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Rainfall-Runoff Process of Pallikaranai Marshland Under the Influence of Perungudi Landfill Site using HEC–HMS

A. Harinadha Babu, N. Kumara Swamy, S. Krishnaiah

***Abstract:** The Wetland River basins are one of the critical urban watershed areas due to complex urban activities. The rainfall-runoff process in urban catchment areas is influenced by solid waste dumping, leachate generation from dumping sites, aquatic weeds, sewage generated by municipalities and town panchayats, effluents generated by industries, sand mining along riverbeds, and encroachment due to urban activities. Considering these complexities, this study aims to predict stream flow in a river basin for a given amount of rainfall using HEC-HMS software models. The sub-basin elements are used to convert rainfall to runoff. A meteorological model is used to assign the boundary conditions for sub-basins, which include precipitation, short-wave and long-wave radiation, and potential evapotranspiration. A time series of flow data is used as input to a model to estimate the average annual rainfall in the basin. Calibrate the model, as it's required for optimisation to be carried out using observed discharge. As a result, considering the three sub-basins and two reach sites, the increase in drainage area is directly proportional to excess volume, direct runoff volume, and discharge volume. The reliability of the model is achieved using both observed data and predicted data.*

***Keywords:** Basin Model, Hydrologic Elements, Rainfall, Run-off, River Basin.*

I. INTRODUCTION

The state of Tamil Nadu in India has been known for its susceptibility to urban flooding. Among the states of India, Chennai ranks as the 7th most vulnerable city to extreme flooding and cyclones. In November 2021, Chennai experienced a devastating month of flooding, with four weeks of rainfall totalling 1000 mm, preceded by catastrophic floods in December 2015 that set a record of 1049 mm. A study conducted by Care Earth Trust, a biodiversity research organisation, reveals that Chennai's built-up area expanded from 47 Km^2 in 1980 to 402 Km^2 in 2012, while wetlands declined from 186 Km^2 to 71 Km^2.

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**Correspondence Author(s)*

A. Harinadha Babu*, Research Scholar, Jawaharlal Nehru Technological University, Anantapuramu (JNTUA), Ananthapuramu, India. E-mail: harinadhababume@gmail.com, ORCID ID: 0009-0000-6957-2582

Dr. N. Kumara Swamy, Dean & Professor, Department of Civil Engineering, Vasireddy Venkatadri Institute of Technology, Guntur, India. E-mail: kumaraswamy41@gmail.com

Prof. S. Krishnaiah, Professor, Department of Civil Engineering, JNTUA College of Engineering -Anantapuramu, Kalikiri, India. E-mail: sankranthi@rediffmail.com

While analysing the ongoing infrastructure development, the city has 30,000 internal roads and 471 bus routes, which account for approximately 5,000 km and 300 km, respectively. Still, the city's drainage network covers just around 2,000 km, and most of these drains were built at least three decades ago, which were designed for 20 mm/hr, whereas the new drains are being constructed for 70 mm/hr.

II. STUDY AREA

Pallikaranai marsh is a freshwater swamp located in the south of Chennai, known as the only urban natural wetland in the city. The wetland, which covered an area of 50 sq km in 1995, had shrunk to 5.9 sq km by 2007 and is now reduced to 3.17 sq km. The prominent uniqueness of the marshland lies in its original course, the presence of water-washed rocks, and its hydrology. The exact location of Marsh Land is 12.949371N latitude and 80.218184E longitude. Velachery, Medavakkam, Kovilambakkam, and Okkiyam Thoraipakkam surrounded it on the north, south, west, and eastern sides, respectively. According to the Tamil Nadu State Wetland Authority, Pallikaranai marsh drains an area of 250 km² in south Chennai, surrounding 65 wetlands through its two outlets, namely Okkiyam Madavu and the Kovalam Creek, and finally joins the Bay of Bengal. Okkiyam Madavu is situated in the southern suburbs of Chennai, where water from the Pallikaranai marshland is collected into this water channel and then drained into the Buckingham Canal. The north and south portions, namely Velachery and Medavakkam, drain the water into the marshland. Residential and institutional buildings occupy the southern and western boundaries, while the north and eastern sides are categorised as areas of human habitation and public infrastructure. Mainly, it receives annual rainfall during the Northeast monsoon (October–November) of 1300 mm and also during the Southwest monsoon (June-August). In the study area, the temperature ranges from 35 °C to 42 °C in the summer season and from 25 °C to 34 °C in the winter season. Generally, the terrain of the area is classified as plain, and the most southern parts of the Chennai soil type consist of alluvium and granite gneiss. The entire marshland is comprised of coastal plains and has overlapping habitats. In Chennai, wetlands and river bodies are preferred locations for the dumping of solid waste and the discharge of domestic sewage and industrial effluents. This environmentally significant wetland is used as a waste dump yard, occupying 250 acres of prime land and receiving 6,000 metric tons of waste per day for storage and disposal.

The Perungudi sewage treatment plant is located adjacent to a waste dump yard that treats domestic and industrial effluents. The resulting leachate from the dump yard and treated effluents migrate approximately 1.5 km horizontally and up to a depth of 100 m vertically, polluting both the ground and surface water systems.

III. METHODOLOGY

The present study aims to develop a rainfall-runoff model for the Adyar basin using available data.

A. HEC-HMS Model

HEC-HMS (Hydrologic Engineering Centre – Hydrological Modelling System) is an open-source software developed for the U.S. Army Corps of Engineers in 1998 for simulating floods of a particular duration in a watershed system. To describe the rainfall-runoff processes in this model, it requires various hydrologic elements of the basin. The model arrangements consist of three main models: the Basin model, the Meteorological model, and the Control specifications. The input data includes time series, paired, and gridded data.

Basin Model: In any drainage system, the basin model helps convert atmospheric conditions into streamflow at the required locations. Hydrologic elements represent the physical process of water movement in the drainage system. The primary elements of basin models are Subbasin, reservoir, reach, junction, diversion, source, and sink. (Salah Ud Din, 2019, [2]) and (U.S Army Corps of Engineers, 2000, [6]).

Meteorological Model: Assigning the boundary conditions for sub-basins during a simulation, this model is useful.

Control Specification Manager: It is used to execute time series data during simulation, starting and stopping at specific conditions, as well as assigning time intervals.

B. Digital Elevation Model

A 3D digital representation of a digital elevation model can be used to demonstrate the topography of a watershed. The surface features that can be extracted from a DEM include drainage boundaries, elevation, rivers, and flow directions, which enable the examination of the watershed's characteristics. In this study, DEM data is used to determine the flood path distribution, quantify flood depth, perform grid size analysis, and simulate extreme rainfall using Shuttle Radar Topography Mission (SRTM) data. The various hydrology tools in ArcGIS can be applied individually or in sequence to create a stream network and delineate watersheds.

Fig. 1: Study Area Map

C. Basin Model

It is used for stream network connectivity and to simulate the hydrological model. The first step is to prepare a Digital Elevation Model (DEM) without pits before using it in hydrological modelling. These pits are cells that accumulate in the water when drainage patterns are disrupted. By using the sink-filling algorithm, the pits were removed from the DEM. After filling sinks, a flow direction map was simulated by encoding eight possible flow directions in each cell. A flow accumulation map was then generated using the flow direction. After that, it is used to identify the stream network of the basin, which is divided into various segments that determine the basin's outlet. The final process is the delineation process, which delineates the basin into sub-basins (Mrugaxi Sheth, 2018,[1]) and (Salah Ud Din, 2019, [2]).

The methods available for converting rainfall to runoff and routing the runoff through the stream network are listed in Table I.

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Table I: Simulation Method for Basin

S. No.	Model	Methods	Categorization
1	Sub-basin Loss	SCS Curve Number method	Event, Lumped, Empirical, and Fitted parameter model
2	Sub-basin Transformation	SCS Unit Hydrograph	
3	Reach Routing	Muskingum	
4	Sub-basin Precipitation	Specified Hyetograph	

D. Estimation of Model Parameters

a. Loss Model

The Soil conservation service curve number (SCS CN) method was developed in 1954 and it is documented in Section 4 of the NEH-4 (National Engineering Handbook) which was published by Soil Conservation Service (Now NRCS - Natural Resources Conservation Service) and is widely used to estimate the direct runoff from the rainfall quantity. The SCS model is empirical and requires only a single parameter – a curve number that indicates the entire hydrological impact of land use. This method is developed for determining excess runoff from precipitation depth in a particular area. The SCS–CN method categorises precipitation into three categories. They are Direct runoff (Q), Actual retention (S), and Initial abstraction (Ia) (C.P.Shankar ., 2018, [3]).

b. Curve Number (CN)

CN is a runoff curve number, and an indicator of land impermeability, is a dimensionless number defined such that $0 \leq CN \leq 100$.

For impervious and water surfaces, CN = 100

For natural surfaces, CN < 100.

Generally, CN is a function of runoff-producing catchment properties such as Hydrologic soil group, land use and land cover, Ground Surface condition, and Antecedent moisture condition. (A.N.A.Hamdan, 2021, [4]).

Hydrological Soil data and land use data sets were used to calculate the CN grid using QGIS, which is required for building the hydrological model. The sub-basin shape file from HEC-HMS and the CN grid are used as inputs in zonal statistics to get an average CN for each sub-basin.

The second most important parameter in the loss model is Initial Abstraction (Ia). It accounts for all losses, including infiltration, interception, evaporation, and surface depression storage, before the occurrence of runoff. The value of initial abstraction is determined by Equations 1 and 2.

$$\text{Initial abstraction (Ia)} = 0.2S \tag{1}$$

$$S = \left(\frac{25400}{CN}\right) - 254 \tag{2}$$

Where

S = Maximum Potential retention

CN = Curve Number

Another parameter required in the loss model is the percentage of imperviousness.

c. Transformation Model

This model is also known as the Direct Runoff Model (DRM), which transforms excess rainfall into a direct runoff hydrograph. In this study, the Soil Conservation Service (SCS) Unit Hydrograph model was chosen. The US Soil Conservation Service (Now NRCS) developed a dimensionless unit hydrograph based on watershed analysis. According to the NRCS, this model defines a linear unit hydrograph, which calculates the runoff resulting from net rainfall. This method requires Lag time (Tlag), defined as the time from the centroid of rainfall excess to the centroid of direct runoff. (L.A.Jabbar , 2021, [5]), (US Army Corps of Engineers, 2000, [6]) and (S.Natarajan, 2021, [7]). The following formula is used to define the lag time.

$$\text{Lag Time} = 0.6\ Tc \tag{3}$$

Time of concentration (Tc) – Defined as the time taken by rainfall drops to travel from the farthest point in the watershed to the outlet.

$$T_c = \frac{l^{0.8}(S+1)^{0.7}}{1900Y^{0.5}} \tag{4}$$

$$S = \left(\frac{25400}{CN}\right) - 254 \tag{5}$$

Time of Concentration (Tc) – Defined as the time taken by rainfall drops to travel from the farthest point in the watershed to the outlet.

Where Tc = Time of concentration (h)

l = Flow length (ft)

Y = Average watershed land slope (%)

S = Maximum potential retention and

CN = Curve Number

d. Routing Model

This method assumes a linear relationship between a channel's storage and its discharge, considering both inflow and outflow. (M.Baláž , 2011, [8]). In the Muskingum routing method, X and K parameters are used. Theoretically, K is the unit of time, and X is a dimensionless constant coefficient; its value varies between 0 (Maximum attenuation) and -0.5 (no attenuation), which corresponds to wedge storage. When the X parameter is set to 0, storage within reach is computed solely as a function of outflow. When the parameter is set to 0.5, storage within reach is determined by giving equal weight to both inflow and outflow. (L.A.Jabbar , 2021, [5]), (A.Majidi ,2012, [9]) and (I.D.Skhakhfa , 2016, [10]). K is determined using the following equation.

$$K = \frac{L}{V}$$

Where L = length of reach

V mean velocity (m/s)

E. Meteorologic Model

The meteorologic model contains information about weather or rainfall, also known as the Precipitation and evapotranspiration method. For the precipitation model, the specified hydrograph method is adopted.

a. Daily Rainfall Data

In the Chennai city region, the rainfall begins in June and ends in September. The rainfall increases from the southwest to the northeast due to topographical effects.

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Chennai experienced a cyclone during November–December 2018, which was an extreme disaster. The rainfall data for the study area from November to December 2018 were downloaded from the Power Data Access Viewer website.

F. Control Specification

Control specification is the final step in the modelling process, providing time-related information for simulating results. It includes periods and time intervals for computations. (Kolekar , 2017, [11]).

G. Model Validation and Calibration

Model calibration is defined as the process involved in altering the model parameters so that the simulation results closely match the observed behavior (N.S.Romali , 2018, [12]). Meanwhile, a validation process is similar to the calibration but uses other hydrological data. (N.S.Romali , 2018, [12]) and (M.P.Shaikh , 2018, [13]). The model validation and calibration process is verified by using Model Efficiency (ME). The model efficiency is a deterministic value that defines the absolute square difference between simulated and observed values (A.Sarminingsih, 2019, [14]) and (R.Visweshwaran, 2017, [15]). The statistical performance of the RMSE, PBIAS, and NSE is listed in Table II for the analysis of results.

Table II: Statistical Indicators

RMSE	PBIAS			NSE	Performance
	Stream Flow	Sediment	N and P		
0 to 0.5	0 to 10	0 to 15	0 to 25	0.75 to 1	Very Good
0.5 to 0.6	10 to 15	15 to 30	25 to 40	0.65 to 0.75	Good
0.6 to 0.7	15 to 25	30 to 55	40 to 70	0.50 to 0.65	Fair
> 0.7	> 25	> 55	> 70	< 0.50	Inadequate

IV. RESULTS AND DISCUSSION

The runoff modelling of the catchment has been assessed by considering the model response during the cyclone period (November-December 2018). The basin was divided into three sub-basins. The runoff from the sub-basins was determined using the SCS-CN method for the loss model, the SCS-UH method for the transformation model, and the Muskingum method for the Routing model, respectively.

A. Digital Elevation Model

The primary procedure in hydrology simulation involves determining the elevation details of the study area, which accurately represent the topographic features of the Earth's surface. If multiple sources of DEM analysis for hydrology modelling are considered, SRTM DEM is often considered the preferred one when compared to other DEM sources. In this paper, the SRTM DEM is used at a 30m resolution and 1:50000 scale, as per the United States Geological Survey (USGS) Earth Explorer website, as shown in Figures 2 and 3. Such DEMs with pits and ponds should be removed as filled DEMs by using QGIS 3.16.8 version before being used in hydrologic modelling. These pits are removed by using an algorithm called SINK Filling.

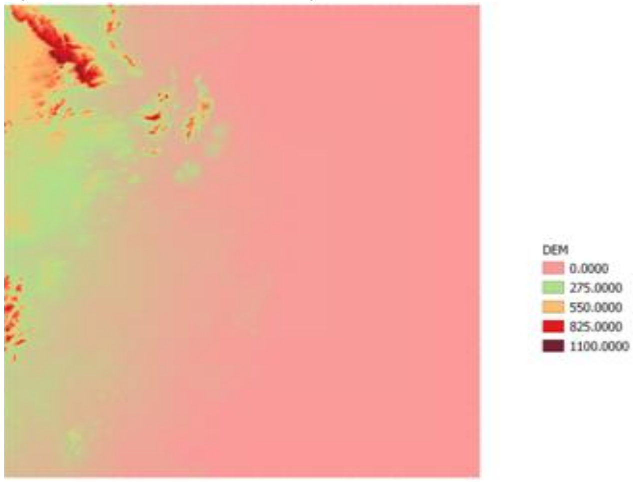

Fig. 2: Filled DEM generated from QGIS

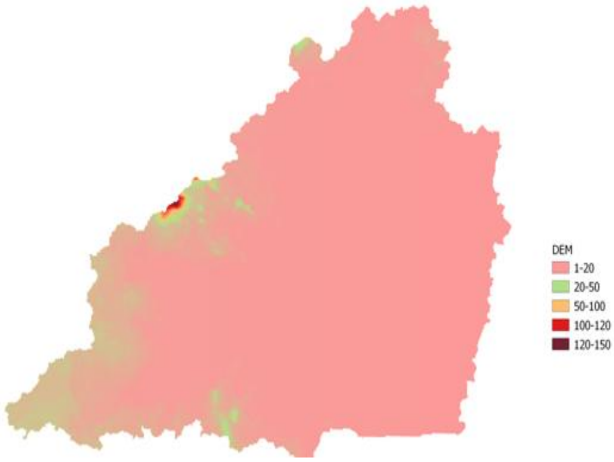

Fig. 3: Filled DEM of Study Area Generated from QGIS

B. HEC-HMS Modelling - Basin Model

The model was developed for the study area by using Filled DEM, and the study area is subdivided into three sub-basins as shown in Figure 4. The hydrological parameters of sub-basins were generated from empirical information. The SCS-CN method was adopted for the loss model. It requires predicting the Curve Number, imperviousness, and initial abstraction for each sub-basin. The basin parameter CN is found to be a function of the soil and land use, as well as land cover conditions, in the study area. Using the soil basin and LULC map of the study area, shown in Figures 5 and 6, the curve number (CN) is generated in QGIS for each sub-basin, and the curve number of the study area is presented in Figure 7. Other parameters, including initial abstraction and imperviousness, were calculated for this model and are attributed in Table 3. For converting rainfall into runoff, the SCS-UH method is used. The Lag time was calculated using the formula described above and is shown in Table III.

The Muskingum method is a common lumped flow routing technique used to route total runoff from the outlet of the sub-basin to the outlet of the entire basin. Here, the parameters X and K are to be evaluated.

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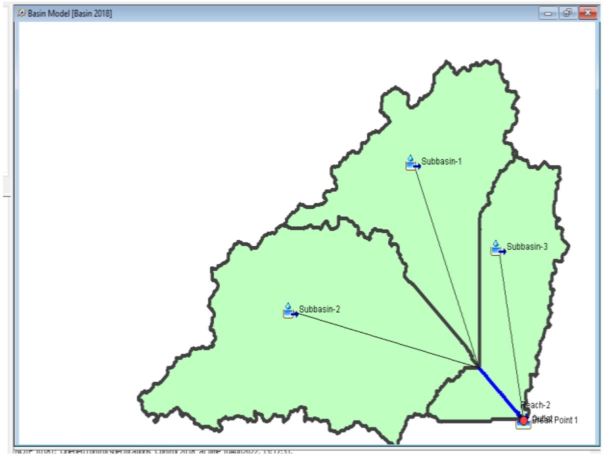

Fig. 4: Study Area Basin Model

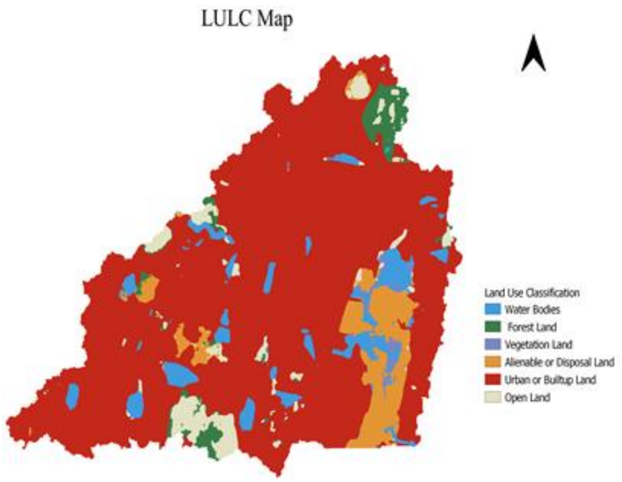

Fig. 5: Land Use Land Cover Map of the Study Area

Table III: Estimation of Parameters

Sub-basin	Curve Number	Initial Abstraction	Imperviousness	Lag Time (hrs)	Lag Time (mins)
SB 1	66	26	20%	0.046	2.76
SB 2	67	25	20%	0.045	2.67
SB 3	62	31	20%	0.057	3.43

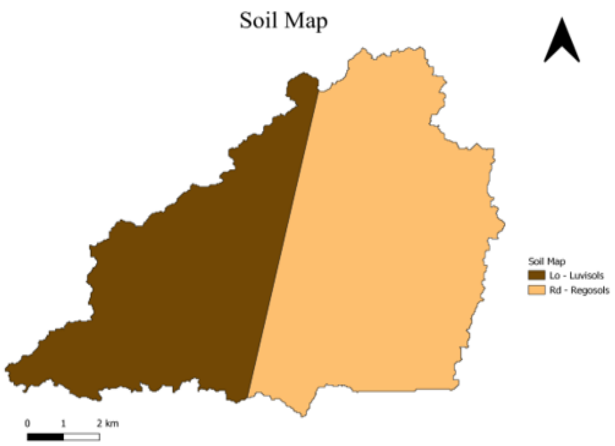

Fig.6: Soil map of the Study Area

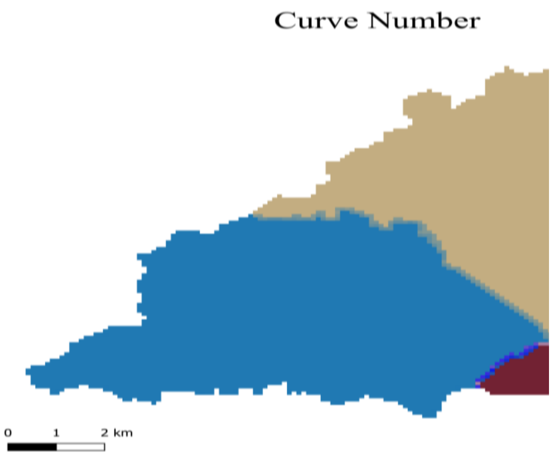

Fig. 7: Curve Number of the Study Area

C. Meteorological Model and Control Specifications

In the meteorological model, a specified hydrograph method is adopted. The rainfall data for the period from November 1, 2018, to December 31, 2018, generated from the Power Data Access Viewer website, was used for hydrological modelling. The control specifications are used to set the running period of the model simulation. The model was run for the periods of November 1, 2018, to December 31, 2018 (Model simulation), November 1, 2016, to December 31, 2016 (Calibration), and September 1, 2018, to October 31, 2018 (Validation), and details are listed in Table IV.

D. Model Simulation

The HEC-HMS model was run from November 1, 2018, to December 31, 2018, for the event, and the hydrological modelling was performed using daily time steps. The simulation results are presented in Tables V and VI, and are also illustrated in Figures 8, 9, 10, 11, and 12. From the analysis and data obtained, the simulated peak flow was 38.1m3/s in the Okkiyam Madavu outlet on 22 November 2018, when the observed flow rate is
45.3 m3/s was recorded.

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Table IV: Meteorological Data of the Study Area

Model			Validation			Calibration		
Period	Precipitation in mm	Observed Flow (m^3/s)	Period	Precipitation in mm	Observed Flow (m^3/s)	Period	Precipitation in mm	Observed Flow (m^3/s)
01.11.2018	17.28	9.95	01.09.2018	9.18	5.28	01.11.2016	2.25	1.30
02.11.2018	4.98	2.87	02.09.2018	0.71	0.41	02.11.2016	6.77	3.90
03.11.2018	6.07	3.49	03.09.2018	0.18	0.10	03.11.2016	2.25	1.30
04.11.2018	2.73	1.57	04.09.2018	0.86	0.50	04.11.2016	0.1	0.06
05.11.2018	0.35	0.20	05.09.2018	0.34	0.20	05.11.2016	0.02	0.01
06.11.2018	0.2	0.12	06.09.2018	0.03	0.02	06.11.2016	0	0.00
07.11.2018	0	0.00	07.09.2018	0.03	0.02	07.11.2016	0.28	0.16
08.11.2018	0.68	0.39	08.09.2018	0.08	0.05	08.11.2016	0.01	0.01
09.11.2018	0.51	0.29	09.09.2018	0.42	0.24	09.11.2016	0	0.00
10.11.2018	0.04	0.02	10.09.2018	0.94	0.54	10.11.2016	0	0.00
11.11.2018	0.02	0.01	11.09.2018	2.5	1.44	11.11.2016	0.02	0.01
12.11.2018	0	0.00	12.09.2018	2.05	1.18	12.11.2016	0.75	0.43
13.11.2018	0	0.00	13.09.2018	2.21	1.27	13.11.2016	6.92	3.98
14.11.2018	0.26	0.15	14.09.2018	5.4	3.11	14.11.2016	0.37	0.21
15.11.2018	7.5	4.32	15.09.2018	9.36	5.39	15.11.2016	0.83	0.48
16.11.2018	8.41	4.84	16.09.2018	21.44	12.34	16.11.2016	2.66	1.53
17.11.2018	4.04	2.33	17.09.2018	28.47	16.39	17.11.2016	0.63	0.36
18.11.2018	0.45	0.26	18.09.2018	16.75	9.64	18.11.2016	0.02	0.01
19.11.2018	0.45	0.26	19.09.2018	1.53	0.88	19.11.2016	0	0.00
20.11.2018	2.73	1.57	20.09.2018	0.63	0.36	20.11.2016	0.02	0.01
21.11.2018	78.67	45.28	21.09.2018	2.39	1.38	21.11.2016	0.01	0.01
22.11.2018	50.27	28.94	22.09.2018	1.04	0.60	22.11.2016	0	0.00
23.11.2018	7.81	4.50	23.09.2018	0.12	0.07	23.11.2016	0	0.00
24.11.2018	0	0.00	24.09.2018	0.01	0.01	24.11.2016	0	0.00
25.11.2018	0	0.00	25.09.2018	0	0.00	25.11.2016	0	0.00
26.11.2018	0.01	0.01	26.09.2018	0.01	0.01	26.11.2016	0	0.00
27.11.2018	0.08	0.05	27.09.2018	0.06	0.03	27.11.2016	0	0.00
28.11.2018	0.97	0.56	28.09.2018	0.26	0.15	28.11.2016	0	0.00
29.11.2018	6.86	3.95	29.09.2018	0.31	0.18	29.11.2016	0	0.00
30.11.2018	1.42	0.82	30.09.2018	1.4	0.81	30.11.2016	0.09	0.05
01.12.2018	0.04	0.02	01.10.2018	2.42	1.39	01.12.2016	25.47	14.66
02.12.2018	0.19	0.11	02.10.2018	1.4	0.81	02.12.2016	23.37	13.45
03.12.2018	5.46	3.14	03.10.2018	12.43	7.16	03.12.2016	15.83	9.11
04.12.2018	23.09	13.29	04.10.2018	29.57	17.02	04.12.2016	12.39	7.13
05.12.2018	11.32	6.52	05.10.2018	25.88	14.90	05.12.2016	4.86	2.80
06.12.2018	1.55	0.89	06.10.2018	8.08	4.65	06.12.2016	0.06	0.03
07.12.2018	0.17	0.10	07.10.2018	1.66	0.96	07.12.2016	0.74	0.43
08.12.2018	0.01	0.01	08.10.2018	3.54	2.04	08.12.2016	0.01	0.01
09.12.2018	0	0.00	09.10.2018	0.43	0.25	09.12.2016	0	0.00
10.12.2018	0	0.00	10.10.2018	0	0.00	10.12.2016	0	0.00
11.12.2018	0	0.00	11.10.2018	0	0.00	11.12.2016	0.63	0.36
12.12.2018	0	0.00	12.10.2018	0.02	0.01	12.12.2016	104.15	59.95
13.12.2018	0.01	0.01	13.10.2018	0.32	0.18	13.12.2016	4.46	2.57
14.12.2018	0.09	0.05	14.10.2018	5.02	2.89	14.12.2016	0.25	0.14
15.12.2018	0.07	0.04	15.10.2018	2.1	1.21	15.12.2016	1.07	0.62
16.12.2018	0.78	0.45	16.10.2018	1.36	0.78	16.12.2016	4.41	2.54
17.12.2018	0.01	0.01	17.10.2018	12.7	7.31	17.12.2016	0.02	0.01
18.12.2018	0	0.00	18.10.2018	12.45	7.17	18.12.2016	0	0.00
19.12.2018	0	0.00	19.10.2018	8.48	4.88	19.12.2016	0	0.00
20.12.2018	0.01	0.01	20.10.2018	1.23	0.71	20.12.2016	0.02	0.01
21.12.2018	0.25	0.14	21.10.2018	4.37	2.52	21.12.2016	0.01	0.01
22.12.2018	9.28	5.34	22.10.2018	0	0.00	22.12.2016	0	0.00
23.12.2018	3.16	1.82	23.10.2018	0	0.00	23.12.2016	0	0.00
24.12.2018	0.04	0.02	24.10.2018	0	0.00	24.12.2016	0	0.00
25.12.2018	0	0.00	25.10.2018	0	0.00	25.12.2016	0	0.00
26.12.2018	0	0.00	26.10.2018	0	0.00	26.12.2016	0	0.00
27.12.2018	0	0.00	27.10.2018	0	0.00	27.12.2016	0	0.00
28.12.2018	0.15	0.09	28.10.2018	0	0.00	28.12.2016	0.03	0.02
29.12.2018	0.16	0.09	29.10.2018	1.23	0.71	29.12.2016	0	0.00
30.12.2018	0.03	0.02	30.10.2018	6.43	3.70	30.12.2016	0	0.00
31.12.2018	0	0.00	31.10.2018	9.51	5. 47	31.12.2016	0.02	0.01

Table V: Summary of Results of the Study Area

Hydrologic Element	Drainage Area (Km^2)	Peak Discharge (m^3/s)	Time of Peak
Sub basin -1	26.440	11.9	22Nov2018
Sub-basin-2	39.874	17.7	22Nov2018
Sub basin -3	16.824	6.9	22Nov2018
Reach -1	66.314	31.2	22Nov2018
Reach -2	66.314	30.5	22Nov2018
Outlet	83.138	38.1	22Nov2018

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Table VI: Summary Results of The Sub-Basin of The Study Area

Sub-basin	Precipitation Volume (1000 mm³)	Loss Volume (1000 mm³)	Excess Volume (1000 mm³)	Direct Runoff Volume (1000 mm³)	Discharge Volume (1000 mm³)
SB 1	6382.1	2205.6	4176.5	4176.3	4176.3
SB 2	9624.8	3425.9	6198.9	6198.5	6198.5
SB 3	4061	1621.4	2439.5	2439.4	2439.4

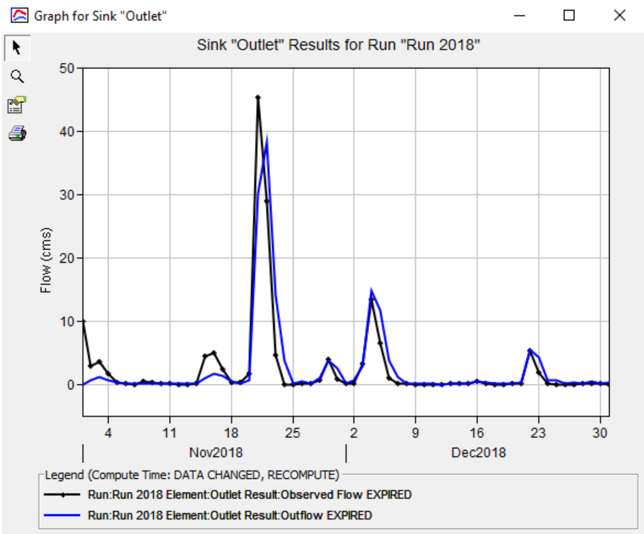

Fig. 8: Modelling Hydro Graph of the Study Area at Period 01 Nov 2018 to 31 Dec 2018

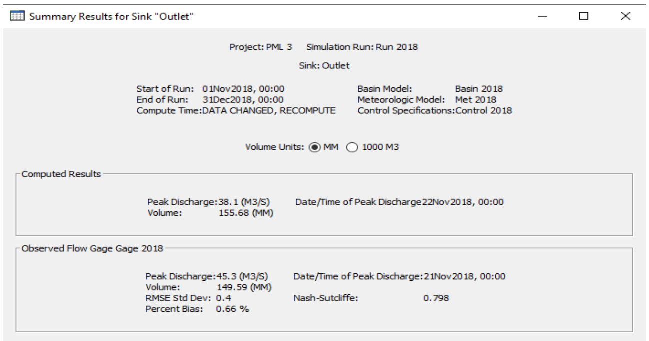

Fig. 9: Summary of Results for Nov-Dec 2018

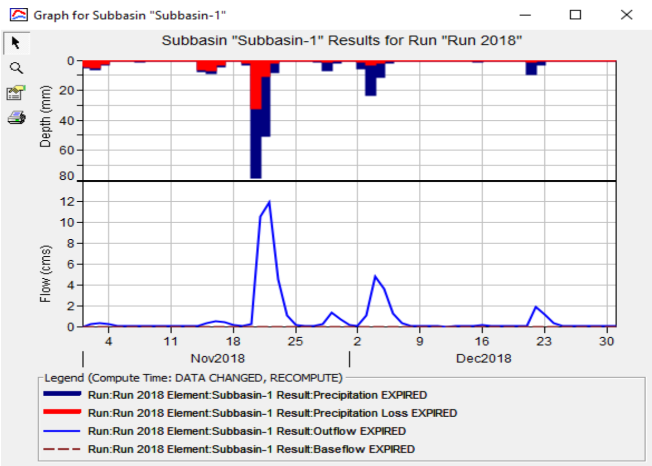

Fig. 10: Simulation Run of Sub-basin 1

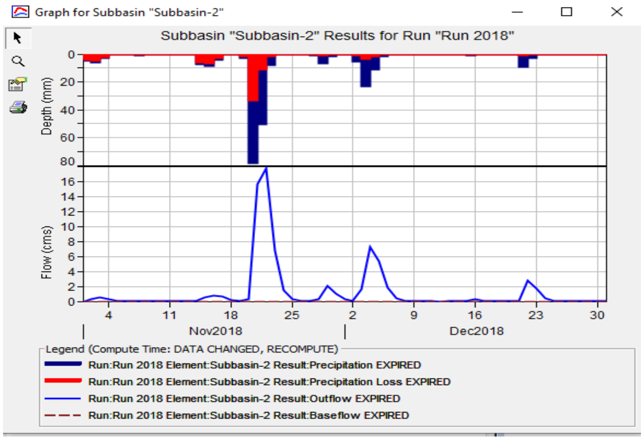

Fig. 11: Simulation Run of Sub-basin 2

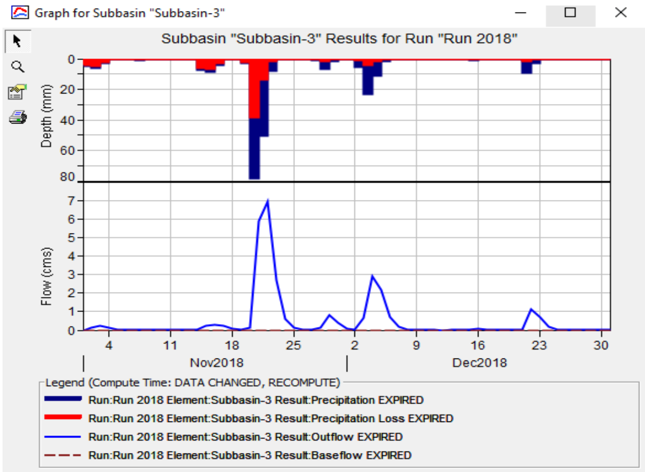

Fig. 12: Simulation Run of Sub-basin 3

E. Model Calibration and Validation

The HEC-HMS model was calibrated using rainfall and flow data from the study area from November 1, 2016, to December 31, 2016, and validated from September 1, 2018, to October 31, 2018. The results are shown in Table VII. The simulated and calibrated hydrograph is shown in Figure 13. The simulated peak flow of the calibration event is 55.0 m3/s, which is close to the observed peak flow of 60.0 m3/s. For the model validation process, the simulated peak flow of the calibration is 17.0 m³/s, which is close to the observed peak flow of 19.7 m³/s. The validated hydrograph is shown in Figure 14.

Table VII: Comparison of Results of Calibration and Validation Process

Simulation	Period	Observed Flow (m³/s)	Simulated Flow (m³/s)
Calibration	Nov–Dec 2016	60.0	55.0
Validation	Sep –Oct 2018	17.0	19.7

Table VIII: Performance of Statistical Indicator

Simulation	Period	RMSE Std Devaition	NSE	PBIAS (%)	Performance
Calibration	Nov–Dec 2016	0.5	0.76	3.09	Very Good
Validation	Sep –Oct 2018	0.4	0.81	14.23	Very Good

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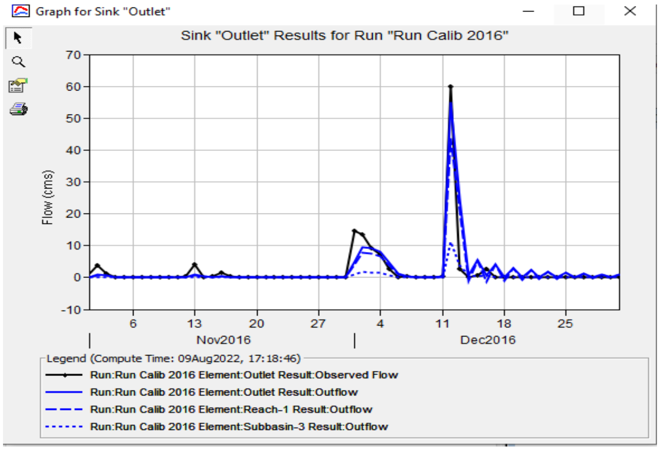

Fig. 13: The Observed and Calibrated Hydrograph Study Area Period 01 Nov 2016 to 31 Dec 2016

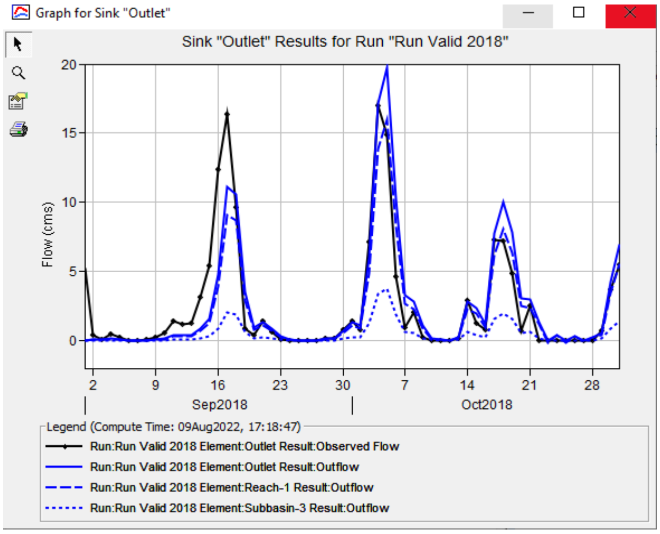

Fig. 14: The Observed and Validated Hydrograph of the Study Area for the Period 01 Sep 2018 to 31 Oct 2018

The performance value of the flow generated in the validation process exceeds that of the calibration process and the values listed in Table 8. The RMSE value for validation is 0.4 and the calibration process is 0.5 which exists between in the range of 0 – 0.5 and the NSE (Nash-Suctile Efficiency) value of the calibration process is 0.76 and the validation process is 0.81 exists in the range of 0.75-1 and the PBIAS value of the calibration process is 3.09% and the validation process is 14.23% exist in the range of 0-15. Finally, the performance of the statistical indicators demonstrates a high level of accuracy, as presented in Table VIII.

V.CONCLUSION

In the present work, DEM data were taken at a 30m resolution to delineate the Okkiyam Maduvu outlet, and its catchment characteristics were determined using QGIS. The rainfall-runoff process is simulated in this study area using the HEC-HMS model. Due to the availability of data, SCS-CN methods are adopted for modelling. In this respect, the curve number, lag time, and Muskingum parameters were obtained, and a model was generated using HEC-HMS. The simulation results for the peak flow discharged by runoff differ slightly from the observed data. From the results, a peak flow of 38.1 m^3/s was obtained for the period from November to December 2018, which corresponds to the maximum rainfall of 78.67 mm, against an observed discharge of 45.28 m^3/s. The simulation of peak flow results with observed data for calibration and validation is carried out with acceptable performance. Thus, the model can be applied in Okkiyam Maduvu Outlet to study the probability of floods and also in flood management.

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Availability of Data Material	Not relevant.
Authors Contribution	All authors contributed equally to this article.

REFERENCES

1. Mrugaxi Sheth. "Review: Rainfall Runoff Modelling". www.ijert.org, 2018.
2. Salah Ud Din, Noor Muhammad Khan, Muhammad Israr, Hazrat Nabi, and Mansoorulla Khan. "Runoff Modelling Using HEC HMS For Rural Watershed. International Journal of Advanced Engineering and Research Development, Vol . 6(12), 2019, pp. 630–636.
3. C.P.Shankar, M.Shanmugam, C.Pradeep, and D.Thirumalaivasan, "Flood modelling for a part of the Adyar river basin using HEC-HMS and HEC-RAS for the December 2015 floods". Ecology, Environment and Conservation, Vol. 24, February 2018, pp. S260–S263.
4. A.N.A.Hamdan, S.Alumuktar, and M.Scholz, "Rainfall-Runoff Modelling Using the HEC-HMS Model for the Al-Adhaim River Catchment, Northern Iraq", Hydrology.Vol. 8, 2021, pp. 58. https://doi.org/10.3390/hydrology8020058.
5. L.A.Jabbar, I.A.Khalil, and L.M.Sidek, "HEC-HMS Hydrological Modelling for Runoff Estimation in Cameron Highlands, Malaysia". International Journal of Civil Engineering and Technology (Ijciet) 12(9), 2021, PP: 40–51. https://doi.org/10.34218/ijciet.12.9.2021.004
6. US Army Corps of Engineers. "Hydrologic Modelling SystemHEC-HMS Technical Reference Manual". Hydrologic Engineering Centre. 2000.
7. S.Natarajan, and N.Radhakrishnan, "Simulation of rainfall–runoff process for an ungauged catchment using an event-based hydrologic model: A case study of Koraiyar basin in Tiruchirappalli city, India". Journal of Earth System Science, Vol . 130(1), 2021. https://doi.org/10.1007/s12040-020-01532-8
8. M. Baláž, M.Danáčová, and J.Szolgay, "On the use of the Muskingum method for the simulation of flood wave movements". Slovak Journal of Civil Engineering, Vol. 18(3), 2011, pp. 14–20. https://doi.org/10.2478/v10189-010-0012-6
9. A.Majidi, and K.Shahedi, "Simulation of Rainfall-Runoff Process Using Green-Ampt Method and HEC-HMS Model (Case Study: Abnama Watershed, Iran)". International Journal of Hydraulic …, Vol.1(1), 2012, pp:5–9. https://doi.org/10.5923/j.ijhe.20120101.02
10. I.D.Skhakhfa, and L.Ouerdachi, Hydrological modelling of wadi Ressoul watershed, Algeria, by HEC-HMS model". Journal of Water and Land Development, Vol. 31(1), 2016, pp. 139–147. https://doi.org/10.1515/jwld-2016-0045.
11. S.V. Kolekar, K.J. Muthappa, Gowtham Prasad M E., Shruthi H G., Shivaprasad H.,& Ram, N S. "Applicability of HEC-HMS Tool To Western Ghats - Nethravathi River Basin". Journal of Advanced Research in Engineering & Management (IJAREM),

Issn:2456-2033//Vol.03(04), 2017, pp:70-79.
12. N.S. Romali, Z.Yusop, and A.Z.Ismail, "Hydrological Modelling using HEC-HMS for Flood Risk Assessment of Segamat Town, Malaysia". IOP Conference Series: Materials Science and Engineering Vol . 318(1), 2018. https://doi.org/10.1088/1757-899X/318/1/012029
13. M.P.Shaikh, V.G. Yadav, and S.M.Yadav, "Simulation of Rainfall-Runoff Event Using HEC-HMS Model for Rel Sub-Basin, Gujarat, India". Journal of Emerging Technologies and Innovative Research, 5(4), 2018, pp. 402–407.
14. 14. A.Sarminingsih , A. Rezagama, and Ridwan. "Simulation of rainfall-runoff process using HEC-HMS model for Garang Watershed, Semarang, Indonesia. Journal of Physics: Conference Series, 1217(1), 2019. https://doi.org/10.1088/1742-6596/1217/1/012134
15. R.Visweshwaran, "Application of the HEC-HMS model for runoff simulation in the Krishna basin ", 2017.. July. https://doi.org/10.13140/RG.2.2.13326.05448

AUTHORS PROFILE

A. Harinadha Babu graduated from N.B.K.R.I.S.T., Vidyanagar, Nellore, which is affiliated with S.V. University, Tirupati, in 1996. He obtained his M.E. degree in Environmental Engineering from Sathyabama Institute of Science & Technology, Chennai, in 2005. He has over 25 years of experience in teaching and is currently conducting research at J.N.T.U. A, Anantapuramu, India, under the guidance of Dr. N. Kumaraswamy and Prof. S. Krishnaiah. His areas of interest include groundwater pollution and Geo-environmental Engineering.

Dr. Nekkanti Kumaraswamy has been serving as the Dean of Administration at Vasireddy Venkatadri Institute of Technology in Guntur, Andhra Pradesh, India, since 2016. Previously, he held the position of Dean (RRC) at the Madanapalli Institute of Technology, Madanapalli, and served as Principal at the Vaagdevi Institute of Technology, Proddatur. He earned his Ph.D. from SV University, Tirupati, and boasts over 40 years of experience in teaching and research within the fields of Civil and Environmental Engineering. Dr. Kumaraswamy has played a pivotal role in guiding six doctoral candidates to successful completion of their degrees, with five Ph.D. scholars currently under his mentorship. He is an accomplished author, having written three books on civil engineering. His extensive research contributions include 166 published papers in National and International Journals, focusing on Civil and Environmental Engineering. A Fellow Member associated with various professional bodies in India and abroad, Dr. Kumaraswamy has actively participated in 179 Faculty Development Programs (FDPs) and certificate courses on Emerging Computer and Information Technology since May 2000. His exceptional contributions to the field have been recognised with prestigious awards such as the LEADING ENGINEER AWARD and LIVING SCIENCE AWARD from the International Biographical Centre, Cambridge, UK. Additionally, he received the MAN OF THE YEAR INDIA 2009 award from the American Biographical Institute, North Carolina, USA, and the SIR ARTHUR COTTON MEMORIAL AWARD from The Institute of Engineers (India).

Prof. S. Krishnaiah graduated from S.V. University, Tirupati, A.P., India, in 1989 with a degree in Civil Engineering. He obtained an M.E. degree from the Goa Government. Engineering College, Goa. He received a doctoral degree in Geotechnical Engineering from IIT Bombay in 2003. He has over 28 years of experience in teaching and 20 years of experience in research. He was honoured with the Rashtriya Gourav Award from the International Friendship Society, New Delhi. His name was cited in Who's Who in the World. He was honoured with the Educational Leadership award by The Indus Foundation Inc., USA, at the Indo-Global Education Summit & Expo 2017 in Bangalore. He has published more than 80 research papers in national and international journals and conferences. He is elected a Fellow of the Institution of Engineers (India) and a Life Member of the Institution of Engineers (India) and the Institution of Engineers (India). He delivered numerous expert lectures and keynote addresses on various technical topics and chaired technical sessions at several International and National Conferences. Under his chairmanship, several conferences and workshops were conducted in the Civil Engineering Department at JNTUA College of Engineering, Anantapur. He has served as the Head of the Civil Engineering Department and ICS Coordinator at JNTUA College of Engineering, Anantapur, as well as OSD and Founder Principal of JNTUA College of Engineering, Kalikiri. He worked as the Registrar of JNT University, Anantapur, for about four and a half years. He served as the Chairman of the UG Board of Studies (Civil Engineering) at JNT University, Anantapur, for three years and was a member of the Board of Studies for various Engineering colleges in A.P., India. His areas of interest include Heat and mass transfer through Geomaterials, Ground Improvement Techniques and Geo-environmental Engineering. He has guided six Ph.D. students and eight more Ph.D. students work under his guidance.