ISSN 2320 - 2602
Volume 3, No.3, March 2014
International Journal of Advances in Computer Science and Technology
Available Online at http://warse.org/pdfs/2014/ijacst11332014.pdf

COMPUTATION OF WATERSHED PARAMETERS USING REMOTE SENSING AND GEOGRAPHICAL INFORMATION SYSTEMS

Dr. G.VENKATA RAMANA
Professor & Dean, Dept. of Civil Engineering, GRIET, Hyderabad, India.
E-mail: ramanagedela@gmail.com

ABSTRACT

Identification and delineation of Land Use/Land Cover (LU/LC), location, extent and their spatial distribution patterns are possible through Remote Sensing (RS) because of its synoptic view and its ability to resolve both macro and micro details on a single imagery. It provides periodic coverage of the same area thus enabling to obtain Multi-temporal data useful for monitoring the dynamic aspects of Land Use/Land Cover. It provides data both in analog and digital form. Such data is amenable for both visual interpretation and digital analysis for extracting thematic information. It is relatively fast, cost effective and economical for inventorying several details of LU/LC than most of the other methods of surveying. The different Multi-spectral and Spatial data can be merged with other satellite data for optimizing the LU/LC identification and discrimination.

The overall objective of image classification procedures is to categorize all pixels in an image into land cover classes or themes. Different feature types manifest different combinations of Digital Numbers (DN) based on their inherent spectral reflectance and emittance properties. The elements of image interpretation are shape, pattern, tone, texture, site, association and resolution.

Finally concluded that the preparation of drainage map, drainage on satellite imagery, drainage map with stream order, prioritized drainage raster map, slope map, prioritized slope raster map, contour map, Digital Elevation Model (DEM) map, aspect map, Triangulated Irregular Network (TIN), drainage draped on TIN, satellite image draped over DEM**,** draped image, flow direction grid, determination of flow direction and flow accumulation map were presented.

Key words: Land Use/Land Cover, Digital Elevation Model, Triangulated Irregular Network, Remote Sensing, Geographical Information Systems.

INTRODUCTION

The visible and near infrared bands on the satellite multi-spectral sensors allow monitoring of the greenness or vigor of vegetation. Green vegetation is highly absorptive in the visible part of the spectrum, mostly owing to the presence of chlorophyll. Beyond a wave length of 700 nanometers, the absence of absorbing pigments and leaf structure results in high reflectivity for green vegetation. In contrast, other features such as bare ground, water, snow and clouds have similar reflectance in visible channel compared to near infrared channel. Stressed vegetation is less reflective in the near infrared channel than non-stressed vegetation and also absorbs less energy in the visible band. Stratification of the Normalized Difference Vegetation Index (NDVI) response to broad scene components. Vegetation indices were found to increase as one proceeds from water through ice, snow, opaque clouds, bare soil, to green vegetation (Holben 1986). Out of the various vegetation indices available, NDVI is very widely used as it minimizes the effect of change in illumination condition and surface topography (Holben, 1986).

The NDVI is defined as the ratio of difference the near infrared and red reflectance to their sum.

$$NDVI = \frac{CH_2 - CH_1}{CH_2 + CH_1}$$

Where
CH_1 = Spectral reflectance form red band / channel
CH_2 = Spectral reflectance form near infrared band/ channel

The thematic map of Land Use/Land Cover has been prepared using ERDAS 8.7. The classification of Land Use/Land Cover classes were evaluated using NDVI of all the available methods of image classification with regard to vegetation and its sub classification, NDVI forms the basis for a better classification and hence adopted for the present study. [12] And also, as the study area is considerably large comprising predominantly of vegetation, NDVI classification is better suited and hence employed for the classification of Land Use/Land Cover.

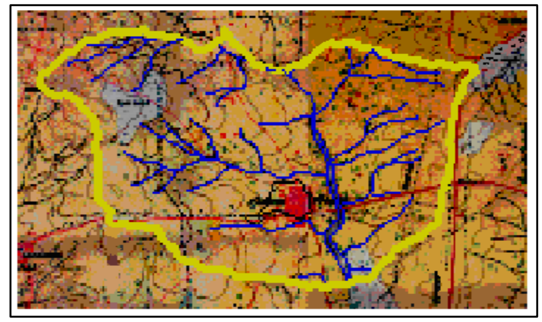
OBJECTIVES OF THE PRESENT STUDY

To achieve the above requirements in this study is taken with the following objectives

i) To prepare the drainage map and drainage on satellite imagery
ii) To prepare the drainage map with stream order and prioritized drainage raster map**.**
iii) To prepare the slope map and prioritized slope raster map.
iv) To prepare the contour map
v) To prepare the Digital Elevation Model (DEM) map and aspect map
vi) Triangulated Irregular Network (TIN) and drainage draped on TIN
vii) To prepare the satellite image draped over DEM**.**
viii) To prepare the draped image and flow direction grid
ix) To determine the flow direction and flow accumulation map

STUDY AREA

Pamena – I Watershed which is the part of Pamena village falls under the agro-climatic zone V of Andhra Pradesh which is designated as North Telangana agro climatic zone. The village is 6 km away from Chevella located on Shabad road and in the southern part of Ranga Reddy district. (Source: Action plan for Watershed Development Program in Pamena – I Watershed, Chevella Mandal, Ranga Reddy District, A.P.). The village lies between longitudes 78º 06' – 78º 09' and latitudes 17º 15'30'' – 17º 17'30'' falling in Survey of India toposheet no.56 K/3. Pamena-I Watershed has a geographical area of 500 ha. The study area with drainage lines on toposheet no. 56 K/3 with a scale of 1: 25000 is shown in Figure 1. The study area on satellite imagery of Indian Remote Sensing (IRS) - 1D, Linear Imaging Self-scanning Sensor (LISS)-III & PAN (Panchromatic) merged map is shown in Figure 2. [9] The distribution of rainfall is unequal and major part of annual rainfall occurs in a few months due to South West monsoon. Early withdrawal of monsoon results in crop failures and makes agriculture a gamble.



LEGEND

Watershed Boundary

Drainage

Figure 1. STUDY AREA ON TOPOSHEET

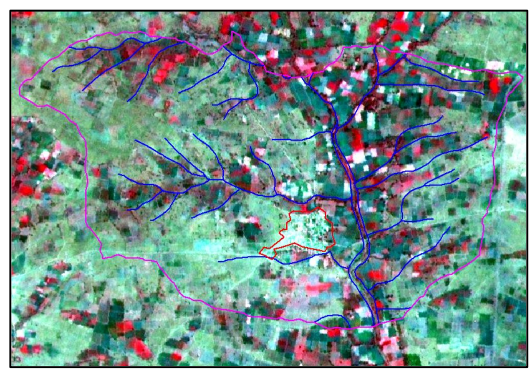


Figure 2. STUDY AREA ON SATELLITE IMAGERY

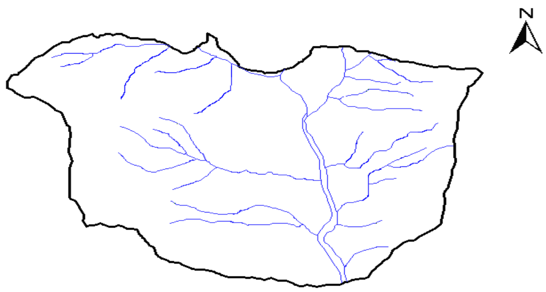
METHODOLOGY

Preparation of Maps using GIS

The methodology of preparation of several maps such as drainage map, slope map, contour map, DEM (Digital Elevation Model) map, aspect map, hill shade map, flow direction map and flow accumulation map were described in detail. Further delineation of watershed boundary and extraction of digitized soil map were discussed.

Drainage Map: Drainage pattern of the Pamena – I watershed was digitized from projected toposheets. Now, the already prepared polygon coverage was overlaid on the drainage map to compute the stream length and drainage density in each sub area of the

Pamena – I watershed in GIS environment. [3] Streams in watershed area along with boundary were shown in Figure 3. The drainage on the satellite imagery was shown in Figure 4. The stream length, perimeter and drainage density were presented in Table 1. Highest and lowest elevations of the study area i.e. Pamena – I watershed were also listed in Table 1.



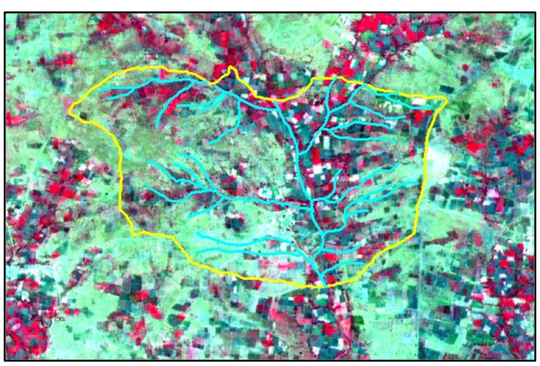
Scale: 1: 25000

LEGEND

Watershed Boundary

Drainage

Figure 3. DRAINAGE MAP



LEGEND

Watershed Boundary

Drainage

Figure 4. DRAINAGE ON SATELLITE IMAGERY

TABLE 1: WATERSHED PARAMETERS DERIVED FROM GIS

Name of the area	Highest elevation & Lowest elevation m	Area in Sq. Km.	Perimeter in Km	Stream Length in Km	Drainage Density
Pamena –I watershed	640 & 595	5.0	1.5	10.75	0.09

SLOPE MAP: The slope function in Arc GIS calculates the maximum rate of change between each cell and its neighbors. Every cell has a slope value in the output raster. The lower slope value indicates a flatter terrain and the higher the slope value, the steeper the terrain. The output slope raster can be calculated either in percent of slope or degree of slope. Slope map was prepared from the DEM and Figure 5 shows the slope of the terrain.

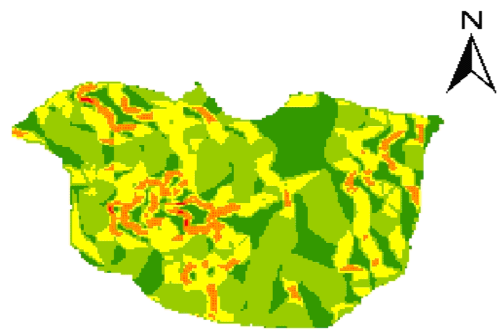


Figure 5. SLOPE MAP

LEGEND

0 - 1 Nearly level

1 - 3 Very gently sloping

3- 5 Gently sloping

5 - 10 Moderately sloping

10 - 15 Strongly sloping

Scale : 1:25000

CONTOUR MAP: Contours are lines that connect points of equal elevation. The equal elevation points were located from toposheet number 56 K/3, on a scale of 1: 50, 000 collected from Survey of India (SOI), Hyderabad. The collected toposheets were scanned and registered with tic points and rectified. Further, the rectified maps were projected. All individual projected maps were finally merged as a single layer. The contours were digitized with an interval of 5 m. The contour attribute table contains an elevation attribute for each contour line. [6] The contour map was prepared using Arc Map of Arc GIS 9.1 and is shown in Figure 6. Contour map is a useful surface representation because it enables to simultaneously visualize flat and steep areas, ridges, valleys in the study area.

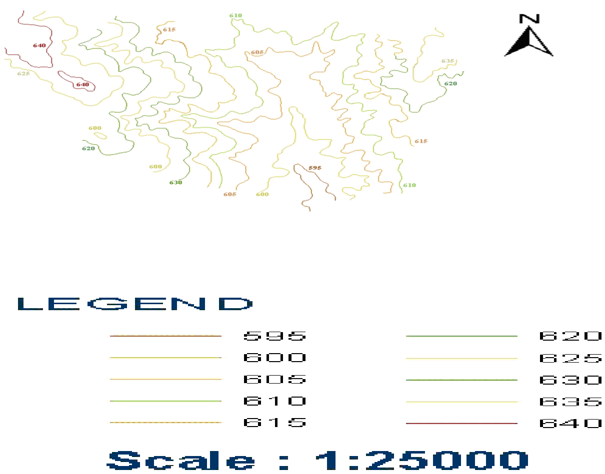


Figure 6. CONTOUR MAP

DIGITAL ELEVATION MODEL (DEM) MAP: A DEM is a raster representation of a continuous surface, usually referring to the surface of the earth. The DEM is used to refer specifically to a regular grid of spot heights. [1] It is the simplest and most common form of digital representation of topography. The Digital Elevation Model of Pamena–I watershed was generated from the contour map using surface analysis tool of spatial analyst in Arc Map and shown in Figure 7.

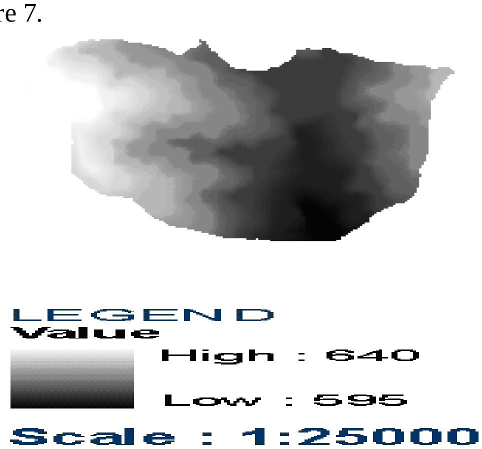


Figure 7. DIGITAL ELEVATION MODEL (DEM) MAP

ASPECT MAP: Aspect identifies the steepest down slope direction from each cell to its neighbours. Aspect map was prepared from DEM map and shown in Figure 8. The data obtained from the aspect map is used in the fully distributed modeling.

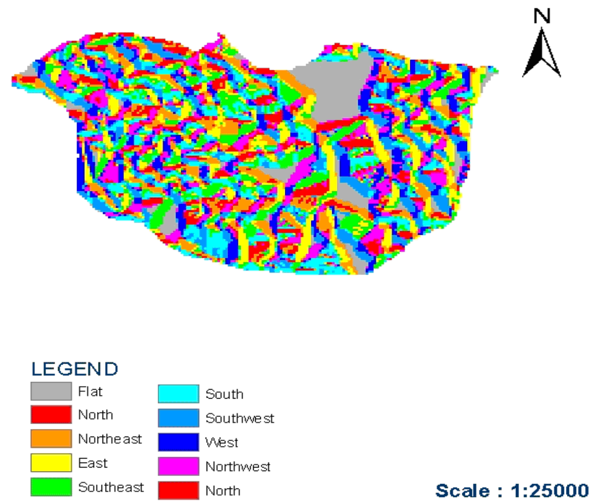


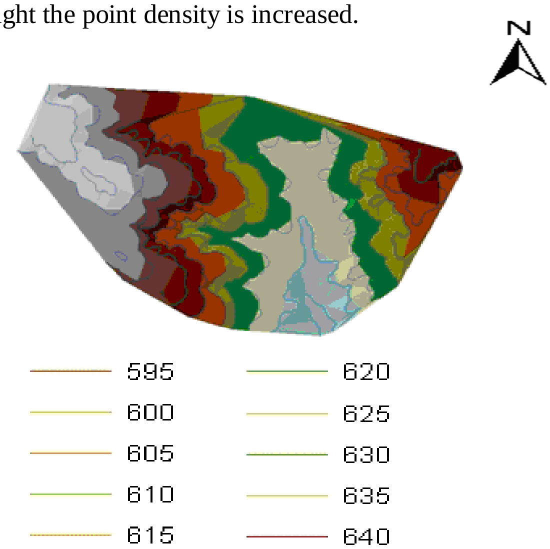
Figure 8 ASPECT MAP

TRIANGULATED IRREGULAR NETWORK (TIN) MAP:

A Triangulated Irregular Network (TIN) is a digital data structure used in a geographic information system (GIS) for the representation of a surface. [7] A TIN is a vector based representation of the physical land surface, made up of irregularly distributed nodes and lines with three dimensional coordinates (x, y, and z) that are arranged in a network of non-overlapping triangles. TIN's are often derived from the elevation data of a rasterized Digital Elevation Model (DEM). The Triangulated Irregular Network (TIN) map was shown in Figure 9. An advantage of using a TIN over a DEM in mapping and analysis is that the points of a TIN are variably distributed based on an algorithm that determines which points are most necessary for an accurate representation of the terrain. The drainage draped on TIN was shown in Figure 10.

Data input is therefore flexible and fewer points need to be stored than in a DEM with regularly distributed points. While a TIN may be less suited than a DEM raster for certain kinds of GIS applications, such as analysis of a surface slope and aspect, TINs have the advantage of being able to portray terrain in three dimensions.

A TIN comprises a triangular network of vertices, known as mass points, with associated coordinates in three dimensions connected by edges to form a triangular tessellation. Three-dimensional visualizations are readily created by rendering of the triangular facets. In regions where there is little variation in surface height, the points may be widely spaced whereas in areas of more intense variation in height the point density is increased.



Scale: 1: 25000

Figure 9 TRIANGULATED IRREGULAR NETWORK (TIN) MAP

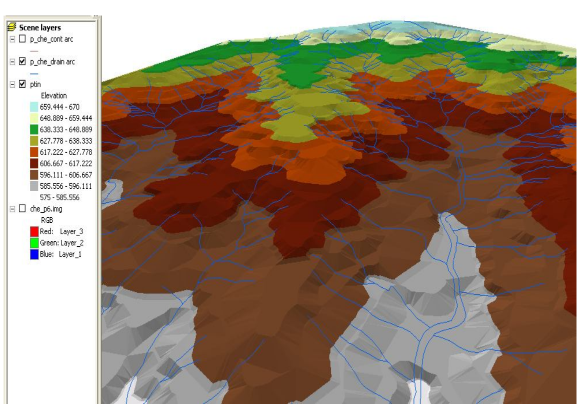


Figure 10 DRAINAGE DRAPED ON TIN

DRAPED IMAGE

A draping contour grid must be superimposed upon a base image before it can be used for draping. This is done visually using simple point and drag operations. There is minimum of numerical information required to setup a drape grid, which makes the process quick and easy to understand. Drape regions are separate parts of a drape image into different drape fabrics or different alignments or lighting effects can be applied. The satellite image draped over DEM was shown in Figure 11. Drape fabrics are added to a "drape library" from which they can be selected visually as and when they are required. [11] Fabrics can be aligned differently in drape regions by simply dragging them within the region. The image is re-draped in real-time as the fabric is dragged. The fabrics can also be scaled differently in different regions. Lighting effects can be applied to each drape region as required. Simple real life sizes can be applied to the base image and fabrics so that the scale of the resulting draped image is correctly maintained. The final draped image can also be "softened" to increase the realism of the image and remove the contrast, which may be found in some drape simulations.

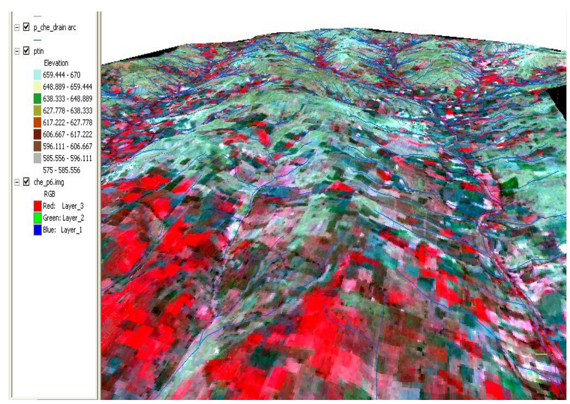


Figure 11 SATELLITE IMAGE DRAPED OVER DEM

FLOW DIRECTION MAP

One of the key requirements in deriving hydrologic characteristics of a watershed is the ability to determine the direction of flow from every cell in the raster. This is done with the flow direction function in Arc Map of Arc GIS 9.1. This function takes a surface as input and outputs a raster showing the direction of flow out of each cell. [10] There are eight valid output directions relating to the eight adjacent cells into which flow could travel. The direction of flow is determined by finding the direction of steepest descent or maximum drop from each cell. When a direction of steepest decent is found, the output cell is coded with the value representing that direction which is observed in the following Diagram: 1 containing Elevation and Flow Direction. Each cell value indicates the flow direction in that corresponding cell. Flow direction grids are used in the other flow functions which are created from an elevation surface. Flow direction raster map was prepared from ARC Map of Arc GIS 9.1 in hydrology tools and shown in Figure 12. The direction values were assigned in the Flow Direction Grid which is shown in Figure 13.

78	72	69	71	58	49
74	67	56	49	46	50
69	53	44	37	38	48
64	58	55	22	31	24
68	61	47	21	16	19
74	53	34	12	11	12

↘	↘	↘	↓	↓	↙
↘	↘	↘	↓	↓	↙
→	→	↘	↓	↙	↓
↗	↗	→	↘	↓	↙
↘	↘	→	↓	↓	↓
→	→	→	→	↓	←

DIAGRAM: 1 FLOW DIRECTION

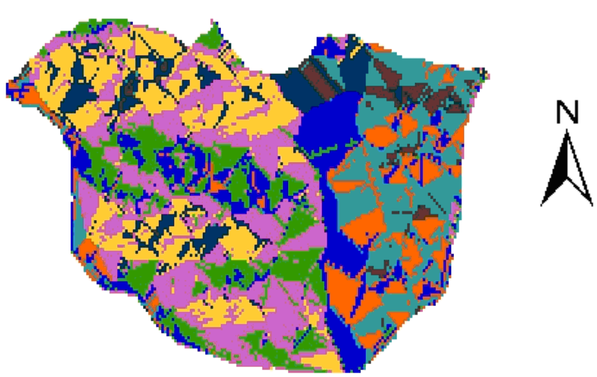


Figure 12 FLOW DIRECTION MAP

Flow Accumulation Map: The flow accumulation function calculates accumulated flow into each lower slope cell in the output raster. Cells with a high flow accumulation are areas of concentrated flow and may be used to identify stream channels. Cells with a flow accumulation of zero are local topographic highs and may be used to identify ridges.

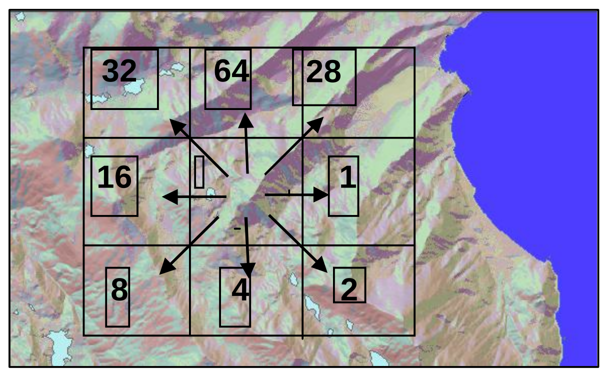
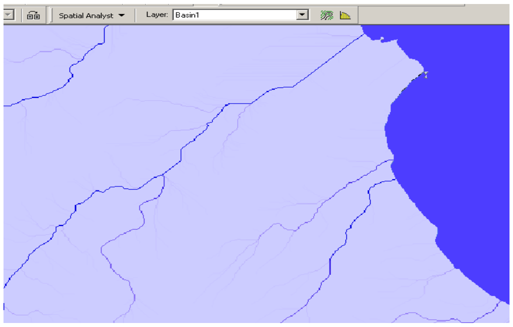


Figure 13 FLOW DIRECTION GRID

It is created from a flow direction grid and it accumulates all uphill water into each cell.
This can be used to estimate rainfall or sediment volumes within a watershed (Weight Grid). [2] These cells with high flow accumulation are areas of concentrated flow which is seen in the following Diagram: 2 and indicated in each cell are their values. The output from the flow accumulation function would then represent the amount of rain that would flow into each cell, assuming that all rain became runoff and there was no interception, evapotranspiration, or loss to ground water. [8] This could also be viewed as the amount of rain that fell on the surface, upslope from each cell.



0	0	0	0	0	0
0	1	1	2	2	0
0	3	7	5	4	0
0	0	0	20	0	1
0	0	0	1	2	0
0	2	4	7	3	1

Flow Accumulation Grid

DIAGRAM: 2

DELINEATION OF PAMENA – I WATERSHED BOUNDARY

A watershed is the upslope area contributing flow to a given location. Such an area may also be referred as a basin/catchment/contributing area. Pamena – I watershed was delineated from DEM by computing the flow direction, [5] and using it in the watershed function of hydrology tools of Arc Map in Arc GIS 9.1.

The watershed function uses a raster of flow direction to determine contributing area. Flow accumulation threshold or the pour points were used to delineate watersheds. When the threshold is used to define a watershed, the pour points for the watershed will be the junctions of a stream network derived from flow accumulation. Therefore, a flow accumulation raster was specified as well as the minimum number of cells that constitute a stream. When a feature dataset is used to define a watershed, the features identify the pour points.

EXTRACTION OF DIGITIZED SOIL MAP

The soil map was collected from National Bureau of Soil Survey and Land Use, Nagpur which was prepared on scale of 1:50,000. The collected soil map was scanned and registered with tic points and rectified. Further, the rectified maps were projected. Later, the delineated study area map of Pamena – I watershed was overlaid on projected soil map and finally, soil map pertaining to the study area was thus extracted in GIS environment. [4] Boundaries of different soil textures were digitized in ARC/INFO and the polygons representing soil classes were assigned different colours for hydrologic soil groups.

Now the already prepared polygon coverage was overlaid on the extracted soil map of the study area to bring out sub areas on the soil map, and to classify soil types in each sub area of the Pamena – I watershed in GIS environment. Table 2 lists out the type of soil, soil group as per USDA classification and areal extent of each sub area of the Pamena – I watershed.

TABLE 2 SOIL CLASSIFICATION USING GIS

Name of the area	**Black loamy soils area in Sq. km**	**Black clayey soils area in Sq. km**
Pamena–I watershed	2.4	2.2

CONCLUSIONS

The specific conclusions are drawn from the present study as follows

i) Prepared the drainage map, drainage on satellite imagery using Remote sensing images of IRS – 1 D
ii) Prepared the maps like drainage with stream order and prioritized drainage raster map
iii) Prepared the slope map, prioritized slope raster map and contour map
iv) Prepared the Digital Elevation Model (DEM) map, aspect map, Triangulated Irregular Network (TIN), drainage draped on TIN using the satellite images
v) Also prepared the satellite image draped over DEM and draped image using remote sensing images
vi) Prepared the flow direction grid, determination of flow direction and flow accumulation map using Arc Map of Arc GIS 9.1 and all these were presented.

REFERENCES

1) Baxter E. Vieux (1993) " DEM Aggregation and Smoothing effects on Surface Runoff Modeling" ASCE, Journal of Comp. in Civil Engineering., Vol.7, Issue 3, pp.310-338 (July 1993).
2) Bell V.A. and Moore R.J. (1998) "A grid-based distributed flood forecasting model For use with weather radar data. 1. Formulation 2. Case Studies", Hydrology and Earth System Science 2: 265-298.
3) David R. Maidment (1993) "Developing a spatially distributed unit Hydrograph by using GIS", Application of Geographic Information Systems in Hydrology and Water Resources (Proceedings of the Vienna Conference, April 1993). IAHS Publications. no. 211, 1993. Dept of Civil Engineering, University of Texas, Austin, TX 78712, USA
4) Department of Environment (DoE)., (1987), Handling Geographical Information, HMSO, London.
5) Gautam. N.C. and Raghavswamy.V, (2003): "Delineation of watershed for land and water resource planning and development", Proceedings of the National conference on Land Use/Land Cover Management Practices, August 21-22, Hyderabad, A.P.
6) Gosain A. K. and Sandhya Rao (2004) "GIS-based technologies for watershed management" Special Section: Application of S&T to Rural Areas, Current Science, Vol. 87, No. 7, 10 October 2004.
7) Krishna Pahari, Jean-Pierre Delsol, Shunji Murai (1996), "Remote sensing and GIS for sustainable watershed management: A study from Nepal", Paper presented at the 4th International Symposium on High Mountain Remote Sensing Cartography, Karlstad – Kiruna - Troms, August 19-29, 1996.
8) Maidment, D. R. (1996), "Using Grid to Perform Watershed Delineation" CE397-GIS in Water Resources, the University of Texas at Austin, Spring 1996.
9) Mohd. Ibrahim Seeni Mohd. and Mohd. Adli Mansor (2000), "Application of Remote Sensing and Hydrological Modeling in Flood Prediction Studies". Malasian Journal of Remote Sensing & GIS, July 2000, Vol. 1.
10) Muzik I.(1996)" A GIS-derived distributed unit hydrograph" , Hydro GIS 96: Application of Geographic Information Systems in Hydrology and Water Resources Management (Proceedings of the Vienna Conference, April 1996). IAHS Publ. no. 235, 1996., The University of Calgary, Calgary, Alberta, Canada T2N 1N4
11) Reddy, P.R. (1997), "Use of Satellite Data in Development and management of Ground water Resource", Proceedings Ground Water Development in Hard Rock Hydro Systems, Central Ground Water Board, Hyderabad.
12) Satellite Imagery Data including with Soils, Land Use / Land Use Cover details from National Institute of Rural Development (NIRD), Rajendra Nagar, Hyderabad.