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 the river bed and encroachment due to urban activities. Considering these complexities, this study aims to predict the stream flow in a river basin concerning a given amount of rainfall using HEC - HMS software models. The sub-basin elements are used to convert rainfall to runoff. A meteorologic model is used to assign the boundary conditions for sub-basins, which include precipitation, short/long wave radiation, and potential evapotranspiration. A time series of flow data is used as input of a model to estimate the average basin rainfall. Calibrate the model and it's required for optimization 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 proportionate to excess volume, direct run-off volume, and discharge volume, and the reliability of the model is achieved using observed data and predicted data.*

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

I. INTRODUCTION

The state of Tamilnadu 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 recent November 2021 was a devasting month for flooding in Chennai with four weeks of rainfall of 1000 mm preceded by devasting floods of December 2015 setting a record of 1049 mm. A study made by Care Earth Trust, a bio-diversity research organization, reveals that Chennai's built-up area grew from 47 Km2 in 1980 to 402 Km2 in 2012 and wetlands declined from 186 Km2 to 71 Km2.

Manuscript received on 06 December 2023 | Revised Manuscript received on 27 December 2023 | Manuscript Accepted on 15 February 2024 | Manuscript published on 28 February 2024.
***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 analyzing the ongoing infrastructure development, the city possesses 30,000 interior roads and 471 bus route roads, which account for 5,000 km and 300 km respectively, but the city's drainage network covers just around 2,000 km only and most of these drains were built at least three decades ago which is designed for 20 mm/hr whereas the new drains are being built for 70 mm/hr.

II. STUDY AREA

Pallikaranai marsh is a freshwater swamp located in the south of Chennai which is known as the only urban natural wetland in Chennai city. The wetland that spread over an area of 50 sq km in 1995 shrunk to 5.9 sq. km in 2007 and at present available as 3.17 sq. km. The main uniqueness of the marshland varies in terms of its original course, the presence of water-wash rocks, and hydrology. The exact location of Marsh Land is 12.949371N latitude and 80.218184E longitude. It was surrounded by Velachery, Medavakkam, Kovilambakkam, and Okkiyam Thoraipakkam on the north, south, west, and eastern sides. As per the Tamilnadu State Wetland Authority, Pallikaranai marsh drains an area of 250 km2 of south Chennai surrounding 65 wetlands through its two outlets, namely Okkiyam Madavu and the Kovalam Creek and finally joins into the Bay of Bengal. Okkiyam Madavu is situated in the southern suburbs of the city of Chennai and water from Pallikaranai marshland is collected into this water channel and drained into the Buckingham Canal. The north and south portions are Velachery, and Medavakkam drains the water into marshland. The southern and western boundaries are occupied by residential and institutional buildings and the north and eastern sides are categorized as human habitation and public infrastructure. Mostly, 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 in summer season from 35°C to 42°C and in winter season, 25°C to 34°C. Generally, the terrain of the area is classified as plain and most southern parts of the Chennai soil type are 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 dumping of solid waste, and discharging domestic sewerage and industrial effluents. This environmentally significant wetland is used as a waste dump yard which occupies 250 acres of prime land and receives 6000 metric tons of waste per day for its 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 from the sources to 1.5 km approximately horizontally and up to a depth of 100 m vertically, polluting the ground and surface water system.

III. METHODOLOGY

The present study aims at developing a rainfall-runoff model for the Adyar basin by using the available data.

A. HEC-HMS Model

HEC-HMS (Hydrologic Engineering Centre – Hydrological Modelling System) is an open-source software that was developed for U.S. Army Corps Engineers in 1998 for flood simulation 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 Basin model, Meteorological model, and Control specifications and the input data is time series data, paired data, and gridded data.

Basin Model: In any drainage system to convert the atmospheric conditions into stream flow at required locations, the basin model is useful. Hydrologic elements represent a physical process of movement of water 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 the time series data during simulation in the start and stop conditions as well as used for assigning the time interval.

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 boundary, elevation, river, and flow direction to examine the characteristics of the watershed. 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 of the arc GIS can be applied individually or in a 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 preparing a Digital Elevation model without pits before being used in hydrological modeling. These pits are cells that will accumulate in the water when drainage patterns are being extracted. By using the sink-filling algorithm, the pits were removed from DEM. After filling sinks, a flow direction map was simulated by encoding eight possible flow directions in each cell. Then a flow accumulation map was generated using flow direction. After that, it is used to identify the stream network of the basin divided into various segments which determine the outlet of the basin. The final process is the delineation process which delineates the basin into sub-basins (Mrugaxi Sheth, 2018,[1][16][17[18]) and (Salah Ud Din, 2019, [2]).

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

Retrieval Number: 100.1/ijitee.C980413030224
DOI: 10.35940/ijitee.C9804.13030224
Journal Website: www.ijitee.org

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

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 just needs a single parameter – A curve number that indicates the entire hydrological impacts of land use. This method is developed for determining excess runoff from precipitation depth in a particular area. The SCS–CN method separates the precipitation into 3 categories. They are Direct runoff (Q), Actual retention (S), and Initial abstraction (Ia) (C.P.Shankar ., 2018, [3][19]).

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 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 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 consisting of infiltration, interception, evaporation, and surface depression storage before the occurrence of runoff. The value of initial abstraction is determined by the following equations 1 and 2.

Initial abstraction (Ia) = 0.2S (1)

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

Where

S = Maximum Potential retention

CN = Curve Number

Another parameter needed in the loss model is the percent imperviousness.

c. Transformation Model

This model is also known as the Direct runoff model (DRM) and it transforms the excess rainfall into a direct runoff hydro-graph. In this study, the Soil Conservation Service (SCS) Unit Hydrograph model was chosen. US Soil Conservation Service (Now NRCS) developed a dimensionless unit hydro-graph based on the analysis of the watershed. As per the NRCS, this model defines a curve-linear unit hydro graph which calculates the runoff resulting from the 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.

Lag Time = 0.6 Tc (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.

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

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

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 inflow and outflow discharge (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 the dimensionless constant coefficient and its value varies between 0 (Maximum attenuation) and -0.5 (no attenuation) which means wedge storage. When the X parameter is set to be 0, storage within the reach is computed solely as a function of outflow and when the parameter is set to be 0.5, when determining storage within the reach, equal weight is given to both inflow and outflow (L.A.Jabbar , 2021, [5]), (A.Majidi ,2012, [9]) and (I.D.Skhakhfa , 2016, [10][20]). 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 specified hyetrograph 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 period and northeast periods due to topographical effects.

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

F. Control Specification

Control specification is the final step in the modeling process and it is time-related information for simulation of results. It includes period 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 up to the simulation results closely reaching 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 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 modeling of the catchment has been assessed by considering the model response of the cyclone period (Nov-Dec 2018). The basin was divided into 3 sub-basins. The runoff from the sub-basins was determined by using the SCS-CN method for the loss model, SCS-UH for the transformation model, and Muskingum for the Routing model respectively.

A. Digital Elevation Model

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

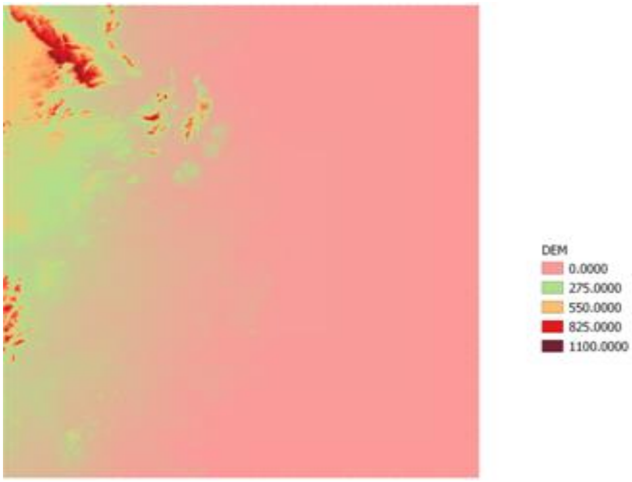

Fig. 2: Filled Dem Generated from QGIS

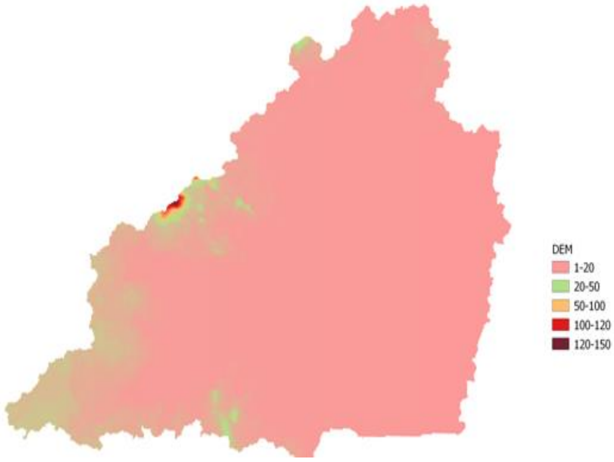

Fig. 3: Filled DEM of Study Area Generated from QGIS

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 3 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 the prediction of Curve Number, imperviousness, and initial abstraction of each sub-basin. The basin parameter CN is found as a function of soil and land use, land cover conditions of 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 with QGIS for each sub-basin and the curve number of the study area is shown in Figure 7. Other parameters, initial abstraction, and imperviousness were calculated for this model and attributed in Table 3. For the conversion of rainfall into a runoff, the hydro-graph SCS-UH method is used. The Lag time was calculated by using the formula described above and shown in Table-III.

The Muskingum method is a common lumped flow routing technique for routing of 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.

Retrieval Number: 100.1/ijitee.C980413030224
DOI: 10.35940/ijitee.C9804.13030224
Journal Website: www.ijitee.org

Published By:
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and Sciences Publication (BEIESP)

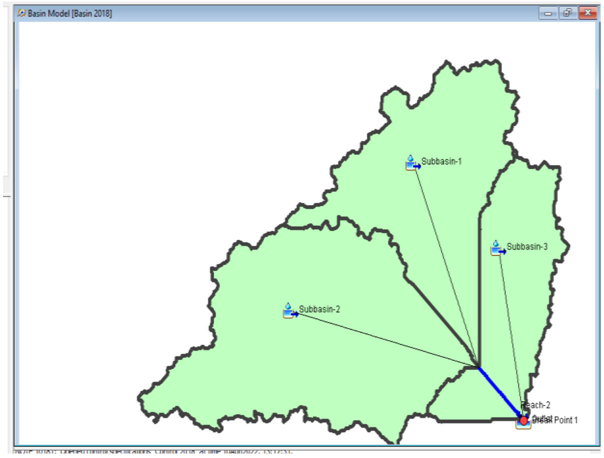

Fig. 4: Study Area Basin Model

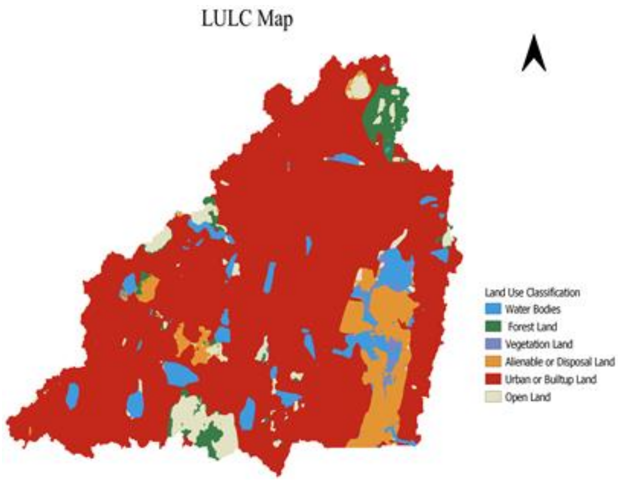

Fig. 5: Land use Land Cover Map of the Study Area

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

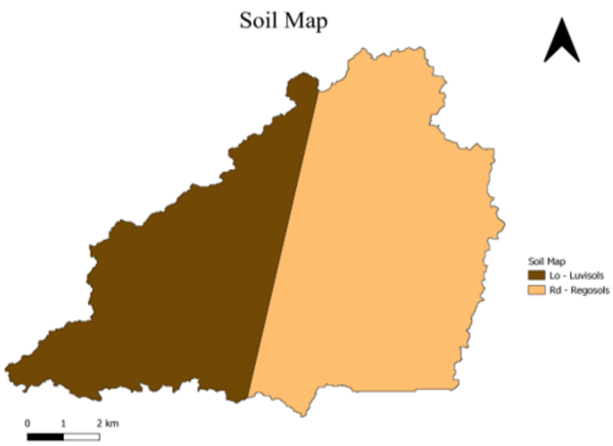

Fig.6: Soil map of the Study Area

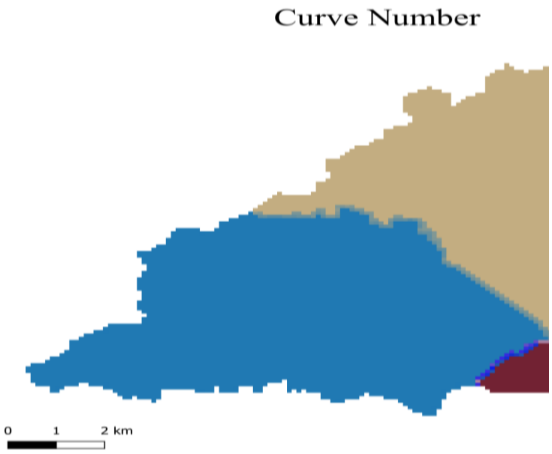

Fig. 7: Curve Number of the Study Area

C. Meteorological Model and Control Specifications

In the meteorological model, a specified hyetrograph method is adopted. The rainfall data for the period from 01 November 2018 to 31 December 2018 which is generated from the power data access viewer website was taken for hydrological modelling. The control specifications are for setting the running period of the model simulation. The model was run for the periods of 01 Nov 2018 to 31 Dec 2018 (Model simulation), 01 Nov 2016 to 31 Dec 2016 (Calibration), and 01 Sep 2018 to 31 Oct 2018 (Validation) and details are listed in Table-IV.

D. Model Simulation

The HEC-HMS model was run from 01 November 2018 to 31 December 2018 event and the hydrological modelling was performed by using daily time steps. The simulation results are presented in Tables-V and VI, also shown 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.

Retrieval Number: 100.1/ijitee.C980413030224
DOI: [10.35940/ijitee.C9804.13030224](https://doi.org/10.35940/ijitee.C9804.13030224)
Journal Website: www.ijitee.org

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)

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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DOI: 10.35940/ijitee.C9804.13030224
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Table-VI: Summary Results of The Sub-Basin of The Study Area

Sub-basin	Precipitation Volume (1000 mm^3)	Loss Volume (1000 mm^3)	Excess Volume (1000 mm^3)	Direct Runoff Volume (1000 mm^3)	Discharge Volume (1000 mm^3)
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

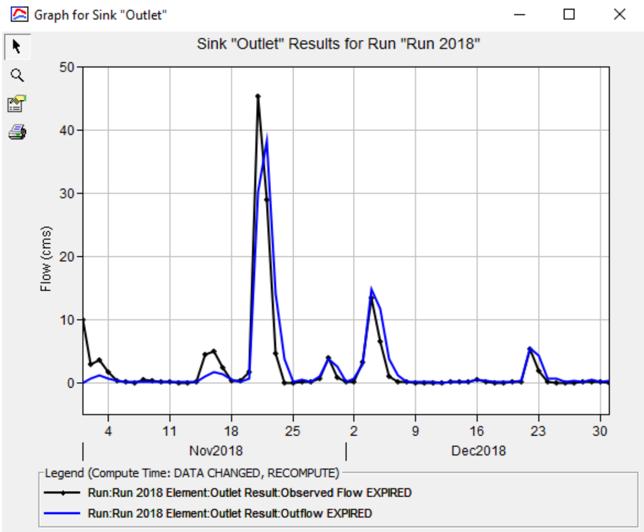

Fig. 8: Modelling Hydro Graph of the Study Area at Period 01 Nov 2018 to 31 Dec 2018

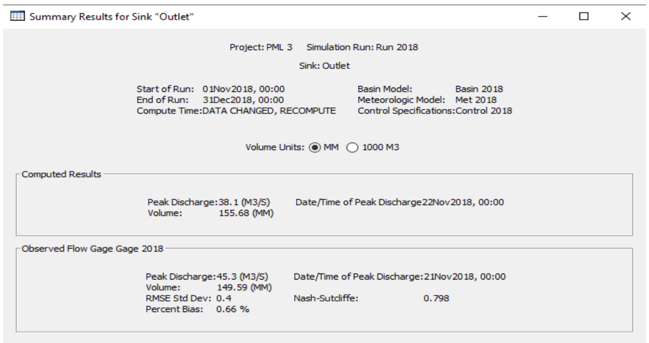

Fig. 9: Summary of Results for Nov-Dec 2018

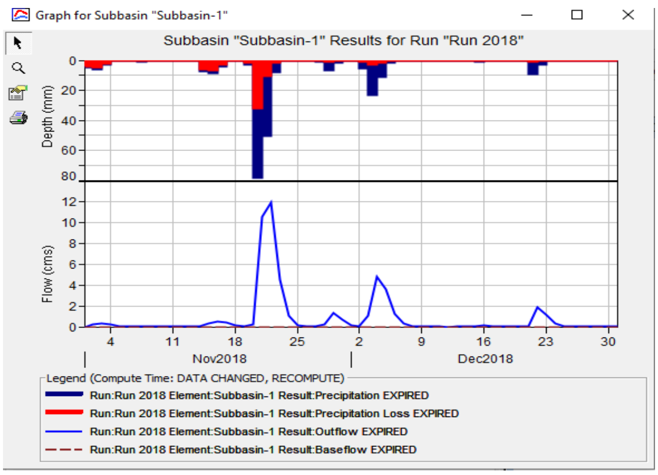

Fig. 10: Simulation Run of Sub-basin 1

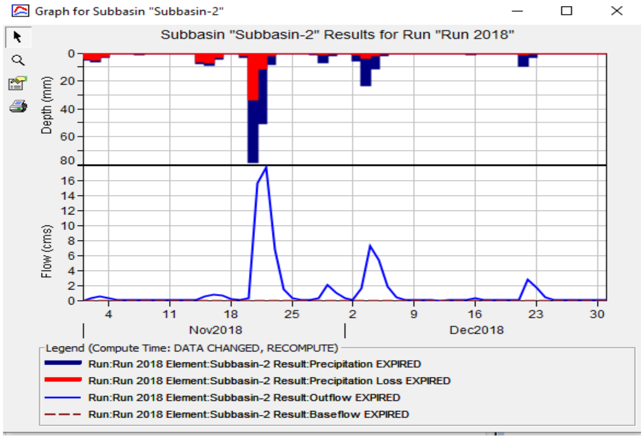

Fig. 11: Simulation Run of Sub-basin 2

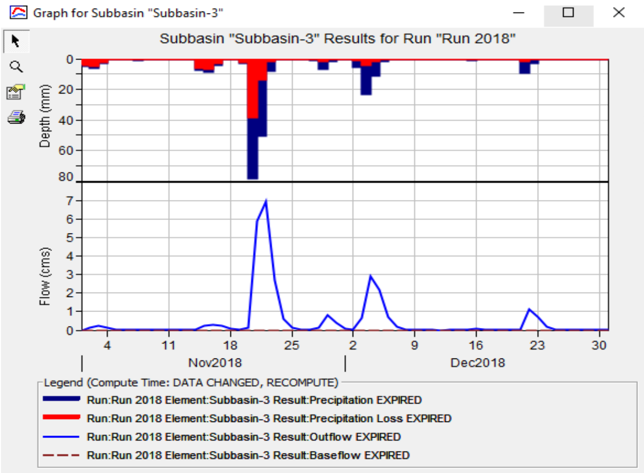

Fig. 12: Simulation Run of Sub-basin 3

E. Model Calibration and Validation

The HEC-HMS model was calibrated using rainfall and flow data of the study area from 01 November 2016 to 31 December 2016 and validated from 01 September 2018 to 31 October 2018 and 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, and the validated hydrograph is shown in Figure 14.

Table-VII: Comparison of Results of Calibration and Validation Process

Simulation	Period	Observed Flow (m^3/s)	Simulated Flow (m^3/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

Retrieval Number: 100.1/ijitee.C980413030224
DOI: 10.35940/ijitee.C9804.13030224
Journal Website: www.ijitee.org

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Validation	Sep –Oct 2018	0.4	0.81	14.23	Very Good

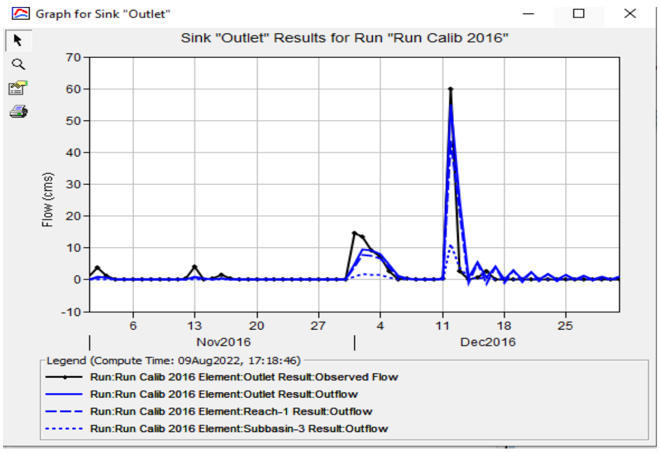

Fig. 13: The Observed and Calibrated Hydrograph Study Area Period 01 Nov 2016 to 31 Dec 2016

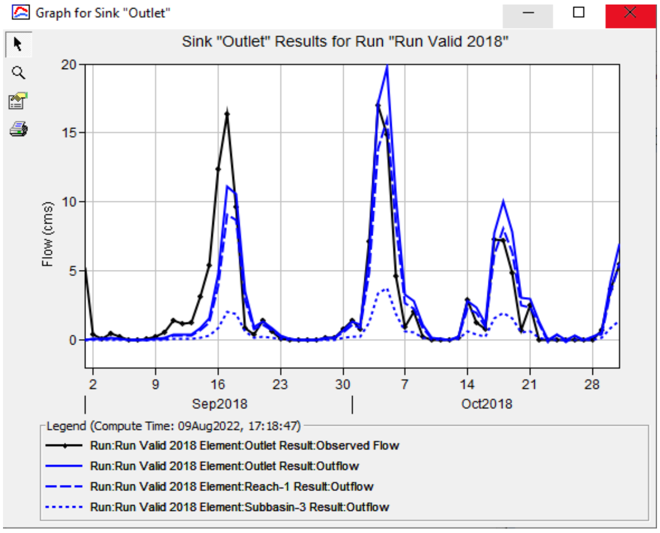

Fig. 14: The Observed and Validated Hydrograph of the Study Area for the Period 01 Sep 2018 to 31 Oct 2018

The performance value of the flow generated in the validation process is more than the performance value 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 statistical indicators shows a good level of accuracy and is listed in Table-VIII.

V.CONCLUSION

In the present work, DEM data was taken at 30m resolution to delineate the Okkiyam Maduvu outlet and its catchment characteristics are determined by using QGIS. Simulation of the rainfall-runoff process is carried out in this study area using the HEC-HMS model. Due to the availability of data, SCS-CN methods are adopted for modeling. In this respect, the curve number, lag time, and Muskingum parameters were obtained and a model was generated using HEC-HMS. The simulation results of runoff discharged the peak flow are slightly different when compared with observed data. From the results, the peak flow is 38.1m3/s was obtained for the period Nov –Dec 2018, which corresponds to the maximum rainfall of 78.67mm against an observed discharge of 45.28 m3/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.

ACKNOWLEDGMENT

I would like to express my sincere gratitude to my guide, Dr. N. Kumaraswamy and Prof. S. Krishnaiah, who encourage me and supported me technically in the course of work.

DECLARATION STATEMENT

Funding	No, we did not receive.
Conflicts of Interest	No conflicts of interest, to the best of my knowledge.
Ethical Approval and Consent to Participate	No, the article does not require ethical approval and consent to participate with evidence.
Availability of Data Material	Not relevant.
Authors Contribution	All the authors have equal participation in the article.

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AUTHORS PROFILE

A. Harinadha Babu has graduated from N.B.K.R.I.S.T, Vidyanagar, Nellore affiliated to S.V. University, Tirupathi in 1996. He obtained his M.E degree in Environmental Engineering from Sathyabama Institute of Science & Technology, Chennai in the year 2005. He has more than 25 years of experience in teaching and is currently doing research in J.N.T.U. A, Anantapuramu, India under the guidance of Dr. N. Kumaraswamy and Prof. S. Krishnaiah. His areas of interests include ground water 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. Prior to this, he held the position of Dean (RRC) at Madanapalli Institute of Technology, Madanapalli, and served as the Principal at 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 degrees, with five Ph.D. scholars currently under his mentorship. He is an accomplished author, having written three books in Civil Engineering, and 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 recognized 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, has graduated from S.V. University, Tirupathi, A.P, India in 1989 in the Civil engineering discipline. He obtained an M.E degree from Goa Govt. Engineering College, Goa. He received a doctoral degree from IIT Bombay in Geotechnical Engineering in the year 2003.He has more than 28 years of experience in teaching and 20 years in research. He was honored 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 honored with Educational Leadership by The Indus Foundation Inc, USA at the Indo-Global Education Summit & Expo2017, Bangalore. He has published more than 80 research papers in national and international journals and conferences. He is elected as a Fellow of the Institute of Engineers (India) and a Life Member of ISTE and IGS. He delivered a number of 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 Head of the Civil Engineering Department and ICS Co-coordinator at JNTUA College of Engineering Anantapur, OSD and Founder Principal of JNTUA College of Engineering, Kalikiri. He worked as Registrar of JNT University Anantapur for about four and a half years. He was the Chairman of UG Board of studies (Civil Engineering) of JNT University Anantapur for three years and member of the Board of studies for various Engineering colleges in A.P., India. His areas of interests include Heat and mass transfer through Geomaterials, Ground Improvement Techniques and Geo-environmental Engineering. He has guided 6 Ph.D students and 8 more Ph.D students work under his guidance.