INTERNATIONAL JOURNAL OF LATEST TECHNOLOGY IN ENGINEERING, MANAGEMENT & APPLIED SCIENCE (IJLTEMAS)

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XIV, Issue V, May 2025

HEC-HMS Based Rainfall-Runoff Model for Araku Valley, Visakhapatnam, Andhra Pradesh, India

Anikul Islam[1], Dr. Kiran Jalem[2]

[1]Department of Geoinformatics, Central University of Jharkhand, India

[2]Assistant Professor, Department of Geoinformatics, Central University of Jharkhand, India

DOI: https://doi.org/10.51583/IJLTEMAS.2025.140500123

Received: 12 June 2025; Accepted: 14 June 2025; Published: 28 June 2025

I. Introduction

It has become necessary to estimate the quantities of runoff by knowing the amount of rainfall tocalculate the required quantities of water storage in river basin and to determine the likelihood of amount of discharge. The present study deals with the development of a hydrological model named Hydrologic Engineering Centre (HEC-HMS), which uses Digital Elevation Models (DEM). This hydrological model was used by means of the Geospatial Hydrologic Modeling Extension (HEC-GeoHMS) and Geographical Information Systems (GIS) to identify the discharge of the Araku valley catchment of Vishakhapatnam by simulated rainfall-runoff processes. The meteorological models were developed within the HEC-HMS from the recorded daily rainfall data for the hydrological years 2023. The control specifications were defined for the specified period and one day time step. The Deficit and Constant method, Clark Unit Hydrograph and Muskingum methods were used for loss, transformation and routing calculations, respectively.

Hydrologic Engineering Centre (HEC-HMS) is hydrologic modeling software developed by the US Army Corps of Engineers of the Hydrologic Engineering Centre (HEC), which contains an integrated tool for modeling hydrologic processes of dendritic watershed systems. This model consists of several components for processing rainfall loss, direct runoffs and routing. The HEC-HMS model has been widely used, for example, in many hydrological studies because of its simplicity and capability to be used in common methods.

The Geospatial Hydrologic Modeling Extension (HEC-GeoHMS) is a public-domain software package for use with Geographical Information Systems (GIS), GeoHMS ArcView and Spatial Analysis to develop several hydrological modeling inputs. After analysing the information of the Digital Elevation Model (DEM), HEC-GeoHMS transforms the drainage paths and watershed boundaries into a hydrologic data structure that represents the watershed response to rainfall.

Study Area

In this field report we have selected the Araku Valley for Rainfall Run-off modelling usingDigital Elevation Model (DEM file) and rainfall over Vishakhapatnam from IMD data. Lat long Extension of the study area is 18-degree 11 minutes to 18-degree 22 minutes and 82-degree 44 minutes to 83degree.

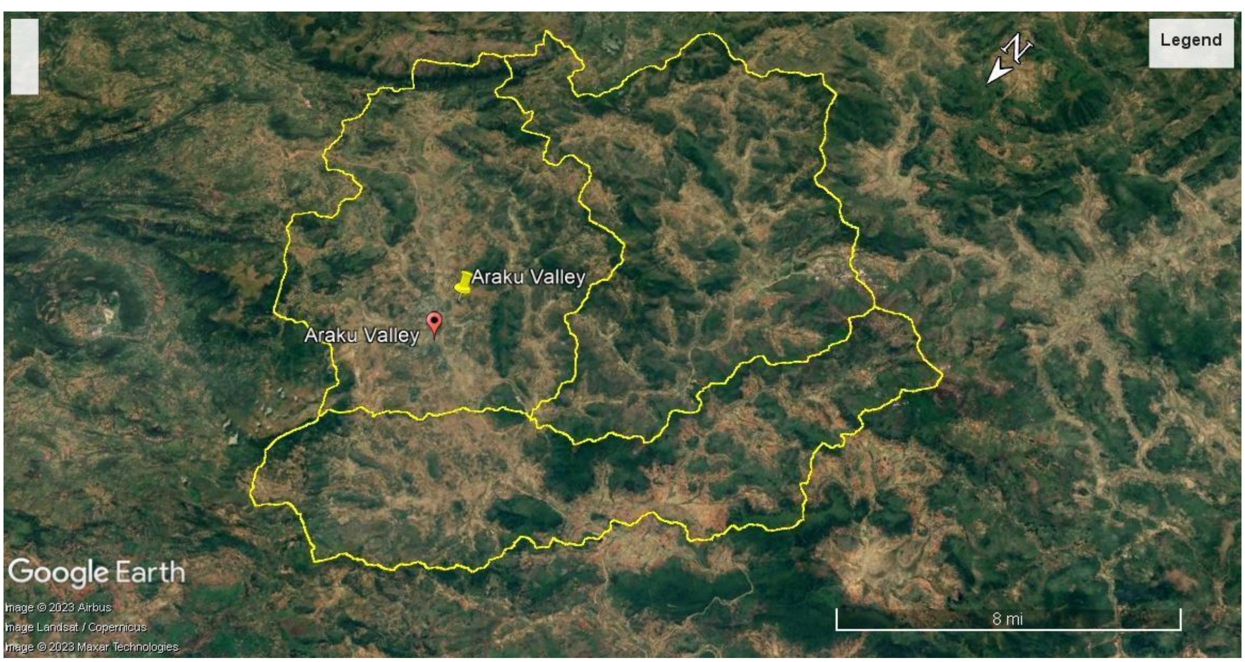


Fig.1: Satellite View of Araku Valley Watershed Boundary

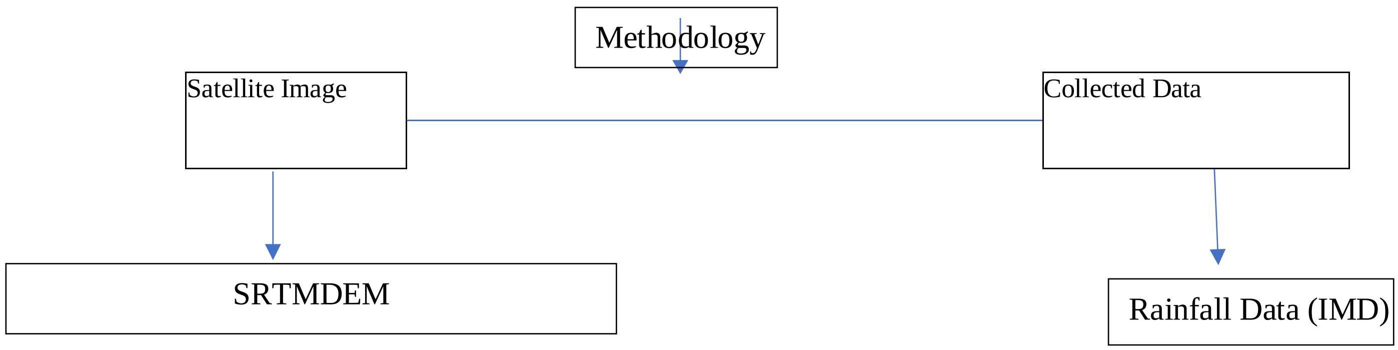
ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XIV, Issue V, May 2025

Araku Valley is a hill station and a Mandal in Visakhapatnam district in the Indian state of Andhra Pradesh. Araku Valley a part of Eastern Ghats and is known as the 'Land of Red Soil' nestled at an altitude of 1166 meter (3084 ft) above sea level and surrounded by Silver, Oak, Pine and Eucalyptus Trees on all side. The scenic beauty of the region comes alive with its natural landscapes. Arakuis spread over an area of about 36 sq. km. Araku Valley is perched with thick greenery of jungles all over, in between small ponds, coffee gardens. The highest point of Araku Valley is ArakuValley top and it offers panoramic view of the whole region.

Data used and methodology:

Used SRTM DEM with spatial resolution of 30-meter. SRTM DEM for the study area was downloaded from Google Earth Engine by Java script in GeoTIFF image format, in Degree, minute, second and datum WGS84.The data were then projected to UTM coordinate system zone 44 N.

Information about drainage networks could be available from topographic maps, but developments in satellite image techniques provide elevation models that derive drainage networks with higher accuracy.



Software used:

In this study, two softwares: (i) ArcGIS 10.8 and (ii) HEC-HMS (Hydrologic EngineeringCentre-Hydrologic Modelling System) were used to generate all models.

Result and Discussion:

A runoff model, also known as a hydrological model or rainfall-runoff model, is a mathematical representation of the processes involved in the transformation of precipitation into runoff within a watershed or catchment area. It simulates the movement of water through various components of the hydrological cycle, including infiltration, evapotranspiration, surface runoff, and groundwater flow.

Morphometric analysis of sub-basin

Morphometric analysis of a sub-basin typically involves the quantitative study of the physical characteristics of the drainage basin or watershed. These characteristics include parameters related to the shape, size, relief, and drainage pattern of the basin. In the output high drainage density denoted by sub-basin 2 (0.12807) and elongation ratio which determines the steepness and elevation of the topography. So, high elongation ratio of the selected sub-basin belongs from sub-basin 3 (0.6332) which denotes highly elevated region, it has been proved from basin relief 785ft (highest). Table 1 showing further details of sub-basin.

Table1: Morphometric Analysis

Subbasin	Longest Flowpath Length (MI)	Longest Flowpath Slope (FT/FT)	Centroidal Flowpath Length (MI)	Centroidal Flowpath Slope (FT/FT)	10-85 Flowpath Length (MI)	10-85 Flowpath Slope (FT/FT)	Basin Slope (FT/FT)	Basin Relief (FT)	Relief Ratio	Elongation Ratio	Drainage Density (MI/MI²)
Subbasin-1	14.08788	0.00618	6.49066	0.00062	10.56591	0.00134	0.06200	724.00000	0.00973	0.59688	0.01995
Subbasin-2	21.03217	0.00642	12.68390	0.00117	15.77413	0.00205	0.08316	724.00000	0.00652	0.41944	0.12807
Subbasin-3	12.30429	0.00803	1.07849	0.00114	9.22822	0.00302	0.06658	785.99995	0.01210	0.63218	0.09081

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XIV, Issue V, May 2025

Rainfall

For this study, monsoon rainfall of Visakhapatnam from 01 June to 30 September, 2023 was considered for rainfall run-off model. The peak rainfall as exhibited on 26th July 2023 over that time period.

Run-off simulation result: Table 2 has clearly explained the run-off simulation report of the model. Like amount of peak point discharge of water with time and how much drainage area contains each perimeter as sub-basin, reach point and sink point. From this table, we have extracted the peak discharge of the water from that time period, sub-basin 2 has highest discharge, approx. 2355 cubic feet per second of 26thjuly 2023 and total discharged from the sink or outlet of all basins is 6614 CFS.

Table 2: Run-off simulation result from sub-basin 2:

Project: Visag_watershed   Simulation Run: Run 3

Start of Run: 01Jun2023, 00:00   Basin Model: Basin
End of Run: 30Sep2023, 00:00   Meteorologic Model: Met
Compute Time: DATA CHANGED, RECOMPUTE   Control Specifications: Control 1

Show Elements: All Elements   Volume Units: IN / ACRE-FT   Sorting: Alphabetic

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
Junction-1	116.654	4495.7	26Jul2023, 00:00	23.85
Reach-1	116.654	4782.7	26Jul2023, 00:00	23.81
Sink-1	164.175	6614.1	26Jul2023, 00:00	23.82
Subbasin-1	55.533	2140.2	26Jul2023, 00:00	23.85
Subbasin-2	61.121	2355.5	26Jul2023, 00:00	23.85
Subbasin-3	47.521	1831.4	26Jul2023, 00:00	23.85

From the whole study, focus was on sub-basin 2 as that area has been visited. Table 3 has clearly expanded the simulation output of the sub-basin 2. Base flow volume exhibited the amount 12.42 inches which is calculated using linear reservoir method. Loss volume 15.56-inches, Discharge volume 23.85 inches, peak discharge volume of 27.05 inches and discharge 2355.5 CFS on 26thJuly 2023. And finally, direct Runoff volume 11.43 inches during that time period was observed.

Table 3 denotes further details of simulation Runoff model for sub-basin 2.and Fig. 4 also visualized the simulation report with hydrograph. Sub-basin1and sub-basin 3 also visualized for further details. Simulation Result of the Rain fall Run-off mode

Table 3: Simulation report of sub-basin 2

Project: Visag_watershed   Simulation Run: Run 3
Subbasin: Subbasin-2

Start of Run: 01Jun2023, 00:00   Basin Model: Basin
End of Run: 30Sep2023, 00:00   Meteorologic Model: Met
Compute Time: DATA CHANGED, RECOMPUTE   Control Specifications: Control 1

Volume Units: IN / ACRE-FT

Computed Results

Peak Discharge:	2355.5 (CFS)	Date/Time of Peak Discharge:	26Jul2023, 00:00
Precipitation Volume:	27.05 (IN)	Direct Runoff Volume:	11.43 (IN)
Loss Volume:	15.56 (IN)	Baseflow Volume:	12.42 (IN)
Excess Volume:	11.49 (IN)	Discharge Volume:	23.85 (IN)

Table 4: Simulation report of sub-basin 1

Project: Visag_watershed   Simulation Run: Run 3

Subbasin: Subbasin-1

Start of Run: 01Jun2023, 00:00   Basin Model: Basin
End of Run: 30Sep2023, 00:00   Meteorologic Model: Met
Compute Time: DATA CHANGED, RECOMPUTE   Control Specifications: Control 1

Volume Units: IN / ACRE-FT

Computed Results

Peak Discharge:	2140.2 (CFS)	Date/Time of Peak Discharge:	26Jul2023, 00:00
Precipitation Volume:	27.05 (IN)	Direct Runoff Volume:	11.43 (IN)
Loss Volume:	15.56 (IN)	Baseflow Volume:	12.42 (IN)
Excess Volume:	11.49 (IN)	Discharge Volume:	23.85 (IN)

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XIV, Issue V, May 2025

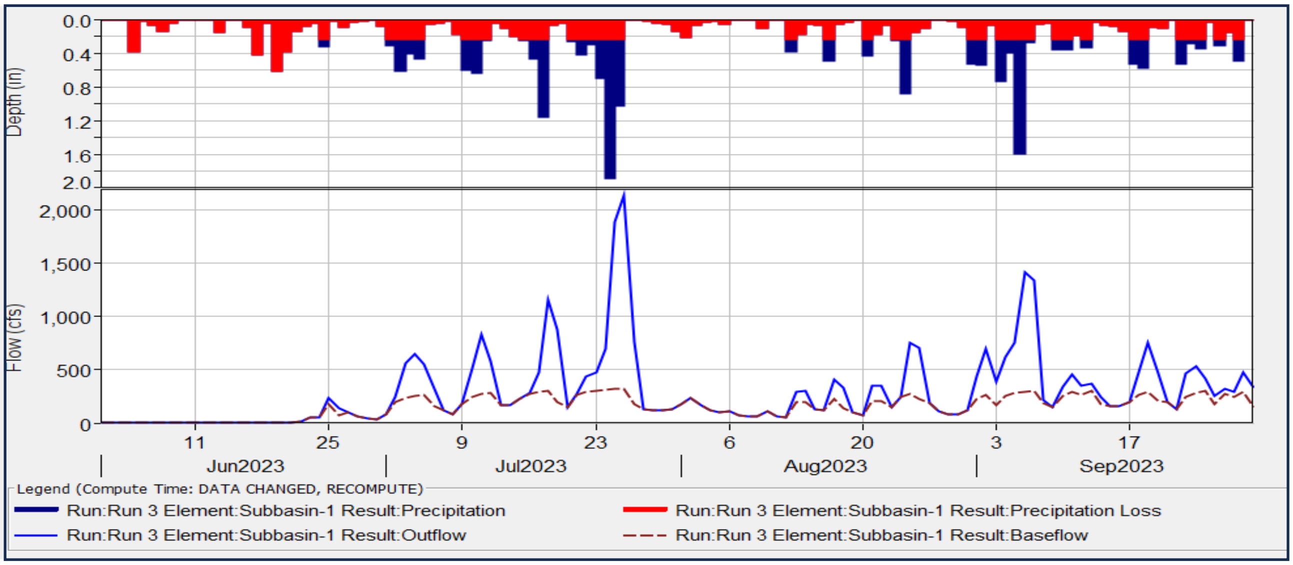


Fig. 5: Graph showing runoff details of sub-basin 1

Table 5: Simulation report of sub-basin

Project: Visag_watershed   Simulation Run: Run 3

Subbasin: Subbasin-3

Start of Run:	01Jun2023, 00:00	Basin Model:	Basin
End of Run:	30Sep2023, 00:00	Meteorologic Model:	Met
Compute Time:	DATA CHANGED, RECOMPUTE	Control Specifications:	Control 1

Volume Units: IN ACRE-FT

Computed Results

Peak Discharge:	1831.4 (CFS)	Date/Time of Peak Discharge:	26Jul2023, 00:00
Precipitation Volume:	27.05 (IN)	Direct Runoff Volume:	11.43 (IN)
Loss Volume:	15.56 (IN)	Baseflow Volume:	12.42 (IN)
Excess Volume:	11.49 (IN)	Discharge Volume:	23.85 (IN)

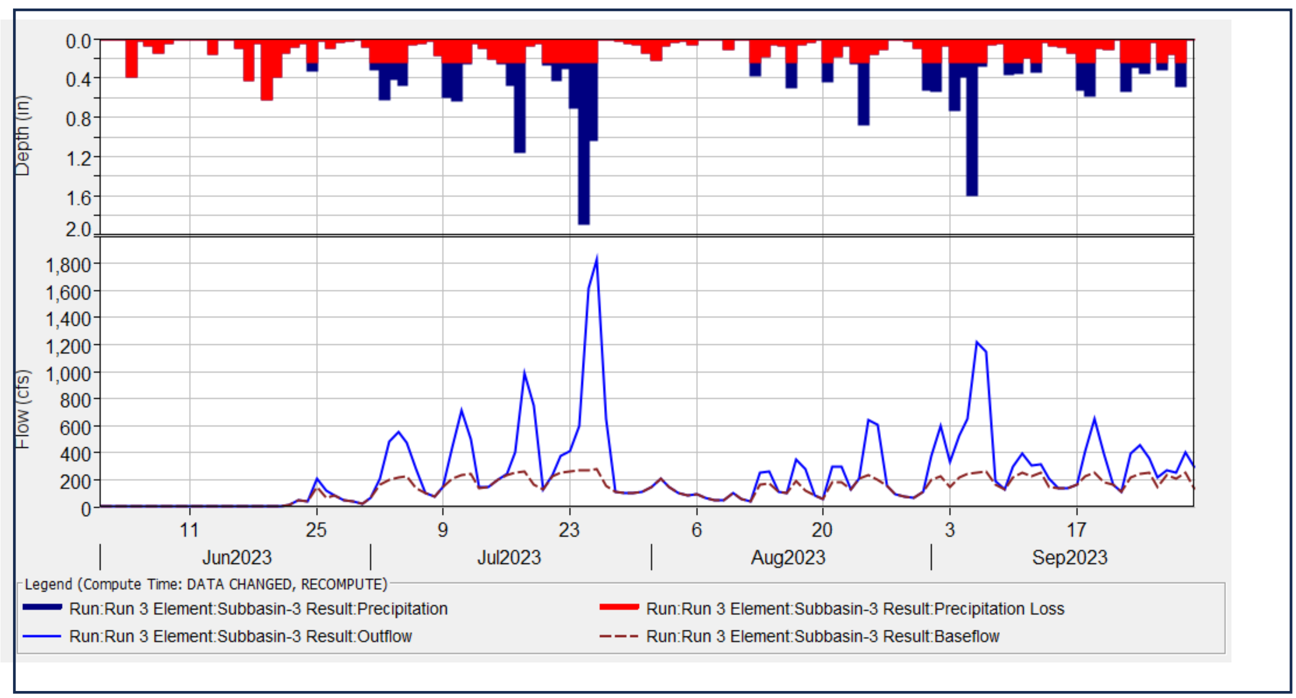


Fig. 6: Graph showing runoff details of sub-basin 1

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XIV, Issue V, May 2025

Run-off simulation result from outlet sink: Table 6 denoted the Runoff details of outlet sink point before the calibration of that time period. Computed peak discharge from the sink is 6614 cubic feet per second at the time on 26th July 2023 and volume 23.82 inches before calibration of the model and table 7 showing after the calibration of the model the amount peak discharge of the sink 6704 CFS and volume 24.4 inches.

Table 6: Simulation report of outlet sink before maximum optimization


Project: Visag_watershed Simulation Run: Run 4

Sink: Sink-1

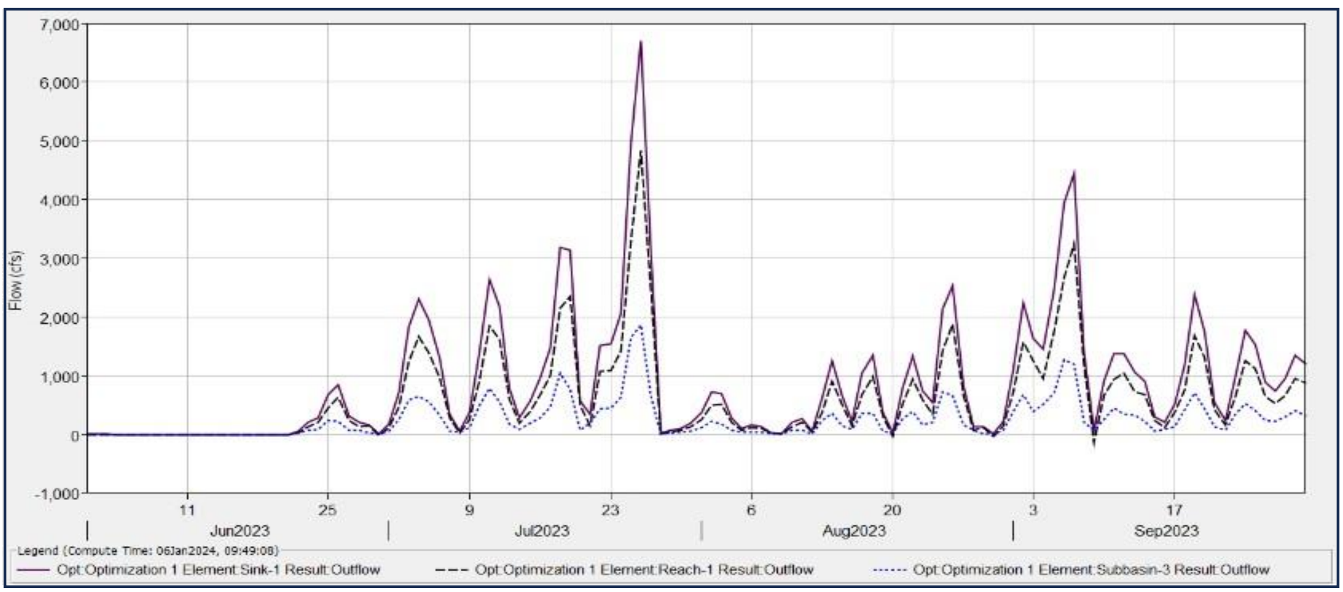
Start of Run: 01Jun2023, 00:00 Basin Model: Basin
End of Run: 30Sep2023, 00:00 Meteorologic Model: Met
Compute Time:DATA CHANGED, RECOMPUTE Control Specifications:Control 1

Volume Units: IN ACRE-FT

Computed Results

Peak Discharge:6614.1 (CFS) Date/Time of Peak Discharge26Jul2023, 00:00
Volume: 23.82 (IN)

Fig. 8: Graph showing runoff details from outlet sink before optimization



II. Conclusion

In conclusion, the implementation of the rainfall-runoff model using HEC- HMS for the Araku watershed has provided valuable insights into the hydrological dynamics of the area. Through a comprehensive approach that involved data collection, model setup, calibration, and scenario analysis, we have gained a deeper understanding of how the watershed responds to rainfall events. This model ensured that the model accurately represents observed stream flow data, enhancing its reliability for future predictions. The sensitivity analysis shed light on the key parameters influencing the model's performance, contributing to the robustness of the simulation results. The results obtained, including hydrographs, peak flow analyses, and volume assessments, serve as a foundation for informed decision-making. By identifying patterns and trends, stakeholders can devise effective flood mitigation measures, sustainable land use planning, and climate change adaptation strategies.

Reference:

1. Al Ansari, N. Management of water resources in Iraq: Perspectives and prognoses. *Engineering* **2013**, *5*, 667–684.
2. Abbas, N.; Wasimia, S.A.; Al-Ansari, N. Assessment of climate change impacts on water resources of Al-Adhaim, Iraq using SWAT model. *Engineering* **2016**, *8*, 716–732.
3. Rahi, K.A.; Al-Madhhachi, A.-S.T.; Al-Husseini, S.N. Assessment of Surface Water Resources of Eastern Iraq. *Hydrology* **2019**, *6*, 57.
4. Jia, Y.; Zhao, H.; Niu, C.; Jiang, Y.; Gan, H.; Xing, Z.; Zhao, X.; Zhao, Z. A WebGIS-based systemforrainfall-

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XIV, Issue V, May 2025

runoffpredictionandreal-timewaterresourcesassessmentforBeijing. *Comput. Geosci.* **2009**, *35*, 1517–1528.

5. Halwatura, D.; Najim, M. Application of the HEC-HMS model for runoff simulation in a tropical catchment. *Environ. Modell. Softw.* **2013**, *46*, 155–162.
6. E.Ismail,"FlashFloodHazardMappingUsingSatelliteImagesandGISTools:Acasestudyof Najran City, Kingdom of Saudi Arabia (KSA)."
7. G.D. Bhatt , S. Komal , P.K. Deka , K. Ajay"Flood Hazard and Risk Assessment in ChamoliDistrict, Uttarakhand Using Satellite Remote Sensing and GIS Techniques."
8. L.Dénes,C.SzabolcsandP.Ervin,"FlashFloodHazards."
9. Bapalu,G.V.,Sinha,R.,2005."GISinfloodhazardmapping:acasestudyofKosiRiverBasin, India."
10. Hamdan,A.N.A.,Almuktar,S.A.,&Scholz,M.(2021).Rainfall-RunoffmodelingusingtheHEC- HMS model for the Al-Adhaim River catchment, northern Iraq. Hydrology, 8(2), 58. https://doi.org/10.3390/hydrology8020058
11. Ranjan,S.,&Singh,V.P.(2022).HEC-HMSbasedrainfall-runoffmodelforPunpunriverbasin. Water Practice & Technology, 17(5), 986–1001. https://doi.org/10.2166/wpt.2022.033
12. Selecting a transform method. (n.d.).https://www.hec.usace.army.mil/confluence/hmsdocs/hmsum/4.8/subbasin-elements/selecting-a-transform-method
13. Applying the Muskingum routing method. (n.d.). https://www.hec.usace.army.mil/confluence/hmsdocs/hmsguides/applying-reach-routing-methods-within-hec-hms/applying-the-muskingum-routing-method