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The Feasibility of Constructing Rainwater Harvesting Dams and Their Storage Capacity in Al-Abyadh Valley West of Iraq

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ABSTRACT

This study's primary emphasis was locating appropriate locations in the valley of Al-Abyadh for water harvesting dams. Water harvesting techniques are one possible answer for Iraq's water difficulties caused by climate change and the existing dams in the high reaches of rivers, which have exposed the world to severe drought. Water harvesting is collecting water from a specific area, beginning with rainwater in the ground and conserving it by building dams to store it. Valley Al-Abyadh, which extends 268 km and has an area of 4188.96 km^2, is situated in Anbar Governorate's western desert. Water flows into the Al-Abyadh valley through four basins. This study aims to examine the four basins hydrologically and analyze the data using the HEC-HMS software to find the best places to put water harvesting dams and how much water they can hold. ArcGIS 10.8 and HEC_HMS 4.11 were used for the analysis of the maps. 2008–2022, We used real rainfall data from the meteorological and seismic monitoring division. The simulations determined a storage capacity of 1045.69056 M $m3$ run using actual rainfall data inside Valley Al-Abyadh. Work on rainwater harvesting dams began in the basins of the valley Al-Abyadh. Every basin has reached its maximum storage capacity, respectively14,11,20,10 (46.27584M m^3, 42.81984M m^3, 63.19296M m^3, 65.00736 M m^3). The study shows that water from these dams might be used since Valley Al-Abyadh has the highest storage capacity among water harvesting dams and the lowest loss rate.

Keywords: Rainwater harvesting dams, Al-Abyadh valley, Western desert, HEC-HMS modeling.

1. INTRODUCTION

Rainfall harvesting is progressively becoming an essential component of the toolset for water rainfall management. Iraq is suffering from water shortages, which are expected to worsen. Water harvesting methods will help eliminate or alleviate water shortages. The Horan and Ghadaf valleys in western Iraq were found to have excellent potential for

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rainwater collection because of their high rainfall levels and low water loss rates. Furthermore, precise dam reservoir surface area and storage capacity estimates are essential for planning water body collection projects **(Kamel and Sulaiman, 2012).** Global warming will cause the Tigris and Euphrates rivers to dry by 2040 if Turkey and Syria continue using more water than they receive **(Al-Ansari, 2013).** Accurate area-volume-elevation curves are crucial to determine the best places to try collecting water and how to build it **(Sayl et al., 2017).** A significant dry environment along the Tigris River in Iraq has been linked to rainfall constraints and a decrease in water resources, which will soon cause serious worry **(Almasraf and Salim, 2018).** To prevent floods, manage water flow rates, and store enough water for dry seasons, new approaches to planning, managing, and carrying out rainwater projects are required. **(Mohy and Abed, 2020).** Within this framework, the most suitable spots for water storage systems were located using outstanding technology and criteria. Iraq may improve its water resource management by measuring the amount of rainwater that runs from land into various bodies of water **(Ibrahim et al., 2019).** For instance, researchers used a SWAT model and a GIS to predict surface runoff in the Al-Mohammedi Valley. Modeling 792 million m^3 of water runoff from 1981 to 2019 could help with better infrastructure planning and construction **(Farhan and Al Thamiry, 2020).** Factors like reduced rainfall, irrigation projects, dam building, and climate change have contributed significantly to the decline in Iraq. Flood control addresses these problems **(AL Thamiry and Azzubaidi, 2020).** One example is the Haqlan Valley in Iraq, where 28% of the selected basins were suitable, according to a primary study that included geographic information systems and remote sensing **(Sayl et al., 2020).** A different study used the SWAT model and ArcGIS software to simulate flow conditions and runoff modeling accurately in places like Maleh.Shoaib Al-Rahimawi, and Kharr (A and B) **(Farhan and Abed, 2021).** In addition, during times of drought and shortage, collecting rainwater is essential for adapting to climate change **(Basim and Ataa, 2022).** To ensure that bioswale systems are functional, it is vital to employ ArcGIS software for modeling and improving bioswale placement and evaluating land use and soil types **(Faraj and Hamaamin, 2023).** In many semi-arid and wetter regions, drought is a natural occurrence. This demonstrates that drought affects all parts of the world. Heat waves and other forms of climate change have brought about devastating droughts **(Mazen and Mohammed, 2023).** One of the most important tools in water resources engineering is the intensity-duration-frequency (IDF) relationship, which helps with water project planning, construction, and management to minimize the impact of water **(Al-Zubaidi et al., 2023).** Flood maps were created using the Hydrologic Engineering Center's River Analysis System (HEC-RAS), which simulated runoff depth and forecasted 100-year climate change impacts on rainfall quantiles for significant locations in the Tigris River basin. There were no substantial variations in Baghdad and Sammara, while precipitation rose in Tikrit and Mosul **(Oleiwi et al., 2023).** Furthermore, we analyzed the Al-Shuwaija marsh's surface water consumption using the Watershed Modelling System (WMS) program, which successfully simulated the depth and discharge feature **(Al-Zubaidi and Abed, 2024).** Simulation tools and advanced hydrologic modeling supported climate change adaptability and water resources in specific locations. Consequently,

In this work, the viability and expediency of building these dams were determined in Valley Al-Abyadh while maximizing their storage capacity and locations.

2. METHODOLOGY

For this study, a hydrological model of Al-Abyadh Valley was developed using the HEC-HMS software. The area's digital elevation model (DEM) data was sourced from data acquired from the United States Geological Survey's (USGS) online repository. The stream network, sub-basin delineations, and other hydrological characteristics were created using HEC-HMS and are crucial components of the input files. A multi-step process was then used to incorporate all data into an ArcGIS environment. The daily precipitation data of the Al-Abyadh Valley catchment area were subsequently simulated using this detailed HEC-HMS model.

2.1 Study Area

The Abyadh Valley ranks second in length among Iraq's valleys. It is a seasonal valley between Karbala and Anbar Governorate in the Western Desert. In the east, close to the Arar area, it stretches around 250 km from the Iraqi-Saudi border. Spread across about 4188.956 km^2 and a length of 268 km; the target watershed is located within the specified geographical area extending from 31º 30' 00" to 32º 38' 00" N and 42º 10' 00" to 43º 50' 00" E. The target watershed is an example of a desert climate regime. A series of narrow springs give rise to this valley. To do this, several smaller valleys in the area empty into the central valley. This valley, comprised of four sub-basins, terminates at the southern end at Lake Al-Razzaza, as seen in **Fig. 1.** The catchment area**: Fig. 2** shows that once the basins formed, the fourth one (which had been leading astray) shared the Valley Al-Abyadh and, according to the boundaries, drains into Razzaza Lake. All four basins contribute to Razzaza Lake's inflow.

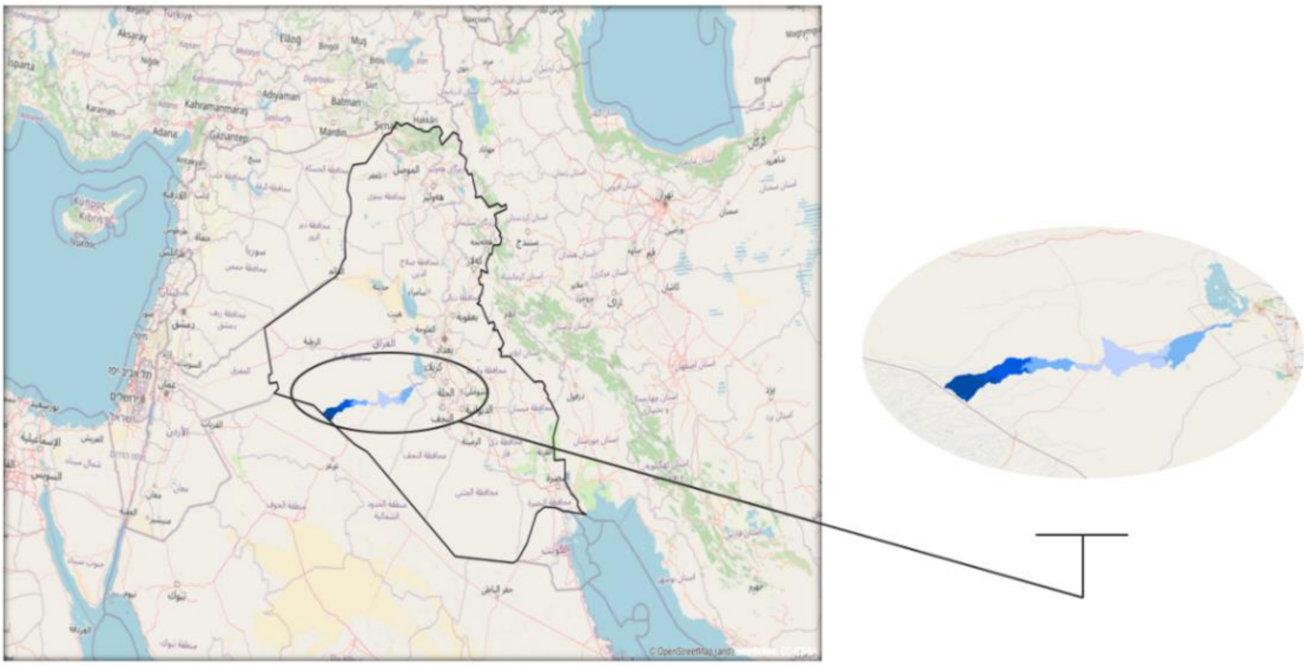

Figure 1. Al-Abyadh Valley System ArcGIS application.

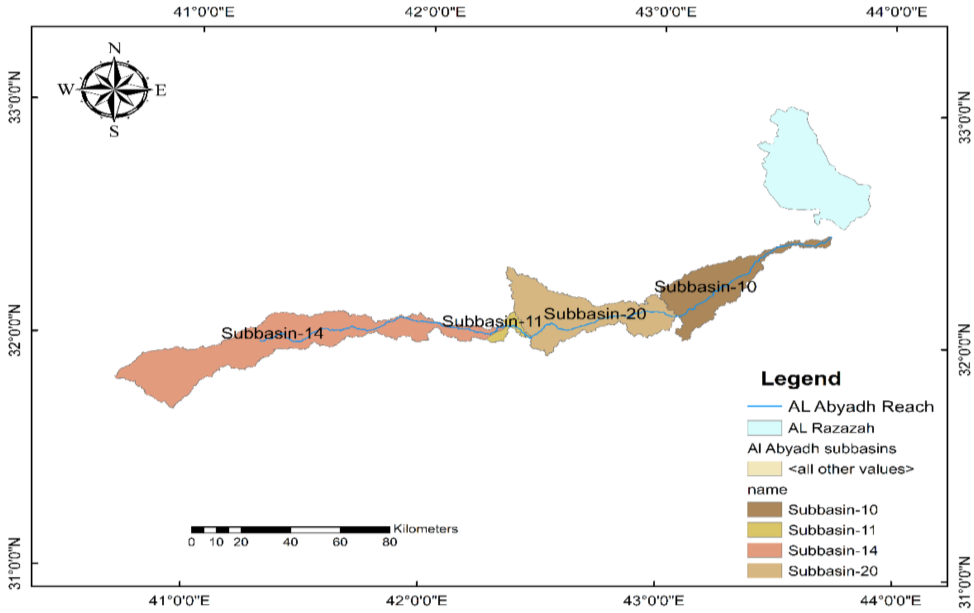

Figure 2. The study region (the four Al-Abyadh valley subbasins).

2.2 A System for Hydrologic Modeling

The Hydrologic Modelling System (HMS), developed by the Hydrologic Engineering Centre (HEC) of the United States Army Corps of Engineers, was used to model the hydrology of Iraq's Al-Abyadh Valley. Runoff water, leakage, heavy rainfall, consumptive water use (evapotranspiration), and baseflow are the main components of the hydrologic cycle that may be modelled using HEC-HMS software. Advanced reservoir modelling skills are also a part of it. Applications in water resources, including reservoir operation, water supply planning, and flood control, have used this extensively used software. The dataset utilized in this study is assumed to cover all water-related activities in the study area comprehensively. Because of this, the Al-Abyadh Valley's water flows may be faithfully simulated using the HEC-HMS model **(Halwatura and Najim, 2013). Table 1** shows input parameters for The Hydrologic Engineering Centre Hydrologic Modeling (HEC-HMS), which controls processing.

Table 1. The input parameters of the HEC-HMS model.

No.	Model	Methodological Parameters	Requisite (Unit)
1	Rate of loss parameters	The curve numbers or CN.	Initial abstraction (mm), curve numbers, and impermeable area (%)
2	Transformation of runoff	The SCS Unit Hydrograph	Lag time (minutes)
3	A routing Method	Muskingum	weight in dimensions X and time to travel K in (hours)

2.3 The Input Data

The Hydrologic Modeling System (HMS) was developed to execute the HEC-HMS software and model the hydrology of Iraq's Al-Abyadh Valley. Using ArcGIS, we gathered data on land use, rainfall, CN value, soil maps, DEM maps, and many other criteria to finish the HEC-HMS hydrologic model simulation.

2.3.1 Digital Elevation Map (DEM) of The Study Region

Defining the catchment's topographic requires the DEM as an input. The study area's edges, heights, and depressions were then found using a DEM with a resolution of 30 meters obtained from the worldwide Shuttle Radar Topography Mission (SRTM) dataset managed by the US Geological Survey (USGS). The DEM was merged and reprojected to the UTM zone before the HEC-HMS running. **Fig. 3** shows the results, which reveal the watersheds and flow directions. The planet's topography is an important component in the HMS model, which evaluates drainage patterns, land surface characteristics, and watersheds. Additionally, it is used for preprocessing topography, basin processing, and catchment delineation **(Oleyiblo and Li, 2010).**

2.3.2 Land Cover Map

The GlobCover land cover dataset, maintained by the European Space Agency and with a resolution of 300 meters, was specifically used in 2009, it served as the study's source of land-use data. The study area had two main types of land cover: bare regions and sparse vegetation (>15%), which comprises grassland, shrubs, and woody vegetation. **Fig. 4** shows this data on land usage.

2.3.3 Soil Map Database

The Food and Agriculture Organization supplied a soil map for the study, which had a scale of 1:5000. A great number of polygons make up the map. Hydrological classifications of soils, physical and chemical characteristics, FAO soil texture, and hydraulic conductivity are all included in each polygon, along with soil features from other study areas. The watershed zone was delineated by trimming these polygons, and the soil type in the study area was determined using ArcMap software. **Fig. 5**. Two basins are found in the study area: loam and clay loam.

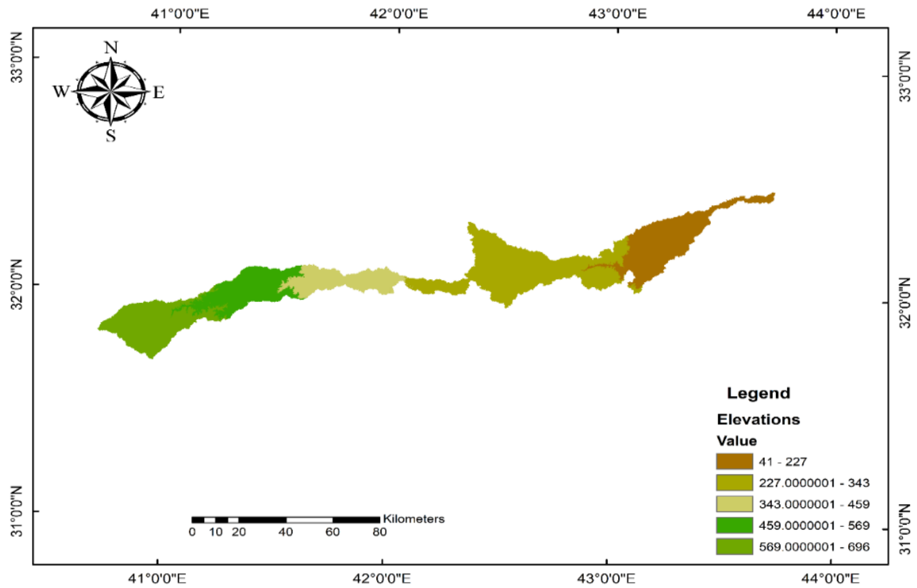

Figure 3. The Al-Abyadh Valley digital elevation map inside the research region.

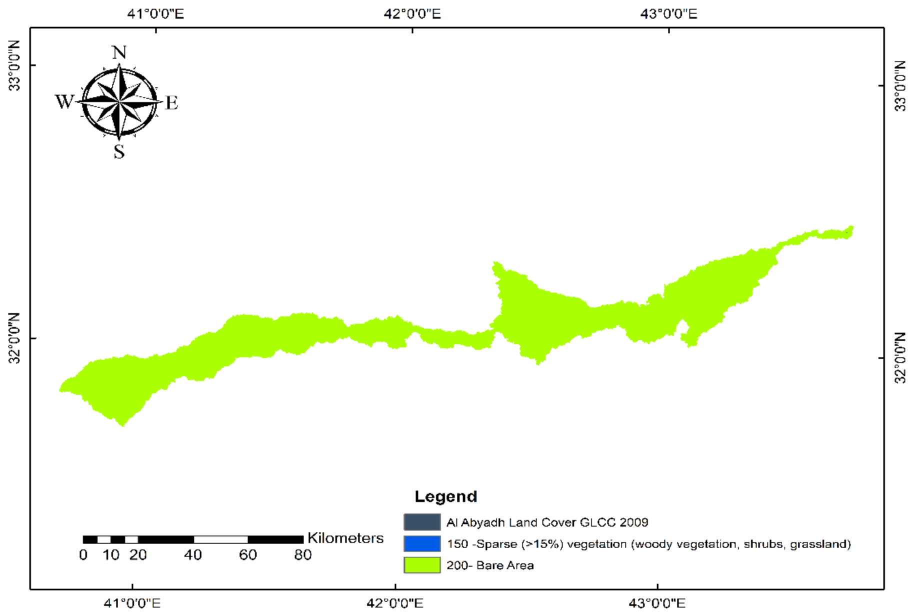

Figure 4. The Al-Abyadh Valley land use map.

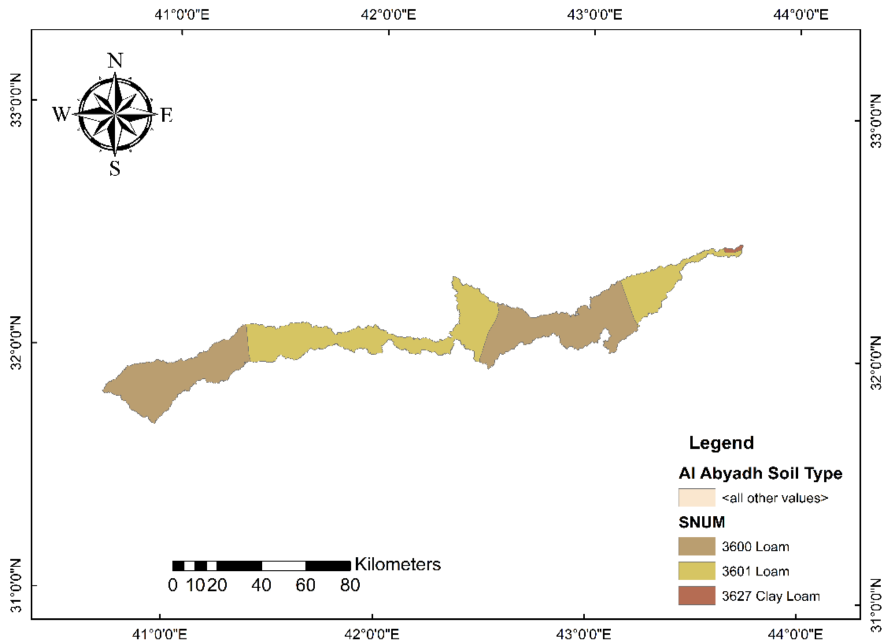

Figure 5. The Al-Abyadh Valley soil map.

2.3.4 Weather Data

Accurate weather data, including humidity, temperature, wind speed, precipitation, and sun radiation, is essential for the HEC_HMS software. **Fig. 6** shows the Iraqi Meteorological Organization and Seismology (IMOS) daily rainfall data for the study region, which includes Rutba, Ramadi, Ain Tamer, and Nakhib, from 2008 to 2022.

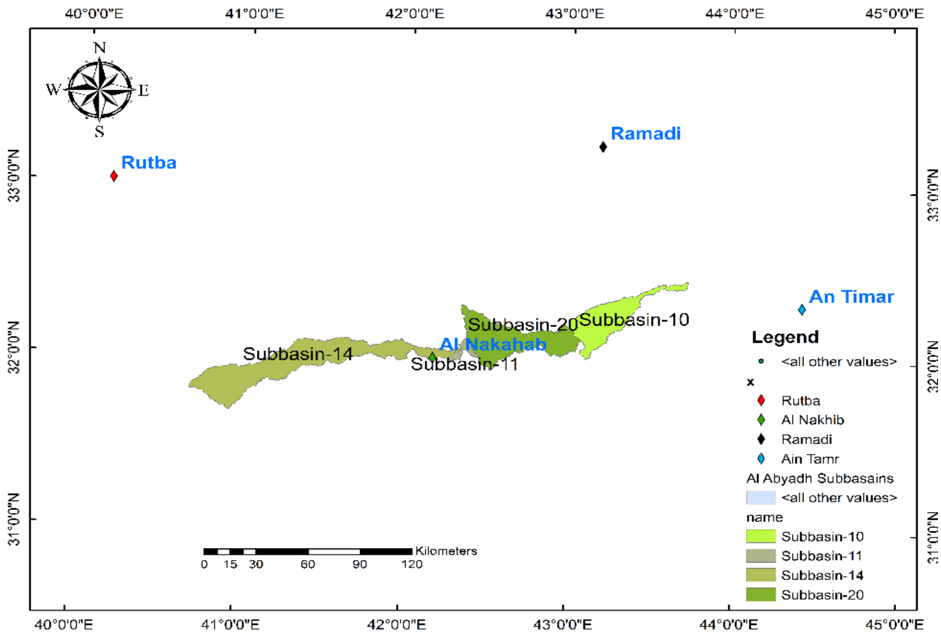

Figure 6. Study region rainfall stations.

2.3.5 Curve Number (CN)

The CN is a valuable and necessary input for the Hydrologic Engineering Centre's Hydrologic Modelling System. It was made by combining the study region's soil map information and land use. These curve numbers Describe the subbasin features and assess the hydrological confines of the HEC-HMS model emulation.

3. ESTIMATING PARAMETERS

To evaluate the water harvesting processes, initial estimates of the model parameters were supplied by using complete soil loss and transform models.

3.1 Model of Sub-basins

Understanding the operation of the subbasin mechanism is necessary to comprehend the whole watershed area's subsequent procedure. We could extract each basin's area, longest flow path, and inclination at the study's formation.

3.2 The Numerical Service for Loss Model in Soil Conservation

The basins' leaching losses were calculated using the curve number approach, considering the soil type and vegetation density. You can get the CN values for each sub-basin by using Eq. (1).

$$CN = \frac{\sum AiCNi}{\sum Ai} \quad (1)$$

Ai (km^2) is the sub-basin area, while CNi is the matching curve number. Initial abstraction (Ia) is the metric for pre-runoff losses like water leakage, evaporation of water, surface depression storage, and plant objection. Multiplying the loss coefficient by the potential abstraction S (mm) is multiplied to get Ia (mm); this, according to Eq. (2) and (3), describes the relationship between the curve number and the potential abstraction.

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

$$Ia = 0.2\,S \quad (3)$$

Where:
Ia: Initial abstraction (mm)
S: potential abstraction (mm)
CN: curve number (Without units).

3.3 Model Transform —Hydrograph Method for The Soil Conservation Service Unit

The transformation method, Which necessitates identifying the concentration period to transform rainfall into surface runoff, was calculated using the SCS Unit Hydrograph method. The amount of vegetation, the basins' size, and the ground's angle all play a role. These estimates and computations were based on the equation from NRCS 1997.

$$Tc = \frac{L^{0.8}(S+1)^{0.7}}{1140\,y^{0.5}} \quad (4)$$

Where:
Concentration time is quantified in hours (means TC).
Potential maximum retention in inches (means S).
The average slope of the watershed land % (means Y).
Concentration time multiplied by 0.6 (means Lag time).

4. RESULTS AND DISCUSSION

4.1 Analysis of Subbasins

Using DEM data, we mapped out the pathways and flows that would eventually define the subbasin boundaries. Each sub-basin's flow rate has been calculated using the HEC-HMS program using the DEM-based approach.

4.1.1 Curve Number

The following presents the basins' curve number rate within the study region. A higher quality or denser vegetative cover has an inverse relationship to the curve number, which increases soil infiltration and affects the watershed. According to **Table 2,** most of the soils in the Al-Abyadh valley are type (B).

4.1.2 Lag Time and Time of Concentration (Tc)

Following the conversion of the basin characteristics to the units given in the equation and the application of the delay time equation, the results are shown in **Table 2.** A discovery was made: It is simultaneously recorded for each scenario, including the time to maximum discharge. Basins differed in concentration time and delay time because their paths were different.

Table 2. The sub-basin characteristics of the study region.

Subbasins	10	11	14	20
Station	Ain Tamer, Ramadi, Nakhib	Nakhib	Rutba, Nakhib	Nakhib
Latitude	32.33, 33.27, 32.02	32.02	33.02, 32.02	32.02
Longitude	44.43, 43.19, 42.17	42.17	40.17, 42.17	42.17
Catchment area (km²)	881.56	86.696	2012.5	1208.2
Longest Flow path (km)	106.06	28.33	233.30	112.84
Basin Slope %	4.334	3.055	4.933	3.641
Curve Number CN	86	85	86	86
Potential Retention inches	1.61	1.79	1.63	1.63
Time of concentration (hr)	21.94	9.53	38.88	25.31
Ia (mm)	8.17	9.08	8.27	8.27
Lag time (hrs)	13.16	5.72	23.33	15.19

4.1.3 Generated Thiessen Polygons Method

The data on how the rain stations affected the rainfall used by the Meteorology and Seismic Monitoring Authority of the Ministry of Transport from 2008 to 2022 was determined using the Thiessen polygon method. This data comes from stations (Rutba, Nakhib, Ramadi, and Ain Tamer). **Fig. 7** shows that out of a total area of 4188.96 km^2, the method determined that the Rutba and Nakhib rain stations impacted 2012.5 km^2.

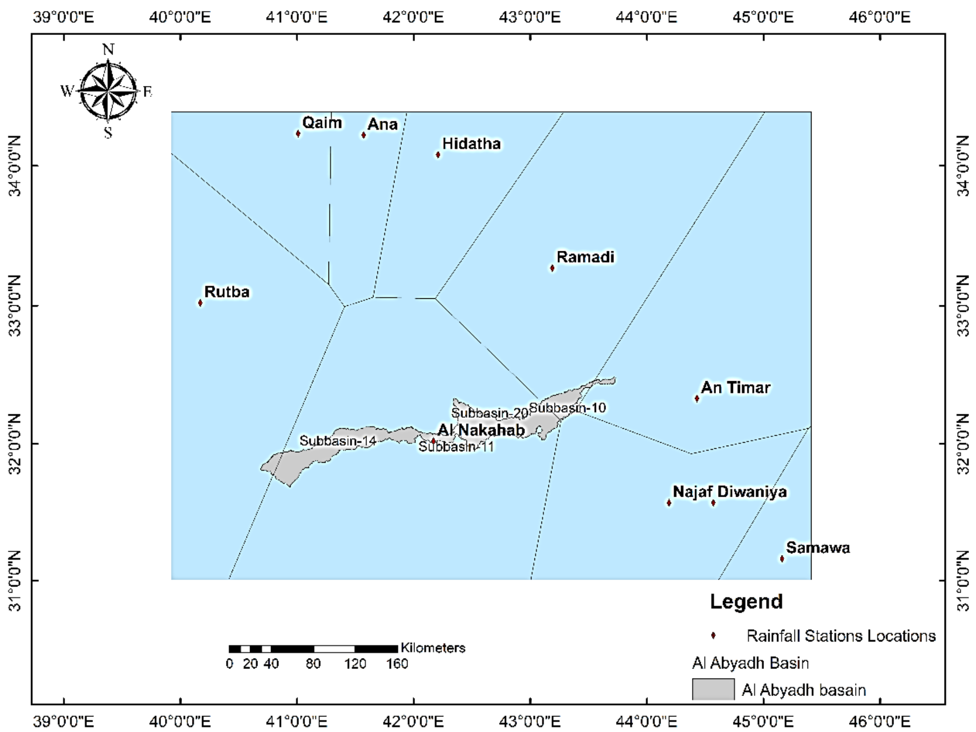

Figure 7. Thiessen polygon method.

The weather station at Nakhib affects a part of the area of subbasin-11- estimated at 86.696 km² out of 4188.96 km² and a part of the area of subbasin-20- estimated at 1208.2 km² out of 4188.96 km². Ain Tamer, Ramadi, and Nakhib rain stations affect a part of the area of subbasin-10- which has an estimated area of 881.56 km² out of 4188.96 km². The results of utilizing According to the HEC-HMS model, the actual rainfall amounts to 1045.69056 mm³.

4.1.4 Discharges Average and at Peak Flow

Table 3 shows the peak flow value for all basins and the durations of each river's draining into the Al-Abyadh valley within the research region.

Table 3. Maximum discharge values (m^3/sec) for the HEC-HMS model throughout the study period (2010).

Values of maximum flow (m³/sec) during 2010.		Value	Date
Sub-Basin, Reach	**Reach1**	1265.8	26 Mar2010.
	Reach 4	1265.8	26 Mar2010.
	Reach 5	532.7	10Nov2020.
	Sink-1	12102.9	26 Mar2010.
	Subbasin 10	425.0	23Feb2022.
	Subbasin 11	933.6	26Mar 2010.
	Subbasin 14	532.7	10Nov2020.
	Subbasin 20	11312.5	26 Mar2010.

4.2 Selecting Appropriate Location for Water-Harvesting Dams

The final maps show the most suitable locations for building water-collecting dams in Valley Al-Abyadh and its four basins based on analyzing the area's geology, hydrology, and surface topography **Figs. 8 to 11**. Four potential dams can collect water.

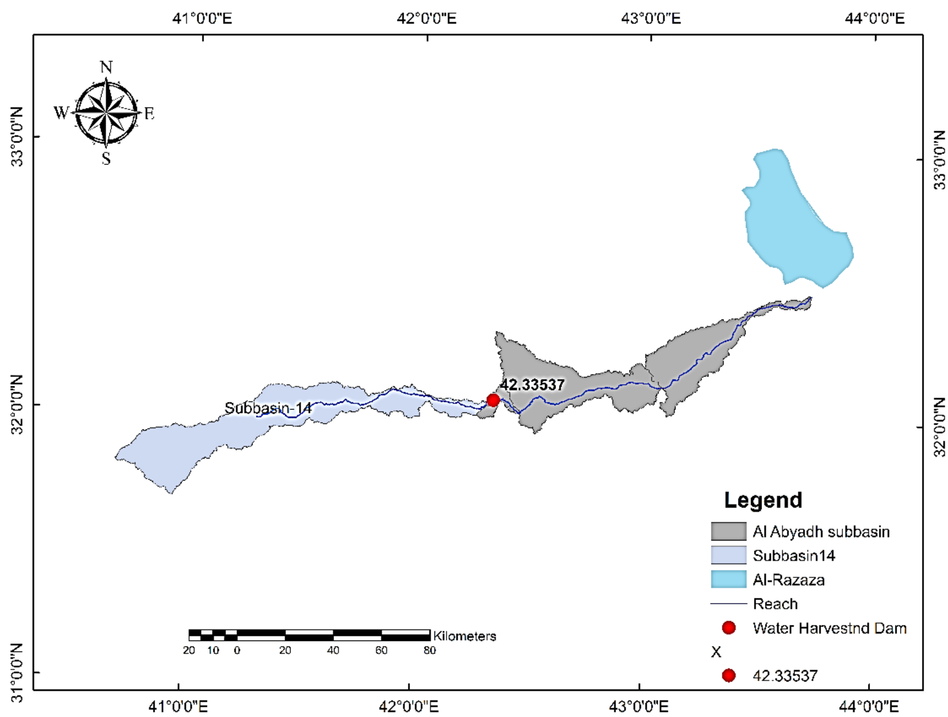

Figure 8. Rainwater harvesting dam for (subbasin 14)

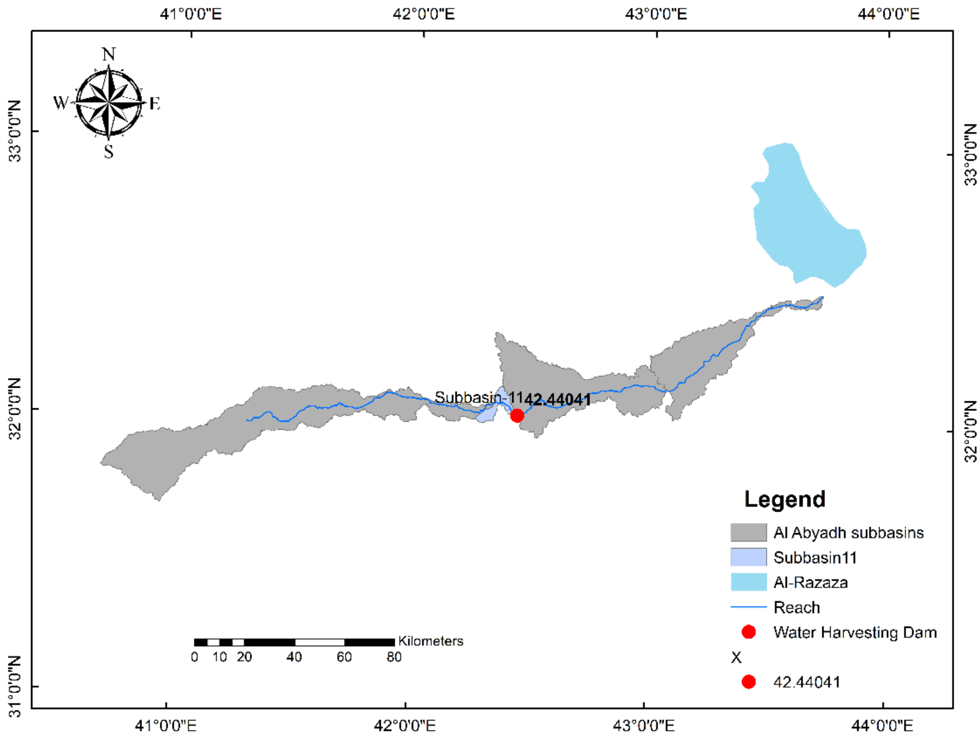

Figure 9. Rainwater harvesting dam for (subbasin 11).

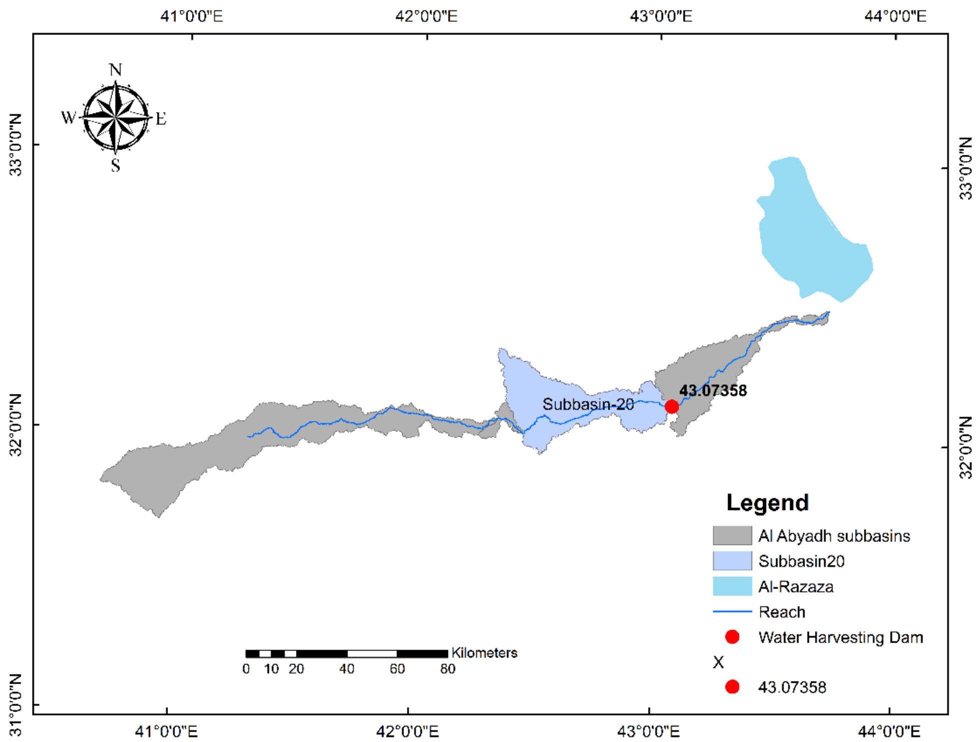

Figure 10. Rainwater harvesting dam for (subbasin 20).

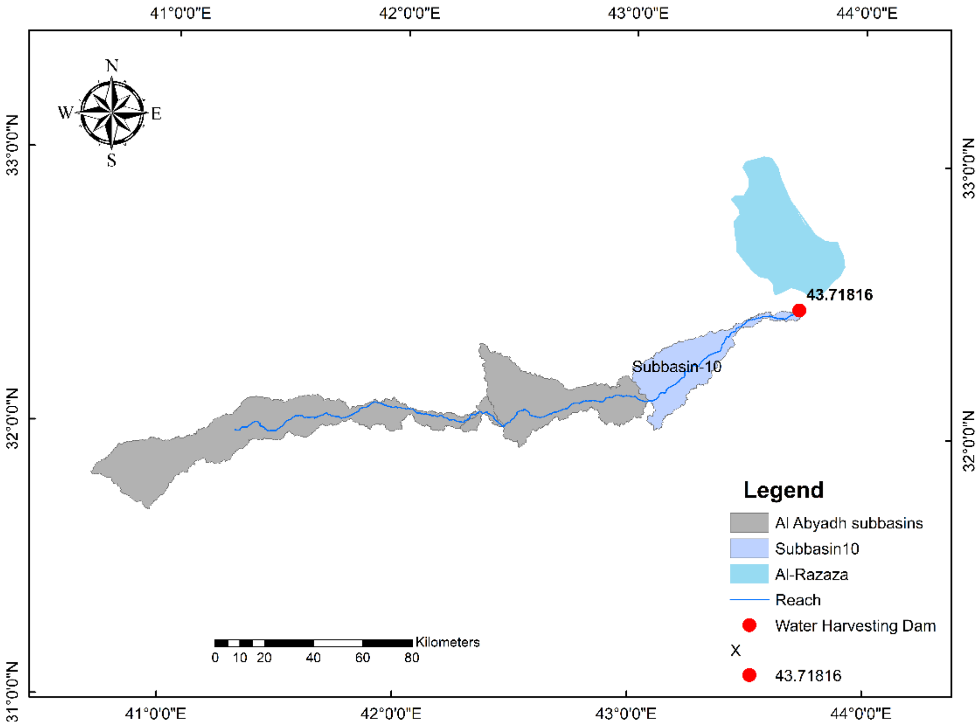

Figure 11. Rainwater harvesting dam for (subbasin 10).

4.3 Storage Capacity

As shown in **Table 4**, all four of Al-Abyadh Valley's sub-basins have dams that collect rainwater and have a peak storage water quantity.

Table 4. Peak quantity of storage (million m^3) for Valley Al-Ubydh of (HEC-HMS) model.

Sub-basins	quantity of storage (million m^3)
10	65.0074
11	42.820
14	46.276
20	63.193

5. CONCLUSIONS

Experts say that the current water shortage in Iraq will only worsen. Water collection methods will be useful in preventing or mitigating this problem. Locations in the Al Abyadh valley in western Iraq's Al Anbar region exhibit unique hydrological and geomorphological features. It was proposed that these spots be used to construct little dams to collect and retain rainfall. Using the HEC-HMS, we could choose the dam sites and calculate their storage capacities. To choose minor dams for catchment regions, use the Hydrologic Modeling System software developed by the Hydrologic Engineering Center with GIS capabilities. For the Al-Abyadh valley, this software models rainfall-runoff processes and makes discharge flow predictions. Here are the key takeaways from the study:

1- The four sub-basins of Valley Al-Abyadh vary in Area and water retention capacity.

2- The opportunity to build dams that collect water for later use due to beneficial water drainage.
3- There are four good spots to build dams, so you cany collect water from four different sources.
4- The first dam had a suitable storage capacity of 65.00736 M m^3, the second dam of 42.81984 M m^3, the third of 46.27584 M m^3, and the fourth of 63.19296 M m^3.
5- The construction of dams for water harvesting will impact Razaza Reservoir's quality and the sources from which it draws water.

NOMENCLATURE

Symbol	Description	Symbol	Description
CN	Curve number, Without units.	M m^3	Volume, million cubic meters.
Hrs	Time, hours.	M^2	Area, square meters.
Mm	Initial abstraction, millimeters.	min	Time, minutes.
Km	Length, kilometers.	mm	Initial abstraction, millimeters.
Km^2	Area, square kilometers.	Sec	Time, seconds.

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Credit Authorship Contribution Statement

Haneen A. Mohammed and Basim Sh. Abed: Writing – review & editing, Writing – original draft, Validation, Methodology.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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الجدوى لانشاء سدود حصاد المياه في وادي الابيض غرب العراق

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الخلاصة

تعتبر تقنيات حصاد المياه إحدى الحلول الممكنة لصعوبات المياه التي يواجهها العراق بسبب تغير المناخ والسدود في أعالي الأنهار، والتي عرضت العالم لجفاف شديد. حصاد المياه هو جمع المياه عند نقطة معينة بدأ من لحظة وصول مياه الأمطار الى الأرض والحفاظ عليها عن طريق بناء سدود لتخزين المياه. تقع منطقة الدراسة (وادي الابيض) في الصحراء الغربية من محافظة الانبار وتبلغ مساحته الاجمالية 4188,96 كيلومتر مربع وطول 268كم تدخل المياه الى وادي الابيض عبر اربعة احواض. تهدف الدراسة الى اجراء دراسة هيدرولوجية وتحليل بيانات الاحواض الاربعة باستخدام برنامجHEC–HMS لتحديد المواقع الامثل لسدود حصاد المياه وقدرتها التخزينية. وقد تم تحليل الخرائط باستخدام برنامج ArcGIS الاصدار 10,8 مع HEC–HMS الاصدار 4,11. تم الحصول على بيانات هطول الامطار الفعلية من هيئة الأرصاد الجوية والرصد الزلزالي للفترة (2008–2022). اظهرت عمليات المحاكاة باستخدام بيانات هطول الأمطار الحقيقية أن أكبر سعة خزنية داخل وادي الابيض يبلغ 1045,69056 مليون م^3 تم العمل على احواض وادي الابيض كسدود لحصاد المياه وتم تحقيقالسعة التخزينية القصوى لكل حوض على التوالي10,20,11,14 (46,27584 مليون م^3 ،42,81984 مليون م^3 ،63,19296 مليون م^3 ،65,00736 مليون م^3). وتشير الدراسة الى امكانية استخدام المياه من سدود حصاد المياه في وادي الابيض ، حيث انها تمتع بأكبر سعة تخزينية من سدود حصاد المياه واقل معدل خسارة .

الكلمات المفتاحية: النمذجة، برنامج النمذجة الهيدرولوجية، وادي الابيض، الصحراء الغربية، سدود حصاد المياه.