	٢
٢٥،١	٥٧	Lands with medium density vegetation cover	٣
٢١،٦	٤٩	Lands with sparse vegetation cover	٤
%١٠٠	٢٢٧	**Total**	

Source: From the work of the two researchers based on map (2).

2.2: classification of hydrological soils (HSC) and calculating the values of (CN)

2.2.1. Classification of the soils of the valley basin

The hydrological characteristics of soils have a fundamental role in influencing the processes of providing surface runoff, controlling rainwater infiltration, and groundwater recharge. Therefore, the soil type must be taken into consideration when estimating surface runoff (Al-Dulaimi, 2015). The US Soil Classification System (SCS) has classified soils into four groups. Hydrological behavior depends on the texture of the soil and its components, as well as the extent of water infiltration into it (Al-Adhari, 2005), and thus it reveals the extent of the influence of the soil type on the emergence of water runoff. As shown in Table 3, the groups are (A-B-C-D), and each type of soil has its own characteristics that affect surface runoff.

Table (3) Classes of hydrological soils according to the (SCS) method

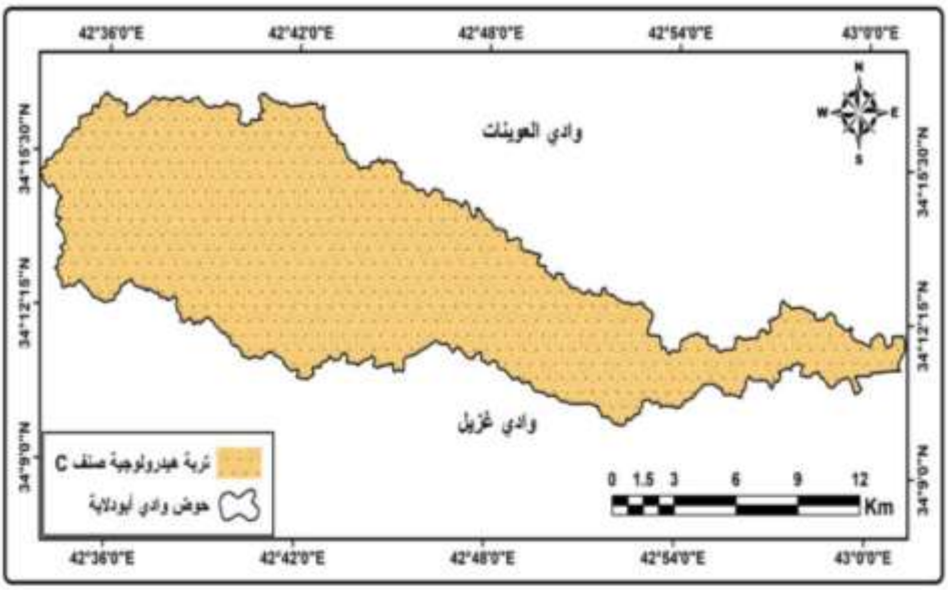
Soil traits	texture depth	Soil class
Deep sandy layer with very little clay and silt	**A little**	**A**
A shallower sandy layer than class A with medium infiltration rate after wetting	**Middle**	**B**
A shallow clay layer with a sub-average infiltration rate before the soil reaches	**Above average**	**C**

saturation		
Clay layer with a high bulging rate with a shallow layer of fine, silty soil at the surface	**High**	**D**

Soil conference . urban Hydrology for small watershed . Teach in careless 55 , 2nd , U.S dept. of Agriculture , Washington O.C .

A map of the hydrological soil groups has been prepared, as shown in map (3), and from its observation, it is clear that the hydrological soil group (2) is the category that represents the study area, as this category prevails in all parts of the basin at a rate of 100%. One of the characteristics of the soils of this group is that they achieve medium and vascular flow in their places of existence; perhaps the rate of infiltration is below medium, and this is due to the fine particles of its various components due to the presence of a layer of clay and silt, as well as the fact that the rate of water infiltration into the soil is low when it is wet and cloudy and the transfer of water through the soil is restricted. To some extent (Akkam and Alwan, 2015) (9), these soils were formed by the seasonal flooding of rivers.

Map (5): The hydrological soil aggregates of the Abu Dalayah basin.



Source: Depending on the World Food Organization, FAO classification, and the outputs of Arc MAP 10.4.1.

2.3.Calculating the values of (CN) for the valley basin: -

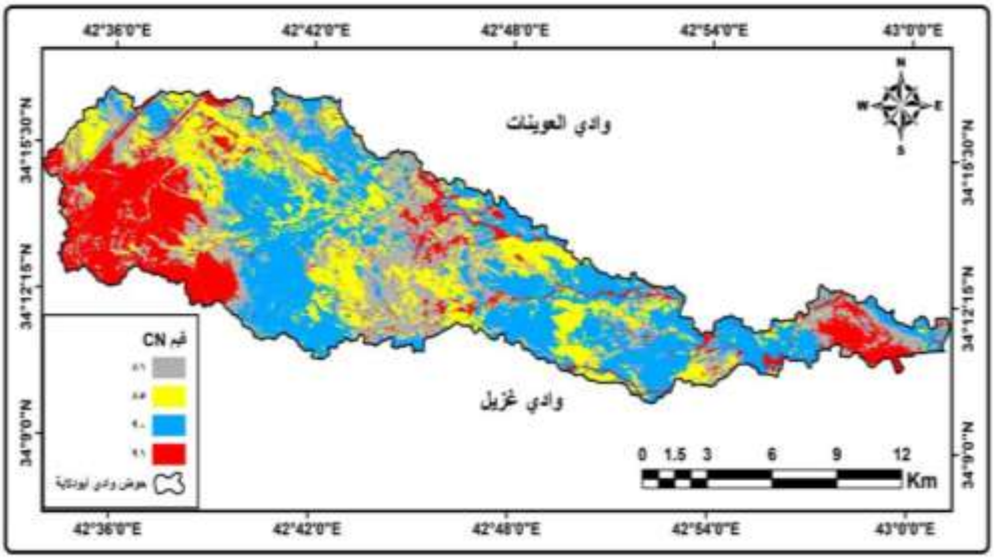
The values of CN were obtained by merging the land cover layer with the layer of the hydrological soil group of the study area in the program (Arc GIS 10.4). And that there is an inverse relationship between the value of CN and the permeability of the surface, so the higher the value of CN, the greater the permeability of the surface. The surface has a low permeability and vice versa (Skarneh and Makhamra, 2019). The study showed that the values of CN for the study area are high, which gives the impression that there is a possibility of high surface runoff in the area, in addition to poor infiltration into the soil and poor soil absorption of water (note Table 4).

Table (4) extracted (CN) values for the study area

The values of (CN) according to the group of hydrological soils	Ground cover classes
C	
٩٠	Barren lands
٨٥	Lands with sparse vegetation cover
٨١	Medium density cover
٩١	Rocky areas covered with coarse sediments

The number of CN values in the Abu Delayah Valley basin reached four values ranging between 81 and 91, as shown in map (6) and table (5). As the ratio occupied (91) mm, the areas covered by each value varied. The highest area reached was 78 km2, with an area percentage estimated at 34.4 percent, which is also the highest value recorded for the study area, while the value of 90 mm occupied the least area of the region, which amounted to 34 km2 and an area ratio estimated at 18.9 percent. As for the value (85), its area reached 49 square kilometers with an area ratio estimated at (21.6%), so it comes in third place after the value (81), which reached an area of 57 square kilometers with an area ratio of (1.25%). It is clear from the foregoing that the study area was within the high categories of CN values, which indicates that it has water permeability and the ability to retain water on its surface. This means an increase in surface runoff operations, which is a positive factor that encourages the establishment of water harvesting projects in the study area.

Map (6) values (CN) for the basin of Abu Dalayah Valley



Source: Based on the map (2-3), and the output of Arc MAP 10.4.2

Table (5) Areas and ratios of curve values (CN)

Percentage	Area is km²	Value of (CN)	No.
%٣٤,٤	٧٨	٩١	١
%١٨,٩	٤٣	٩٠	٢
%٢١,٦	٤٩	٨٥	٣
%٢٥,١	٥٧	٨١	٤
%١٠٠	٢٢٧	Total	٥

Source: From the work of the two researchers based on the map (4).

2. 3.1. Calculation of the coefficient of possibility of retaining water after run-off (S):-

This factor shows the extent to which the soil can retain water after the start of the surface runoff. Maximum Credential Retention After runoff, the values of S were calculated through equation (3-4) (Jamal and Kazem, 2019) that was previously mentioned in the calculation of surface runoff and obtaining The results were applied based on the program (Arc GIS 10.4). From table 6, it is clear that the values of the coefficient (S) ranged between 25 and 60. High values indicate the ability of the soil to retain water and thus a decrease in the amount of surface runoff, while low values close to zero indicate a decrease in the ability of the soil to retain water. water retention, which in turn generates runoff. Most of the values of the coefficient (S) in the study area were low, so we find that the value of (S) of (25 mm), which represents the lowest value recorded, occupies an area of (78 km2) with an area ratio of (34.4%), and the value of (28 mm) occupies an area of (43 km2) with an area ratio of (18.6%), while the value of (45 mm) occupies an area of (49 km2) with an area percentage estimated at (21.6%), while the highest value of the coefficient (S), amounting to (60 mm, occupies an area of (57 km2) with an area ratio of (25.1%. Thus, most of the lands in the study area are characterized by their inability to retain water and their ability to provide surface runoff.

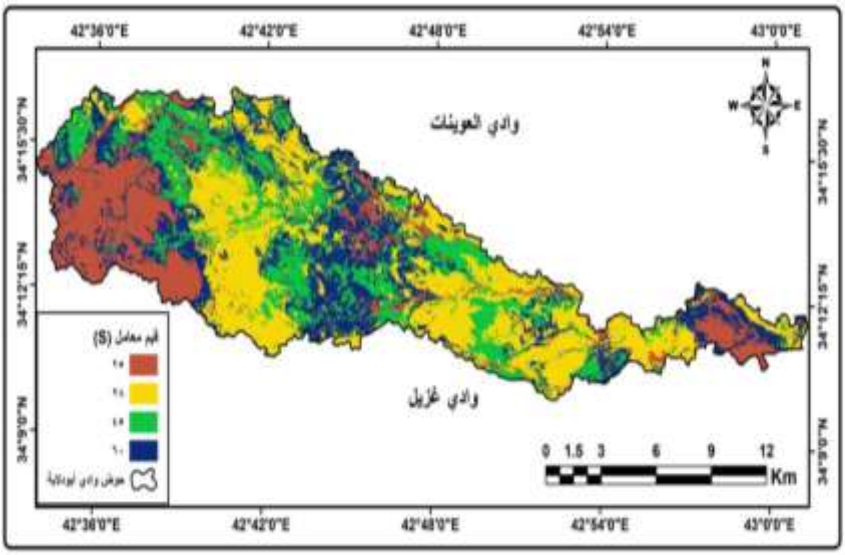
Table (6) the values of the modulus (S) mm for the study area

Percentage	Area is km²	Value of (S)	No.
%٣٤,٤	٧٨	٢٥	١
%١٨,٩	٤٣	٢٨	٢
%٢١,٦	٤٩	٤٥	٣
%٢٥,١	٥٧	٦٠	٤
%١٠٠	٢٢٧	**Total**	

Source: From the work of the two researchers based on the equation of the coefficient (S) and Table (4).

It can be said by observing maps (6) and (7) that the areas in which low (S) values appeared are the same areas that represent the highest (CN) values, and this indicates that there is a correlation between the two variables.

Map (7) values of the coefficient (S) mm for the Abu Dalayah basin



Source: From the work of the two researchers based on satellite visuals and Table (5).

2. 3.2. Calculation of the primary extraction coefficient of the basin (La):-

The initial extraction coefficient (La) Initial abstraction is one of the important criteria in calculating the amount of surface runoff, and it shows the amount of rainwater lost before the start of the surface runoff process through evaporation, leakage, or the interception of water by plants, in addition to the water that collects in the depressions. There is a relationship between the coefficient (La) and the coefficient (S), as it represents one-fifth of the value of (S) (Al-Dulaimi, 2015), as we mentioned about the coefficient (La). The low values of the coefficient (LA) close to zero indicate that there is little loss of rainwater before the start of the runoff process, and this helps to increase the amount of surface runoff in the area; if the value is 5.8, then it is considered an average value for the rate of runoff; if the values are high, this indicates an increase in the amount of rainwater lost and, as a result, a decrease in the amount of surface runoff (Saleh, Shaish, and Zaboun, 2009).

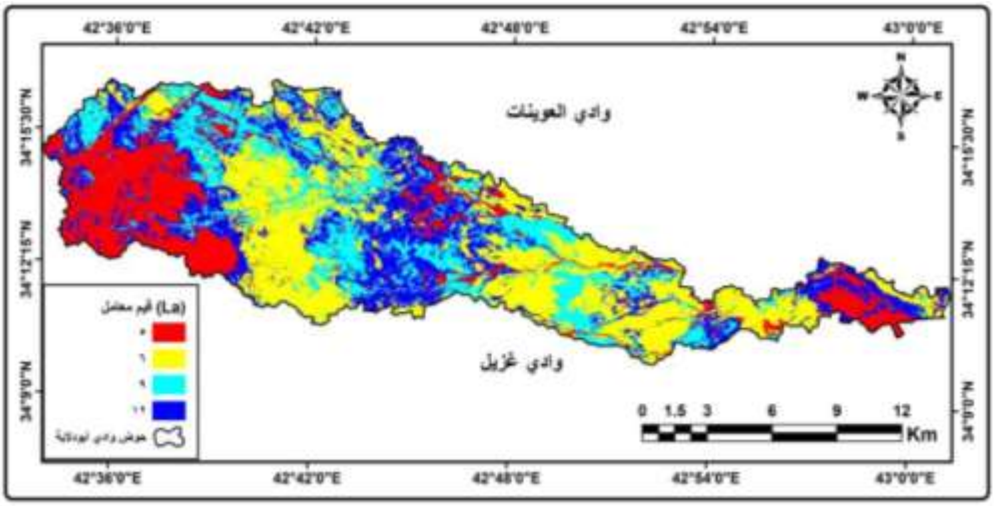
By observing table (7) and map (8) resulting from equation (2), most of the L values are low, which helps to generate high surface runoff in the study area, as it reached the lowest value of (5) mm and occupied an area of (78) km2 with a rate of (34.3%), and the value of (6 mm) occupied an area of (43 km2) with a rate of (18.9%), while the value of (9 mm) occupied an area of (49 km2) with a rate of (21.6%), while the highest value and occupies an area of (57) km2 with a rate of (25.1%).

Table (7) Modulus values (La) mm for the study area

Percentage	Area is km^2	Value of (La)	No.
%٣٤,٣	٧٨	٥	١
%١٨,٩	٤٣	٦	٢
%٢١,٦	٤٩	٩	٣
%٢٥,١	٥٧	١٢	٤
%١٠٠	٢٢٧	Total	

Source: Statistical analysis of (La) values.

Map (8) values of (La) for the Abu Dalayah basin



Source: From the work of the two researchers based on satellite visuals and Table (7).

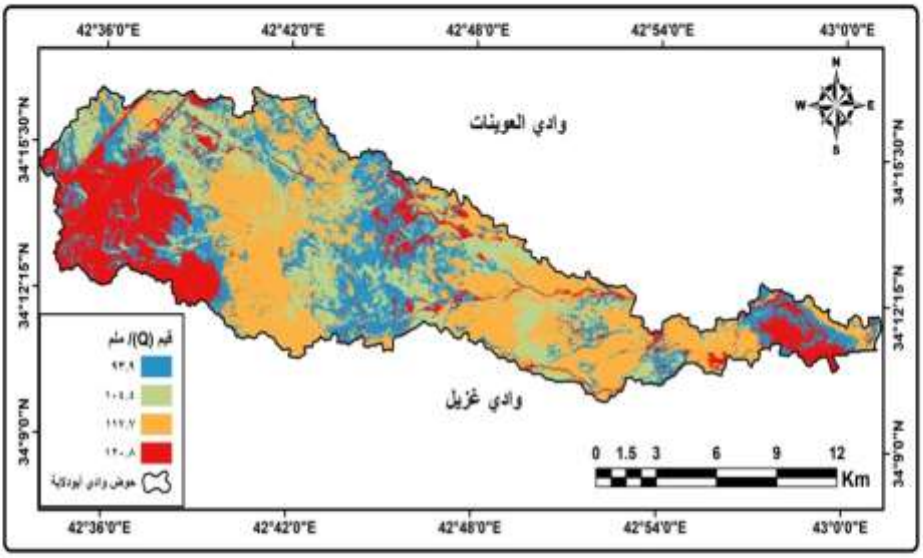
Surface runoff depth, by which we mean the amount of water running in an area, and that the Abu Dalay basin is a dry basin in which there is no permanent watercourse, so rainwater represents the main source of runoff in it, through the application of equation (3), which I mentioned previously, and the amount of rainfall was relied upon for the period (1980-2014), and from Table (8), and Map (9), it is clear that the runoff depth values for the study area are high. The highest depth of runoff was recorded at (120.8 mm), for an area of (78 km2), and for an area estimated at (57) km2, while the depth (117.7 mm) occupied an area estimated at (43 km2), and the depth (104.4 mm) occupied an area estimated at (49 km 2), while the depth (93.9) was recorded as the lowest depth and an area estimated at (75) km 2. Thus, the study area is characterized by high surface runoff, as most of the results were higher than the average, which amounted to (19.2) mm, and this encourages the establishment of Water harvesting projects within the Abu Dalayah basin.

Table (8) Q values (mm) for the study area

Percentage	Area is km²	(Q values (mm	No.
%٣٤,٤	٧٨	١٢٠,٨	١
%١٨,٩	٤٣	١١٧,٧٤	٢
%٢١,٦	٤٩	١٠٤,٤١	٣
%٢١,١	٥٧	٩٣,٩	٤
%١٠٠	٢٢٧	١٠٩,٢	Average

Source: Depending on the statistical analysis of the values of equation (Q).

Map (9) Estimating the volume of surface runoff (Q) for the Abu Dalayah basin



Source: From the work of the two researchers, based on satellite images and table data (7).

2. 3.3- Runoff Volume Estimation (QV)

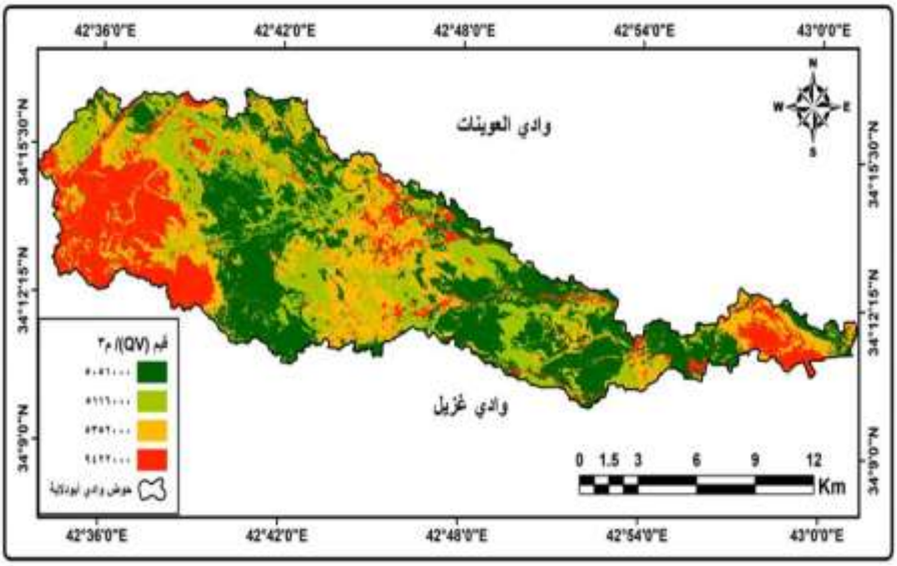
The volume of surface runoff (Wotan Runoff) expresses the total surface runoff to the area of the basin. The volume of runoff is of great importance in hydrological studies, especially in determining the locations of dams and reservoirs. It helps to know the volume of flooding to which the study area is exposed. The volume of surface runoff (QV) has been estimated through equation No. (5) and according to the area for each value of the (CN) (Al-Rubaie and Muhammad, 2021) and through what is shown in Table (9) and Map (10), we notice that the highest value of the surface runoff volume has reached (9, 422000) m3 with an area of (78) km2, while the lowest value of (5.051000) m3 occupied an area of (43) km2 with the least area in the basin.

Table (9) Values (QV) of the surface runoff volume of the study area (m3)

Percentage	Area is km²	CN values	No.
٩,٤٢٢٠٠٠	٧٨	٩١	١
٥,٠٥١٠٠٠	٤٣	٩٠	٢
٥,١١٦٠٠٠	٤٩	٨٥	٣
٥,٣٥٢٠٠٠	٥٧	٨١	٤
٢٤,٩٤١	٢٢٧	Total	
٦,٢٣٥٠٠٠	-	Average	

Source: From the work of the two researchers by adopting the statistical analysis of the values of (Qv) in the application of equation (5).

Map (10) values (QV) for the basin of Abu Dalayah Valley



Source: Depending on satellite visualizations and table (8) data.

Chapter Three: Water harvesting according to the amount of annual precipitation

After applying the SCS-CN model, it became clear that the study area is characterized by its high capacity for surface runoff and that carrying out water harvesting operations requires knowing the quantities of water available in the area, which depends mainly on rain because it represents the only water resource for the area (http://chrsdata.eng.uci.edu). Based on this website, the rainfall amounts were extracted at the level of hours for the rainy season (2018-2019). In order to obtain the amounts of precipitation, three sites were chosen for the study area (the downstream, the middle, and the source), and it was shown from Table (9) that the amounts of precipitation ranged between 652 and 761 mm, which are large quantities that the study area had not witnessed before, as they were not estimated with the authority's data. The General Meteorological Department of the two stations (Haditha and Baiji) for the period 1980–2014 averaged total rainfall of 147.25 mm, and thus these large quantities of water must be preserved instead of being subjected to evaporation or leakage into the soil and benefiting from it through the establishment of barriers or earth dams for the study area. As it is clear from Table 10, the site with the second sequence (the middle) recorded the highest rainfall amounts by 761 mm, while the first site recorded less than the amounts by 652 mm, and the third site recorded rainfall by 681 mm.

Table 10: Locations and amounts of rainfall data for the season (2018–2019).

Rainfall (mm)	Latitude	Longitude	The site	NO.
٦٥٢	٣٤° - ١١ – ٣٥ N	٤٢°– ٥٨ – ١١ E	Downstream	١
٧٦١	٣٤° - ١٣ – ١٣ N	42° - 45 - 11 E	The middle	٢
٦٨١	٣٤° - ١٤ – ٤٢ N	42° - 37 - 17 E	Upstream	٣

Source: **http://chrsdata.eng.uci.edu**

3.1Choosing suitable sites for water harvesting:

The process of selecting suitable sites for water harvesting is carried out according to several steps:

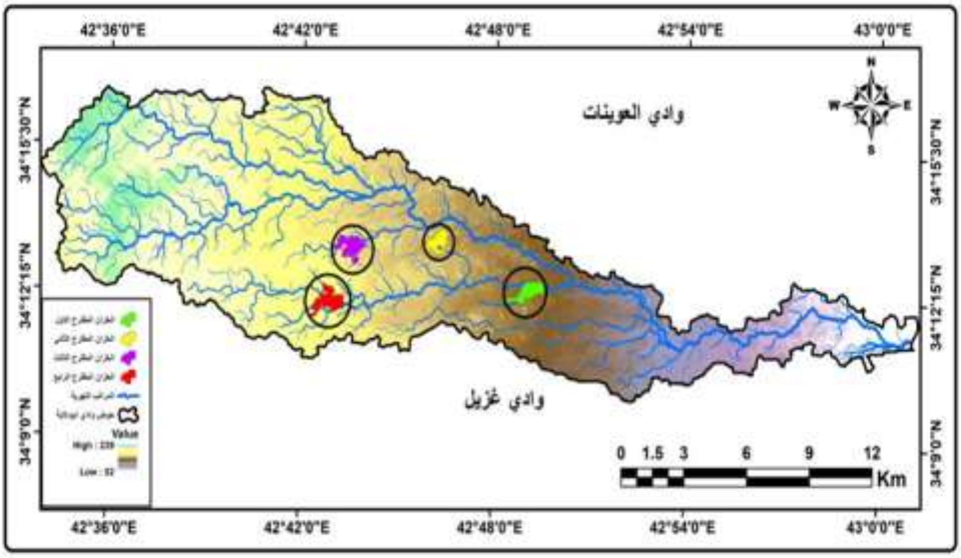
1. The first step: In this step, the height of the area in which the water is impounded is determined through the digital elevation model (DEM) of the study area, and then the areas characterized by a slight slope are determined according to the contour lines.

2. The second step is to match the map of the riverbeds with the contour lines to know the direction of the watercourses.

3. The third step: identifying areas that human variables can benefit from in agricultural production (plant and animal).

After taking these steps, four hypothetical sites were identified for the construction of earthen dams: The earthen dam is an earthen barrier that intercepts the watercourse, forming a lake behind it. This type of dam was chosen for reasons including the lack of costs because nature has provided us with building materials and provided them in the required quantity, in addition to the possibility of building them. On top of any type of foundation in the study area (Hamid and Kaoud, 2018), note the map (11), which was intended to store water in the rainy seasons and use it in times of drought to irrigate crops and livestock.

Maps (11) Proposed sites for the construction of earthen dams for the Abu Dalayah basin



Source: Based on the Digital Elevation Model (DEM) with a discriminant resolution (30×30), and the output of Arc MAP 10.4.1

3.2. Proposed sites for the construction of earthen dams for the study area:

3.2.1. The first location: This site is located in the center of the study area, specifically in the second valley basin. Note map (9) and figure (3), in addition to the proposed dam being located within the areas of low slope. Table 11 shows that this dam provides storage capacity for the lake. The proposed area is 3,673,292 m3, for a height of 146 m above sea level.

Table (11) Appropriate height of proposed dams for the study area and storage volume (m3)

Storage volume (m3)	Sea level (m)	NO.
٣٦٧٣٢٩٢	١٤٦	١
١٢٠٩٣٥٣	١٦٠	٢
٣٧٩٥٣٣٦	١٨٤	٣
٢٥٠٥٧٥٩	١٧٠	٤

Source: The researcher based on map (9) and Arc MAP 10.4.1.

Figure 3: Cross section of the first proposed dam

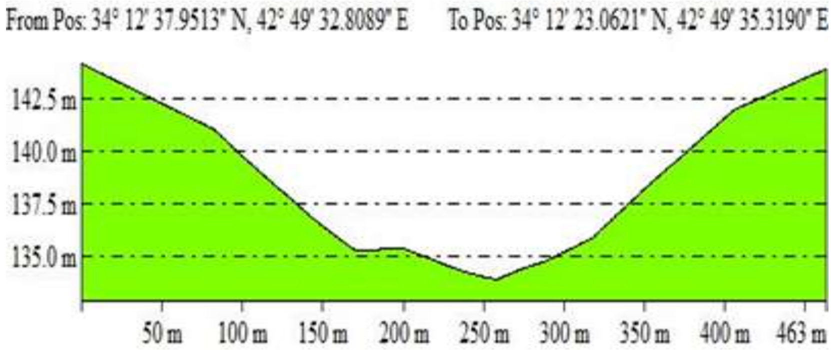
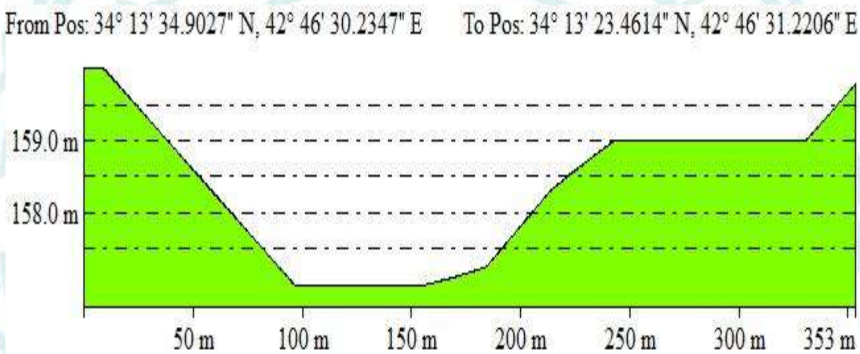


Figure (4) Cross section of the second proposed dam



3.2.2. The second location: This dam is located in the middle of the study area on the first valley basin. Take note of the map (9), as well as the figure (4). The proposed lake has a storage capacity of 1,209,353 m3 and an elevation of 160 m above sea level.

Figure (5) Cross section of the third proposed dam

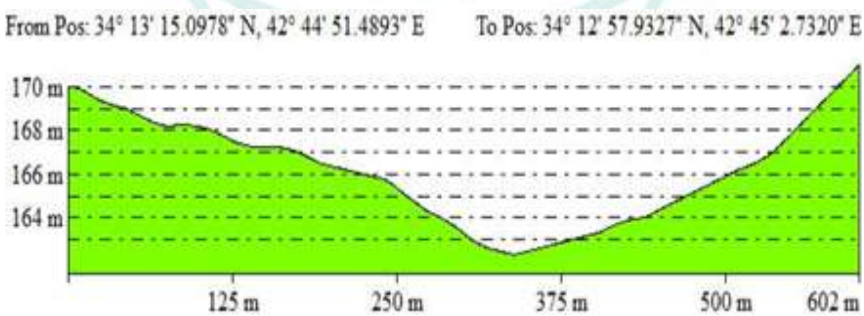
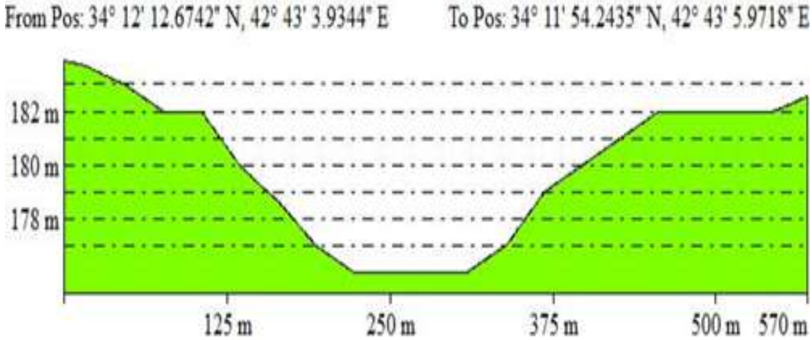


Figure (6) Cross section of the fourth proposed dam



3.2.3-The third location: Through map (9) and figure (5), the proposed dam appears in the middle of the Abu Dalayah basin, located specifically within the first basin, and its storage capacity is 379,533.7 m3, and thus it represents the largest storage capacity of the proposed lakes, which is At the same time, the highest level of altitude was recorded, which reached 184 meters above sea level.

4- The fourth site: This dam is located within the low-slope areas, as it is located within a height of 170 meters above sea level and has a storage capacity of 250,575,959 m3 (see map (9), and figure (6).

Conclusions:

1. The Abu Dalayah basin, which has an area of 227 km2, contains three secondary basins; the area of the first basin is 82 km2, the area of the second basin is 45 km2, and the area of the third basin is 101 km2.

2. The study showed that the values of cn for the study area were high, and this gives the impression that there is a possibility of large surface runoff in the area.

3. There is one class of hydrological soils, which is class C according to the American soil classification system (scs-cn).

Four proposed sites were chosen for the construction of earthen dams suitable for water harvesting in the study area, and they were arranged according to their designations: site No. 1; site No. 2; site No. 3; and site No. 4; and according to their height above sea level.

5. Integration Remote sensing data and natural data of the region are able to give a complete analytical picture for development and investment, especially if the outputs of that data have been issued using geographic information systems.

6. The results of the proposed dams proved that the storage quantities will be large and suitable for water harvesting operations for the purpose of achieving all future investments in the study area.

Recommendations:

1. Establishing climatic and hydrological stations in the study area to provide the data that the researcher may need when carrying out his research.

2. the importance of disseminating water harvesting technologies in Iraq according to specialized scientific foundations and studies and teaching this subject to all geography students at the bachelor's, master's, and doctoral levels.

3. expanding the use of modern irrigation methods to reduce water waste and creating programs to raise awareness of the importance of preserving this wealth in anticipation of any future water emergencies and crises.

4. The necessity of establishing water harvesting projects in the study area and relying on the earth dam method because it is a low-cost and easy-to-implement method.

5. Taking care of the waters of the geographical areas, especially in the Western Sahara; the fact that Iraq will be the most affected in the region in the event that Turkey and Syria complete all their irrigation projects in the coming years, which is expected to deprive Iraq of the waters of the two rivers completely; and the fact that alternative water measures must be taken.

Six countries' competition in building dams and securing their water is information that encourages interest in water harvesting projects.

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