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APPLICATION OF GIS IN SURFACE WATER HYDROLOGY

BY

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APPLICATION OF GIS IN SURFACE WATER HYDROLOGY

1.0 GENERAL

A Geographic Information System (GIS) which is a system of hardware, software and procedures designed to support the capture, management, manipulation, analysis, modelling and display of spatially referenced data (Fig. 1). From the ancient times to the present day, spatial data have been collected and collated by surveyors, geographers, navigators, etc. and these were used to plan and make decisions about future activities of the societies. During the 1960's and 1970' new trends arose in the ways and means of handling and using spatial data for assessment, planning and monitoring.

The early concepts of map handling had a serious difficulty as it could not handle the tabular or attribute data in conjunction with spatial features. This led to the development of additional methods and techniques where the spatial and attribute data both could be handled and integrated so that the outputs are more meaningful for planners and decision-makers. All these efforts have been oriented towards the same sort of operations-developing powerful tools for collecting, storing, retrieving, transforming and integrating and displaying spatial and non-spatial data-either in isolation or in conjunction. These set of tools constitute the Geographical Information System (GIS). Using a GIS:

a) Users can interrogate geographical features displayed on a computer map and retrieve associated attribute information for display or further analysis.
b) Maps can be constructed by querying or analysing attribute data.
c) New sets of information can be generated by performing spatial operations (such as polygon overlay) on the integrated database.
d) Different items of attribute data can be associated with one another through a shared locational code.

Before any spatial analysis or modelling operations can be carried out in a GIS, it is necessary to input the requisite data. Data input is the procedure of encoding data into computer readable form and writing the data to the GIS database. Data collection and input require considerable time in using GIS and these are partially solved by the advances in remote sensing technology.

The data to be entered in a GIS are of two types-spatial data and associated non-spatial attribute data. The spatial data represent the geographic location of features. Points, lines and areas are used to represent geographic features like a street, a lake or a forest land. These data will normally be obtained from one or more of the following sources:

- Existing maps,
- Aerial Photographs,
- Satellite imageries,
- Existing digital data ,and
- Other GIS data bases,

Computerised database systems consists of following major components :

* data, which are stored in one or more databases forming the database systems.
* hardware, the equipment that makes it physically possible to input, store, retrieve and visualize data.
* software, which provides users with a set of statements to access and analyse the stored data.
* users, a person or group of persons who use the stored data.

Database provides facilities to perform several operations commonly required in manipulation of attributes data. These operations include:-

- adding new database to the database.
- inserting new data in to existing datasets.
- retrieving data from the existing datasets.
- updating,editing and/or transforming from existing datasets.
- deleting data from existing datasets.
- removing datasets from the database.

Spatial data has three major components: its geographic position, attributes or properties, and time or dynamics.

Position: Position refers to the fact that each feature has a location that must be specified in a unique way. The location can be absolute or relative. Absolute such as coordinate position using a coordinate system like cartesian (X,Y) or global geographic (latitude/longitude), eastings and northings, row and column position describing a position on a grid etc. Relative location with reference to some other object e.g. topologic position which is described through relationship to other objects-"adjacent to" or "intersects with".

Attributes: Attributes are often termed as non spatial data since they do not in themselves represent locational information. An attribute is a characteristics of an entity.

Time: Time is important and critical since geographic information is referenced to a point in point in time or a period of time. Knowing the time where geographic data were collected is of utmost importance to using these data appropriately, e.g. an area may be covered by forest one year and have been clear out the next.

Spatial Data and its Creation

There are four elementary types of geometric entities to encode spatial data: Points, lines, polygons and continuous surface (area). These are shown in Fig. 2.

Point data: Points are the simplest type of spatial data. Points can be of two kinds, observations relating to discretely distributed phenomena such as oil and water wells and observations relating to continuous distributions such as weather station reporting precipitation measurements of soil temperature.

Line data: Line entities are all linear features made of many points or straight line segments made up of two or more coordinates, Line entities can be static (structural type) or dynamic (flow), An arc, chain, or a string is a set of x-y coordinate pairs describing a continuous complex line.

Polygons or Area Data: Polygons constitute the most common data type used in GIS. They are bounded regions made of many segments. The boundaries may be defined by natural phenomena such a land forms or by man made such as forest stand or land use units.

Continuous surfaces: Examples of continuous surfaces are elevation (as part of topographic data), rainfall, temperature, etc. Most of the GIS handles 3-D data employing topographic data, usually as Digital Elevation Model (DEM).

Spatial Data Structure

In a computer there are two types of spatial data representation which are commonly used: the raster model and the vector model (Fig. 3). The vector model consists of representation of object by mean of points, lines and polygons as vector into 2-D or in 3-D. The fundamental primitive in the vector model in the point objects are created by connecting point with straight lines, areas are define by set of lines. The position of each object define by its placement in a map space, that is organise by coordinate reference systems. The spatial entities in the vector model correspond more or less to the spatial entities that represent in the real world.

The raster model consists of a rectangular array of picture elements or pixels which are in one to one correspondence with small rectangular areas on original picture material that they represent. The area that each call represent defines the spatial resolution available.

In the raster structure a value for the parameter of interest landuse class, soil type and so on is developed for every call in an array over space. Operations are multiple raster files in involve the retrieval and processing of the data from corresponding all positions in the different data files or layers.

Comparison between two data models are given below:

RASTER	VECTOR
ADVANTAGES	
Simple structure Easy overlaying Efficient for highly spatial variability	More 'compact' structure Efficient topology encoding Better suited for graphics (e.g. hand-drawn maps)
DISADVANTAGES	
Less compact (if not compressed) Topology more difficult Errors in estimating parameter	More complex structure Overlaying more difficult Inefficient for high spatial and shape variability Not effective for enhancement of digital images

Analysis Functions

The power of GIS lies in its ability to analyse spatial and attribute data together. The large range of analysis procedures can be divided into four categories:

i) Retrieval, reclassification and measurement,
ii) Overlay,
iii) Distance and connectivity,
iv) Neighbourhood

Retrieval, Reclassification and Measurement Operation

In these functions retrieval of both spatial and attribute data are made and only attribute data are modified. New spatial elements are not created.

Retrieval operations

These involve the selective search and manipulation and output of data. Retrieval operation includes the retrieval of data using:

- Geometric Classifications
- Symbolic Specifications
- A name of code of an attribute
- Conditional and logical statement

Retrieval operations on the spatial and attribute data involve the selective search and manipulation, and output of data with out the need to modify the geographic location of features or to create new special entities. Retrieval operations include:

- ¤ Retrieval of data using geometric classification. Specifying the spatial domain of a point, line or area, retrieve all spatial entities and nonspatial attributes contained in the entire or in position of that spatial domain.
- ¤ Retrieval of data using symbolic specifications.
- ¤ Retrieve data using a name of code of an attribute. Retrieve using a name or code of an attribute. Example, retrieve effective depth and dominant texture of a given soil.
- ¤ Retrieval of data using conditional and logical statements. Retrieve data that satisfy alphanumeric conditions using logical expressions. Example retrieve all soil series with a pH range of 6.0 to 7.5 and silty clay texture.

Reclassification Procedures

This procedure involves the operations that reassign thematic values to the categories of an existing map as a function of the initial value, the position, size or shape of the spatial configuration associated with each category, for instance a soil map reclassified into a permeability map. In a raster based GIS, numerical values are often used to indicate classes. A cell might be assigned value to indicate a class. For example a cell might be assigned the value 1 to indicate an agriculture land, 2 for forest land, and so on. Classification is done using single data layer as well as with multiple data layers as part of an overlay operation.

Measurement Functions

Every GIS provides some measurement functions. The measurement of spatial data involves the calculation of distances, lengths of lines, area and perimeter of polygons. The measurements involving points include distances from a point to a other point, lines or a polygon enumeration of total number as well as the enumeration of points falling within polygon.

Overlay Operations

Overlaying of maps results in the creation of a map where the values assigned to every location on that map are computed as a function of independent values associated with that location on two or more existing maps. Overlaying operation creates a new data set containing new polygons formed from the intersection of the boundary of the two or more sets of separate polygon layers. Arithmetical and logical overlay operations are common in all GIS software packages.

Arithmetical overlay includes operations such as addition, substraction, division and multiplication of each value in a data layer by the value in the corresponding location in the second data layer. Logical overlay involves the selection of an area where a set of conditions are satisfied.

Neighbourhood operations

Neighbourhood operations involve the creation of new data based on the consideration of 'roving window' of neighbourhood points about selected target locations. They evaluate characteristics of an area surrounding a specified target location. In all neighbourhood operations it is necessary to indicate one or more target locations, the neighbourhood considered around each target and the type of function to be executed on the attributes within the neighbourhood. The typical neighbourhood operations in most GIS are search function, topographic function and interpolation.

Interpolation

Interpolation is the procedure of predicting unknown values using the known values at neighbouring locations. The neighbouring points may be regularly or irregularly spaced. Interpolation programmes employ a range of methods to predict unknown values including polynomial regression, Fourier series, moving averages, and krigging, etc.

In so far as it is considered to involve some degree of automation, GIS is a new technology. Yet, as tabel given below shows, many GIS operations have certain advantages and accuracy is there as compare to Traditional systems.

GIS Operations	Traditional Tasks
Data input: map digitizing, scanning data entry from key boeard	 map drafting writing/typing tables, etc.
Map editing,e.g. with digitizer	erase/redraw map features
Map retrieval from database	search in map archive
Map aggregate	recompilation, usually involving scale change and generalization
Area computation from coordinates	dot grid or planimeter measurment
Distance computation	map measruement with ruler or curvimeter
Special search from database	visual examination of maps and assosiated data
Route selection using digital elevation model, etc.	measurment of terrain slopes on contours of topographic map
Map overlay	physical overlay of maps and tracing of relevant combinations
Data display Map display on monitor or production of hardcopy Output of tables Production of charts, graphs	cartographic design and construction map reproduction data compilation, typing data compilation, hand drawing

GIS has many applications in surface water hydrology. They include flood plain mapping and management, soil erosion and sediment yield estimation, land capability classification, landuse studies, geomorphological studies and water quality studies etc. GIS provide a digital representation of watershed characteristics used in hydrologic modelling. Also GIS provide for studying the hydrologic impact of physical changes within a catchment. Another important capability of a GIS to hydrologic applications is the description of the topography of the watershed. The advent of Digital Elevation Model (DEM) within GIS, can help in the computation of slope, slope length and aspect etc. which are important parameters required for hydrologic modelling.

2.0 FLOOD PLAIN MAPPING AND MANAGEMENT

Floods are regular phenomenon in India during monsoon season. Flood are the natural phenomena recurring with regular frequency every year in many rivers. Flood damage surveys are essential not only to assess the extent and severity of damage caused by the floods periodically in river valleys, but also for economic evaluation of flood control measures. The flood plain is an area adjoining a river, stream or other water course which gets flooded during periods of high water when stream flow exceeds the carrying capacity of normal channel. It is built of alluvium, the sediments carried, posited and reworked by the river. The construction of flood plains is a depositional process due to deposition of bed or suspended load. A typical flood plain will include various features. Meanders are perhaps the most prominent feature of the average flood plain. Meandering is the zigzag path followed by the flowing stream through loose alluvial material. Other features are: the river channel, alluvial fans which we formed due to reduction in discharge or in the slope, Oxbow Lakes which are low lying areas that get inundated during floods etc.

GIS can be used for determining areas affected by floods or forecasting areas likely to be flooded. For an effective management of flood water in low lying flood prone areas, GIS and remote sensing technology is proving to be a useful and efficient instrument. Satellite images taken during and after the period of flooding provide an effective means of mapping the extent of the flooded areas. The frequent coverege by the satellites provides the most up-to-date data relevant to the flooded area. Spatial data stored in the digital data base of the GIS, such as digital elevation model (DEM)(explained later), can be used to predict the effects of future events. The extent of inundation and flooding can be forecasted. The GIS data base may also contain agriculture, socioeconomic, population and infrastructral data. This can be used, in conjunction with the flooding data, for evaluation strategy, rehabilitation planning or damage assessment.

3.0 SOIL EROSION AND SEDIMENTATION

Soil erosion is of great concern to humanity because, it effects food production through land degradation, limits the supply of hydro electric power through siltation of reservoirs and create catastropic floods damaged huge area of low lying fields and human settlements. Impact of direct rainfall on the soil surface is crucial to the start of erosion process. Overland flow detaches soil particles but mostly transports previously detached sediment to surface stream and to accelerate erosion than are managed ecosystems. Despite the high rainfall and rugged topography generally associated with highland head water, run-off and erosion are minimum from natural ecosystems.

The problem of assessing the effect of erosion over the longer term is more difficult. To assess the effect of erosion on crop productivity some assumptions have to be made not only on the frequency of erosion of top layer but also about the relationship of crop yield to depth of soil, depth profile characteristics, level of management and technology provided.

A conventional approach to erosion hazard assessment is the use of empirical soil loss equations. These are usually presented in the form of a multivariate algorithm of erosion factors, derived from empirical data using statistical regression and correlation techniques. Their origin implies that they are classified under a specific time (e.g. annual, month, storm period) and spatial domain (e.g. plot, field, hillslope or catchment).

Prediction of soil loss using Universal Soil Loss Equation (USLE) is one of the method most popularly used. The USLE is an empirical model most widely used for estimation of soil loss from sheet and rill erosion. USLE is given by the following equation:

SOIL LOSS =	f(RAINFALL EROSIVITY, SOIL SUSCEPTIBILITY, TOPOGRAPHY, AND MANAGEMENT)
$A = R * K * L * S * C * P$	.... (3)

Where,

A = Annual soil loss from specific site (t/ha)
R = Rainfall erosivity factor
K = Soil susceptibility factor

L, S = Topographic factor
C = Cropping - management factor
P = Erosion - control practice factor

Application of a soil loss equation within a GIS format usually requires an overlay (i.e. crossing, multiplication or adding) of georeferenced data planes representing the erosion factors, i.e., rainfall eorisivty, soil erodibility, topography, vegetative cover effects including soil management practices.

Table 1 gives an overview of the data layers and procedures used in solving soil loss equation in GIS format. Various ways for including the effect of relief on erosion can however be incorporated in soil loss equations. Due to the usually strong geomorphic interdependence between slope steepness and slope length on most lithological facies, a combined LS factor evaluation is common in erosion studies. In GIS, the effect of two variables can be weighted conveniently by use of two dimensional table operations.

Table 1 : Data layers and procedures used in solving soil loss equations in GIS format

Erosion Factors	Data Bases, Data Layers	Description of GIS Procedures
Erosivity	Rainfall Map	Spatial interpolation of station EI values; stored as R factor map
Erodibility	Soil data	Assignment of numerical K values to soil units by reclassification of the soil unit polygon map with the K value column from the soil attribute table; stored as K factor map
Combined LS Slope Gradient	Geomorphic	If regional geomorphologic relief classes exists, combined LS gradient or terrain factor values can be lengthy using a 2-Dim table with row-wise, relief steepness classes and column wise the slope length classes, resulting directly in a LS-value distribution for the area; stored as an LS map file.
Slope Length	TMU	1. Using TMU: assign slope length values to terrain units as a functions of steepness using a 2-Dim table, resulting in a length map; compute numerical L factor values by applying a slope function to length map.
	DEM	2. Using DEM: If field boundaries are available in digital format, assessment of field slope lengths is possible using DEM connectivity and neighbour-hood operations.
Slope Gradient	TMU	1. Using TMU: assign numerical slope radient values to TMU map using a TMU attribute table; compute S-factor values by applying a slope function to this reclassified map; stored as a S factor map.
	DEM	2. Using DEM: Reclassification of the slope gradient surface in user defined slope class intervals; compute numerical S-factor values by applying a slope steepness function to map and store as an S factor file;
Land Cover	Land Cover. Farm dbs.	If necessary pre-processing or spectral classification of remote sensing data; assignment of C factor values to land cover RS data classes using cover attribute table; stored as C factor map.
Conservation Practice	Land Cover	For land use types with soil conservation practices, reclassify C factor map with P-factor values of land cover attribute table, using P=1 for non-conservation areas.

4.0 APPLICATION IN LAND CAPABILITY

Land capability classification is useful in understanding hazards affecting agricultural landuse and in managing land. Land is affected by many hazards which render it unsuitable or limit its suitability for agricultural activity. The suitability of land to carry out agricultural activity is depicted in a land capability classification.

Land capability classification is a systematic classification of different kinds of land according to those properties which determine the ability of the land to produce common cultivated crops and pasture plants virtually on permanent basis. This classification is made primarily for agriculture purposes and it enables the farmer to use the land according to its capability and to treat it according to its need. Land is arranged in various capability classes by considering a number of soil characteristics and associated land features and environmental factors (climate). The chief soil characteristics to be taken into account are texture, depth, permeability, salinity and alkalinity of soil. The important associated land features are slope of land, effect of past erosion or susceptibility to erosion, natural soil drainage, frequency of overflow etc. Land-capability classes are not enough for planning and execution of works. For practical purposes, it is necessary to know the kind of limitation and the hazard involved. The sub classes are designated by letters e,w,c, and s for hazards caused due to erosion, wetness, climate and soil respectively.

In preparation of a land capability map following maps are required as input:

1. Physiographic map
2. Soil maps
   - Texture
   - Class
   - Permeability
   - Electrical conductivity
3. Landuse/cover map
4. Slope map
5. Erosion map
6. Wetness

GIS is very effective tool in land capability classification. In the study the variables e.g. soil texture, type, slope, electrical conductivity, soil erosion and gully formation affecting the utilization of land for agriculture activity are useful. Overlaying of these large number of variables is facilitated by GIS overlay operations. Many variables useful in land capability can be mapped by visual interpretation technique of satellite data. These variables are landuse/cover, physiography and soil. In landuse /cover agriculture area and urban categories are clearly interpreted visually. Yellow (alluvial) soil of different texture are mapped by visual interpretation technique. The various maps thus prepared are input to GIS and analysed further, for land capability classification in a part of Narmada basin. Small scale maps gives synoptic detail of the area and thus helps in taking broad management decision. A suitable practice of land and water management has to be adopted in hazard areas using this map.

5.0 APPLICATION IN LANDUSE MAPPING

Land is the most significant of all the natural resources of our country, as the larger proportion of its inhabitants depends on the exploitation of this resources. Land use is a function of four variables - land, water, air and man. Land constitutesits body, water runs trough its veins such as blood, air gives its life and man acts as dynamic actor to refelect its types,pattern and distribution. Landuse pattern in a region is thus goverened, in a large measure, by physical controls and thereafter modified by socio-economic and techenical organisational variants.

Land use information is an important input to a host of planning decisions and for this reason has been gathered by various users. Land use/land cover inventories are needed for the optimal utilisation and management of land resources of the country. In recent years, the term 'Land cover' has come to be commonly used in association with the term 'Land use'. The two are not synonymous. Land use includes 'everything land is used for by residents of the country, from farms to play grounds, houses to hotels etc. Land cover refers more to 'the vegetational and artificial constructions covering the land surface'.

Remote sensing and GIS have revolutionized the task of identifying and mapping landuse and its changes over space and time. Remote sensing provides multispectral and multitemporal synoptic coverages for any area of interest while GIS provides the facility to integrate multidisciplinary data for dedicated interpretations in an easy and logical way. Using all GIS all types of data can be brought to a common scale and handled with ease for integrated interpretation.

6.0 APPLICATION IN GEOMORPHOLOGY

The linking of the geomorphological parameters with the hydrological characteristics of the basin provides a simple way to understand the hydrologic behaviour of the different basins particularly of the ungauged basins. Before taking up the studies related with hydrologic simulations using the geomorphologic characteristics, the important geomorphological properties have to be quantified from the available topographical map of the basin. The geomorphological properties which are important from the hydrological studies point of view include the linear, areal and relief aspect of the watersheds.

In many hydrological studies such as design flood estimation, water availability studies and runoff estimation, geomorpho-logical characteristics have been frequently used, particularly in the regional studies, in order to make the required estimates for ungauged catchments. Some of the hydrological studies, wherein the different aspects of the geomorphological characteristics are utilized include: Regional unit hydrograph studies using geomorphological and physical characteristics of catchment, regional flood frequency analysis using geomorpho-logical characteristics, development of geomorphological Instantaneous Unit Hydrograph (GIUH), application of geomor-phological parameters and physiographic characteristics in model studies.

The quantitative analysis of channel networks began with Horton's (1945) method of classifying streams by order. He developed a system for ordering stream networks and derived laws relating the number and length of streams of different order. Strahler (1957) slightly revised Horton's classification scheme in which ordering procedure is based on the following rules:

❶ Channels that originate at a source are defined to be first- order streams;
❷ When two streams of order u join, a stream of order (u+1) is created.
❸ When two streams of different orders join, the channel segment immediately downstream has the higher of the order of the two continuing streams.
❹ The order of the basin is the highest stream order, u.

The mapping of drainge pattern can be carried out using satellite data. Computation of the parameters required for morphometric analysis using manual methods like area measurement using dot grid method or using planimeter and length measurement using curvimeter are very tedious and time consuming. It is more difficult if the map is on higher scale like 1:50,000 and 1:25,000. The ordering, lengths, area and perimeter etc. can be easily estimated using Geographic Information System (GIS) technique. Use of GIS can not only make this task relatively easy but accurate as well.

Linear Aspects

Stream order :

Using GIS, ordering of streams can be carried out once the stream netrwork is digitized properly.

Stream Number:

The stream numbers in each order are stored in a table and then the total numbers for each order is computed. The ratio of the number of stream segments of a given order(N_u) to the number of stream segment of the high order N_{u+1} is called as the bifurcation ratio:

$$R_b = N_u / N_{u-1}$$

Stream number vs. stream order:

Horton's law of stream number states that the number of stream segments of each order is in inverse geometric sequence with order number i.e.

$$N_u = R_b^{u-k}$$

where, k is the order of trunk segment, when logarthim of number of streams is plotted against order, this shows a linear relationship.

Stream order vs. mean stream length:

The mean length of channel segment of a given order is greater than that of the next lower order, but less than that of next higher order. Horton (1945) postulated that the ratio of R_l which is the ratio of mean length of segment of order u, to the mean length of segment. If the law of stream lengths is valid, a plot of logarithm of stream length (ordinate) as a function of order (abscissa) should yield a set of points lying essentially along a straight line.

Areal Aspects

Stream area : The area of drainage basin is another important parameter just like length of the stream draining it. The area of a basin can be directly computed using GIS tech.

Stream order vs mean stream area:

Horton inferred that mean drainage basin areas of progressively higher order should increase in a geometric sequence, as do stream lengths. The law of stream areas may written as:

$$A_u = A_1/A^{u-1}$$

where, A_u is the mean area of basin of order u. As with steam length, the regression of logarithm of basin area is linear.

Relief Aspects

The relief aspects of a drainage basin can be carried out using contour data. In GIS, once the contour map is created, digital elevation map can be prepapred using interpolation tech.

Relief ratio : Relief ratio is the maximum basin relief (i.e. the elevation difference between highest point of the basin perimeter and mouth) divided by maximum measured length of the drainage basin.

Ruggedness number : The ruggedness number is givern by the product of relief of the basin and drainge density.

7.0 APPLICATION IN HYDROLOGIC MODELLING

The hydrological studies require handling of various spatial data for computation of parameters associated with the hydrological models and for optimal water resource management. This can be laborious, repetitive, costly and even error prone. These problems can be effectively tackled by incorporating the spatial data in a Geographic Information System (GIS). A GIS provides a digital representation of watershed characterisation which are used in hydrologic modelling. To integration of GIS and hydrologic models follows one of the two approaches can be followed:(i) develop hydrologic models that operate within a GIS frame work, (ii) to develop GIS techniques that particularly parameterize existing hydrologic models. For modelling purposes a series of further distributed digital maps such as soil type, land use and cover, soil moisture content, etc. should be provided. Another important capability of a GIS relevant to hydrologic applications is the description of the topography of the watershed.

SCS Method:

For the estimation of the amount of direct run-off that will be produced from a given precipitation from a basin, various hydrologic models are available. These models range from complex to simple, having different structures and input data requirements. Amongst these models, Soil Conservation Service (SCS) model is most widely used for the estimation of direct run-off.

The SCS method of estimating direct run-off from storm rainfall is based on methods developed by SCS hydrologist in the last three decades. The Soil Conservation Service (1986) method is perhaps the most commonly used method all over the world for estimation of run-off depth from storm rainfall. The SCS approach involves the use of simple empirical formulae and readily available tables and curves, developed by the Soil Conservation Service U.S.D.A. Scientists. The SCS model is attractive because the major input parameters are defined in terms of land use and soil type. As satellite data can be used for estimating the land cover distributions, hence these provide useful input support for SCS model.

In developing a relationship for Q (Run-off depth) the SCS derived the expression:

$$Q = \frac{(P-I_a)^2}{(P-I_a)+S} \quad ...(1)$$

where,

Q = The run-off depth in mm
P = Storm rainfall in mm
I_a = Initial Abstraction
S = Potential maximum retention.

To simplify the Eq. (1) empirical relationship between the variables S and I was developed from data collected from various watersheds in U.S.A. This empirical evidence resulted in the following equations:

$I_a = 0.3S$ for AMC I
$I_a = 0.2S$ for AMC II
$I_a = 0.1S$ for AMC III

The Central Soil and Water Conservation Research & Training Institute (ICAR), Dehradun has suggested some of the empirical relations for Indian conditions which are as follows and these are used in the present study.

Black Soils region AMC-II and III	$I_a = 0.1S$
Black Soils region AMC-I,	$I_a = 0.3S$
All other regions	$I_a = 0.3S$

To show the rainfall run-off relationship graphically, S values are transformed into curve number (CN) by the following equation:

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

Curve Number (CN) is an index that represents the combination of hydrologic Soil group and land use and land treatment classes. Empirical analysis suggests that the CN was a function of three factors, the soil group, the cover complex and antecedent moisture conditions. CN values for different land uses, treatment and hydrologic conditions can be obtained using standard tables. All the factors of SCS run-off empirical models are (or have parameters which are) geographic in character, i.e. they can be referred to a particular location. In most of the cases, rainfall distribution, soil characteristics, land use pattern from which the factors like rainfall and curve number can be derived. are often available in the form of maps or can be mapped through collection of data from possible sources or field investigation or/and remote sensing studies. Due to the geographic nature of these factors SCS-run-off models can easily be modelled into GIS. In other words, assessment and prediction of run-off potential from any basin will be much simpler using GIS provided data for each factor is available. Basic structure of the model is given in Fig. 4.

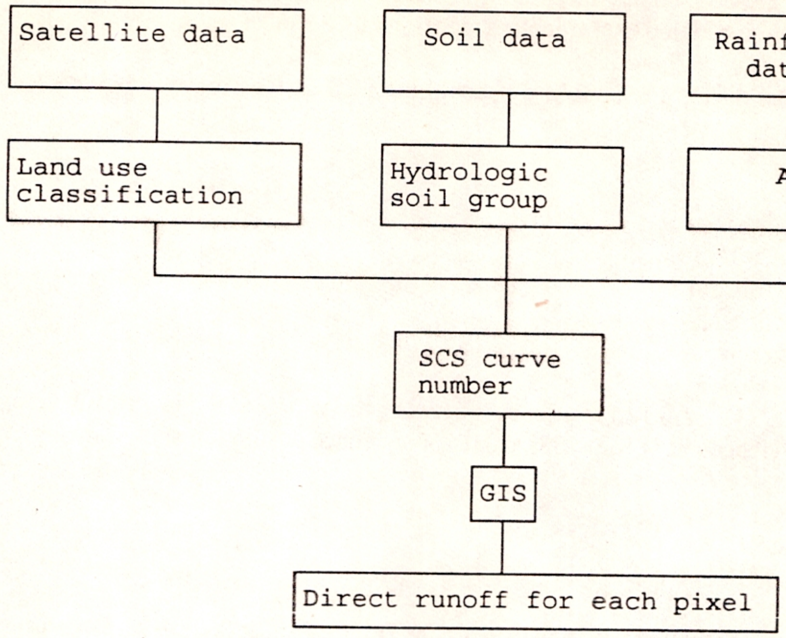

Fig. 4 : Flow chart showing the methodology

8.0 DIGITAL ELEVATION MODEL IN HYDROLOGY

One of the capabilities of a GIS is the description of the topography of a region. Techniques used in the computer description of topography are called as digital elevation model (DEM). DEMs are arrays of numbers that represent the spatial distribution of terrain altitudes. Main data sources for DEMs are ground surveys, existing topographic maps, photogrammetric stereomodels and surveys done by radar or laser altimeters carried in aircrafts and spacecrafts. When the quantitative characteristics of the terrain is considered instead of topography, then it can be termed as Digital Terrain Model (DTM). These characteristics include information about soils,geology,landuse/cover and drainage etc.

The structure of DEMs:

Various data structures are in use for DEMs, each with their own merits and shortcomings. There is no structure which satisfies all requirements; much will depend on the purpose and also on the computer facilities available. The basic structure are the line model, the trigulated irregular network and the grid network.

Grid Structure :

The grid based methods may involve the use of a regularly spaced triangular, square or regular angular grid. The element area is the cell bounded by three or four adjacent grid points, depending upon the method. The raster based GISs use the square grid networks. The advantage of the regular grid method is the simplicity of the data storage usually as sequential z coordinate along the x (or y) direction, with a specified starting point and grid spacing.

Triangular Irregular Network (TIN):

An alternate approach to producing DEM's relies upon determination of significant peaks and valley points into a collection of irregularly spaced points connected by lines. The TIN model splits up the surface into triangular element planes. The terrain surface is sampled by points (nodes) that are located at positions which capture the terrain characteristics.

Line Model:

The third major form of representing topography is contour line mapping. The contours can be represented digitally as a set of point to point paths (vectors) of a common elevation. The line model describes the elevation of terrain by contours (stored as Digital Line Graphs), the x,y coordinate pairs along each contour of specified elevation. Typical GIS operations based on the line model are carried out by overlaying the contours on thematic maps or remotely sensed classifications.

The most common method of acquiring elevation data in digital raster format of often the least square one, namely digitizing contours from a topographic map and applying an interpolation method to transform the contour data into a DEM. Although the DEMs quality essentially depends on the topographic map used, the interpolation algorithm used in DEM resampling technique has also a significant influence. The interpolation algorithm used in a DEM resampling technique may be designed according to different requirements. Many technique may be aim at minimising the RMS-error (standardization of elevation descripancies): this first order criterion is the most commonly applied in DEM quality assessment. On the contrary some tech. tends to preserve the terrain texture.

DTM can be put in use invariety of applications. Depending upon the requirements of the specific project, the necessary informations can be derived from DTM. The most common products derived from DTM are with respect to elevation, slope and aspect, convexity/concavityof terrain etc. Considerable research has been carried in the field of drainage network extraction and watershed boundary delineation by hydrologists and geologists.

9.0 REMARKS

GIS is therefore a rapidly evolving technology that consist of computer based programs containing specialized algorithms and associated data-base management structures, frequently in an integrated package. These systems are expressly designed to store information about the location, topology, and attributes of the spatially refernced objects. GIS can also provide analysis of the spatial properties of these geographic objetcs. GIS can support many database queries tied to spatially refernced and their associated attributes. Remote sensing provides one the readily available sources of data for updating the data base in a GIS. The integrated use of remote sensing and GIS technology can not only improve the quality of geographic information but also enable information previously unavailable to be economically produced.

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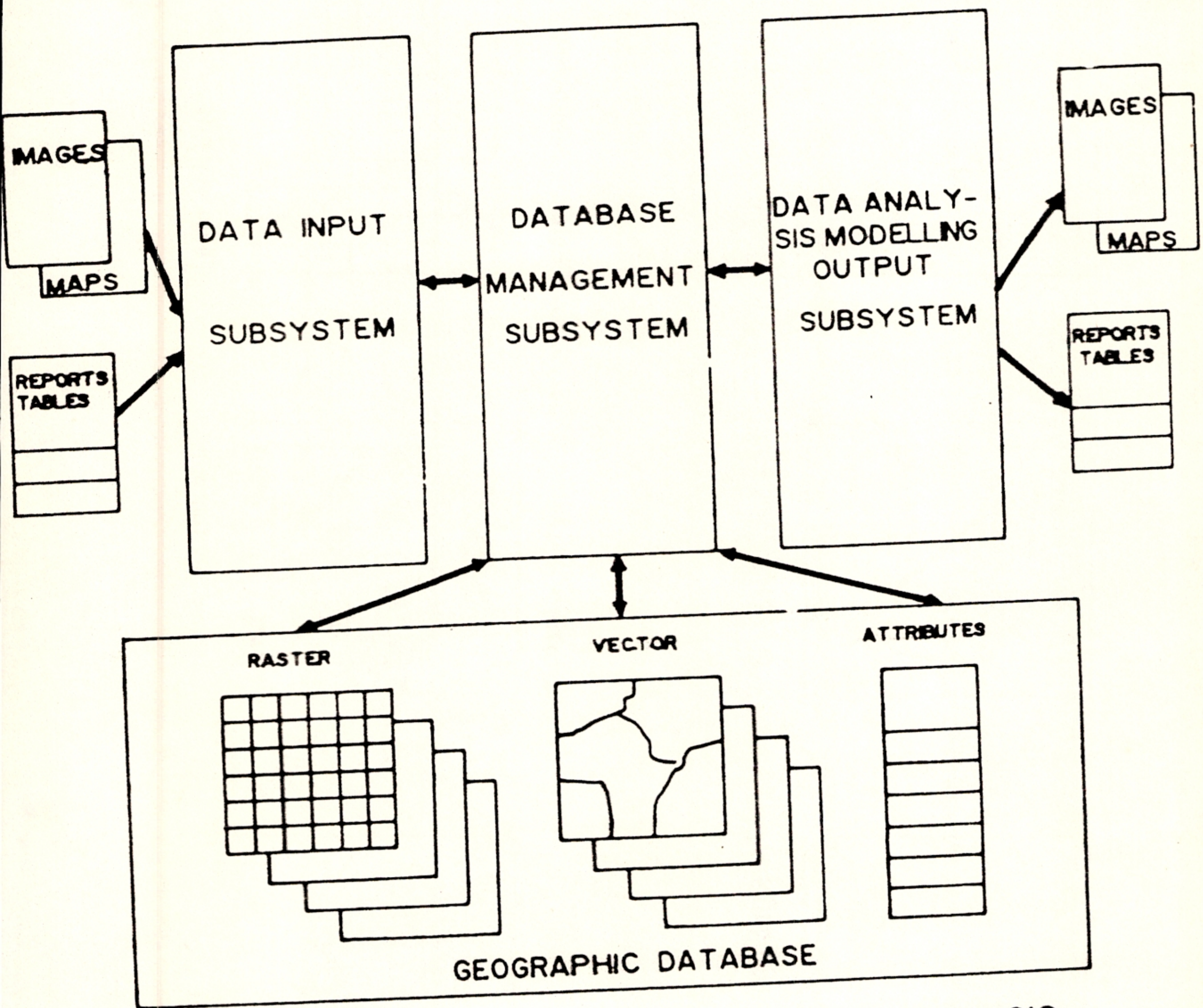
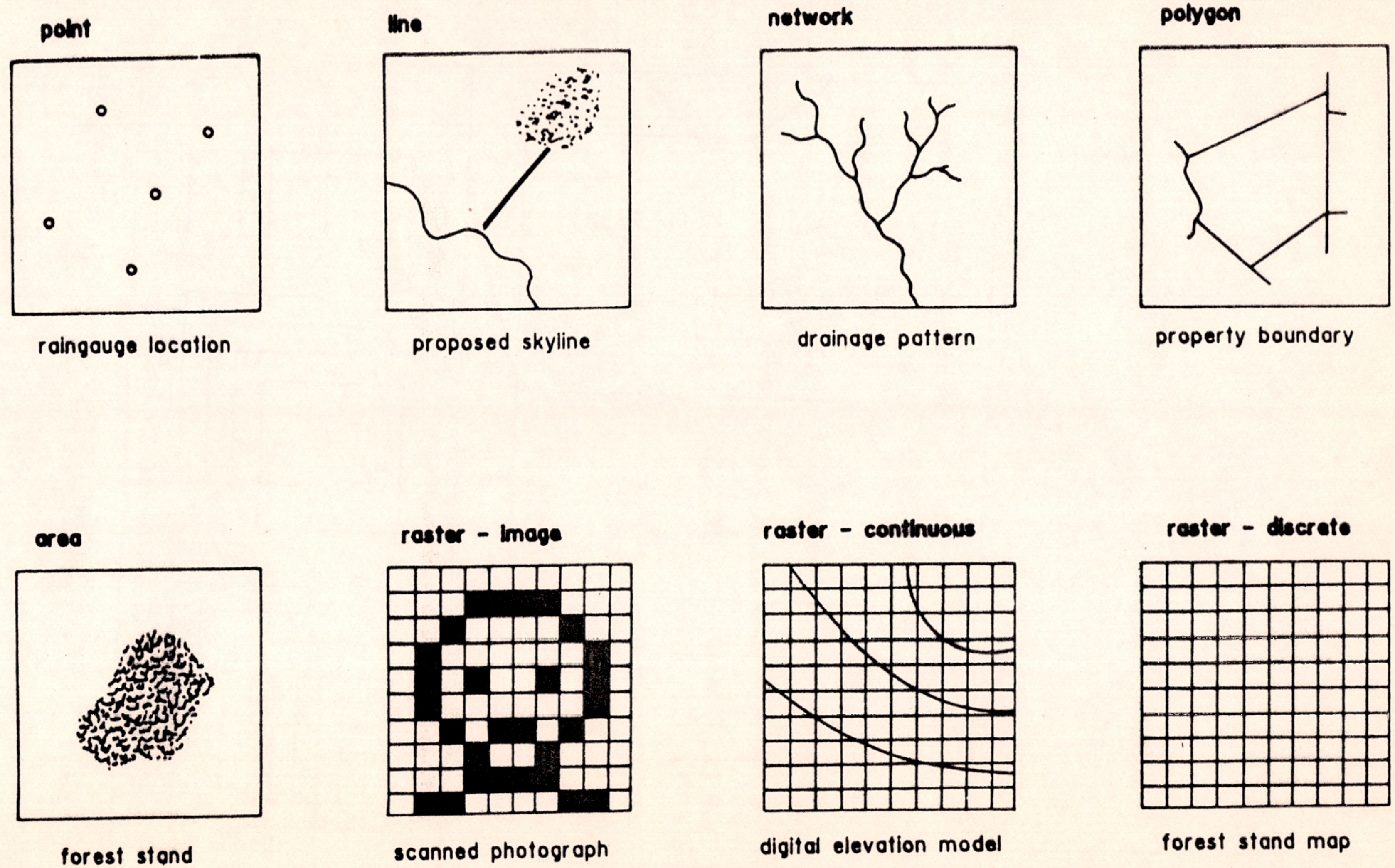


FIG. 1 SCHEMATIC REPRESENTATION OF A GIS

FIG. 2 : TYPES OF SPATIAL DATA



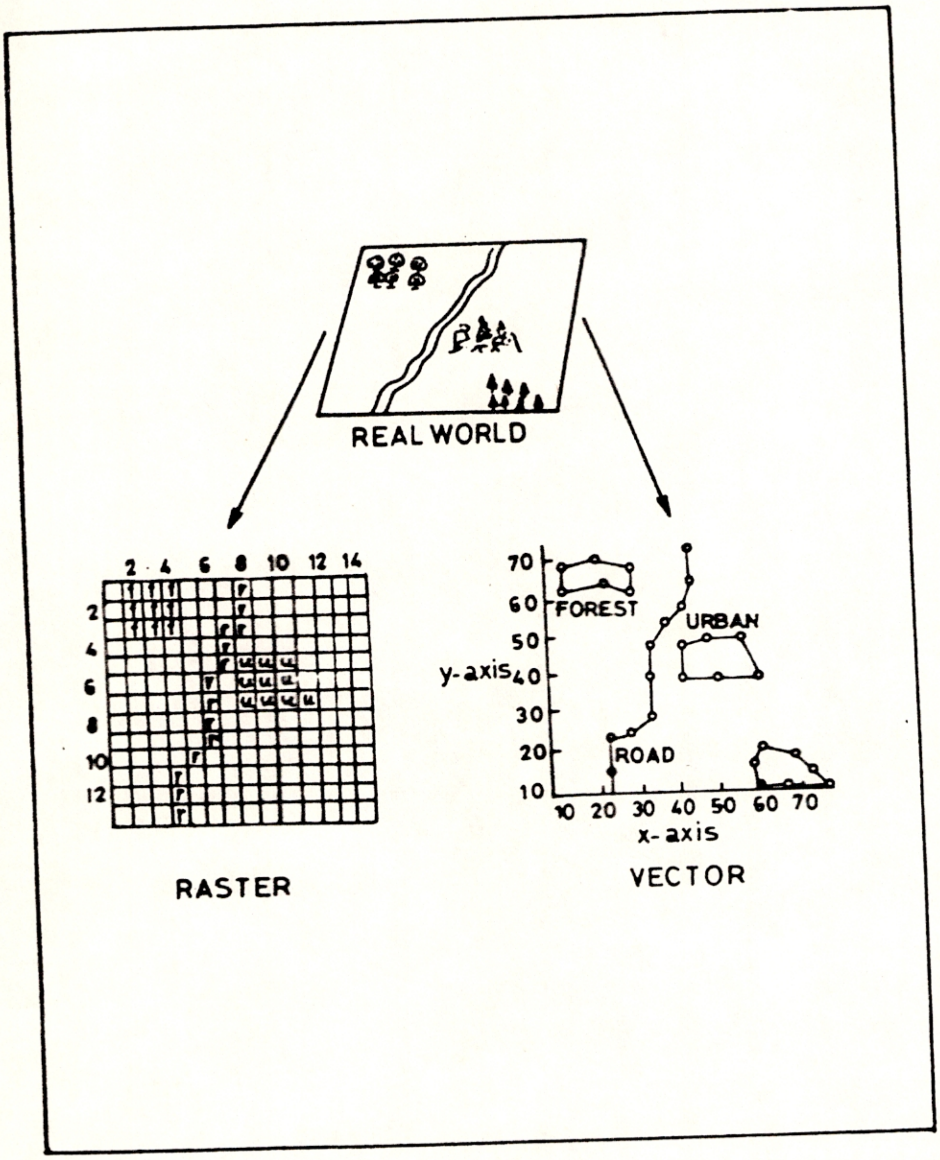


Fig 3. Representation of data in vector and raster models