RAINFALL-RUNOFF ESTIMATION OF ONG RIVER BASIN USING SCS-CN METHOD IN HEC-HMS WITH THE HELP OF GIS AND REMOTE SENSING

A thesis submitted towards partial fulfilment of the requirements for the degree of

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CERTIFICATE OF RECOMMENDATION

This is to certify that the thesis entitled **"RAINFALL-RUNOFF ESTIMATION OF ONG RIVER BASIN USING SCS-CN METHOD IN HEC-HMS WITH THE HELP OF GIS AND REMOTE SENSING"** is bonafide work carried out by **BISHWAJIT LENKA** under our supervision and guidance for partial fulfilment of the requirement for Post Graduate Degree of Master of Engineering in Water Resources & Hydraulic Engineering during the academic session 2018-2019.

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I hereby declare that this thesis contains literature survey and original research work by the undersigned candidate, as a part of my Master of Water Resources & Hydraulic Engineering degree during academic session 2018-2019.

All information in this document has been obtained and presented in accordance with academic rules and ethical conduct.

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Abstract

One of the basic challenges of hydrology is the estimation and quantification of surface-runoff at a point in a catchment area. In this study, the catchment of interest is Ong River basin stretched over the regions in the states- Chhattisgarh and Odisha, of India. The Ong river Basin is having an area about 5000 km^2 at lower Mahanadi region.

Among various methods used for hydrological modelling, this paper is dealing with Soil Conservation Service- Curve Number method (SCS-CN) with the help of Geographical Information System (GIS) and Remote Sensing. Simulation is done using Hydrological Modelling system (HEC-HMS) for which the corresponding data required in the model are prepared using Arc-Hydro tool and HEC-Geo HMS tool of ArcGIS software. The present study demonstrates the integration of GIS and SCS-CN method and exhibits satisfactory validation based on historical data.

Keywords: Ong River Basin; SCS-CN; GIS; Remote Sensing; Rainfall-Runoff; HEC-HMS; ArcGIS.

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INTRODUCTION

CHAPTER1

1.1 General

Among all the resources available to us, the importance of the resource- water can never be over-emphasized. Water resource is the very base of life and its growth, on the planet. But effects of climate change along with rapidly increasing human activities are continuously putting pressure on water as a scarce resource. It is not that the planet is losing water, it remains the same. The matter of concern is the form or state in which it is present. Of all the water available, about 97.5% is saline and the other 2.5% is freshwater, of which, 68.7% is in form of glaciers and ice caps, 30.1% is groundwater and 1.2% surface or other fresh water (Wikipedia). And it is the fresh water that is mainly used by humans and animals. So, this resource is needed to be monitored and managed as carefully as we can, in order to achieve its sustainability.

Rainfall and runoff constitute a significant source of fresh water, as a source for recharge of ground water and surface water sources in the catchment area. A good understanding of rainfall-runoff relation and variability of a catchment area is essential to develop an effective management to any corresponding hydrological situation. Hydrological modelling provides a mean to understand the relationship between rainfall and runoff corresponding to various parameters like hydrological soil group, land use pattern etc. affecting their relation. This will finally help to get runoff estimation of the catchment area to a given rainfall. Runoff estimation facilitates prediction of probable amount of water drained by the catchment.

1.2 Hydrological Modelling

Modelling is replicating the real case scenario in order to predict and quantify possible output to various input, using the science and knowledge we have in the corresponding field. Today, various hydrological models have been developed each of which requires various input data such as rainfall, soil types, soil properties, its distribution, temperature, land use pattern and various other parameters depending upon the unique characteristics of model, approach and methods used in the model such as Rational method, Green-Ampt method, Soil Conservation Service Curve number (SCS-CN) method. These methods differ from each other depending on factors such as size of the area of interest, input parameters etc.

There are various generalised physically based and spatially distributed hydrological computer models of catchments that are capable of computing sequences of runoff generated from given rainfall event(s). The major advantage of such models is its accuracy in their predictions. On the other hand the main disadvantage of such models is that they require considerable amount of time, expertise, effort and lots of data being used effectively. In between these extremes there are methods like the SCS-CN (Soil Conservation Service Curve Number) method which are relatively easy to use and yield satisfactory results (Schulze et al. 1992).

1.3 SCS-CN Method

The SCS-CN method developed by Soil Conservation Services (SCS), now called National Resources Conservation Services (NRCS), USA. It is among the most popular methods used for estimating the surface runoff in a catchment for given rainfall event(s) because of its simplicity and stable conceptual method.

1.3.1Basic Theory

The SCS-CN method is based on the 'Water Balance Equation of the rainfall for a given time interval' and two other concepts. The first concept states that the ratio of actual amount of direct runoff (Q) to maximum potential runoff (= $P - I_a$) is equal to the ratio of the amount of actual infiltration (F) to the potential maximum retention (or infiltration), S. The second concept states that the amount of initial abstraction (I_a) is some fraction of the potential maximum retention (S). Mathematically the above can be expressed, respectively, as below:

$$P = I_a + F + Q \quad (1)$$

$$\frac{Q}{P - Ia} = \frac{F}{S} \quad (2)$$

$$I_a = \lambda S \quad (3)$$

Where P = total precipitation; I_a= initial abstraction; F = cumulative infiltration excluding I_a; Q = direct runoff; and S = potential maximum retention or infiltration.

Combining equation 2 and 3, and using 1,

$$Q = \frac{(P - Ia)^2}{P - Ia + S} = \frac{(P - \lambda S)^2}{P + (1 - \lambda)S} \text{ for } P > \lambda S$$

Further $Q = 0$ for $P \leq \lambda S$

For operation purposes, a time interval Δt = 1 day is adopted. Thus P = daily rainfall and Q = daily runoff from the catchment.

1.3.2 Curve Number (CN)

The potential maximum retention represented as the parameter S depends upon the soil type and land use complex of the catchment area and also depends upon the antecedent soil moisture condition in the catchment just prior to the commencement of the rainfall event. For convenience in practical application the Soil Conservation Services (SCS) of USA expressed the S (in mm) in terms of Curve Number (CN) a dimensionless parameter as

$$S = \frac{25400}{CN} - 254$$

Or, $$S = 254\left(\frac{100}{CN} - 1\right)$$

The constant 254 is used to express S in mm.

The curve number CN is now related to S as

$$CN = \frac{25400}{S + 254}$$

And has a range of 100 ≥ CN ≥ 0. A high curve number means low infiltration and hence, high runoff (as in urban areas), whereas a low curve number would mean high infiltration and low runoff (dry soil). So, the curve number can be said to be a function of land use and hydrological soil group (HSG).

Generally, a given catchment area will consist of various soil types and covering different type of land use pattern. So, this situation will force us either to calculate curve number of each soil type corresponding to various land cover pattern followed by calculating runoff from each such cases (which is impractical manually for a large area) or to calculate a composite curve number for the catchment area. The traditional method of calculating the composite curve number of a catchment area is too tedious, and takes up a major part of the hydrologic modelling time. GIS and Remote Sensing combined with SCS-CN number facilitates to overcome this difficulties.

1.4 GIS and Remote Sensing

Remote sensing, as the name suggest, is the science of 'sensing something remotely' i.e. without getting in contact with the area of interest. So, remote sensing is the process of detecting and monitoring the physical characteristics of an area by measuring the reflected and emitted radiation from it at a distance from the targeted region or area. Special cameras are used to collect remotely sensed images of earth which helps us to detect things about the specific region of earth we are interested. For example Digital elevation model (DEM) are commonly built using data collected from remote sensing techniques, which otherwise can be prepared by land surveying taking a lot of time comparatively.

Geographic Information System (GIS) is a computerized database management system used to enable the user in capturing, storing, retrieving, manipulating, analysing, managing and visualizing the spatial or geographical data that are linked to the real-world coordinates. In general, GIS is hugely used in the field of environment particularly in hydrologic and hydraulic modelling, flood mapping and watershed management etc. In our case, as mentioned earlier, the curve number (CN), being a function of soil type (Hydrological Soil Type) and land use type; the use of GIS becomes important in providing accurate spatial information required to apply for this method. The use of GIS will help in easily retrieve and process the soil type and land use shape files and intersecting both the files will create a base file for generation of CN grid which will provide the curve number value of each point (cell grid). This very process will significantly simplify the curve number calculation process.

1.5 Objective

The main aim of the work is to prepare a hydrological model of Ong River Basin for Rainfall-Runoff estimation using SCS-CN method taking GIS and remote sensing approach. To attain this aim the following objectives are defined-

(i) Terrain processing - which involves delineating streams and watersheds, and getting some basic watershed properties such as area, slope, flow length, stream network density, etc. using Digital Elevation Model (DEM) and GIS tools.

(ii) HMS model development – here we create input files for hydrologic modelling with HEC-HMS which also includes preparing CN grid file.

(iii) Simulation using HEC-HMS and getting results, followed by its validation.

1.6 Thesis Outline

The thesis consists of six chapters, a general introduction on hydrological modelling, various methods and tools used for modelling are provides in Chapter 1. In Chapter 2 a literature review is presented on various works carried out.

Chapter 3 covers the details of the study area selected and the data utilized to carry out the work. This is followed by Chapter 4 which focuses on the detailed Methodology applied to develop the hydrological Model and the simulation.

Chapter 5 presents the Results generated from the model and the validation of the model. The last chapter concludes the whole study done to develop the hydrological model and its results, including its limitation and the future scope of study.

LITERATURE REVIEW

CHAPTER 2

2. Literature Review

Ponce et al. (1989) states that the continuous hydrologic models, unlike event models, account for a watershed's soil moisture balance over a long term period and are suitable for simulating daily, monthly and seasonal stream flow. The Hydrologic Engineering Centre (HEC) added soil moisture accounting (SMA) algorithm to the Hydrological Modelling System (HMS) program which deals with the loss accounting through the soil strata as well as the upper vegetation characteristics. The initial program release was called Version 1.0 and included most of the event-simulation capabilities of HEC-I program. It did introduce several notable improvements over the legacy software including the unlimited number of hydrograph ordinates and gridded runoff representation. He tool for parameter estimation and with optimization were much more flexible compared to the previous programs. The maiden release also included a number of 'first' for HEC including object-oriented development in the C++ programming language and multiplatform support in a program with graphical user interface. The second major release was version 2.0 and focused on continuous simulation. The addition of soil moisture accounting method extended the program from an event-simulation package to one that could work equally well with event or continuous simulation applications. The reservoir element was also expanded to include physical description for an outlet spillway and overflow. The third party graphics libraries used to implement the multiplatform interface used in version 1.0 and Version 2.0 were soon sold and became unavailable. Faced with the prospect of using unsupported graphic tools, the design team evaluated alternative and chose to move the program to Java Language. The simulation engine was designed. During the process, careful attention was paid. The result was Version 3.0 with new interface plus new simulation capabilities for infiltrations, reservoir outlet structures. And it has upgraded to version 4. In our case version 4.2.1 is used.

Mishra and Singh et al. (1999) derived SCS-CN method analytically. The method was modified and a general form was given. Using data of five watersheds (catchment area) the existing SCS-CN method, its modified version using the general form of the model, the Mockus method and the method of Fogel and Duckstein (1970) were compared for performance. Finally the relation between potential maximum retention S and CN were critically examined and generalized.

Amrutha and Porchelvan et al. (2009) inferred that estimation of runoff by SCS-CN method integrated with GIS can be used in watershed management effectively. Their study showed that monthly runoff values and the seasonal runoff values in the watershed can be studied for reliable accuracy along with spatial variation of soil type and land use type.

Shadeed and Almasri et al. (2010) studied a GIS based SCS- CN approach developed to calculate the composite curve number of West Bank Catchment. They found the major advantage of employing GIS in rainfall-runoff modelling is the more accurate sizing and catchment characterization achievement. Though because of the insufficiency of rainfall – runoff data limited their verification of the proposed approach to generally arid and semi- arid catchments, however four rainfall events were simulated in the Al-Badan sub-catchment of Al-Faria Catchment using the curve number map.

Xiao, Wang, Fan, Han and Dai et al.(2011) evaluated the applicability of the SCS-CN method to a small watershed on the Loess Plateau of China with high spatial heterogeneity. They found out that the runoff in the Liudaogou watershed predicted by the SCS-CN model with modified I_a/S value increased gradually with the rainfall when the rainfall was less than 50 mm and increased rapidly when the rainfall exceeded 50 mm. These findings may be useful or helpful in solving the problem of serious soil and water loss on the Loess Plateau of China.

Majidi et al. (2012) described the Estimation of surface runoff in a watershed based on the rate of received precipitation and quantifying discharges at outlet is important in hydrologic studies. In this study, HEC-HMS hydrological model in version 3.4 was developed and used to simulate rainfall-runoff process in Abnama watershed located in the south of Iran. To compute infiltration, rainfall-runoff excess conversion to runoff and flow routing methods like Green Ampt, SCS unit Hydrograph and Muskingam routing were chosen respectively. Rainfall-Runoff simulation has been conducted using five rainfall events.

Satheeshkumar, Venkateswaram, Kannan et al. (2017) studied Rainfall-Runoff estimation using SCS-CN and GIS approach in the Pappiredipatti Watershed of the Vaniyar Sub basin, south India. They concluded that Soil Conservation Service Curve Number method approached in GIS way is an efficiently better proven method, which on one hand consumes less time and on the other is also able to facilitate extensive data set as well as for larger environmental area to identify the site selection for artificial recharge structures.

Behera, S.K., et al. (2015) studied about mapping the soil erosion in Ong catchment area using ArcGIS v10.2 combined with USLE model estimating the gross erosion rates and evaluated spatial distribution of soil loss rates under different land uses at the catchment.

STUDY AREA AND DATA SET UTILISED

CHAPTER 3

This chapter covers a brief description of the Ong River Basin at Salebhata gauging along with the sets of data required for the preparation of the model and its simulation to get the results followed by its validation.

3.1 The Study Area

The study area covers Salebhata gauging station of the Ong catchment in Odisha. It covers four districts in Odisha namely Balangir, Bargarh, Nuapada and Sonpur. The Ong river basin lies between latitude 20˚39'31'' N and21˚28'42'' N and longitude 82˚33'13'' E and 83˚50'39'' E, covering regions of Chhattisgarh and Odisha. It is the right bank tributary of the Mahanadi river basin which is situated in the Balangir District of Odisha, India. The total Catchment area of Ong catchment is approximately 5128 sq.km. It flows all across Odisha and joins Mahanadi in Sambalpur 11 km upstream of Sonpur where Tel River is merge. The normal yearly rainfall in the basin is 1,300 mm which varies from 1,600 mm in the east and 900 mm in the west part of the basin. Around 75% of annual rainfall is focused in the four monsoon months of June, July, August and September.

3.1.1 Topography

The area of the catchment has a mountainous topography. The elevation ranges from 96m to 1016m from mean sea level. So the slope in the area is high. Entire area is covered by undulating hilly tracts. The basin is surrounded by hills from the eastern side.

3.1.2 Land Use/ Land Cover

In the catchment area is cover by mostly forested land. About 25.38% of the total geographical area of the district is covered with dense forest. The major forest products of the district are Wood, firewood and Sal leaves. While adequate growth is mainly located in the river valleys. Unproductive lands are present in patches. Currently the forest cover is regularly decreasing due to quick extension of mine areas around the basin.

3.1.3 Soil

The large part of the catchment area of Ong River Basin at Salebhata Gauge Station is covered with *Red Loamy Soil* and *Red Sandy Soil*. But there are also regions where the catchment area is covered with *Mixed Red and Black Soil, Lateritic Soil* and some of *Medium Black Soil*.

3.2 Data Collection and Analysis

3.2.1 Digital Elevation Model (DEM)

A digital elevation model, commonly known as DEM is a 3-dimentional computer graphics representation of a terrain's surface created from a terrain's elevation data. This is a remote sensing data.

To obtain the DEM file (.tif) of Ong River Basin we will need the DEM of that area (preferably, larger area) and the Shape file of Ong River Basin (a polygon file .shp). Using the Shape file available we will mask over DEM file and obtain the DEM file of Ong River Basin.

The DEM file is an Advanced Spaceborne Thermal and Reflection Radiometer, Global Digital Elevation Model (ASTERGTM) product with *Pixel Size* of **30** and having a *spatial reference* of **GCS WGS 1984.**The DEM file covers a square region covering longitude across **82° E to 84° E** andlatitude across **20° N to 22° N**, so covering our area of interest.

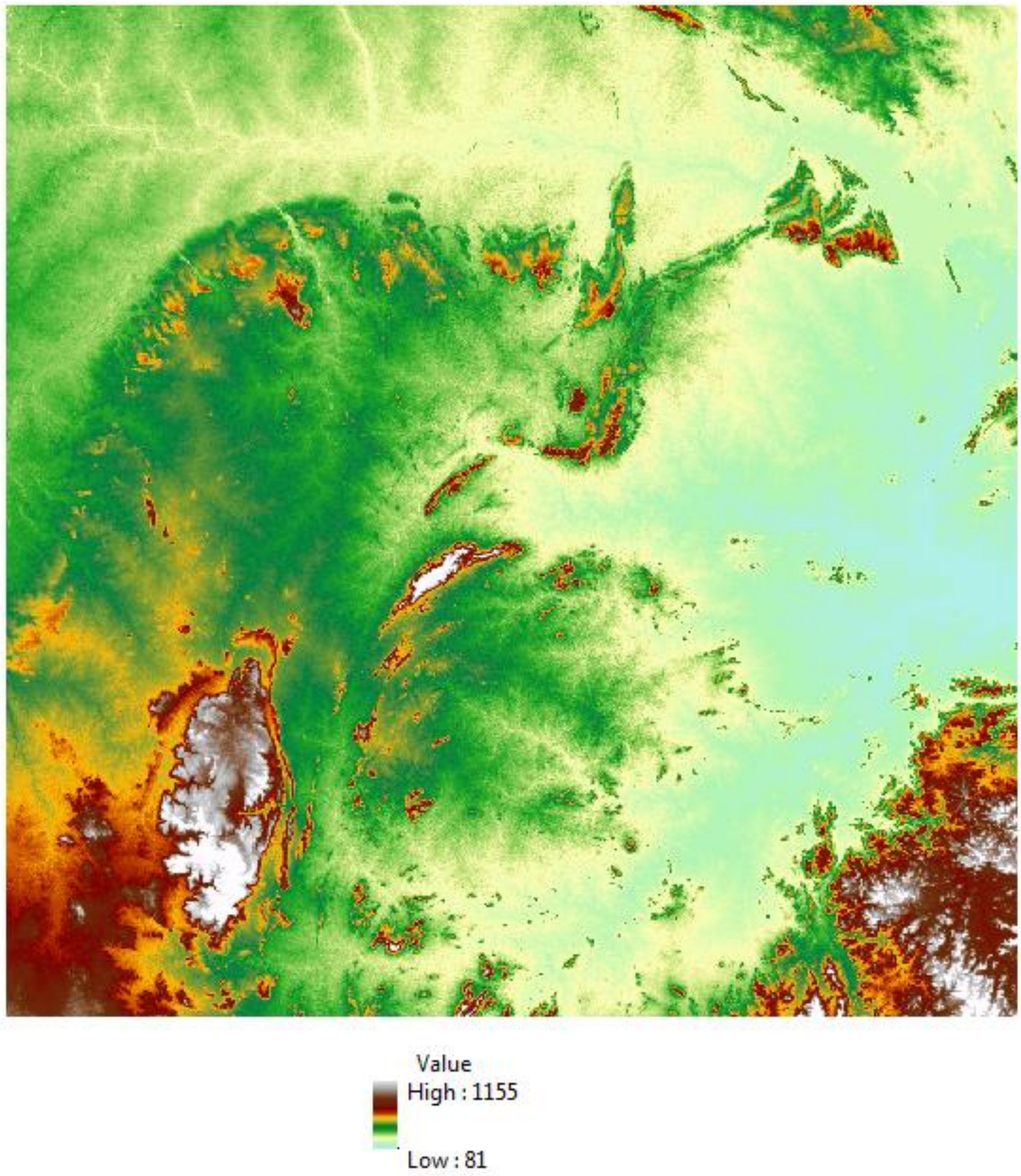


Fig 3.1: Digital Elevation Model of the concerned Region, Elevation in Metre

(Source: USGS)

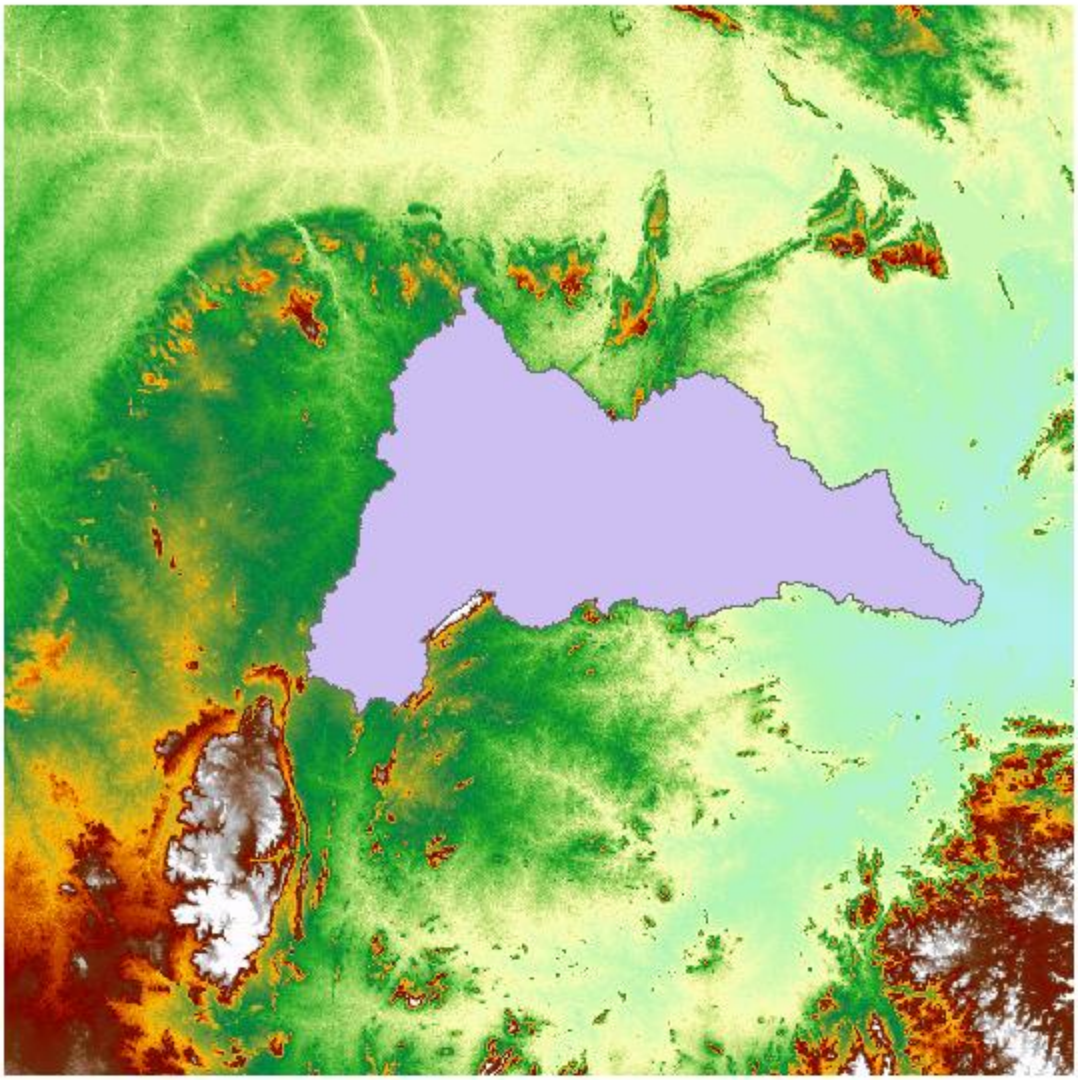


Fig 3.2: Shape file of Ong Basin layered over Digital Elevation Model of the concerned Region

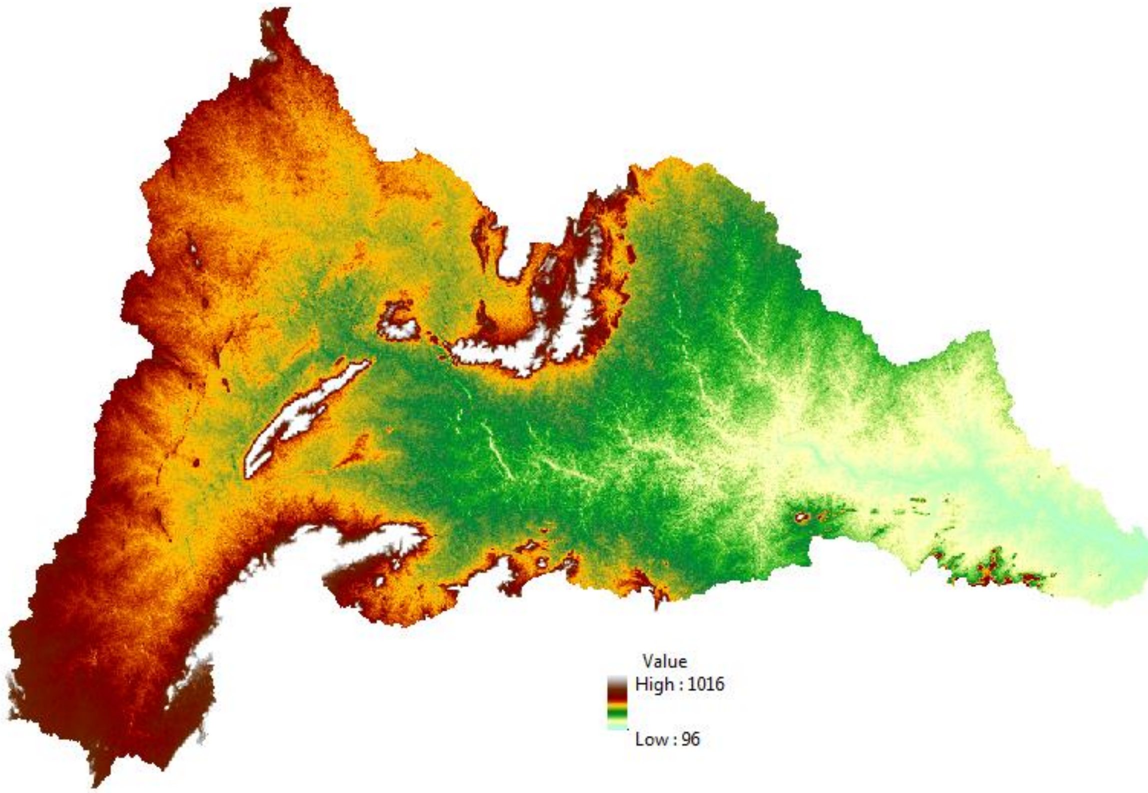


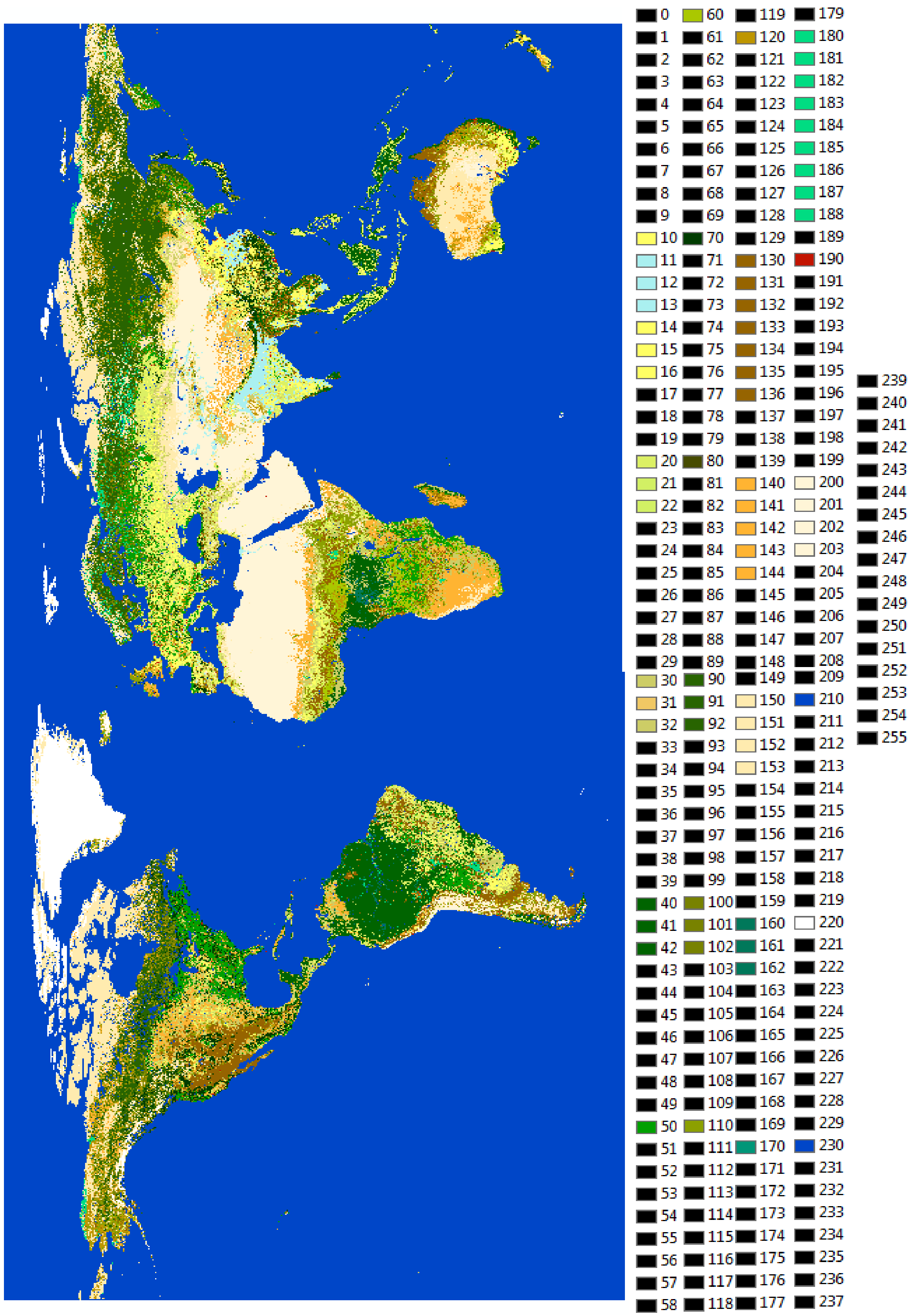
Fig 3.3: Digital Elevation Model of Ong River Basin, Elevation in Metre

3.2.2 Land Use / Land Cover

One of the most challenging tasks of the work was to collect land use/ Land cover pattern of Ong River Basin. On one hand the data collected or prepared should be a reliable one and also compatible with the software or tools being used. On the other hand the time frame or year of which the Land Use/ Land Cover Pattern is collected should also match with the time period of which reliable meteorological and hydrological data (rainfall and discharge) are available that will be further used for simulation in HEC-HMS.

Among various Land Use data available, the one that was selected for the work was that of **GLOBCOVER 2009** a product distributed by ***UCLouvain & ESA Team***. This is a Global Land Use Map of 2009 which is compatible with ArcMap 10.2.

Following is the Fig 3.4: The GlobCover 2009 global land cover map as the first 300-m global land cover map for the year2009 (Source: website of*GLOBCOVER 2009)*


0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58
60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118
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239 240 241 242 243 244 245 246 247 248 249 250 251 252 253 254 255

Table 3.1: LEGEND DESCRIPTION

Value	GlobCover global legend
11	Post-flooding or irrigated croplands
14	Rainfed croplands
20	Mosaic Cropland (50-70%) / Vegetation (grassland, shrubland, forest) (20-50%)
30	Mosaic Vegetation (grassland, shrubland, forest) (50-70%) / Cropland (20-50%)
40	Closed to open (>15%) broadleaved evergreen and/or semi-deciduous forest (>5m)
50	Closed (>40%) broadleaved deciduous forest (>5m)
60	Open (15-40%) broadleaved deciduous forest (>5m)
70	Closed (>40%) needleleaved evergreen forest (>5m)
90	Open (15-40%) needleleaved deciduous or evergreen forest (>5m)
100	Closed to open (>15%) mixed broadleaved and needleleaved forest (>5m)
110	Mosaic Forest/Shrubland (50-70%) / Grassland (20-50%)
120	Mosaic Grassland (50-70%) / Forest/Shrubland (20-50%)
130	Closed to open (>15%) shrubland (<5m)
140	Closed to open (>15%) grassland
150	Sparse (>15%) vegetation (woody vegetation, shrubs, grassland)
160	Closed (>40%) broadleaved forest regularly flooded - Fresh water
170	Closed (>40%) broadleaved semi-deciduous and/or evergreen forest regularly flooded - Saline water
180	Closed to open (>15%) vegetation (grassland, shrubland, woody vegetation) on regularly flooded or waterlogged soil - Fresh, brackish or saline water
190	Artificial surfaces and associated areas (urban areas >50%)
200	Bare areas
210	Water bodies
220	Permanent snow and ice

In this case we will use ASTERGTM DEM file (a raster file) to**clip** the region we are interested in from the Global Land Use, followed by **projecting**, **resampling, masking, reclassifying** and finally converting the Land Use Map into ***polygon shape file***; which will be explained in following chapters in details with results.

3.2.3 Soil Map

Soil map of Central India prepared by 'Survey of India Maps' obtained from www.esdac.jrc.ec.eurora.eu. It covers the region we are interested in, but the file being in image format, we will need to **Geo-reference** it, followed by **projecting, masking** (using the shapefile of basin) and finally converting the file into ***polygon shapefile***; described in details in following chapters.

Fig 3.5: Soil Map of Central India Plate (source: www.esdac.jrc.ec.eurora.eu)

3.2.4 Rainfall Data

The first step of collecting the rainfall data is to decide for which are the rain gauges to be selected of which rainfall data will be collected. So, the following Thiessen-Polygon of the basin is prepared by taking the shape file of the basin and the location (latitudes and longitudes) of the rain gauges.

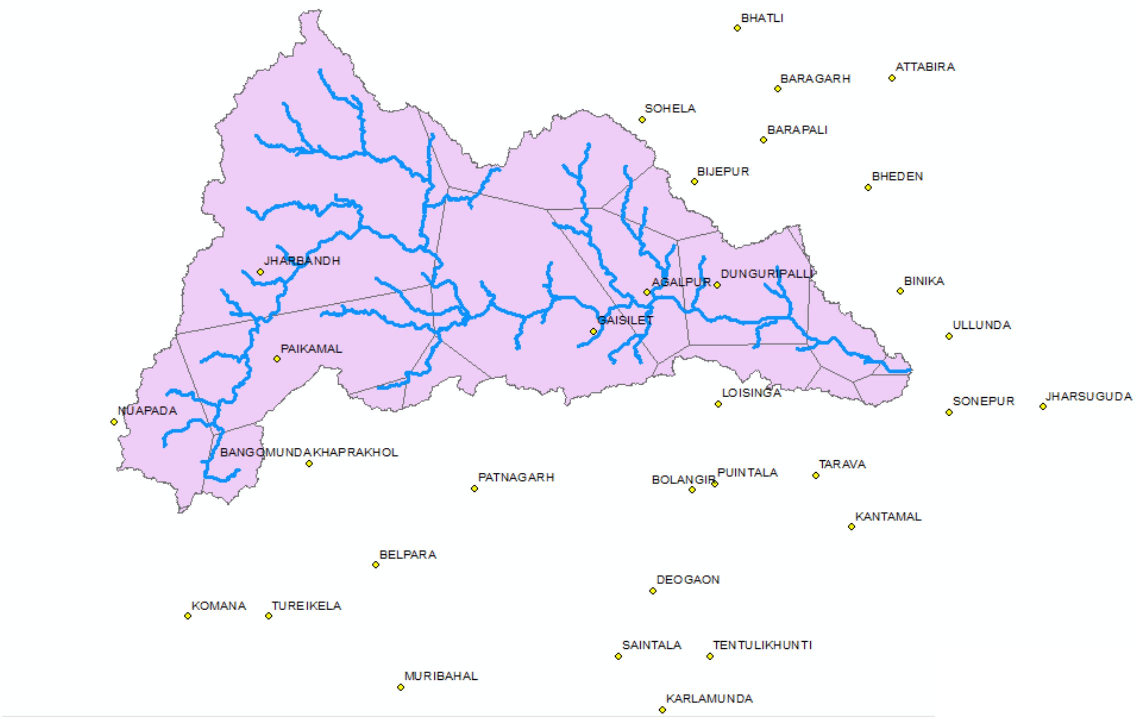


Fig 3.6: Thiessen Polygon of Ong River Basin

Based on the above figure the Rain Gauges of which data will be considered for simulating the Model in HEC-HMS are:

- Nuapada
- Paikamal
- Jharbandh
- Gaililet
- Agalpur
- Dunguripalli

3.2.4 Discharge Data

Daily discharge data of Ong River Basin at **Salebhata Gauge Station** for the year 2009 will be used along with the daily rainfall data of the previously mentioned 6 Rain gauge for the corresponding year for model validation purpose. Since the Land Use obtained is for the year 2009, so the model prepared is being used and validated for the data of 2009.

METHODOLOGY

CHAPTER 4

In order to simulate a run in the model prepared in HEC-HMS, there are various raw data processing, file preparation and procedures to be followed for model development using GIS tools. The initial steps includes processing the raw data of terrain using Arc Hydro tools in Arc Map. This will produce input data required for HMS model development using HEC-Geo HMS tools in Arc Map. Meanwhile, CN Grid- a raster file is generated by merging Land use Polygon Shape file and Soil map Polygon Shape file with the help of CN Lookup table. Generating CN Grid by itself is a complex task that will requires effort and time, without CN grid HMS model developed cannot be simulated using SCS-CN method. Finally the output-model developed will be exported to a format compatible to be used in HEC-HMS and followed by process of simulation. The following are the methodology in detail:

4.1 Terrain Processing Using Arc Hydro Tools

The first step in doing any kind of hydrologic modeling involves delineating streams and watersheds, and getting some basic watershed properties such as area, slope, flow length, stream network density, etc. Traditionally this was (and still is!) being done manually by using topographic/contour maps. With the availability of digital elevation models (DEM) and GIS tools, watershed properties can be extracted by using automated procedures. The processing of DEM to delineate watersheds is referred to as terrain pre-processing. The results from this procedure can be used to create input files for many hydrologic models.

Software required in order to carry out this work are Arc GIS 10.0 or above and Arc Hydro tool compatible to the corresponding version of Arc GIS.

Data used are DEM for Ong River Basin and Stream shape file of Ong River. Before continuing any further it was made sure that both the files are having a common ***Projected Coordinate System*** *as Spatial Reference* as all these processing requires the data to have a Projected Coordinate System*.* In this case the Spatial Reference is **WGS 1984 UTM Zone 44N**.

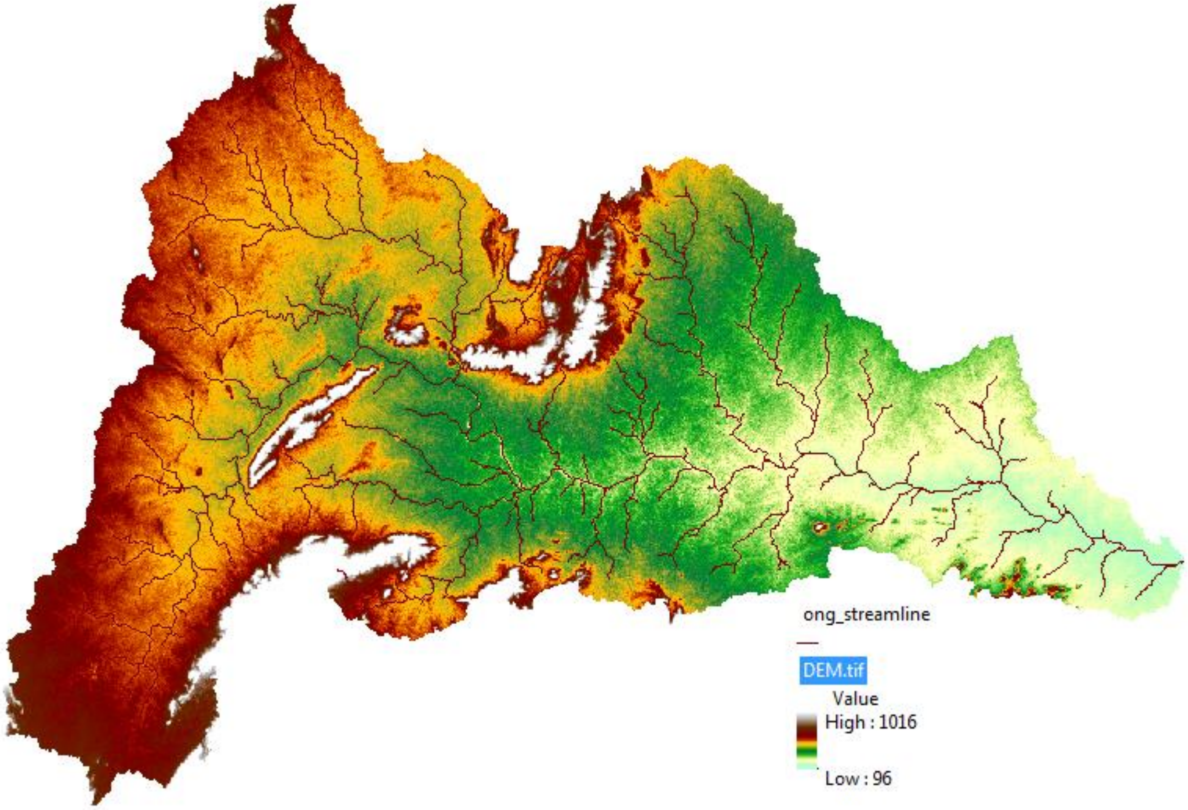


Fig 4.1: DEM and STREAMLINE as Raw Data for Terrain Processing

Terrain Preprocessing

Arc Hydro Terrain Preprocessing is performed in sequential order. All of the preprocessing must be completed before Watershed Processing functions can be used. DEM reconditioning and filling sinks might not be required depending on the quality of the initial DEM. DEM reconditioning involves modifying the elevation data to be more consistent with the input vector stream network. This implies an assumption that the stream network data are more reliable than the DEM data. By doing the DEM reconditioning, we are increasing the degree of agreement between stream networks delineated from the DEM and the input vector stream networks.

4.1.1DEM Reconditioning

This function modifies the DEM by imposing linear features onto it (burning/fencing). It is an implementation of the AGREE method developed at the Center for Research in Water Resources at the University of Texas at Austin.

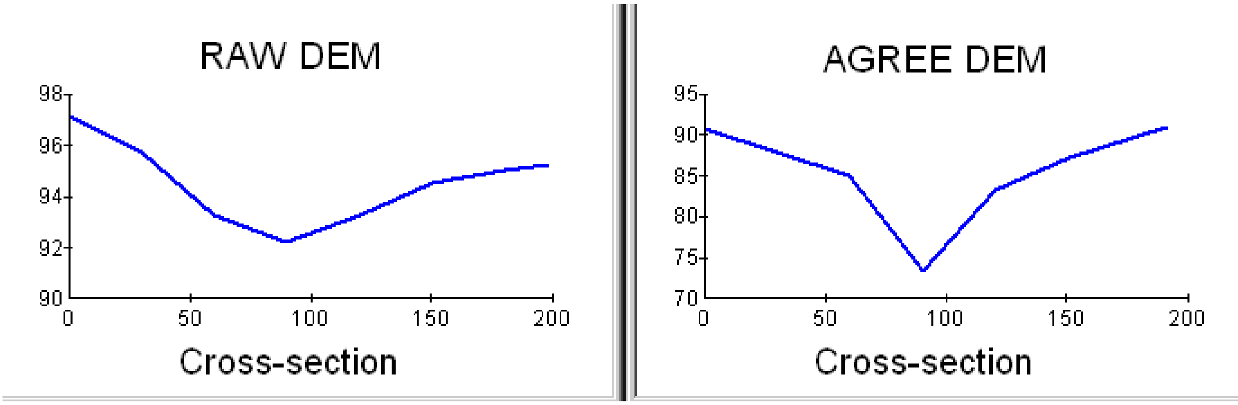


Fig 4.2: Comparing Raw DEM and AgreeDEM

AgreeDEM (or DEM reconditioning) pushes the raw DEM along the stream to create a distinct profile along the streams which otherwise may not exist in the raw DEM. This is mainly due to lack of elevation data along streams in the raw DEM. For example, the figure below shows how the cross-section profile at a given location changes when the DEM is reconditioned.

4.1.2Fill Sinks

This function fills the sinks in a grid. If cells with higher elevation surround a cell, the water is trapped in that cell and cannot flow downstream. The Fill Sinks function modifies the elevation value to eliminate these problems.

4.1.3 Flow Direction

This function computes the flow direction for a given DEM by using the pour point eight direction (D8) method. The values in the cells of the flow direction grid indicate the direction of the steepest descent from that cell. As per pour point eight direction (D8) method, at any point on surface water can flow in either of eight directions- North, North-East, East, South-East, South, South-West, West or North-West, each of which is represented as 1, 2, 4, 8, 16, 32, 64 and 128 respectively. It depends upon the slope of elevation at that point in each of the direction. The direction having maximum slope will be the direction of flow at that point represented as a colour corresponding to the eight numbers.

The input for this function is the output of *fil* function.

The zoomed-in version of the **Fdr grid** should look the map below with each color in the cell having one of the eight numbers shown in the legend representing the flow direction according to the eight-point pour flow direction model.

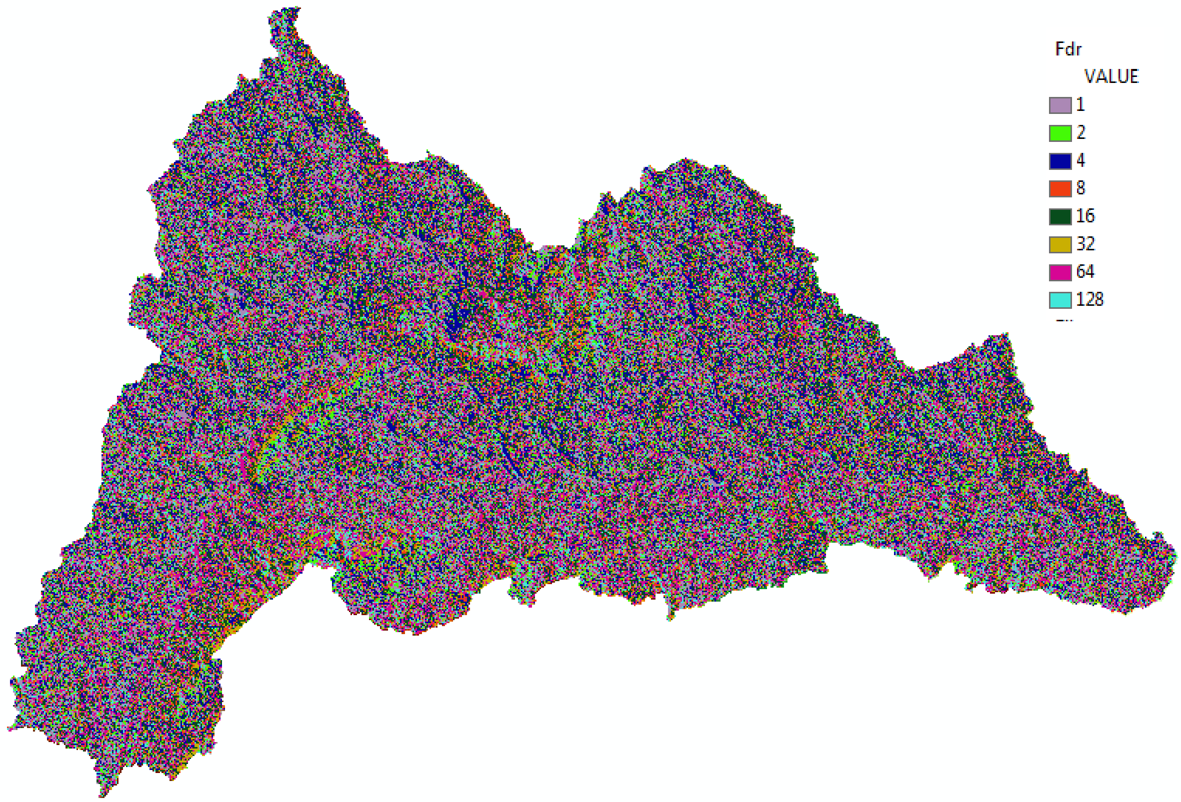


Fig 4.3: Flow Direction (Fdr) Grid

4.1.4 Flow Accumulation

This function computes the flow accumulation grid that contains the accumulated number of cells upstream of a cell, for each cell in the input grid.

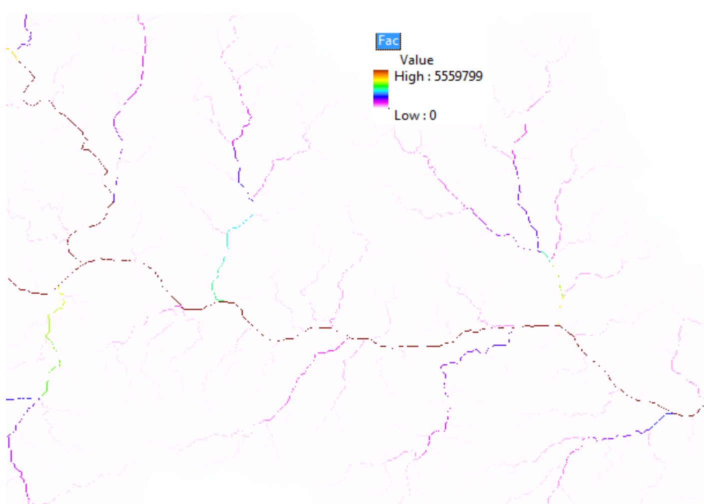


Fig 4.4: Flow Accumulation (Fac) grid

4.1.5 Stream Definition

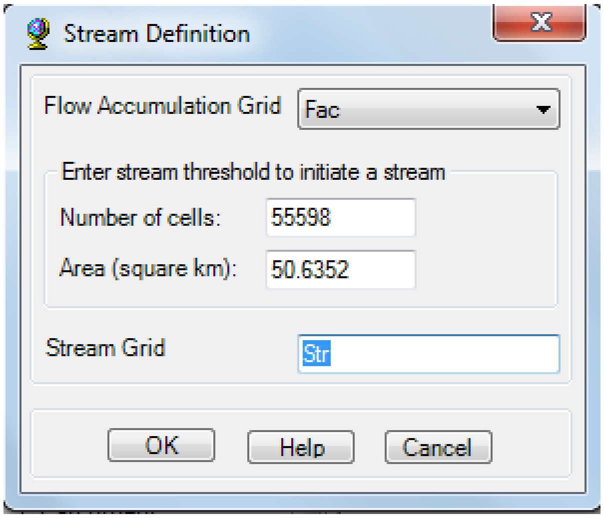


Fig 4.5: Stream Threshold in Stream Definition

A default value is displayed for the river threshold. This value represents 1% of the maximum flow accumulation: a simple rule of thumb for stream determination threshold. A smaller threshold will result in a denser stream network and usually in a greater number of delineated catchments. Upon successful completion of the process, the stream grid Str is added to the map. This Str grid contains a value of "1" for all the cells in the input flow accumulation grid (Fac) that have a value greater than the given threshold (55598 as shown in above figure). All other cells in the Stream Grid contain no data.

4.1.6 Stream Segmentation

This function creates a grid of stream segments that have a unique identification. Either a segment may be a head segment, or it may be defined as a segment between two segment junctions. All the cells in a particular segment have the same grid code that is specific to that segment.

4.1.7 Catchment Grid Delineation

This function creates a grid in which each cell carries a value (grid code) indicating to which catchment the cell belongs. The value corresponds to the value carried by the stream segment that drains that area, defined in the stream segment link grid.

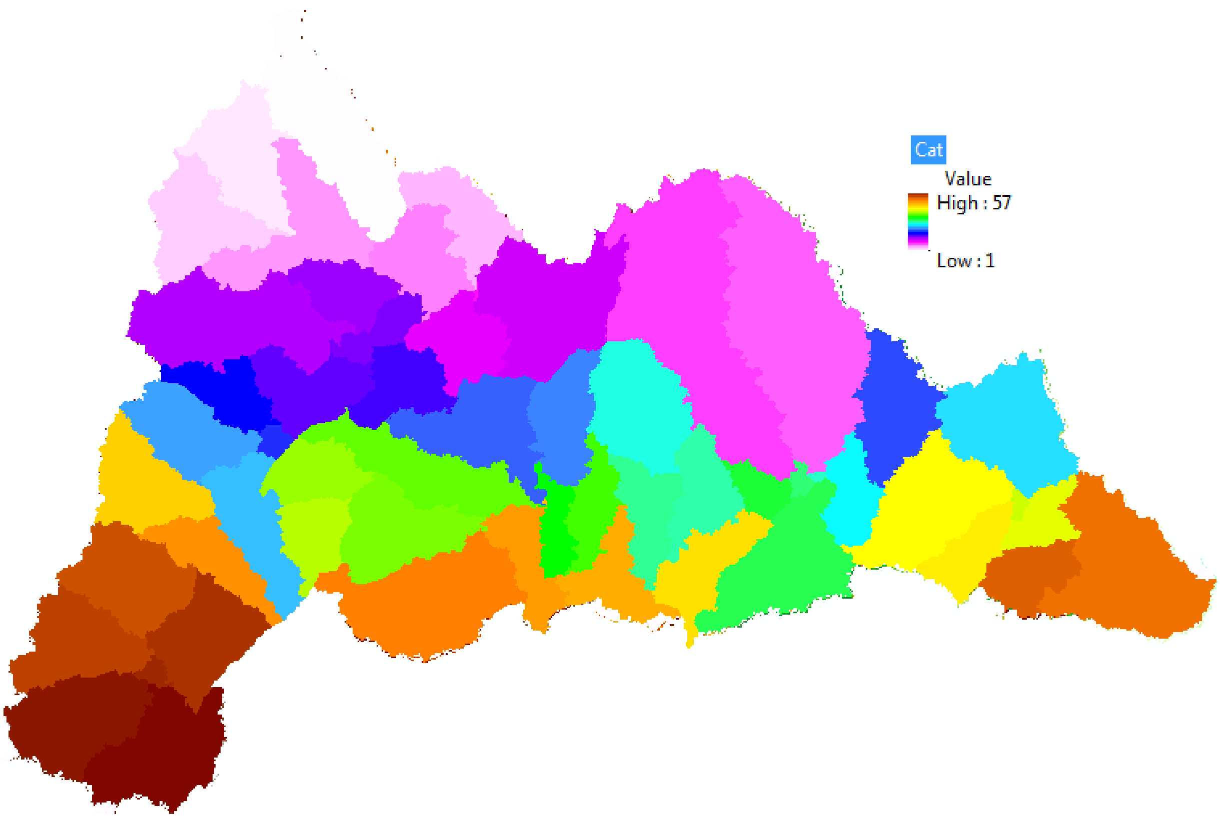


Fig 4.6 Catchment generated in the whole Area

4.1.8 Catchment Polygon Processing

The three functions Catchment Polygon Processing, Drainage Line Processing and Adjoint Catchment Processing converts the raster data so far developed to vector format. This function converts the catchment grid into a catchment polygon feature.

This process also generated the attribute table of all the catchments.

OBJECTID *	Shape *	Shape_Length	Shape_Area	HydroID *	GridID *	NextDownID *
1	Polygon	119084.045	164082024.893988	1	1	6
2	Polygon	97898.7936	103478851.061883	2	2	5
3	Polygon	93613.4594	101030790.096979	3	3	5
4	Polygon	86068.8528	72134015.079546	4	4	9
5	Polygon	119325.4724	118006017.427831	5	5	6
6	Polygon	77075.6828	78309722.722766	6	6	9
7	Polygon	168455.94	306098712.893934	7	7	25
8	Polygon	193443.6706	326226912.285698	8	8	30
9	Polygon	7242.8212	626587.117813	9	9	10
10	Polygon	64098.964	69856261.732318	10	10	20
11	Polygon	103934.4768	170125675.447018	11	11	10
12	Polygon	125361.155	175535453.795349	12	12	14
13	Polygon	58908.2762	58773502.967238	13	13	14
14	Polygon	54743.654	35585227.706589	14	14	16
15	Polygon	71583.2108	79522824.521664	15	15	16
16	Polygon	64219.6786	65113143.418359	16	16	20
17	Polygon	65547.5282	56110507.951931	17	17	15
18	Polygon	19615.9738	9931587.186478	18	18	15
19	Polygon	91440.6114	98888736.756088	19	19	41
20	Polygon	107918.03	115596207.479302	20	20	45
21	Polygon	74238.913	79021919.186327	21	21	34
22	Polygon	72005.7104	89583736.316226	22	22	18
23	Polygon	88845.2682	91105577.979807	23	23	18
24	Polygon	95484.5206	141729806.160258	24	24	40
25	Polygon	59632.5572	50861019.757908	25	25	41
26	Polygon	80153.882	119737328.591052	26	26	28
27	Polygon	9294.9532	1946245.038594	27	27	25
28	Polygon	73937.1282	66563947.370597	28	28	32
29	Polygon	75808.1904	62137765.38985	29	29	28
30	Polygon	20702.3964	7053658.356158	30	30	27
31	Polygon	106469.4652	135692530.549783	31	31	27
32	Polygon	43215.4988	27264734.216232	32	32	30
33	Polygon	62831.4698	34238247.566151	33	33	34
34	Polygon	75264.98	50353739.190304	34	34	29
35	Polygon	118178.6916	111349440.368869	35	35	45
36	Polygon	79007.1032	104004346.183057	36	36	47
37	Polygon	56494.001	59369125.021681	37	37	36
38	Polygon	54019.3702	54987569.226201	38	38	36
39	Polygon	15873.8486	4767708.34424	39	39	40
40	Polygon	53657.2302	37526919.026819	40	40	50
41	Polygon	95967.3758	138754428.125713	41	41	39
42	Polygon	58727.204	51995798.058437	42	42	39
43	Polygon	85103.1428	73246025.035717	43	43	32
44	Polygon	76230.6892	93772216.05008	44	44	23
45	Polygon	4768.1902	325133.148794	45	45	33
46	Polygon	79972.8132	62577651.503272	46	46	29
47	Polygon	70436.4322	57064049.632852	47	47	33
48	Polygon	76653.187	64507503.278881	48	48	23
49	Polygon	106046.9682	173343309.443802	49	49	47
50	Polygon	114255.4972	184719325.79689	50	50	-1
51	Polygon	54381.5134	57684261.521414	51	51	50
52	Polygon	78222.4658	109890439.851533	52	52	48
53	Polygon	84559.9338	101530784.714597	53	53	54
54	Polygon	76351.4014	100476151.299592	54	54	48
55	Polygon	22513.1014	7741264.750205	55	55	54
56	Polygon	82024.9448	122803780.111683	56	56	55
57	Polygon	94458.4534	128755446.530318	57	57	55

Table 4.1: Attribute Table of Catchment

4.1.9 Drainage Line Processing

This function converts the input Stream Link grid into a Drainage Line feature class. Each line in the feature class carries the identifier of the catchment in which it resides.

Table 4.2: Attribute Table of Drainage Line

OBJECTID *	Shape *	arcid	from_node *	to_node *	Shape_Length	HydroID *	GridID *	NextDownID *	DrainID
1	Polyline	1	2	5	8417.773826	58	2	61	2
2	Polyline	2	3	5	9728.466762	59	3	61	3
3	Polyline	3	1	6	19871.511899	60	1	62	1
4	Polyline	4	5	6	11107.130568	61	5	62	5
5	Polyline	5	6	10	13904.471465	62	6	64	6
6	Polyline	6	4	10	7115.964828	63	4	64	4
7	Polyline	7	10	11	2040.888565	64	9	69	9
8	Polyline	8	9	11	12780.807589	65	11	69	11
9	Polyline	9	12	13	1298.300255	66	13	68	13
10	Polyline	10	14	13	22711.868392	67	12	68	12
11	Polyline	11	13	15	4353.750783	68	14	70	14
12	Polyline	12	11	16	13033.739421	69	10	89	10
13	Polyline	13	15	16	11096.25441	70	16	89	16
14	Polyline	14	17	18	2016.516086	71	17	72	17
15	Polyline	15	18	15	15546.607087	72	15	70	15
16	Polyline	16	22	18	4649.468973	73	18	72	18
17	Polyline	17	20	22	8798.297293	74	22	73	22
18	Polyline	18	7	25	29936.706602	75	7	82	7
19	Polyline	19	23	27	4210.441622	76	26	94	26
20	Polyline	20	8	28	32946.337054	77	8	79	8
21	Polyline	21	29	25	1868.396953	78	27	82	27
22	Polyline	22	28	29	3160.891288	79	30	78	30
23	Polyline	23	21	30	5907.235121	80	21	90	21
24	Polyline	24	19	31	7875.082643	81	19	96	19
25	Polyline	25	25	31	8060.886682	82	25	96	25
26	Polyline	26	32	33	1865.623974	83	37	99	37
27	Polyline	27	24	34	4294.726713	84	24	102	24
28	Polyline	28	35	34	2061.599703	85	39	102	39
29	Polyline	29	36	28	7161.600193	86	32	79	32
30	Polyline	30	37	33	1455.626418	87	38	99	38
31	Polyline	31	26	38	15738.661007	88	35	92	35
32	Polyline	32	16	38	22815.011644	89	20	92	20
33	Polyline	33	30	39	6319.637692	90	34	91	34
34	Polyline	34	39	27	7565.531709	91	29	94	29
35	Polyline	35	38	41	128.036249	92	45	93	45
36	Polyline	36	41	30	4582.677951	93	33	90	33
37	Polyline	37	27	36	9250.713378	94	28	86	28
38	Polyline	38	42	35	1771.871704	95	42	85	42
39	Polyline	39	31	35	16065.337767	96	41	85	41
40	Polyline	40	40	43	3289.371509	97	44	98	44
41	Polyline	41	43	22	10987.305208	98	23	73	23
42	Polyline	42	33	44	18383.746339	99	36	100	36
43	Polyline	43	44	41	8435.528073	100	47	93	47
44	Polyline	44	45	29	9871.331497	101	31	78	31
45	Polyline	45	34	46	7487.864805	102	40	108	40
46	Polyline	46	47	36	5780.087333	103	43	86	43
47	Polyline	47	48	46	1528.483649	104	51	108	51
48	Polyline	48	49	39	6176.696296	105	46	91	46
49	Polyline	49	50	43	7411.606651	106	48	98	48
50	Polyline	50	51	50	5509.369815	107	52	106	52
51	Polyline	51	46	52	19119.716175	108	50	-1	50
52	Polyline	52	53	44	19744.180296	109	49	100	49
53	Polyline	53	54	55	9187.583745	110	53	111	53
54	Polyline	54	55	50	14008.916112	111	54	106	54
55	Polyline	55	56	55	3422.141398	112	55	111	55
56	Polyline	56	57	56	10120.0815	113	56	112	56
57	Polyline	57	58	56	13542.222927	114	57	112	57

4.1.10 Adjoint Catchment Processing

This function generates the aggregated upstream catchments from the Catchment feature class. For each catchment that is not a head catchment, a polygon representing the whole upstream area draining to its inlet point is constructed and stored in a feature class that has an Adjoint Catchment tag. This feature class is used to speed up the watershed delineation process later.

4.1.11 Drainage Point Processing

This function generates the drainage points corresponding to each catchment.

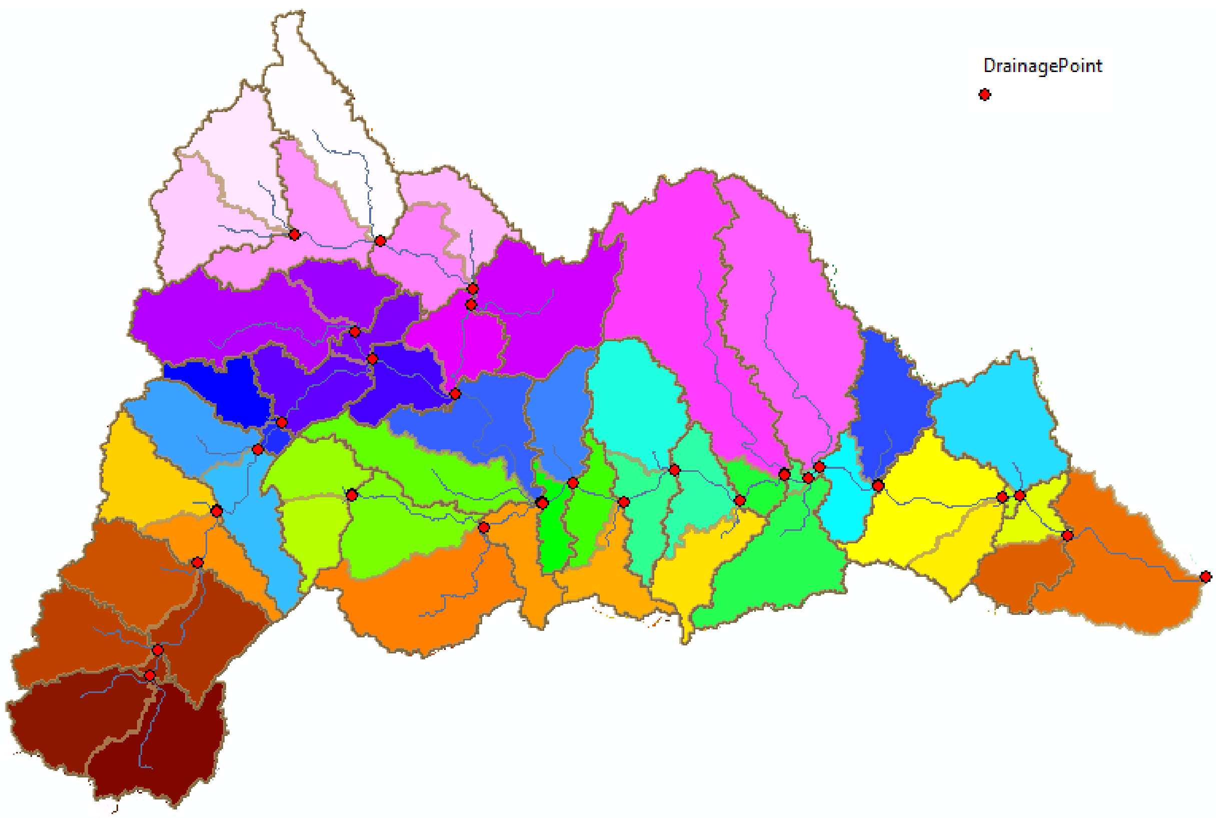


Fig 4.7 Drainage Point Generated Over the Catchment

4.1.11 Slope Grid

This function generates slope at each point. The output will be a slope grid with the default name WshSlope that can be overwritten.

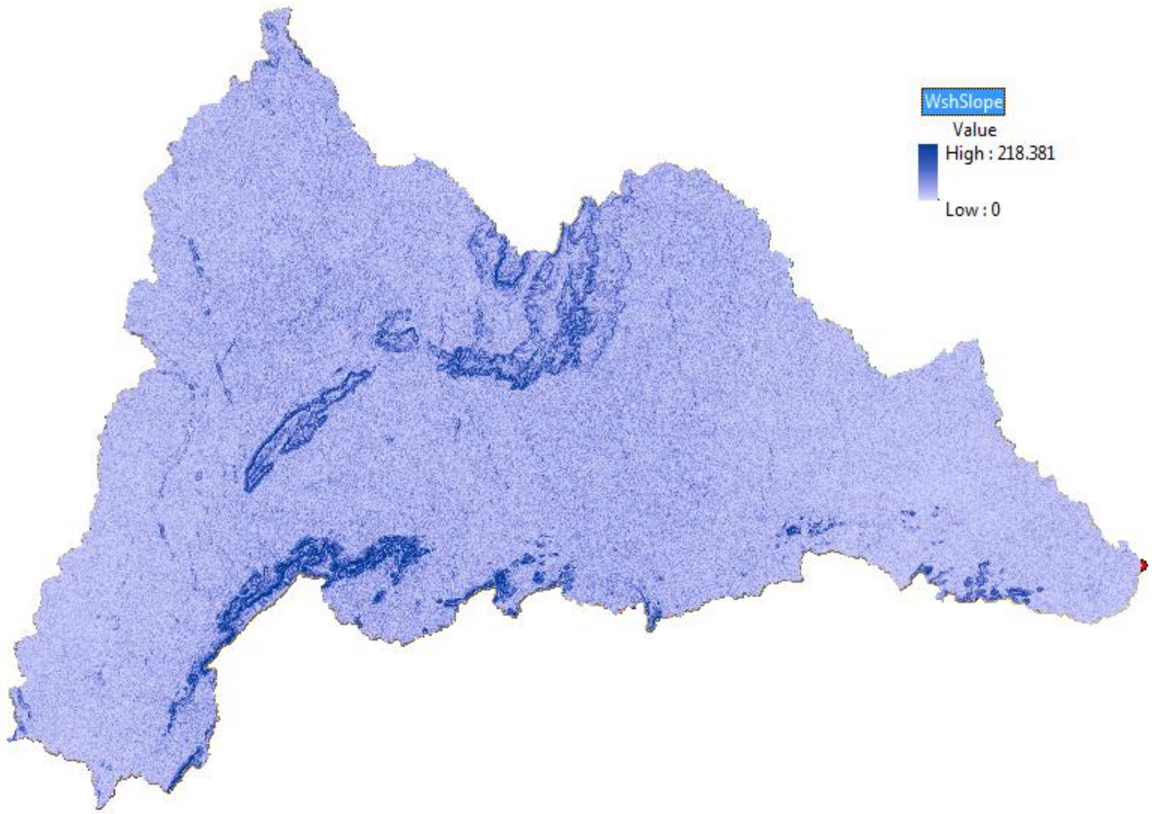


Fig 4.8 Slope Grid

4.2 CN GRID Generation

One of the most essential data that is prepared for the development of HMS model is CN Grid. CN grid generated allocates the CN value corresponding to each cell grid/ point of the catchment area. Along with Runoff calculation,, this CN grid is also used to populate Basin Lag field in each Sub basin feature class, later on.

To generate CN grid we will be dealing with Land Use Map and Soil Map. So, first of all Land Use Polygon file and Soil Polygon file is prepared, followed by merging of the two files.

4.2.1 Land Use/ Land Cover

The Global Land Use/ Land Cover collected is firstly, *Clipped* to the concerned region in order to simplify the process.

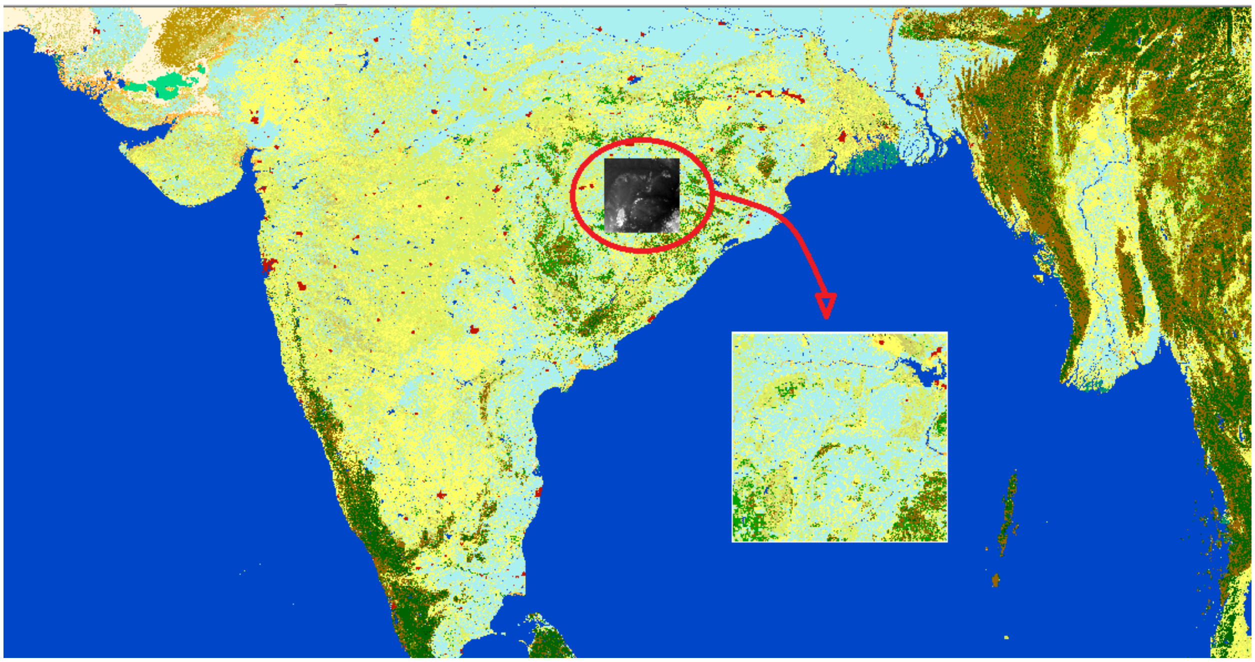


Fig 4.9: Clipping of Required Area from Global Land Use

The properties of Clipped Land Use is then converted to the properties of DEM and its outputs from previous processes by specifying the same Projected Coordinate System *WGS 1984 UTM Zone 44N* and *Resampling* the file to similar cell size i.e. 30 x 30.

After making sure that the clipped file is having the same properties of that of file we have generated and will be dealing later on; **Land use of Ong River Basin** is ***masked*** using the shape polygon file of Ong River Basin.

Following is the Fig4.10: Masking of Land Use of Ong River Basin. The figure deals with the same legends specified in Table 3.1 of previous chapter.

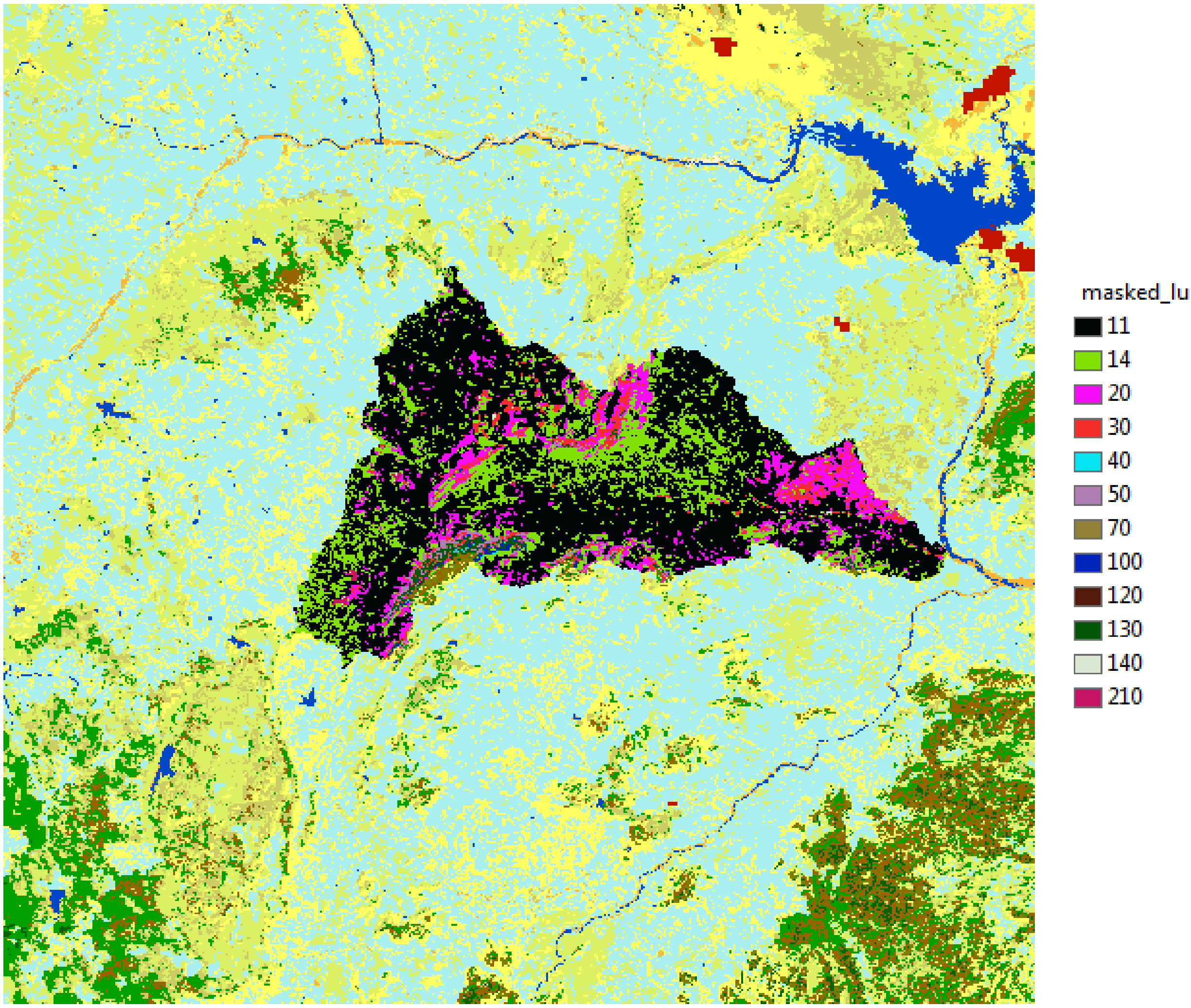
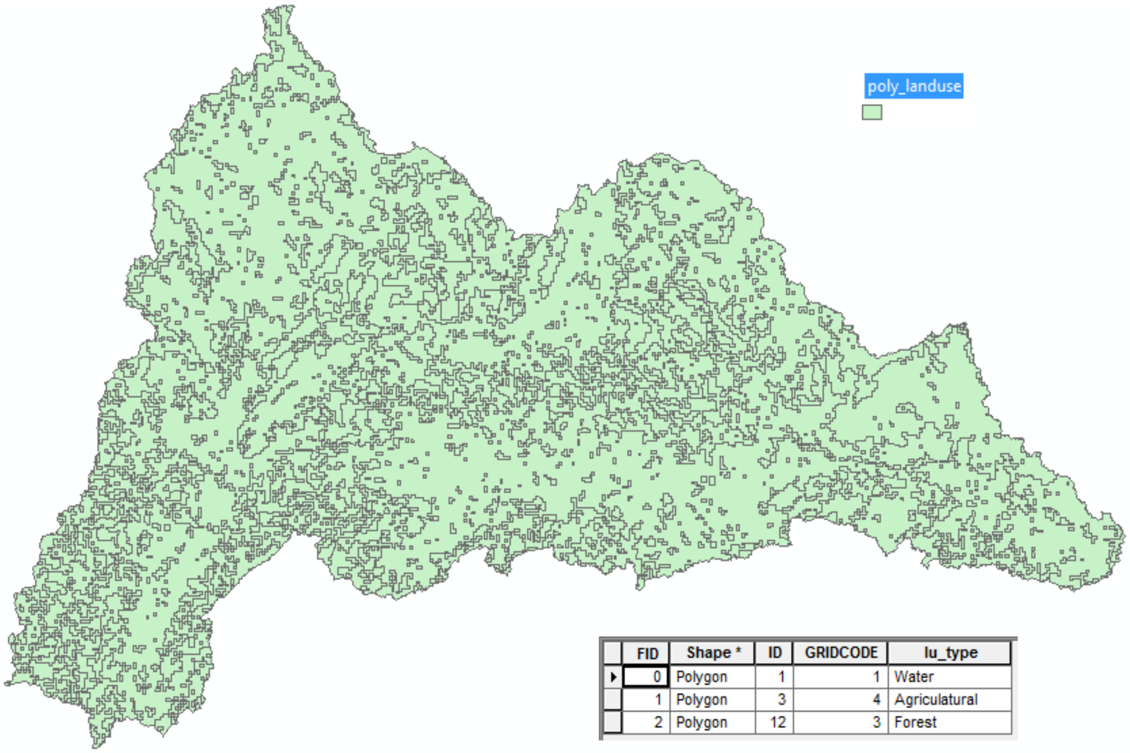


Fig 4.10: Masking of Land Use of Ong River Basin

For the purpose of simplicity the various land use values obtained above are re-classed into *Post flooding or Irrigated Crop land/Water Bodies as 1; Forest as 3 and Agricultural Land as 4.*

Finally the Re-classed Land Use is converted to Polygon Shape file with the following attribute table, which will be needed in following procedures.



FID	Shape *	ID	GRIDCODE	lu_type
0	Polygon	1	1	Water
1	Polygon	3	4	Agriculatural
2	Polygon	12	3	Forest

Fig 4.11: Land Use Polygon Shape File along with its re-classed attribute table

4.2.2 Soil Map

Using the Soil Map of Central India Plate, we will classify the Soil types of Ong River Basin into four Hydrological Soil Classes A, B, C and D based upon the infiltration rate another characteristics.

Group A: (Low Runoff Potential) Soil having high infiltration rates even when it is thoroughly wet. It consists of mainly deep, well to excessively drained Sand or Gravels. These soil have high transmission rates. Example: Deep sand, Deep Loess.

Group B: (Moderately Low Runoff Potential) these soils have moderate infiltration rates, when thoroughly wetted; mainly consisting of moderately fine to moderately coarse textures, having moderate transmission rates. Example Sandy Loam, Red Loamy Soil.

Group C: (Moderately high runoff potential) Soil having low infiltration rates when thoroughly wetted; consisting of mainly moderately well to well-drained soil with moderately fine to moderately coarse textures; having moderate rate of transmission. Example Clayey loam, mixed Red and Black Soil.

Group D: (Hugh Runoff Potential)) Soil having very low infiltration rates when thoroughly wetted; consisting of mainly of clay soil with a high swelling potential, soil with permanent high water table. Example Deep Black Soil.

After ***Geo-referencing*** *and* ***projecting to the same*** Projected Coordinate system Soil Map of Ong River Basin is obtained out by ***Masking*** from the map, followed by converting it to a polygon shape file and then ***Digitized*** to produce Soil Polygon Shape File with required attribute table.

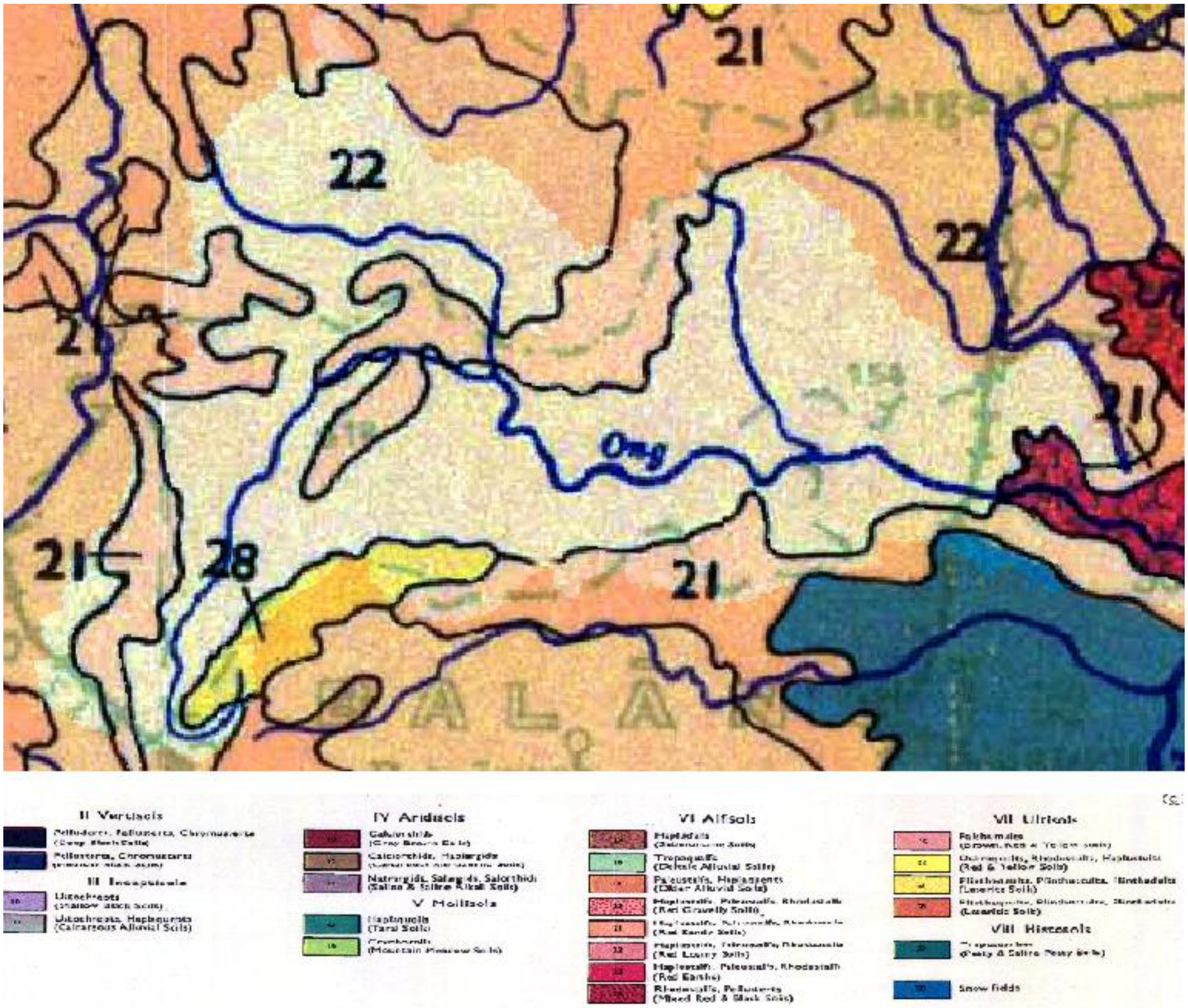


Fig 4.12: Soil Map of Ong River Basin

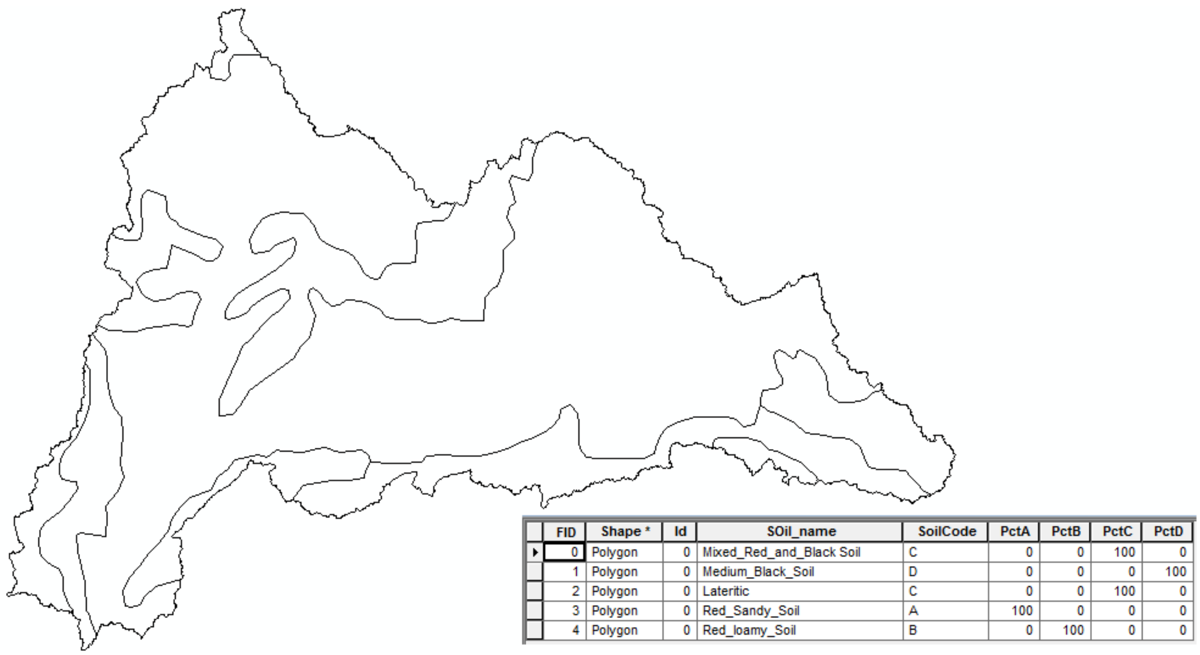
As seen above the soil cover in the Ong River Basin are Medium Black Soil (9), Red Sandy Soil (21), Red Loamy Soil (22), Mixed Red and Black Soil (24) and Lateritic Soil (28).

These are classed into Hydrological Soil Group as: Medium Black Soil- D, Red Sandy Soil- A,

Red Loamy Soil- B, Mixed Red and Black Soil- C and Lateritic Soil- C.

4.2.3 Generating CN Grid

CN grid is generated using DEM of the Basin, Merge of Land Use and Soil Type and a Curve Number Look-Up table. But before all these the Merge file of Land Use and Soil Type is prepared after creating Attribute table of the Digitized Soil Map, followed by preparing The CN Look-Up Table, from which each point will be allotted a Curve Number based on the Soil Type and Land Use Pattern at that point.



FID	Shape *	Id	SOil_name	SoilCode	PctA	PctB	PctC	PctD
0	Polygon	0	Mixed_Red_and_Black Soil	C	0	0	100	0
1	Polygon	0	Medium_Black_Soil	D	0	0	0	100
2	Polygon	0	Lateritic	C	0	0	100	0
3	Polygon	0	Red_Sandy_Soil	A	100	0	0	0
4	Polygon	0	Red_loamy_Soil	B	0	100	0	0

Fig 4.13 Digitized Soil Map of Basin along with its Attribute Table

Table

CNLookup

OBJECTID *	LUValue	Description	A	B	C	D
1	1	Water	10	10	10	10
2	3	Forest	30	58	71	78
3	4	Agriculture	67	77	83	87

Table 4.3: CN Look-Up Table

Now, the Land Use Polygon Shape file and Soil polygon Shape file prepared are merged and the following Land Use-Soil Type Polygon Shape File is obtained with following Attribute table.

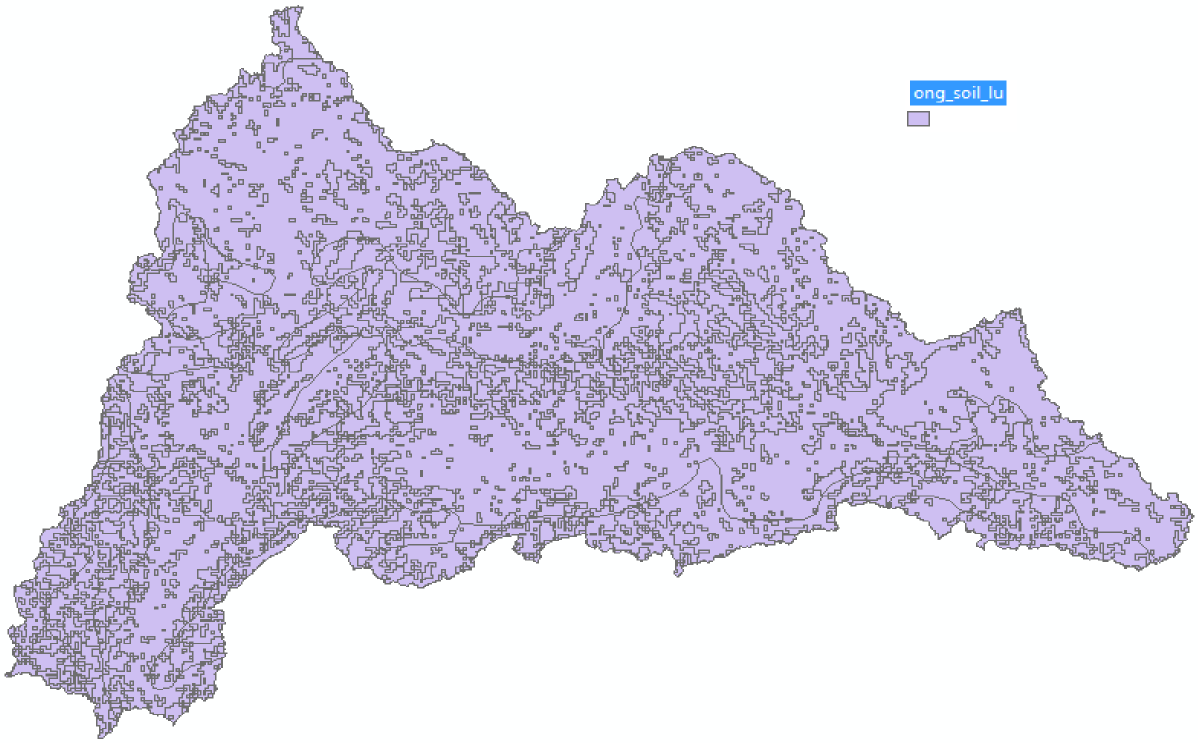


Fig 4.14: Land Use- Soil Type Shape merged file of Ong River Basin

FID	Shape	FID_SOIL_P	Id	SOil_name	SoilCode	PctA	PctB	PctC	PctD	FID_poly_l	ID_1	GRIDCODE	lu_type	LandUse	CN
0	Polygon	0	0	Mixed_Red_and_Black Soil	C	0	0	100	0	0	1	1	Water	1	100
3	Polygon	1	0	Medium_Black_Soil	D	0	0	0	100	0	1	1	Water	1	100
6	Polygon	2	0	Lateritic	C	0	0	100	0	0	1	1	Water	1	100
9	Polygon	3	0	Red_Sandy_Soil	A	100	0	0	0	0	1	1	Water	1	100
12	Polygon	4	0	Red_loamy_Soil	B	0	100	0	0	0	1	1	Water	1	100
15	Polygon	2	0	Lateritic	C	0	0	100	0	0	1	1	Water	1	100
16	Polygon	3	0	Red_Sandy_Soil	A	100	0	0	0	0	1	1	Water	1	100
19	Polygon	3	0	Red_Sandy_Soil	A	100	0	0	0	0	1	1	Water	1	100
20	Polygon	4	0	Red_loamy_Soil	B	0	100	0	0	0	1	1	Water	1	100
1	Polygon	0	0	Mixed_Red_and_Black Soil	C	0	0	100	0	1	3	4	Agriculatural	4	83
4	Polygon	1	0	Medium_Black_Soil	D	0	0	0	100	1	3	4	Agriculatural	4	87
7	Polygon	2	0	Lateritic	C	0	0	100	0	1	3	4	Agriculatural	4	83
10	Polygon	3	0	Red_Sandy_Soil	A	100	0	0	0	1	3	4	Agriculatural	4	67
13	Polygon	4	0	Red_loamy_Soil	B	0	100	0	0	1	3	4	Agriculatural	4	77
17	Polygon	2	0	Lateritic	C	0	0	100	0	1	3	4	Agriculatural	4	83
18	Polygon	3	0	Red_Sandy_Soil	A	100	0	0	0	1	3	4	Agriculatural	4	67
2	Polygon	0	0	Mixed_Red_and_Black Soil	C	0	0	100	0	2	12	3	Forest	3	71
5	Polygon	1	0	Medium_Black_Soil	D	0	0	0	100	2	12	3	Forest	3	78
8	Polygon	2	0	Lateritic	C	0	0	100	0	2	12	3	Forest	3	71
11	Polygon	3	0	Red_Sandy_Soil	A	100	0	0	0	2	12	3	Forest	3	30
14	Polygon	4	0	Red_loamy_Soil	B	0	100	0	0	2	12	3	Forest	3	58

Table 4.4: Attribute Table of Land Use-Soil Type Shape File

Finally Using the *DEM* file of the Basin, *CN Look-Up Table* and *Land Use-Soil Type Shape file* Following CN Grid is successfully generated.

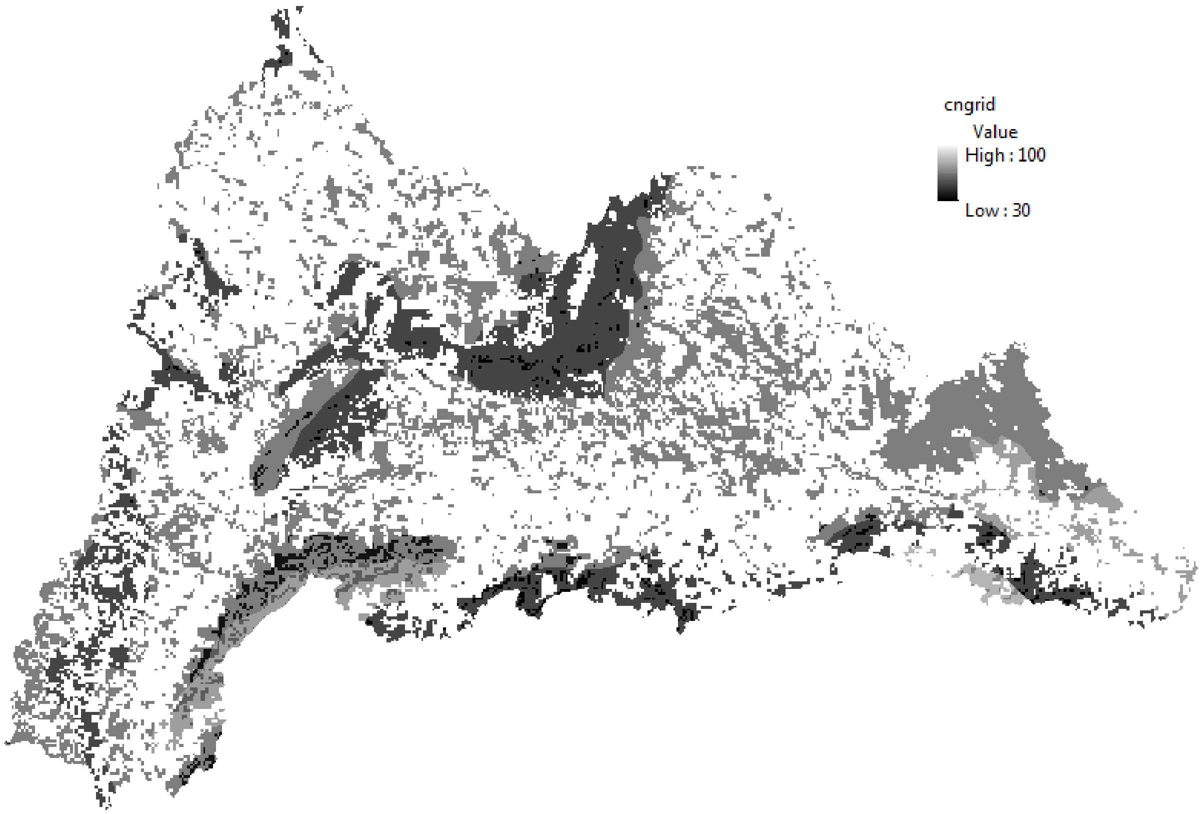


Fig 4.15: CN GRID

This generated CN Grid will be used for HMS Model development in the following part of the chapter.

4.3 HMS Model Development Using Geo-HMS

The basic function of HEC geo-HMS tool is to create input files for hydrological modelling with HEC-HMS. This creation of input files will be requiring the Outputs of Terrain Processing and CN Grid.

The outputs of Terrain Processing required in HEC geo-HMS are the followings:

Raster Data
1. Raw DEM
2. HydroDEM (DEM after reconditioning and filling sinks)
3. Flow Direction Grid
4. Flow Accumulation Grid
5. Stream Grid
6. Stream Link Grid
7. Catchment Grid
8. Slope Grid

Vector Data
1. Catchment Polygons
2. Drainage Line Polygons
3. Adjoint Catchment Polygons

Firstly a Project Area is generated based on the Project point Selected (Outlet point- Salebhata Gauge Station). Then the project is generated using all the above data stated as followed.

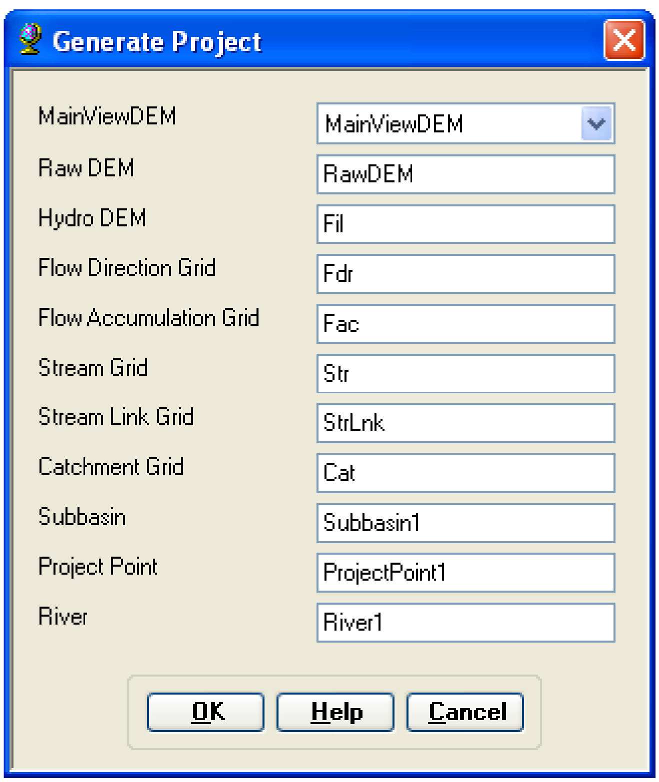


Fig 4.16: Project Generation in geo-HMS using data

4.3.1 Basin Processing

The basin processing menu has features such as revising sub-basin delineations, dividing basins, and merging streams.

Basin Merge

This process merges two or more adjacent basins into one. This simplifies the model that is to be developed. The various sub basin generated in the above processes are merged into 6 Sub-basins as per the Rain Gauges selected for the modelling based on Thiessen Polygon prepared.

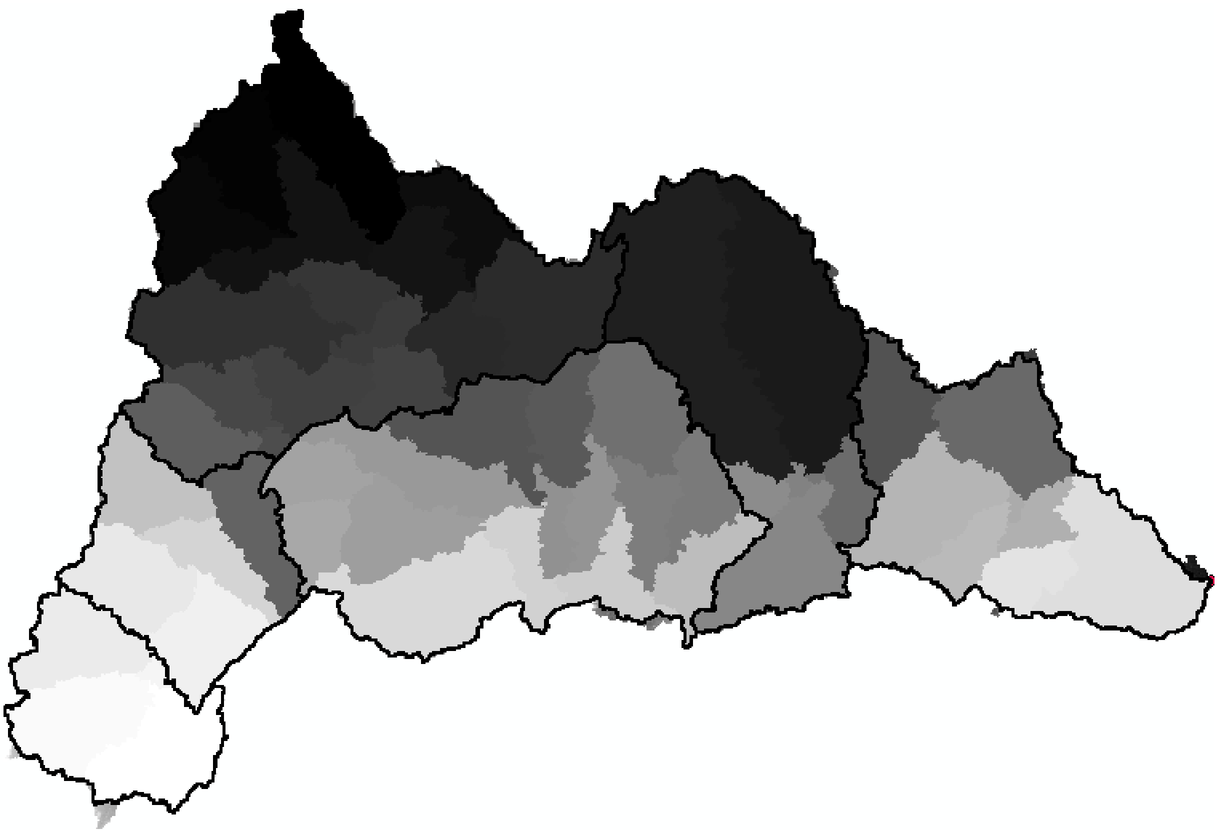


Fig 4.17: Merged Sub Basins

4.3.2 Extracting Basin Characteristics

Physical Characteristics of Streams and Sub-Basins are extracted into the attribute tables. The following are the characteristics extracted:

1. River Length (populated in attribute table of River)
2. River Slope (populated in attribute table of River)

3. Basin Slope (populated in Attribute Table of Sub-basin)
4. Longest Flow Path (a new feature class with polyline feature is created)
5. Basin Centroid - This will create a Centroid point feature class to store the centroid of each sub-basin.

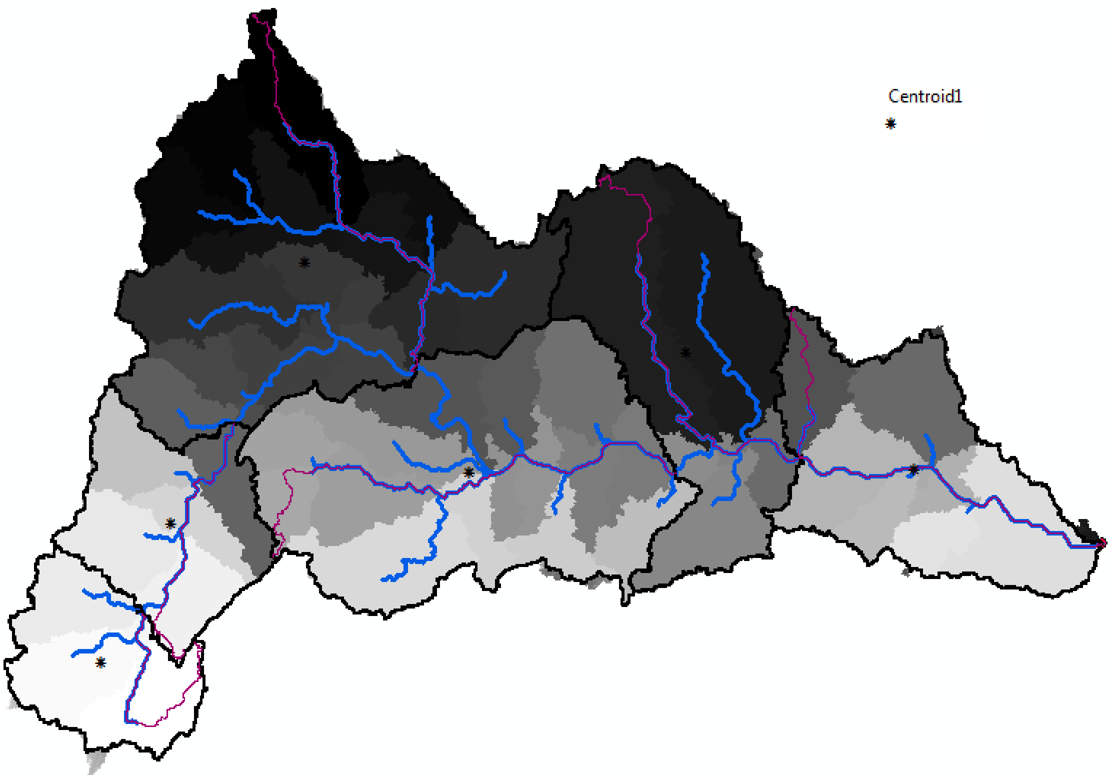


Fig 4.18: Basin Centroid

Center of Gravity Method computes the centroid as the center of gravity of the sub basin if it is located within the sub basin. If the Center of Gravity is outside, it is snapped to the closest boundary. Longest Flow Path Method computes the centroid as the midpoint of the longest flow path within the sub basin. The quality of the results by the two methods is a function of the shape of the sub basin and should be evaluated after they are generated.

6. Basin Centroid Elevation - This will compute the elevation for each centroid point using the underlying DEM. This populates the attribute table of Centroid of Basins.

OBJECTID *	Shape *	DrainID	Elevation	Elevation_HMS
1	Point	67	233	764.435696
2	Point	78	204	669.291339
3	Point	89	184	603.674541
4	Point	99	118	387.139108
5	Point	110	295	967.847769
6	Point	111	250	820.209974

Table 4.5: Attribute Table of Centroid of Basins

7. Centroidal Longest Flow Path - This creates a new polyline feature class showing the flowpath for each centroid point along longest flow path.

4.3.2 HMS Input and Parameters

We specify the methods that HMS should use for transform (rainfall to runoff) and routing (channel routing) using this function. Of course, this can be modified and/or assigned inside HMS. In our case the loss and transform methods are done using SCS method. Then the following processes are done:

a. River Auto Name - This function assigns names to river segments. The Name field in the input River feature class is populated with names that have "R###" format, where "R" stands for river/reach "###" is an integer.
b. Basin Auto Name - This function assigns names to sub-basins. Like river names, the Name field in the input Sub-basin feature class is populated with names that have "W###" format, where "W" stands for watershed, and "###" is an integer.
c. *Sub-basin Parameters* - Depending on the method (HMS process) you intend to use for your HMS model, each sub-basin must have parameters such as SCS curve number for SCS method. So, **CN Grid** is now added to the Project.

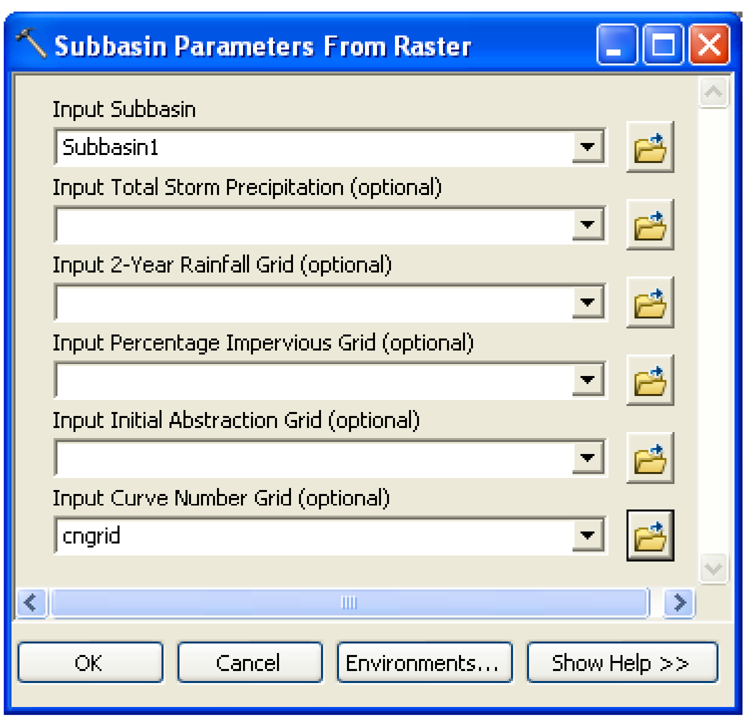


Fig 4.19: CN grid added to the Project

After the computations are complete, we can open the attribute table for sub-basin, and see that a field named Basin-CN is populated with average curve number for each sub-basin.

d. CN Lag Method- The function computes basin lag in hours (weighted time of concentration or time from the center of mass of excess rainfall hyetograph to the peak of runoff hydrograph) using the NRCS National Engineering Handbook (1972) curve number method.

4.3.2 HMS

a. Map to HMS Units - This tool is used to convert units.

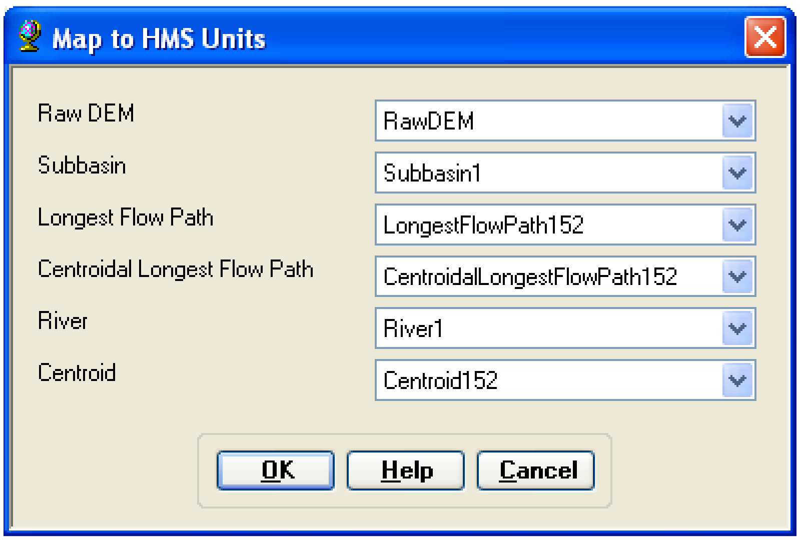


Fig 4.20: Mapping to HMS Units

b. Check Data - This tool verifies all the input datasets.

```
CHECKING SUMMARY
****************

Unique names           - no problems.
River containment      - no problems.
Center containment     - no problems.
River connectivity     - no problems.
VIP relevance          - no problems.
```

Fig 4.21: Checking Summary

c. HMS Schematics - This tool creates a GIS representation of the hydrologic system using a schematic network with basin elements (nodes/links or junctions/edges) and their connectivity.

Two new feature classes *HMS Link* and *HMS-Node* are generated and added to the map document.

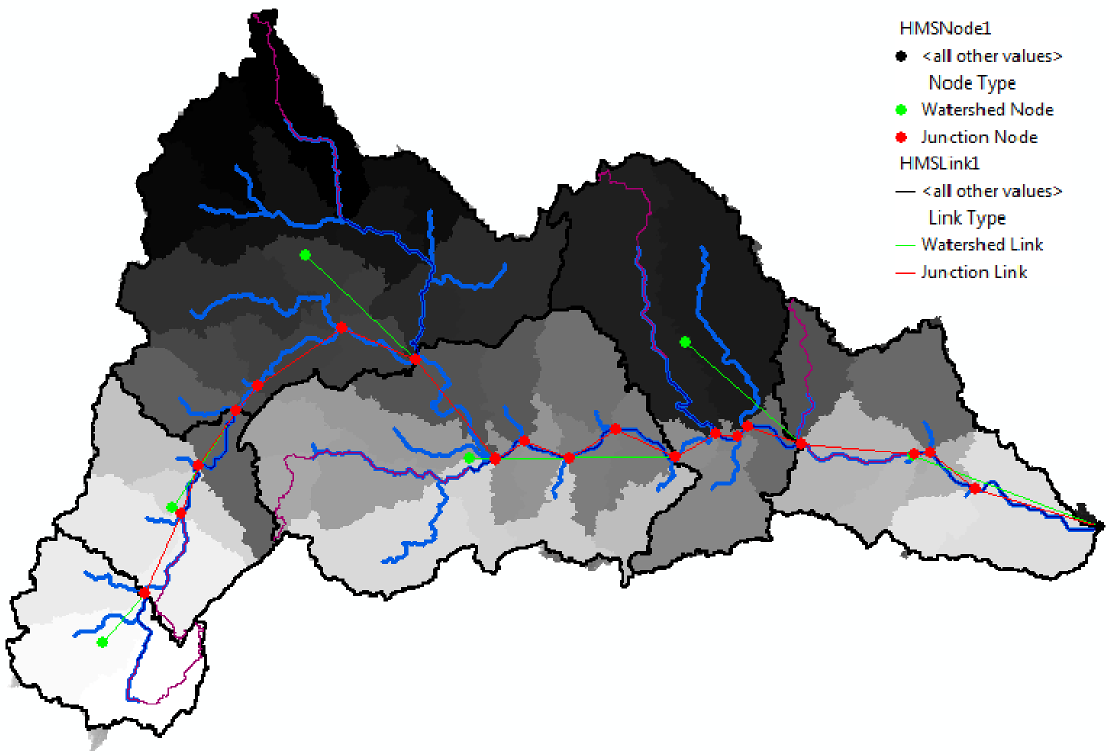


Fig 4.22: HMS Link and HMS Nodes

d. Add Coordinates - This tool attaches geographic coordinates to features in HMS-Link and HMS-Node feature classes. This is useful for exporting the schematic to other models or programs without losing the geospatial information.

e. Prepare Data for Model Export - This function allows preparing sub-basin and river features for export.

Background Shape File

This function captures the geographic information (x,y) of the sub-basin boundaries and stream alignments in a text file that can be read and displayed within HMS. Two shapefiles: one for river and one for sub-basin are created.

Basin Model

This function will export the information on hydrologic elements (nodes and links), their connectivity and related geographic information to a text file with .basin extension.

We have successfully created a HEC-HMS project for Ong River Basin.

4.4 Opening the HMS model in HEC-HMS

After developing the whole model in Arc Map, it is opened in HEC-HMS to provide Meteorological data and Discharge data for simulation and validation.

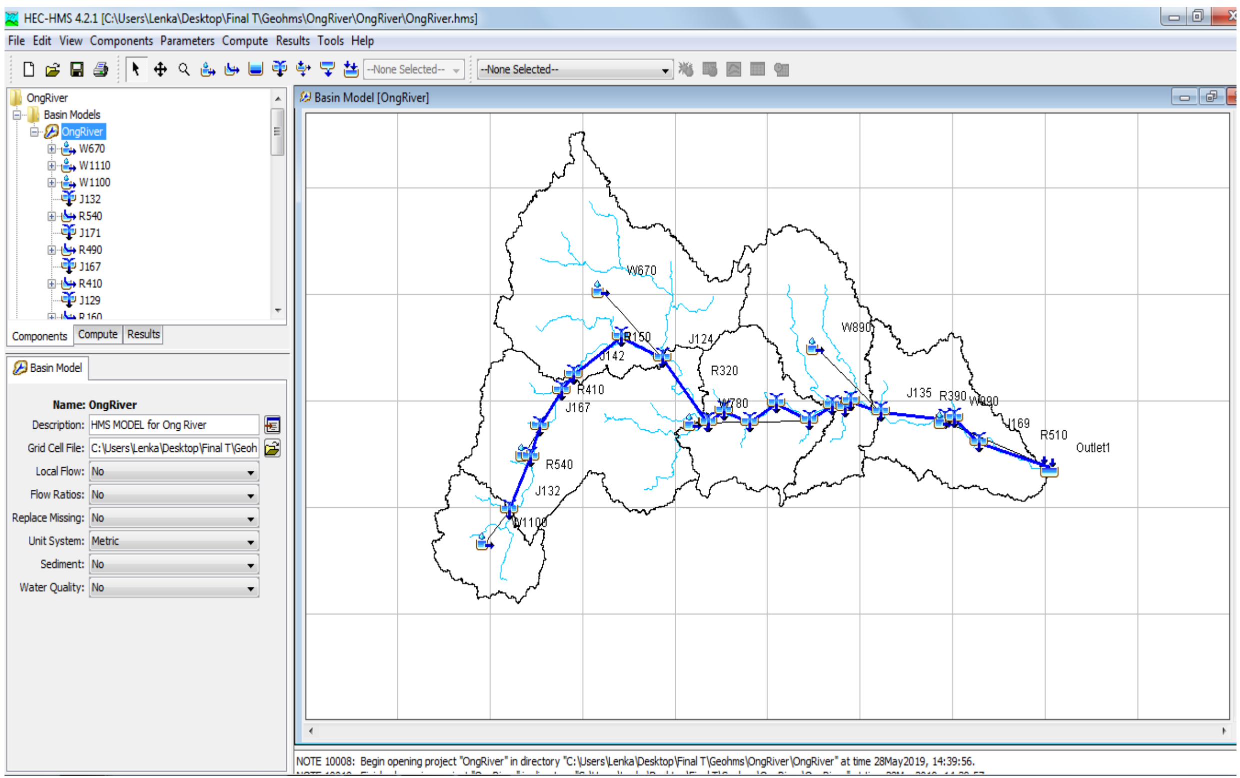


Fig 4.23: HMS model in HEC-HMS

4.4.1 Preparing Model for Simulation

The model obtained in HEC-HMS is now prepared for simulation. The final inputs are time series data i.e. the daily Rainfall data from the six Precipitation Gauge and the Discharge Data at the Outlet – Salebhata Gauge Station, for the year 2009.

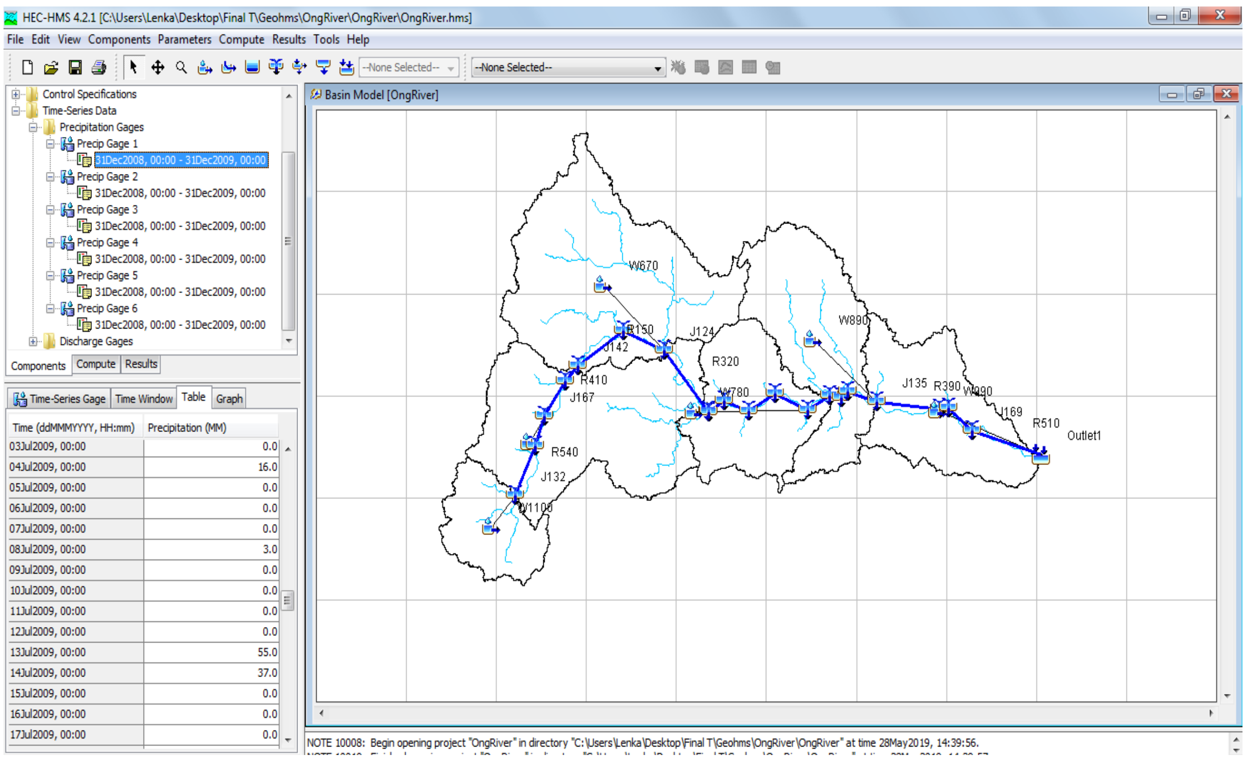


Fig 4.24: Precipitation Data Input of Rain Gauges in HMS model

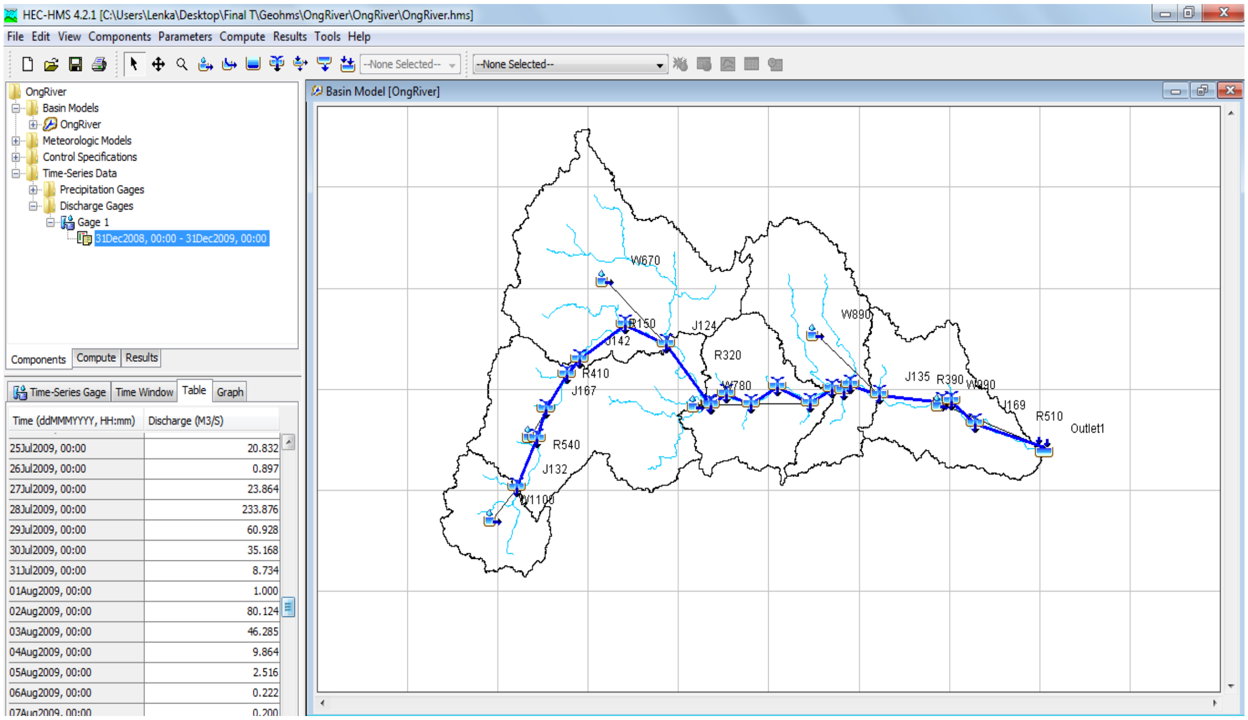


Fig 4.25: Discharge Data Input of Salebhata Station in HMS model

4.4.2 Simulation of the Model

Finally the model is prepared with all the required input data and its own structures. A Run is simulated using the input data of 2009 provided.

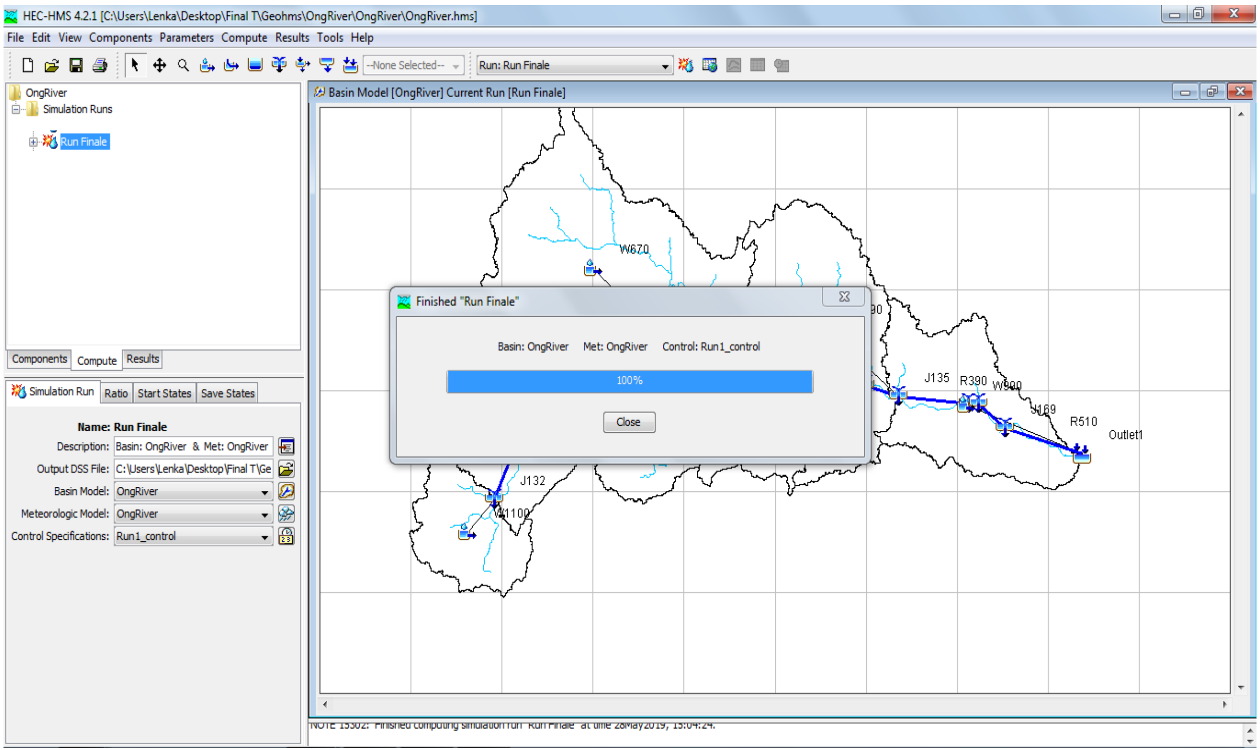


Fig 4.26: Successful simulation of the HMS model for Ong River Basin

RESULTS AND DISCUSSIONS

CHAPTER 5

5.1 MODEL OUTPUT RESULTS

5.1.1 Global Summary

Global Summary Results for Run "Run Finale"

Project: OngRiver Simulation Run: Run Finale

Start of Run: 01Jan2009, 00:00 Basin Model: OngRiver
End of Run: 31Dec2009, 00:00 Meteorologic Model: OngRiver
Compute Time: 28May2019, 15:04:22 Control Specifications: Run1_control

Show Elements: All Elements Volume Units: MM 1000 M3 Sorting: Hydrologic

Hydrologic Element	Drainage Area (KM2)	Peak Discharge (M3/S)	Time of Peak	Volume (MM)
W670	1447.80	1602.5	21Jul2009, 00:00	726.46
W1110	459.75	539.5	21Jul2009, 00:00	1240.31
W1100	360.84	365.1	27Aug2009, 00:00	908.11
J132	360.84	365.1	27Aug2009, 00:00	908.11
R540	360.84	365.1	27Aug2009, 00:00	908.11
J171	360.84	365.1	27Aug2009, 00:00	908.11
R490	360.84	365.1	27Aug2009, 00:00	908.11
J167	360.84	365.1	27Aug2009, 00:00	908.11
R410	360.84	365.1	27Aug2009, 00:00	908.11
J129	820.59	850.3	21Jul2009, 00:00	1094.23
R160	820.59	850.3	21Jul2009, 00:00	1094.23
J142	820.59	850.3	21Jul2009, 00:00	1094.23
R150	820.59	850.3	21Jul2009, 00:00	1094.23
J140	820.59	850.3	21Jul2009, 00:00	1094.23
R130	820.59	850.3	21Jul2009, 00:00	1094.23
J124	2268.39	2452.7	21Jul2009, 00:00	859.50
R320	2268.39	2452.7	21Jul2009, 00:00	859.50
J155	2268.39	2452.7	21Jul2009, 00:00	859.50
R350	2268.39	2452.7	21Jul2009, 00:00	859.50
J162	2268.39	2452.7	21Jul2009, 00:00	859.50
R360	2268.39	2452.7	21Jul2009, 00:00	859.50
J157	2268.39	2452.7	21Jul2009, 00:00	859.50
R330	2268.39	2452.7	21Jul2009, 00:00	859.50
J158	2268.39	2452.7	21Jul2009, 00:00	859.50
R340	2268.39	2452.7	21Jul2009, 00:00	859.50
J160	2268.39	2452.7	21Jul2009, 00:00	859.50
R370	2268.39	2452.7	21Jul2009, 00:00	859.50
W780	1223.92	1089.9	21Jul2009, 00:00	1034.78
J138	3492.31	3542.6	21Jul2009, 00:00	920.93
R290	3492.31	3542.6	21Jul2009, 00:00	920.93
J148	3492.31	3542.6	21Jul2009, 00:00	920.93
R220	3492.31	3542.6	21Jul2009, 00:00	920.93
J145	3492.31	3542.6	21Jul2009, 00:00	920.93
R210	3492.31	3542.6	21Jul2009, 00:00	920.93
J146	3492.31	3542.6	21Jul2009, 00:00	920.93
R250	3492.31	3542.6	21Jul2009, 00:00	920.93
W890	855.14	1157.8	21Jul2009, 00:00	1834.89
J135	4347.45	4700.4	21Jul2009, 00:00	1100.70
R390	4347.45	4700.4	21Jul2009, 00:00	1100.70
J151	4347.45	4700.4	21Jul2009, 00:00	1100.70
R280	4347.45	4700.4	21Jul2009, 00:00	1100.70
J152	4347.45	4700.4	21Jul2009, 00:00	1100.70
R450	4347.45	4700.4	21Jul2009, 00:00	1100.70
J169	4347.45	4700.4	21Jul2009, 00:00	1100.70
R510	4347.45	4700.4	21Jul2009, 00:00	1100.70
W990	716.03	714.4	21Jul2009, 00:00	1386.72
Outlet1	5063.48	5414.8	21Jul2009, 00:00	1141.15

Table 5.1: Global Summary

As per Global Summary the Peak discharge was attained on 21st July 2009. The sudden rise of discharge implies occurrence of “flash flood” in the area.

5.1.2 Graph

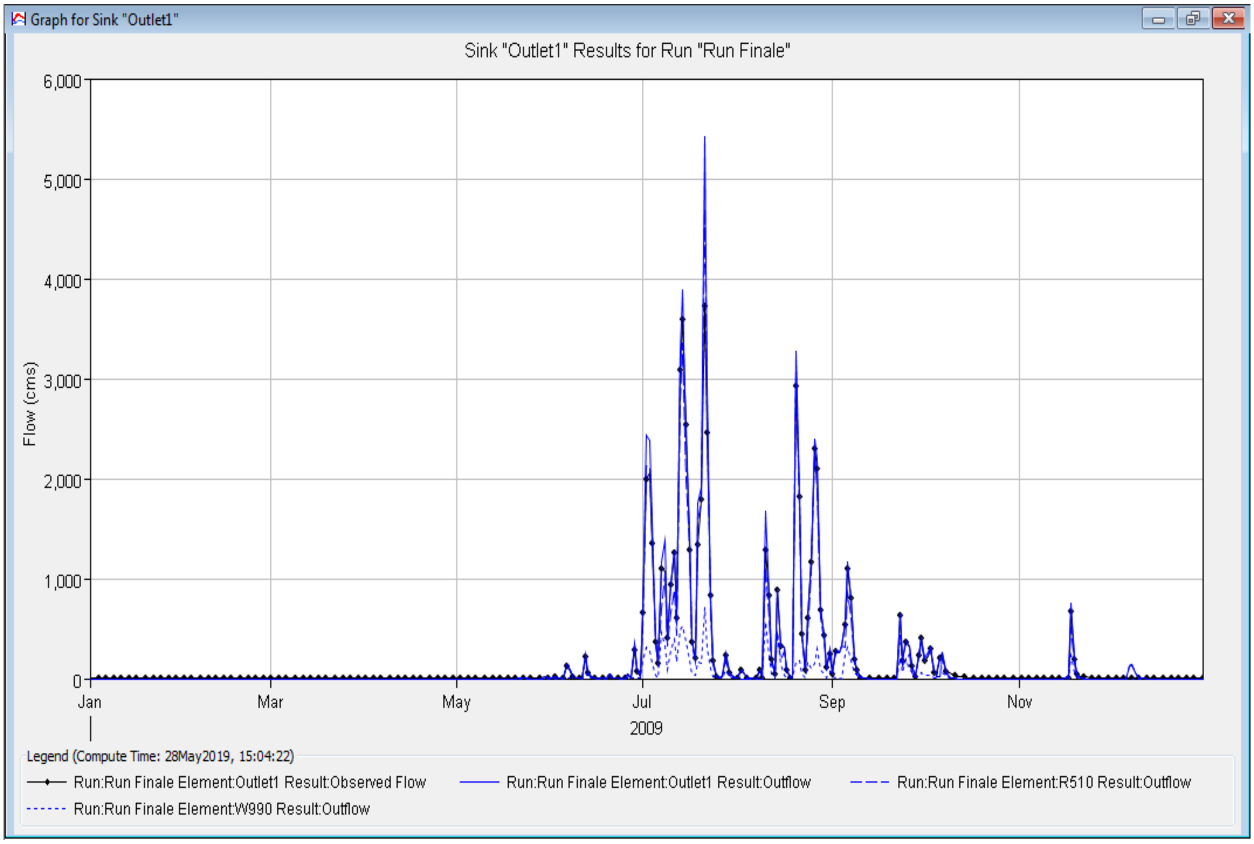


Fig 5.1: Graph

As per the graph the Result Outflow and the Observed Outflow are comparable and close. The Peak Discharge as per the Computed Result is 5414.8 m^3/sec and the peak discharge as per Observed Flow is 3732.7 m^3/sec, both attained on 21st July 2009.

5.2 Model Validation

Nash-Sutcliffe model efficiency coefficient

The Nash-Sutcliffe model efficiency coefficient is used to assess the predictive power of hydrological models. It is defined as:

$$E = 1 - \frac{\sum_{t=1}^{T}\left(Q_o^t - Q_m^t\right)^2}{\sum_{t=1}^{T}\left(Q_o^t - \overline{Q_o}\right)^2}$$

Where $Q_0$is the mean of observed discharges, and $Q_m$is modelled discharge. Q_0' is observed discharge at time t[1]. Its definition is identical to the co-efficient of determination R^2used in linear regression. Nash-Sutcliffe efficiencies can range from -∞ to 1. An efficiency of value 1 corresponds to perfect match of modelled discharge to the observed data. So the closer the model efficiency is to 1, the more accurate the model is.

Fig 5.2: Result Summary Table

In this case the Nash-Sutcliffe coefficient of the developed model based on historical data is found to be 0.954 which is a satisfactory validation of the model.

SUMMARY AND CONCLUSION

CHAPTER 6

6.1 SUMMARY

The present study created a hydrological model of Ong river basin for rainfall-runoff estimation and the model is validated based on historical data.

The GIS software- ArcGIS was used to prepare data required for model development and HEC-geo-HMS tool of ArcGIS was used to develop the model. Then, the Hydrological Modelling System (HEC-HMS) was used to estimate runoff generation based on rainfall data of 2009 on the Ong River Basin. The model is then validated using the discharge data of Salebhata Gauge Station based on the results obtained from the model using HEC-HMS.

As per the results the peak discharge of 3732.7 m^3/s was attained on 21st July 2009 and as per the observed data a peak discharge of 5414.8 m^3/s was attained on the same day, implying a satisfactory result.

Also, the Nash-Sutcliffe coefficient of the model is found to be 0.954. Thus, the hydrological model developed exhibits a satisfactory validation.

6.2 CONCLUSIONS

- The hydrological model developed has provided rainfall-runoff estimation of Ong River Basin based on historical data (2009) and has exhibit satisfactory validation.
- The hydrological model is ready for estimation of runoff for future predicted rainfall on Ong River Basin.
- GIS and Remote Sensing has proved to be a very important and useful tool for hydrological modelling using SCS-Curve Number Method. The SCS- CN method deals with a large spatial data of soil and land use, which makes the work very time taking and requires a lot of effort. GIS provides accurate spatial information and easily retrieve and process soil types and land use, which otherwise would have been very difficult.

6.3 Future Scope of Study

- The hydrological model is ready for estimation of runoff for future predicted rainfall on Ong River Basin.
- The results of hydrological model can be compared to the hydrological models based on other methods.
- As the model is based on SCS-CN method which is a function of land use type; so the variation of runoff as the land use type changes over the time can be compared to study the effect of change of land use pattern on runoff produced by Ong River catchment.

6.4 Limitation of the Study

As hydrological model is based SCS-CN method, it is a function of land use pattern and soil type of the catchment. And land use depends upon various parameters, one of which is human activity and development over the catchment. As the land Use pattern changes the runoff produced from the catchment will change accordingly. And this hydrological model will be needed to modified and developed again.

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