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Extraction of Watershed Characteristics using GIS and Digital Elevation Model

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***Abstract*—Knowledge of watershed characteristics like aerial extent, slope, relief, aspect and drainage networks is prerequisite for watershed management. Manual computation of these characteristics from the topographic maps and stream network map of the watershed is tedious and time consuming. Geographical Information systems (GIS) with Digital Elevation model can be used for the computation of various watershed characteristics effectively and efficiently. This paper presents a case study of generating digital elevation model (DEM) and extraction of geo-morphological characteristics from DEM using GIS. While results presented in this paper can be specific to the watershed considered, the study clearly shows the applicability of GIS for the extraction of geo-morphological characteristics of a watershed.**

Index Terms—DEM, GIS, Watershed characteristics, Watershed delineation, Watershed Characteristics

I. Introduction

GIS stands for Geographic Information System. Geographic Information Science in new interdisciplinary field. GIS is a combination of geography, cartography, computer science, mathematics etc.

GIS can be defined as “A system for capturing, storing, checking, integrating, manipulating, analysing and displaying data which are spatially referenced to the earth”.

Characterization of watershed is a necessary and important step in planning and management of a watershed. Defining the geographic boundaries of watersheds and sub-watersheds helps in gathering and evaluating data for watershed management. Watershed boundary delineated by government organization is often available at ‘macro level’ only which is not at all suitable for watershed management at ‘micro level’. Therefore, watershed delineation at micro watershed level is an essential task for effective planning and implementation of watershed management programme. Further, information on topographic characteristics of the watershed helps in determining runoff and sedimentation to the outlet of the watershed. For example, a sub-watershed with steep slopes might contribute more sediment loads to the water body than with flat landscapes. While characterizing a watershed, it is also essential to visualize stream networks in order to have information on their location and connectivity.

Now a day, digital elevation models (DEM) are being widely used for watershed delineation, extraction of stream networks and characterization of watershed topography (elevation map, slope map and aspect map) by using watershed delineation tool in GIS software. Digital elevation models (DEMs) are grid-based GIS coverage’s that represent elevation. One DEM typically consists of thousands of grid cells that represent the topography of an area. DEMs with 10m, 30m, and 90m cell sizes can be prepared by interpolation of contour lines available in contour map. The smaller cell sizes represent smaller areas and provide more detailed and accurate topographic data. The 30-meter and 10-meter DEMs are appropriate for smaller watersheds. Shuttle Radar Topographic Mission (SRTM) DEM data having a spatial resolution of 90m can be downloaded from https://earthexplorer.usgs.gov/ for a particular area. The initial stream network and sub-watershed are defined based on drainage area threshold approach in GIS software. The techniques of automated watershed and sub-watershed delineation have been adopted a majority of GIS software packages including DEM Hydro-processing operation of ILWIS, ArcHydro extension package for ArcGIS, Map Window and GIS-coupled watershed modeling software packages like HEC, GeoHMS, AGWA, and ArcSWAT.

The purpose of this exercise is to demonstrate the steps involved in delineating a watershed analysis from a Digital Elevation model (DEM) using the spatial analyst hydrology tools in ArcGIS and to reveal the pour point so that we can install the pump station.

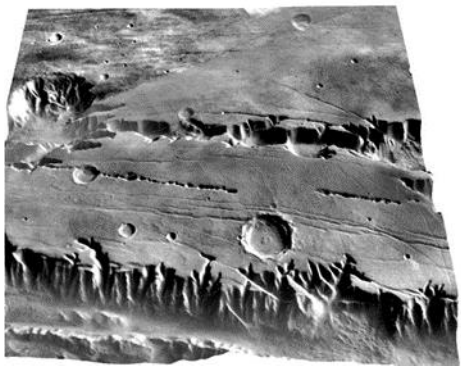

Fig. 1. 3D DEM

DEM is a digital image of terrains surface- commonly for a planet, it can be either in 2D or 3D. There is no common usage of terms DEM, DTM and DSM in scientific literature. In most cases the term digital surface model represents the earth’s surface and includes all objects on it. In contrast to a DSM, the digital terrain model represents the bare ground surface without any objects like plants & buildings.

Most of the data providers (USGS, ERSDAC, CCGIAR, and SPOT IMAGE etc.) use the term DEM as a generic term for DSM‟s & DTM‟s. there are also definitions which equalize the terms DEM & DSM on the web definitions can be found which define DEM as a regular GRID & DTM as TIN (Triangular Irregular Network).

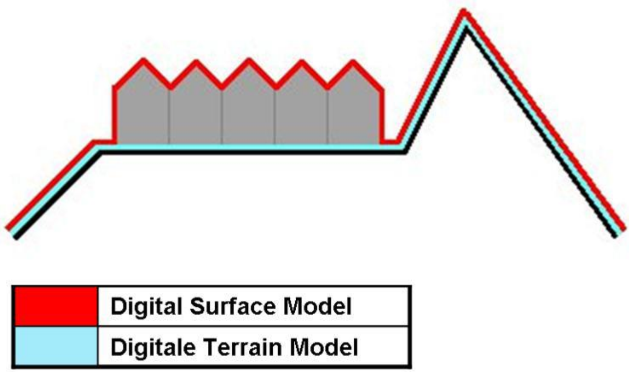

Fig. 2. Surfaces represented by a Digital Surface Model include buildings and other objects. Digital Terrain Models represent the bare ground.

TIN is a digital data structure used in a GIS for the representation of a surface. A TIN is a vector based representation of the physical land surface or sea bottom, made up of irregularly distributed nodes and lines with 3D coordinates that are arranged in a network of non-overlapping triangles.

II. Location of Study Area

Considering the location of the part of nar-tapi-narmada interlinking of river project from where the canal is going to cross and considering the Karjan reservoir basin (one of the basin line and its sub basin line) and its Coordinates: 21.815009,73.538070 latitude in the karjan River basin of Eastern India. While flowing towards west, it meets the Narmada River and finally joins the Arabian Sea. The easiest way to prepare your document is to use this document as a template and simply type your text into it.

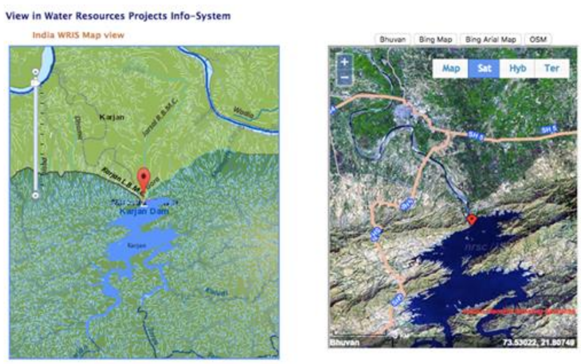

Fig. 3. Satellite Images of Karjan Reservoir

III. Software

A) ArcGIS 10.3 Desktop:

ArcGIS is software or we can say it is an application through which we can work with maps and geographic information. This software is used for: to analyze map information; to create map; to compile geographic data; and to manage geographic database.

B) Spatial Analysis Tools:

The ArcGIS analysis tools provides a rich set of spatial analysis and modeling tools for both raster and vector data. The spatial analysis tools have rich amount of capabilities and are broken down into categories or groups of related functionality. Knowing the categories will help you identify which particular tool to use. The tools in spatial analyst extension are: density, distance, groundwater, hydrology, interpolation etc. Out of all these tools we will use hydrology tools for watershed delineation.

IV. Spatial Information

A) DEM Data:

DEM is a digital model or 3D representation of terrains surface- commonly for a planet. This can be fetch from data provider such as USGS, ERSDAC, CGIAR, SRTM etc.

The methods or tools which will be used for watershed delineation is Spatial Analyst. This is available in arc toolbox of ArcGIS. If arc toolbox is not activated within the map document, then right click on menu bar and select Spatial Analyst. If it is already activated (i.e. spatial analyst) then select spatial analyst tools in arc toolbox & then hydrology tools for watershed delineation.

Hydrology tools can be found by selecting spatial analyst tools.
Hydrology within arc toolbox as shown in Fig. 4.

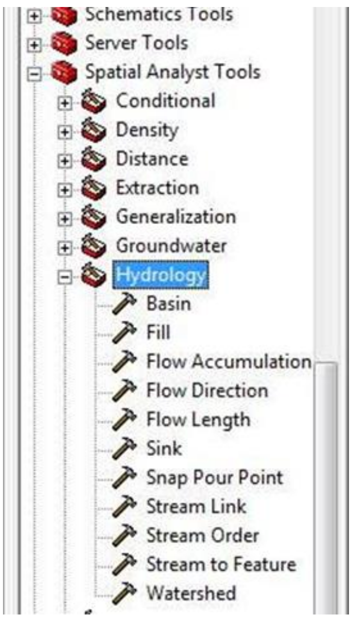

Fig. 4. Hydrology tools

There are following steps involved for using hydrology tools. The steps are: -

- Filling Sinks
- Flow Direction
- Flow Accumulation
- Stream to order
- Stream to feature
- Basin
- Snap Pour Point

- Watershed
- Raster to polygon

These methods can be explained by flow diagram which is made in ArcGIS Model Builder:

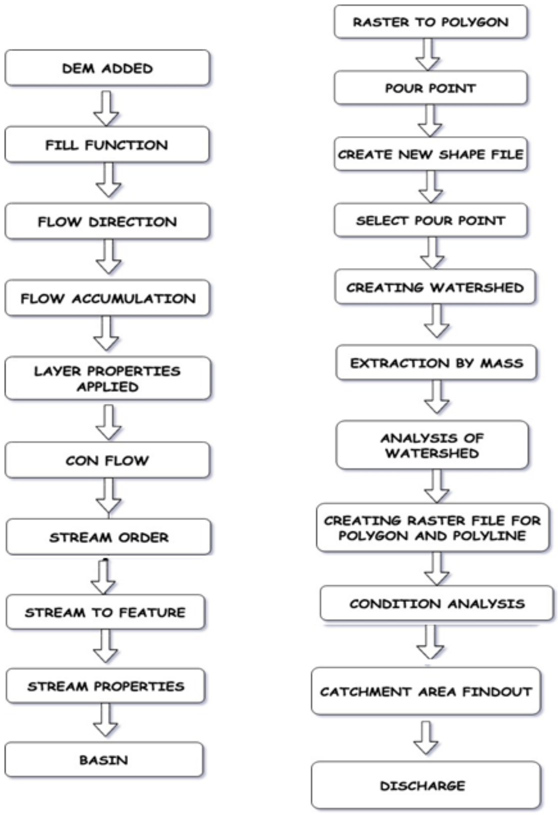

Fig. 5. Flow diagram of methods involved for watershed delineation

V. RESULTS AND DISCUSSION

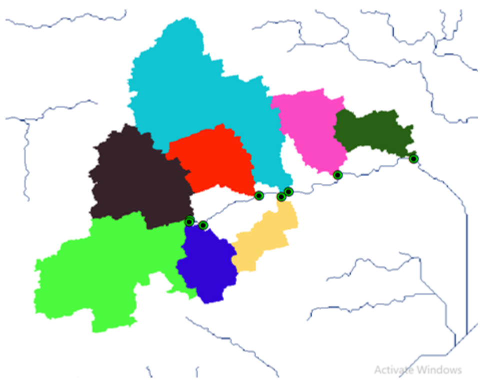

Fig. 6. Watershed of sub-basin for individual

For Discharge:

We have used the Dickens's Formula for determining and calculation of discharge:

Q=CA^3/4

Where, Q – Discharge

C – Constant (1.15)

A – Area (Results from the arc-gis software)

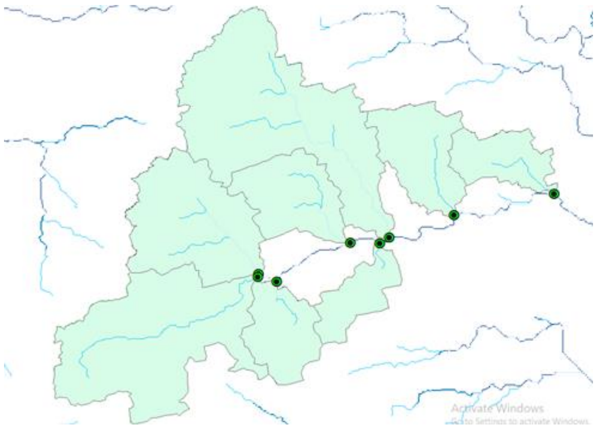

Fig. 7. Polygon area of Watershed of sub-basin for individual

Table

RasterT_Warsh_F1

FID	Shape *	ID	GRIDCODE	area
0	Polygon	1	7	5.67751
1	Polygon	2	6	8.64524
2	Polygon	3	4	2.84414
3	Polygon	4	3	8.72179
4	Polygon	5	5	6.1447
5	Polygon	6	0	1.56325
6	Polygon	7	5	4.9745
7	Polygon	8	2	6.84807
8	Polygon	9	1	2.42493

Fig. 8. Area of Watershed of sub-basin for individual (output by Arc-Gis 10.3)

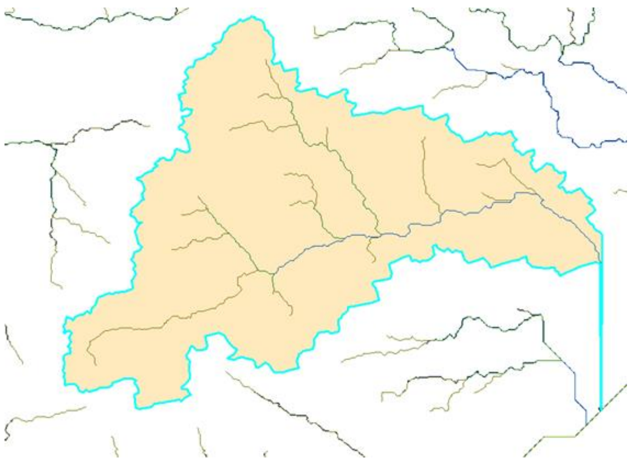

Fig. 9. Polygon area of Watershed of Stream line

For Sub basin

Q = CA^3/4

=1.15*(47.84413) ^3/4

=20.374 cumes

Table

RasterT_Watersh5

FID	SHAPE	ID	GRIDCODE	AREA
0	Polygon	9	1	69.65572

Fig. 10. Area of Watershed Polygon (output by Arc-Gis 10.3)

For main stream line.

Q = CA^3/4

=1.15*(69.65572) ^3/4

=26.9758 cumes

VI. SUMMARY

This report describes the procedure for automated watershed delineation and characterization in an Arc GIS environment. The methodology is explained in watersheds delineation using digital elevation model (DEM) data and serval tools from the Spatial Analyst toolbox in Arc GIS.

The methodology is then applied to a case study where watershed are delineated upstream of hydrometric stations in Madhya Pradesh, and the spatial distribution of each attribute is mapped over there basin. The outcome can be employed in regional flood frequency analysis studies where watershed are grouped into homogeneous hydrologic regions based on the similarly of their attributes. The hydrometric records measured within the same homogeneous regions are combined into regional probability distribution from which hydrologic design values are estimated for specified exceed probabilities.

VII. CONCLUSION

Geographical information system (GIS) tools are used in the drainage delineation and their updating the delineated watershed boundaries would assist the planning authorities in identifying the after effects of an urban development. The average surface runoff is calculated by combining the average rainfall and runoff coefficient.

The surface runoff calculation could be used in flood planning.

In 3D view analysis of the basin area, it is found that streams are originated from high relief or high slope region then comes to steep slope region and then flows in gentle slopes areas to meet area to meet Narmada River. Due to medium drainage density and slope the basin area indicates moderate ground water recharge zone.

The morphometric characteristics evaluated using GIS helped us to understand various terrain parameters which are important for basin area planning and management.

GIS has an important application for example in civil engineering projects like involve the management, analysis and integration of large amount of geographic information to ensure success. This can include a wide range of information such as detailed design drawing originating from ARC GIS solutions, detailed mapping, air photography, geological investigations, popular information, traffic flows and environmental models.

Watershed can be delineated in geographical information system(GIS) by keeping track of flow direction and number of upstream points for each grid point in a DEM. once the watershed is delineated it can be then be used to crop out data from other layers (e.g. land cover, area etc.), that are useful in hydrology. We will use spatial analyst extension in arc GIS.

GISs have provided tools to compute average values more efficiently and to include at some level of spatial effects by watershed into sub watersheds.

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