International Journal of Engineering Applied Sciences and Technology, 2023
Vol. 8, Issue 06, ISSN No. 2455-2143, Pages 69-78
Published Online October 2023 in IJEAST (http://www.ijeast.com)

FLOOD HYDROGRAPH ASSESSMENT OF NORTH KOEL CATCHMENT BASED ON GLOBAL CURVE NUMBER GRID DATA OF DIFFERENT ARC CONDITIONS USING HEC-HMS MODEL -A COMPREHENSIVE ANALYSIS

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Abstract— **Flood Hydrograph simulation is an essential step in analyzing the impacts of extreme flood events. This can aid in water resources management and planning. In areas that are prone to floods, it become necessary to perform an extensive hydrological study. North Koel sub-basin is one of the flood prone watershed, mainly due to the confluence of two large rivers 'Auranga' and Amanat, in eastern side of catchment. This study mainly focused on simulation of flood hydrographs based on Global Curve Number Grid data with 250 m resolution (GCN250m) of 3 different Antecedent Runoff Conditions (ARC) using HEC-HMS model. In this study, hydrograph simulation was done using 3 types of ARCs Grid data namely ARC-I (named Dry condition), ARC-II (noted as Average condition) and ARC-III (Wet condition). Curve Number is one of the vital input parameter for runoff volume computation based on SCS-CN method, the direct runoff computed based on SCS-UH method. Also, Muskingum method used for routing of flood through reaches. The HEC-HMS model simulation reveals that the Wet condition (ARC-III) CN grid data predicted higher flood discharge than Dry and Average conditions. The peak flood discharge of 1,66,844 m^3/s, 1,97,926 m^3/s and 2,26,485 m^3/s predicted from model simulation based on Dry, Average and Wet conditions grid data respectively. The model simulation results shows that the Wet condition peak flood deliver a 26.33% higher discharge than Dry condition and 12.6% higher flood occurred than Average condition. The GCN250m grid data of ARC-III (Wet condition) condition weighted average Curve Number obtained a higher value, accordingly HEC-HMS model simulation results a higher flood discharge.**

Keywords—**GCN250m, Antecedent Runoff Condition, Flood Hydrograph, Hydrologic Modeling System, Flood discharge, SCS-CN, Unit Hydrograph**

I. INTRODUCTION

Precipitation and runoff represent pivotal elements within the hydrological cycle. Runoff arises at the land's surface due to the accumulation of surplus precipitation. Any precipitations within a watershed after undergoing infiltration and evaporation gathers as runoff at drainage points and ultimately flows towards an outlet. The quantity of runoff generated is shaped by a confluence of climatic, physiographic, and geological factors within the catchment area [1]. The change in the climate affects the amount of precipitation and also alters intensity and frequency [2]. The effects on precipitation influences the amount of streamflow and peak flows [3].When the amount of runoff volume is known, it can be help in solving several watershed management problems. The primary factor leading to flooding is the exceeding runoff volumes that are routed to channels than that of stream flow capacity [4]. It is important to estimate the magnitude of flood, frequency and intensity for flood risk management [5] and these are also altered by the urbanization which increases the peak [6]. The variability in climate has also resulted change in peak discharges as well as shifts in the peak flow [7]. As an example, when peak flow can be predicted, it is possible to in early flood warnings which will improve flood preparedness. In addition, peak flow prediction is also vital to assess for the strategies for different management options and solve water related problems [8]. Yet another illustration of the significance of assessing surface runoff lies in its relevance to agriculture. Surface runoff plays a crucial role in the transportation of nutrients across agricultural fields, and determining runoff patterns can provide valuable insights into these transport processes, ultimately supporting improved agricultural management practices. Therefore, understanding rainfall-runoff process is extremely important in watershed management and for designing sustainable systems [9]. However, it is difficult to understand the process within rainfall-runoff and predicting the amount of runoff generated can be challenging, mainly due to its nonlinear and multidimensional dynamics [10].

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The Soil Conservation Service (SCS) Curve Number (CN) method has gained general acceptance in the Engineering practice due to its simplicity in estimating storm water runoff depth from rainfall depth and its endorsement by the United States Department of Agriculture (USDA). Originally developed from daily rainfall data from small agricultural watersheds in the Midwestern United States [11],[12],this method was first introduced in 1954 [13]. The CN method continues to be updated and amended with increasing data and research [14], as well as innovative applications such as water quality modelling [15]. Many researchers have demonstrated from rainfall and runoff data that its key parameter CM has variable components and it is not a constant for a watershed [16], [17], and varies with rainfall. More than 80% of the rainfall occurs during the monsoon periods in North Koel basin of Jharkhand. Moreover, intensity of monsoon rainfall very uneven both in space and time, resulting in scarcity of availability of water in some parts of the region during non-monsoon periods. Thus, it is essential to analyze the variation of Curve Number during various seasons.

In general, variation in CN between events can result from variations in storm characteristics and surface conditions. Much of the variability in CN has been attributed to antecedent runoff condition (ARC) such that soils that are wetter have a higher Curve Number, creating more runoff for a given amount of precipitation, than soils that are drier [18]. The Curve Number method currently lacks a parameter accounting for the influence of seasonal variations on runoff volume forecasting. Consequently, it overlooks the effects of seasonal and monthly variations on evaporation, transpiration, and interception. Although the Curve Number method is well documented and widely used, as Jacobs and Srinivasan [19] pointed out, a need to use the method as a guideline and interpret inputs on a local and regional level combined with seasonal variation is essential. Runoff simulation with annually consistent parameters has limited application because watershed response varies remarkably from season to season and the seasonal tank model developed by Paik et al. [20]. This model showed better performance compared to the non-seasonal tank model because it can successfully simulated runoff with little error.

Varying the Curve Number on a seasonal basis, therefore, may also result in more accurate runoff estimation and improve the Curve Number performance. Some of the previous works carried out in the seasonal variation of CN at various locations. However, detailed study on the seasonal variation and distribution of CN in North Koel sub-basin has not been included. So it is necessary to analyze the effect of seasonal and monthly variation on the Curve Number for selected watersheds of North Koel basin based on observed rainfall and runoff volume.

II. MATERIALS AND METHODS

A. Study Area

The present study has been conducted in North Koel sub-basin upto confluence of Sone River. The North Koel River is the second largest right bank tributary of the river Sone. The North Koel River, which rises in the Ranchi plateau and joins the Sone River a few miles north-west of Haidarnagar. The river initially flows in the northern direction through the narrow valley of Bishupur in Palamu district and thereafter turns towards west and flows in this direction for about 32 km. It then takes an almost right angle turn through a gorge at ‘Kutku’ and flows in north-east direction upto its confluence with the ‘Auranga’ river. It later turns towards north-west and is met by the Amanat River just downstream of ‘Daltonganj’. After flowing for another 30 to 40 km in the north-west direction it turns towards north and meets the river Sone at an elevation of 140 m in Palamu district of Jharkhand, a few Kilometers north-west of Haidarnagar, opposite the famous hill fort of Rohtasgarh of 24^{o} 30’N,longitude 83^{o} 55’ E.

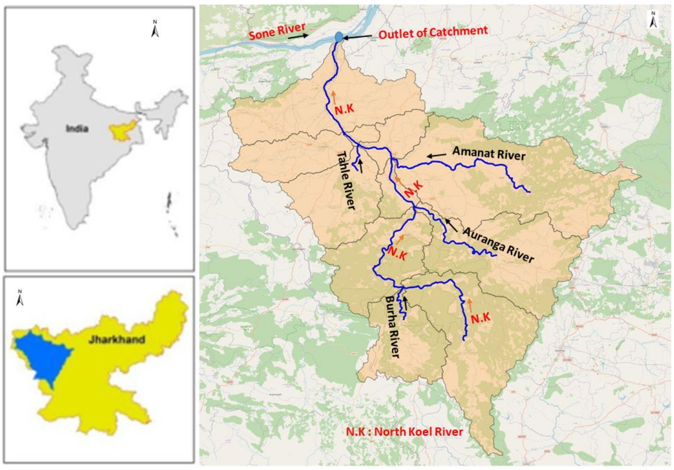

Fig. 1. Location map of study area

Fig. 2. Along its entire course of flow, North Koel river flows through plateau region mostly formed of metamorphic rocks. Hence, structural control seems to be the primary control on the landscape evolution of this sub-basin [21]. The study area stretches between 23^{0} N, 83^{0} 30’ E to 24^{0} 30’ N, 85^{0} E and the maximum elevation is 1177m and minimum elevation of the basin is 122m. The total length of the river is 259 km and its catchment area is 11,100 km^{2}.The North Koel River has three important tributaries namely the Auranga, the Amanat and the Tahle as shown in Figure.1.

B. Data collection

The data used in the present study were collected from various sources summarized in the table 1.

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Table-1: Data used in the study

Data Type	Source
Digital Elevation Model	**Bhuvan-ISRO**
Rainfall	**IMD-Pune**
GCN250m Grid data	**Google Earth Engine**

The Digital Elevation Model (DEM) data downloaded from Bhuvan-ISRO web portal [22] of Cartosat-1 satellite with a resolution of 30m as shown in Fig.2. Rainfall data collected from Indian Meteorological Department (IMD)-Pune for about 36 years daily data from 4 stations covered within the North Koel catchment. The 4 stations were Manika, Balumath, Latehar and Chandwa as shown in Fig. 3. The major important data for computation of losses and transform method of hydrograph in HEC-HMS model was Curve Number data of the study area. The Global Curve Number (GCN 250m) grid data available in 3 different types of ARC conditions downloaded from Google Earth Engine [23] web portal. The brief description about three ARCs (GCN250m) grid data explained in the next paragraph

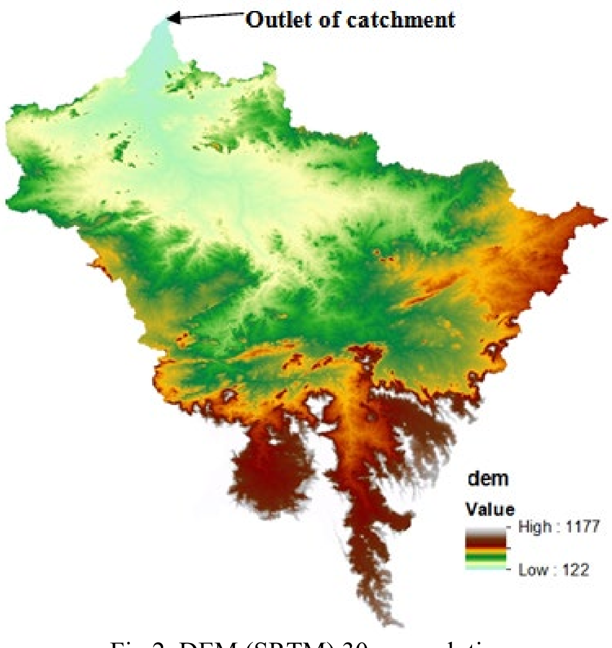

Fig.2 DEM (SRTM) 30 m resolution

C. GCN250m Grid Map - Scientifical Background

Land cover and soils play a fundamental role in the hydrologic cycle by controlling infiltration and affecting surface and ground water flows. The Natural Resources Conservation Service (NRSC) of the United States Department of Agriculture (USDA) developed a simple, stable and predictable method for calculating runoff from rainfall events. Recently and with the increasing availability of routine land cover products, there have been few attempts to develop regional and global curve number datasets. Hong and Adler [24] generated a global CN dataset at the 0.1^0 resolution based on (1) the global land cover data from the Moderate Resolution Imaging Spectroradiometer (MODIS) at 1-km resolution produced in 2003 and (2) the Digital Soil Map of the World (DSMW) published in 2003 (100-km resolution) by the Food and Agriculture Organisation (FAO) of the United Nations. However, their global CN dataset was not published. Zeng et al. [25] used the MODIS 500m Land Cover product of 2013 with the Harmonized World Soil Database (HWSD)v.1.2 and the Digital Soil map of the World (DSMW)v3.6 as amended by FAO in 2007 to generate global CN map at a “fine” resolution, believed to be 500m (by downscaling the 30 arc-second HWSD data). The Zeng et al. global CN dataset was also not publicly available. In the two works (Hong and Adler, Zeng et al.), the CN datasets were produced by converting the soil classification in the FAO database to Hydrologic Soil Group (HSG) using the provided soil properties based on the USDA soil texture classification scheme.

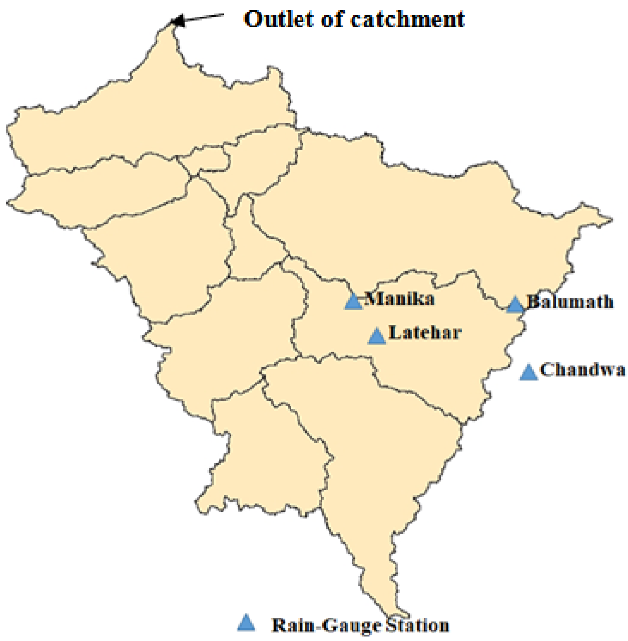

Fig.3 Location of rain-gauge stations

Ross et al. [26] generated the first publicly available gridded dataset of HSG at the 250m resolution (HYSOGs250m) from soil texture, depth to bedrock, and ground water, also following USDA specifications. The generation of HYSOGs250m data triggered our attempt to create a synergetic curve number product exploiting the most recent land cover (LC) data (2015) at a similar resolution (300m). The newly released global LC maps for 2015 were developed by the European Space Agency (ESA) Climate Change Land Cover Project (CCI-LC) [27]. This project produces global annual LC maps starting from the 1990s through 2015 (and beyond) based on several satellite sensors: Advanced Very High Resolution Radiometer (AVHRR), Satellite Pour l'Observation de la Terre Vegetation (SPOT-VGT), Medium Resolution Imaging Spectrometer (MERIS), and Project for On-Board Autonomy-Vegetation (PROBA-V).

The first generated Global Gridded CN dataset (GCN250) from the ESA CCI-LC maps (2015) and the HYSOGs250m soils data based on the USDA curve number tables [28] and plant functional types [29]. The GCN250m datasets represent the Global Curve Numbers at approximately 250 m spatial resolution under Dry, Average and Wet Antecedent Runoff Conditions (ARC). The soil was assumed undrained soil, and hence the CN of dual HSG were treated the same as the HSG class D. The GCN250 dataset is valuable for hydrological analysis and design, flood risk assessment, and mapping, watershed water management, and other related applications. Rainfall-Runoff modeling is a potential application given the available techniques in downscaling gridded precipitation data. There are three main inputs used to generate GCN250m datasets: a land use/land cover map, a Hydrologic Soil Group (HSG) map, and three CN look-up tables. For the land cover product, used the most recent ESA-CCI LC data of 2015 (ESA) [29]. The Hydrologic Soil Groups were acquired from Ross et al.[26]. The CN look-up table was created based on the USDA Soil Conservation Service (SCS) Runoff Curve Number (CN) method [28]. GCN250m was created within the R open source environment [30] using the Raster library functions [31].

D. GCN250m - Antecedent Runoff Conditions (ARC)

The CN values vary depending on Antecedent Runoff Conditions (ARC), which is affected by the rainfall intensity and duration, total rainfall, soil moisture conditions, cover density, stage of growth and temperature. For this reason, generated three curve number maps for three ARCs: ARC-I is Dry condition, ARC-II is Average condition, and ARC-III meant for Wet condition [32]. The brief description of each condition as follows.

E. ARC-I Dry Condition

The North Koel catchment divided into 11 number of sub-basins. The weighted average curve number was computed for each sub-basin based on ARC-I grid map of catchment as shown in Fig.4. The weighted average curve number for the entire North Koel catchment was computed and the composite CN was 57.34. The sub basin No.5 has lowest curve number of 51.2, and the highest curve number was 58.35 of sub basin no.4. The curve numbers of all sub basins of North Koel catchment was shown in Fig.5.

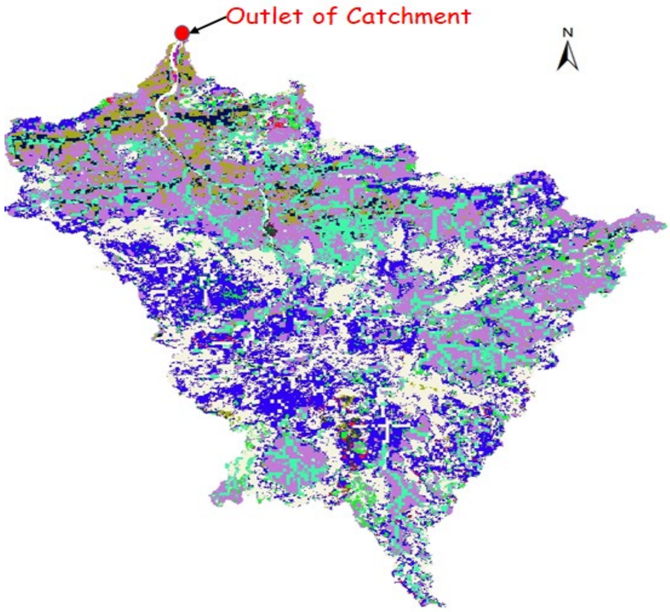

Fig. 4 GCN250m grid map of ARC-I (Dry)

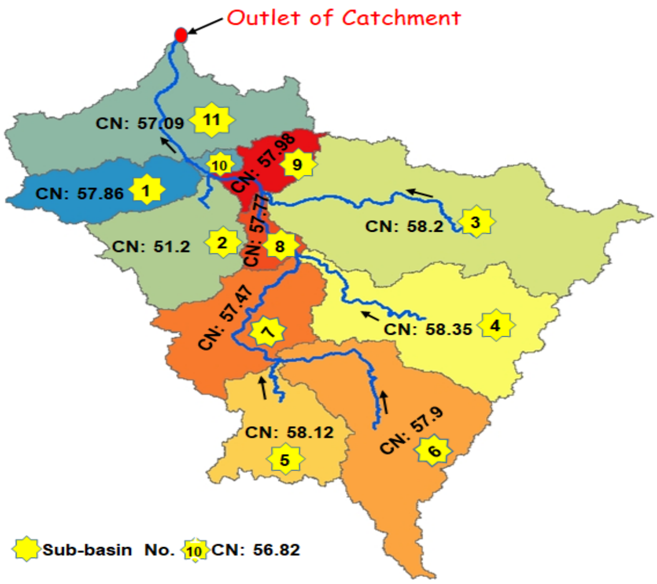

Fig. 5 CNs of all sub-basins (ARC-I)

F. ARC-II Average Condition

The weighted average curve number was computed for each sub-basin based on ARC-II (Average condition) grid map of catchment as shown in Fig.6. The weighted average curve number for the entire North Koel catchment was computed as 75.66. The North Koel catchment divided into 11 number of sub-basins out of which, the sub-basin No.10 has lowest curve number of 74.18, and the highest curve number obtained for sub-basin no.4 as 76.24. The curve numbers of all 11 sub-basins of North Koel catchment was shown in Fig.7.

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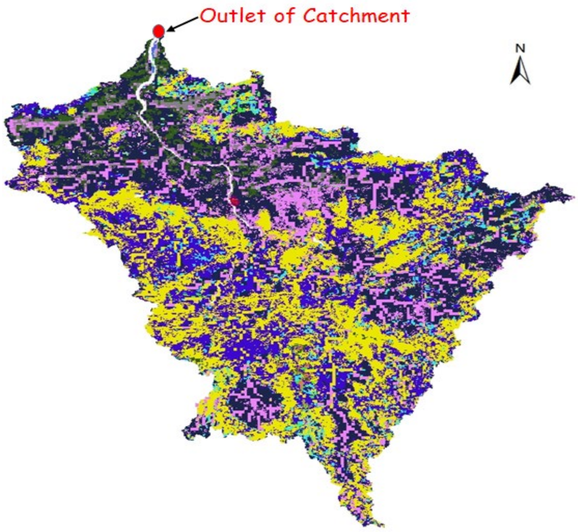

Fig 6 GCN250m grid map of ARC-II (Average)

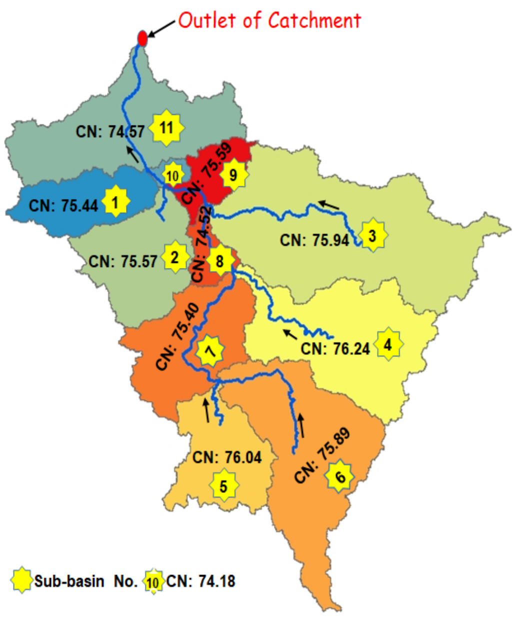

Fig 7 CNs of all sub-basins (ARC-II)

G. ARC-III Wet Condition

The North Koel catchment was divided into 11 sub-basins. To calculate the weighted average curve number for each sub-basin, used the ARC-III (wet condition) grid map of the catchment, as illustrated in Fig.8. The computed weighted average curve number for the entire North Koel catchment was 88.32. Among the sub-basins, the lowest curve number, 86.23, was observed in sub-basin No.10, while the highest curve number, 88.97, was recorded in sub-basin No.4. The visual representation of the curve numbers for all the sub-basins of the North Koel catchment in Fig.9.

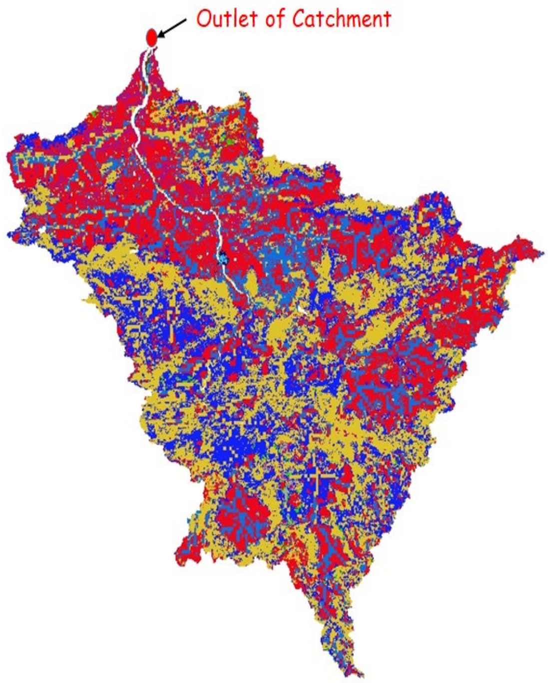

Fig.8 GCN250m grid map of ARC-III (Wet)

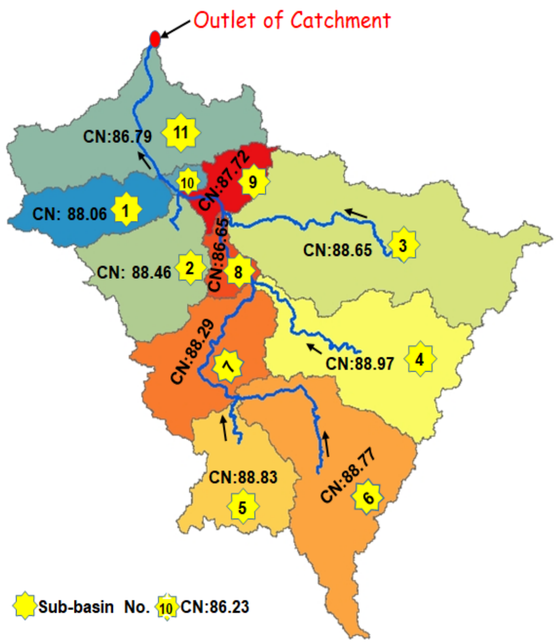

Fig.9 CNs of all sub-basins ARC-III

The weighted average curve numbers of North Koel catchment computed from three different Antecedent Runoff Conditions (ARC) and Curve Numbers (CNs) of each sub-basin used in HEC-HMS model were illustrated in the Table 2.

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Table 2: Curve Numbers of all Sub-basins

	Global Curve Number Grid data – GCN250m for different ARC conditions		
	ARC-I Dry condition CNs	ARC-II Average condition, CNs	ARC-III Wet condition, CNs
North Koel Catchment	57.34	75.66	88.32
Sub-basin No.1	57.67	75.44	88.06
Sub-basin No.2	51.2	75.57	88.46
Sub-basin No.3	58.02	75.94	88.65
Sub-basin No.4	58.35	76.24	88.97
Sub-basin No.5	58.13	76.04	88.83
Sub-basin No.6	57.9	75.89	88.77
Sub-basin No.7	57.47	75.4	88.29
Sub-basin No.8	57.77	74.52	86.65
Sub-basin No.9	57.98	75.59	87.72
Sub-basin No.10	56.82	74.18	86.23
Sub-basin No.11	57.09	74.57	86.79

III. HEC-HMS MODEL

In this study, the Hydrologic Engineering Center-Hydrologic Modeling System (HEC-HMS) was used for runoff simulation. HEC-HMS, developed by US Army Corps of Engineers Hydrologic Engineering Center, is designed for both continuous and event-based hydrologic modelling system [33]. It provides several options to the users for modeling various components of hydrologic cycle. Initially, it was developed to simulate the rainfall-runoff processes of dendritic watershed systems but later it was improved to solve widest possible range of problems includes necessary procedures for continuous simulation including evapo-transpiration, snowmelt and soil moisture content. The model has supplemental analysis tools for model optimization, forecasting stream flow, depth-area reduction, assessing model uncertainty, erosion and sediment transport and water quality.

The software HEC-HMS (v4.10) used in the study was downloaded from HEC website. The HEC-HMS model used for North Koel catchment to derive different sub-basins and reaches and junctions as shown in Fig.10.

The reach connects the two junctions and the outflow joins the junctions. The outflow was determined at the outlet by applying the loss model, runoff transform model and baseflow model. Muskingum method was used to route the flow one junction to the other. To develop HMS process different models were used on the issue to be considered while selecting the methods. The several geomorphological parameters like the centriodal flow length, the longest flow path and average slope was extracted for each basin. Different hydrologic nodes were assigned with in each sub-basin and an outlet was defined as shown in Fig.10

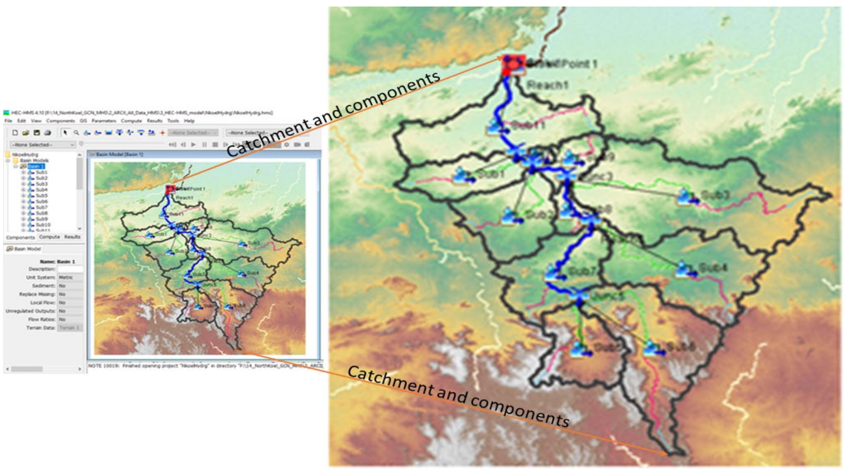

Fig.10 Schematic representation of HEC-HMS model and derived components

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A. HEC-HMS Model Components for Simulation

HEC-HMS uses separate models to represent each component of the hydrological process that are represented in Fig.10. It includes models for computation of runoff volume, models for direct runoff, including overland flow and interflow, models for base flow and models of channel flow. There are different methods for each process in HEC-HMS model. User can select any method according to data availability and flexibility in use. In this study SCS-CN model, SCS Unit Hydrograph (SCS-UH) model, and Muskingum routing models are used for computation of runoff volume, computation of direct runoff, and channel flow(flow routing) respectively. The brief description of each model as follows.

B. SCS-CN Model

The Soil Conservation Service Curve Number (SCS-CN) method estimates rainfall excess as a function of cumulative precipitation, soil cover, land use and antecedent moisture, using the following equation.

$P_e = (P-I_a)/(P-I_a+S)$ (1)

Where P_e = accumulated rainfall excess (runoff) time t; P = accumulated precipitation depth at time t; I_a = the initial abstraction (initial loss); S = potential maximum retention (watershed storage) which is a measure of the ability of a watershed to abstract and retain precipitation.

From analysis of results from many small experimental watersheds, the SCS developed an empirical relationship between I_a and S as

$I_a = 0.2\ S$ (2)

Hence, the cumulative rainfall excess at time t is represented as:

$P_e = (P-0.2\ S)^2/(P + 0.8\ S)$, $P>- 0.2\ S$ (3)

Incremental excess for a time interval is computed as the difference between the accumulated excess at the end and beginning of the period. Watershed characteristics and the maximum retention (S) are related through an intermediate parameter called as Curve Number (CN).

$S = (25400 – 254\ CN)/ CN$ (4)

CN value ranges from 0 to 100, and the CN value for a watershed can be estimated from Global Curve Number (GCN) 250 m resolution grid map downloaded from Google Earth Engine (GEE) for 3 different Antecedent Runoff Condition (ARC) such as ARC-I Dry condition, ARC-II Average condition, and ARC-III Wet condition as explained in the earlier paragraphs.

C. SCS-UH Model

The Soil Conservation Service (SCS) proposed a parametric Unit Hydrograph (UH) model. The SCS Unit Hydrograph method makes use of dimensionless, curvilinear unit hydrograph to route excess precipitation to the sub-basin outlet.

D. Muskingum Routing Model

The Muskingum routing method is based on the conservation of mass approach is used to route flow through the stream reach. The Muskingum method accounts for looped storage vs. outflow relationships that commonly exist in most rivers. This can simulate the commonly observed increased channel storage during the rising side and decreased channel storage during the falling side of a passing flood wave.

Parameters that are required to utilize this method within HEC-HMS includes the initial condition, K (hours), X, and the number of sub reaches. 'K' is equivalent to the travel time through the reach. The initial estimates of this parameter can made using observed streamflow data or through approximations of flood wave celerity. 'X' is a dimensionless coefficient that lacks a strong physical meaning. This parameter must range between 0.0 (maximum attenuation) and 0.5 (no attenuation). When 'x' parameter is set to a value of 0, storage within the reach is computed solely as a function of outflow. This is equivalent to level pool routing and results in the maximum possible amount of attenuation. When this parameter (x) is set to a value of 0.5, equal weight is given to both inflow and outflow when determining storage within the reach. This results in no attenuation to the inflow hydrograph as it progresses through the reach.

For most stream reaches, an intermediate value is found through calibration. The specified number of sub-reaches affects attenuation. One sub-reach results in the maximum amount of attenuation and increasing the number of sub-reaches approaches zero attenuation.

IV.HEC-HMS APPLICATION - RESULTS AND DISSCUSSIONS

The HEC-HMS model simulation carried out in 3-scenarios. These are based on the three verities of GCN250m grid data with three Antecedent Runoff Conditions (ARC) of Dry, Average and Wet. The dry condition denoted as ARC-I, the average condition noted as ARC-II, and Wet condition mentioned as ARC-III. The composite Curve Number (CN) was computed for each sub-basin in the North Koel catchment for three ARC conditions. These CN values used in loss model, transform model for simulation of HEC-HMS model in 3 scenarios. The results of 3-scenario simulation discussed as follows.

A. Scenario-I

The HEC-HMS model simulation was conducted using weighted average CN values derived from the GCN250m grid data of ARC-I (representing dry condition) in scenario-I. This simulation yielded a peak discharge of 1,66,844 m^3/s and a peak volume of 2807.40 mm. Under dry conditions, the computed weighted average CN for the entire North Koel catchment was 57.34 based on the GCN250m grid data.

B. Scenario-II

The simulation was conducted using CN values obtained from the average condition of ARC-II representing the average values from the GCN250m grid data. This simulation resulted in a peak discharge of 1,97,926.3 m^3/s and a peak volume of 2937.87 mm for the North Koel catchment. Under the average conditions of GCN250m grid data, the computed weighted average CN value for the entire North Koel catchment was 75.66.

C. Scenario-III

The HMS model simulation was conducted using CN values obtained from the wet condition of ARC-III, which represents the wet conditions in the GCN250m grid data. This simulation resulted in a peak discharge of 2,26,485.3 m^3/s and a peak volume of 3053.74 mm for the North Koel catchment. Under the wet conditions of ARC-III, the computed composite CN for the catchment was 88.32. The comparison of flood hydrographs represented in graphical form as shown in Fig.11.

The wet condition of ARC-III results shows highest peak flood, and next ARC-II condition represents average condition flood hydrograph shows a little lower peak value as shown in the figure 11. The hydrograph reveals that, the Dry condition of ARC-I has lower peak flood discharge than other Average and Wet conditions.

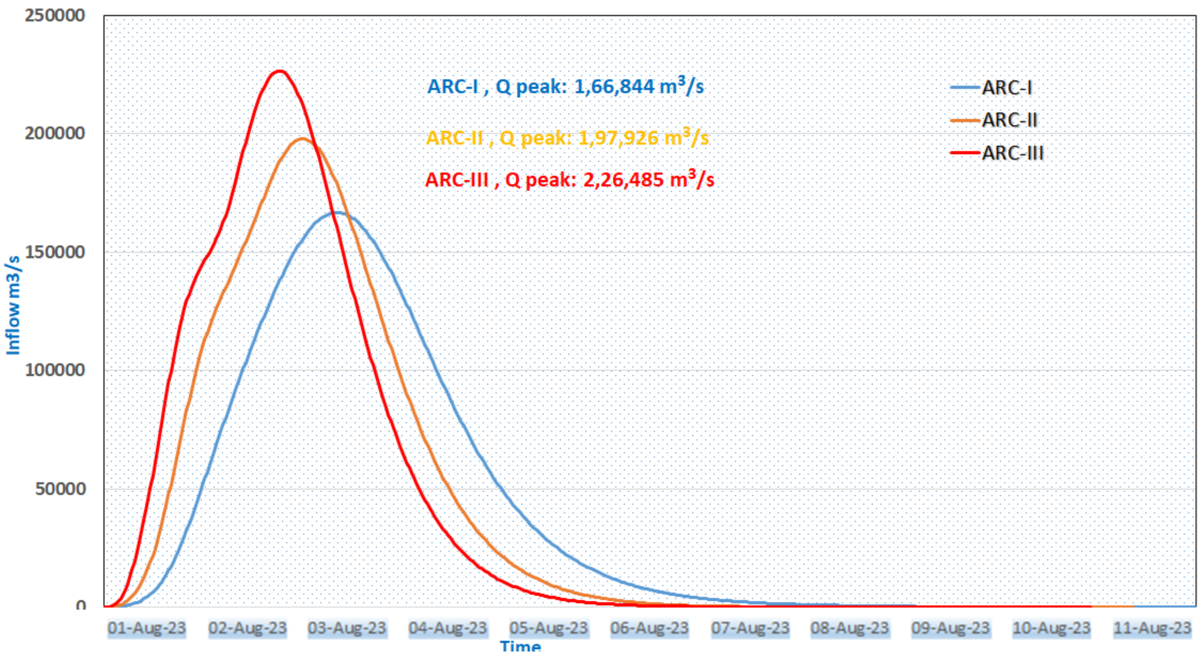

Fig.11 Flood Hydrographs for 3-ARC conditions

As shown figure 11, the flood hydrograph of ARC-I condition (represent dry condition) shows a standard shape of hydrograph, While the flood hydrograph for ARC-II and ARC-III conditions the hydrograph represents a bend or curvilinear shape in rising limb before reach peak of hydrograph. The bend in the rising limb of a hydrograph is a result of the complex interplay of factors such as initial abstraction, variable infiltration rates, time lag in flow paths, and variable rainfall intensity. These factors can cause delays and variations in the timing and rate of runoff response to a rainfall event, resulting in the characteristic curvature of the hydrograph's rising limb.

If the rainfall event has varying intensities over time, it can lead to different rates of runoff generation at different points in time. This variability in rainfall intensity can result in fluctuations in the rising limb of the hydrograph.

Time lag in flow path is another reason to cause bend in rising limb, as such water takes time to travel from various points within a watershed to the stream or river where it contributes to the hydrograph. This time lag is influenced by factors such as the slope of the land, soil types, and the presence of flow pathways like streams or subsurface flow channels. Different flow paths may have different time lags, leading to the gradual rise and curvature of the hydrographs.

Variable infiltration rates at which rainfall infiltrates into the soil can vary across the watershed. In some areas, the soil may be saturated or have low infiltration capacity, leading to rapid runoff, while in other areas, infiltration may occur more slowly. This spatial variability in infiltration rates can contribute to the curvature of the rising limb as runoff from different parts of the watershed.

V. CONCLUSIONS

The principle tenet of this research article is to utilization of Global Curve Number (GCN) 250 m resolution grid data from Google Earth Engine. This grid data available in 3 Antecedent Runoff Conditions (ARC). The ARC-I condition represented as Dry condition, ARC-II represents average condition, and ARC-III represents Wet condition. The Curve Numbers are derived in three different conditions and incorporated as input parameter for various component models such as loss model and transform model. Based on these component models the HEC-HMS model simulation was performed to derive flood hydrographs of North Koel Catchment according three ARC conditions as 3 different scenarios.

Among three ARC condition, Dry condition (ARC-III) delivered high peak flood discharge of 2,26,485m^3/s and Average condition (ARC-II) predicted a little lower value of 1,97,926 m^3/s flood discharge.

The Dry condition (ARC-I) predicted lower flood discharge of 1,66,844m^3/s comparatively with Average and Wet conditions. The HMS model simulated flood hydrographs of the three conditions are shown in Figure 9. The ARC-III condition simulation predicted a 12.6% higher flood discharge comparatively with ARC-II condition and a 26.33% of higher discharge computed to ARC-I condition. However, Dry condition (ARC-I) grid map delivered a lowest flood discharge than Average (ARC-II) and Wet (ARC-III) conditions. In other words the peak flood difference between Wet condition and Average condition was 28,559 m^3/s and between Wet condition and Dry condition was 59,641 m^3/s.

The overall flood discharges of 3 ARC conditions computed based on HEC-HMS simulation, results reveals that the higher CN values predicted higher flow and lower CN values predicted lower flood discharges at the outlet of North Koel catchment. Accordingly ARC-III (Wet condition) delivered higher and ARC-II (Average condition), ARC-I (Dry condition) grid map delivered lower flood discharges.

VI. REFERENCES

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