Hydrograph simulation for a rural watershed using SCS curve number and Geographic Information System

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Introduction

- Floods are the one of the most cataclysmic disaster which impacts on human lives, infrastructure and environment.
- The threats to floods are influenced by the rate and speed of runoff within the catchment.
- Implementation of proper flood management system can help to mitigate flood induced hazards.
- Integration of Remote Sensing (RS), Geographic Information System (GIS) and hydrological models help us to characterize the spatial extent of flooding and associated risks over the watershed

Problems due to floods

- Flooding in coastal cities due to urbanization.
- Erosion and sedimentation creating degraded areas.
- Contamination of surface and ground water sources with effluent.
- Sewage, storm water and solid waste discharges in to river.

  - Many of these problems may be due to improper approach to the control of storm water by the community and professionals, who give priority to developmental projects with no holistic view of the watershed or social and institutional aspects within the basin

RS and GIS

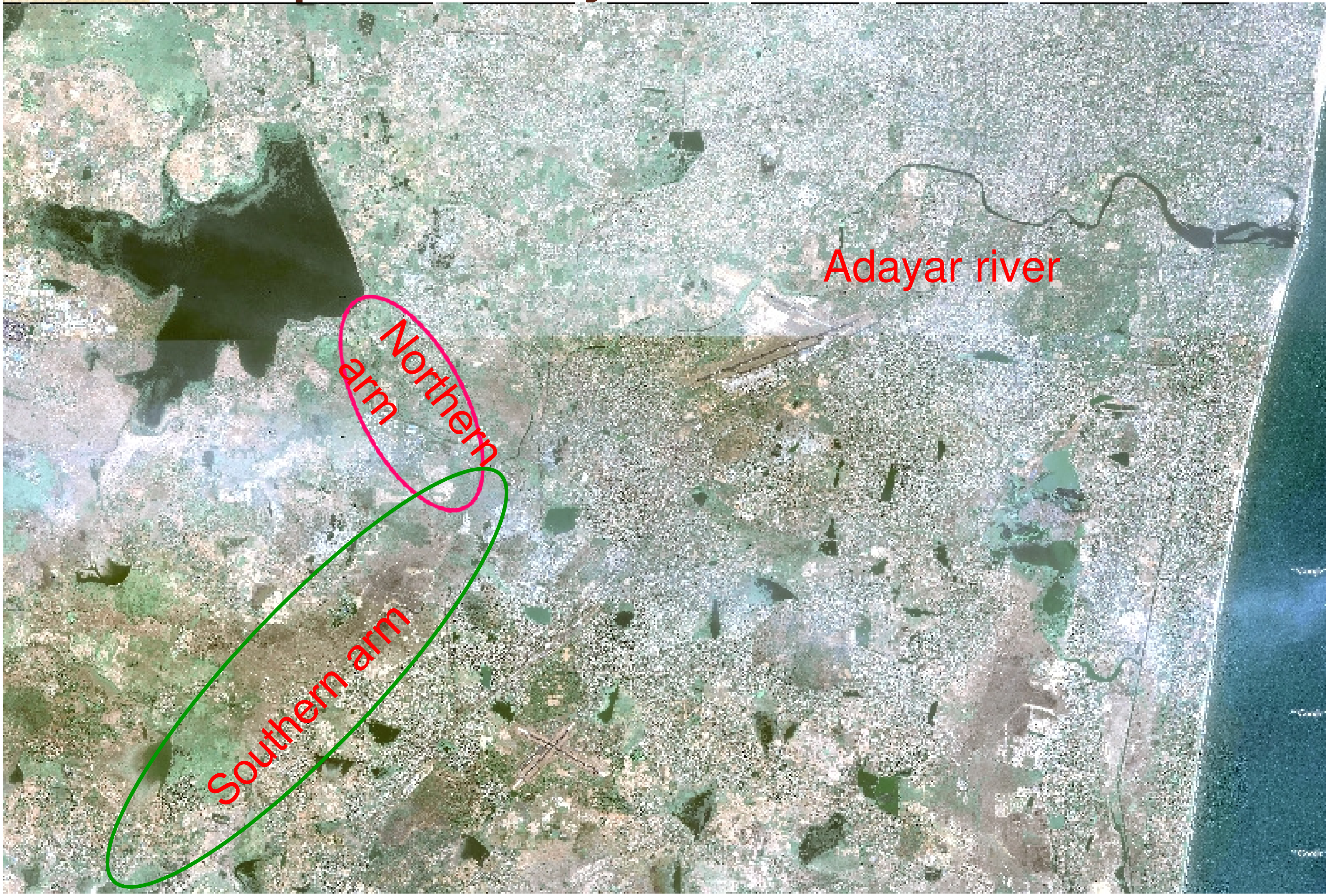
- RS is a scientific tool adapted for mapping and monitoring the natural resources.
- A GIS can bring spatial dimensions into the traditional water resource data base, and it has the ability to present an integrated view of the world.
- In order to solve water related issues, both a spatial representation of the system and an insight into water resource problems are necessary.

Objectives

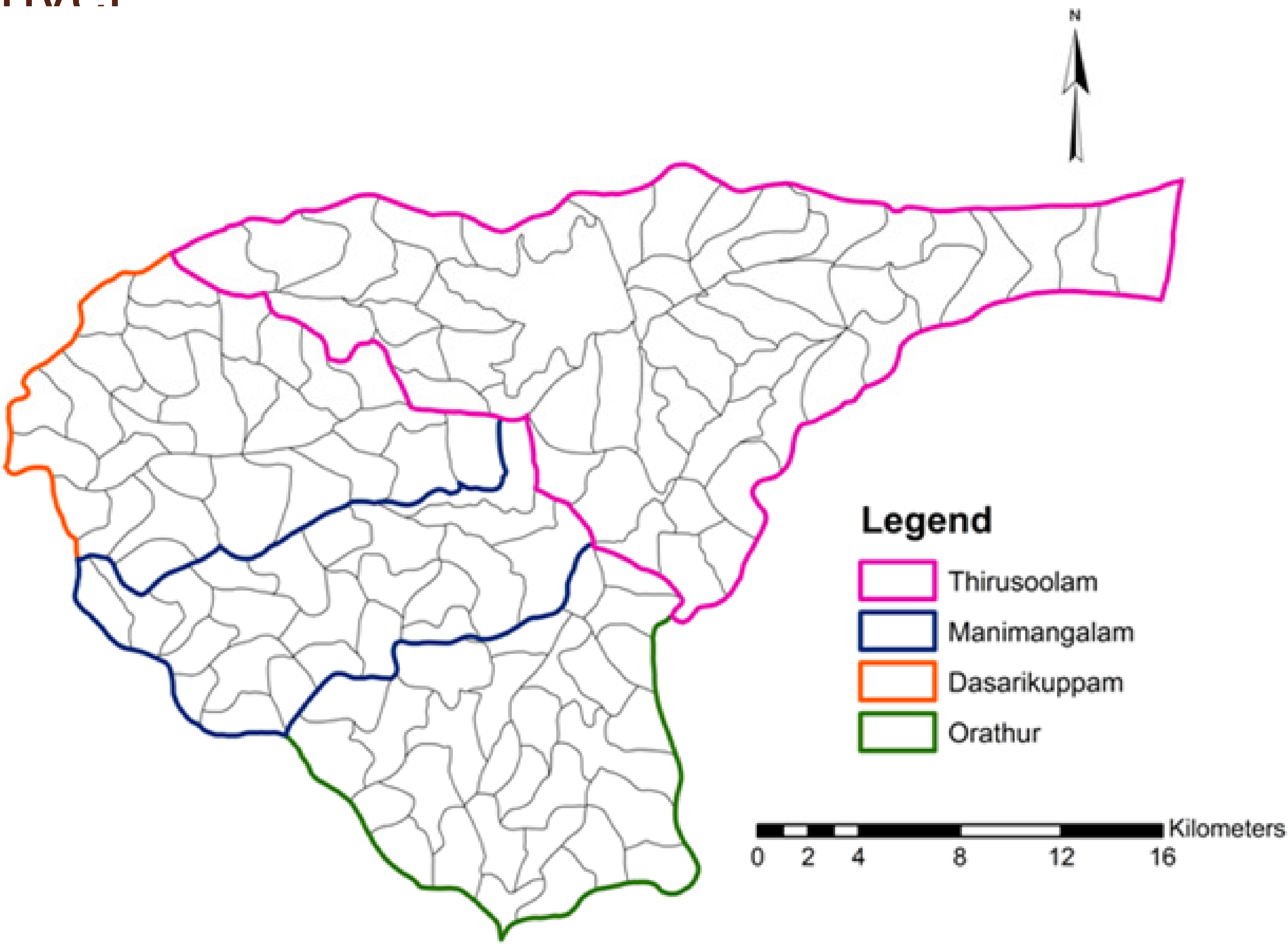
The objectives of the study are

- to illustrate the relationship between land use change and runoff response;
- to emphasize the linkage of RS and GIS with hydrological models (HEC-HMS) in flood management.
- to generate flood inundation hydrograph of the Dasarikuppam watershed using SRTM DEM, SCS curve number and hydrological model HEC- HMS.

Map of Adayar river

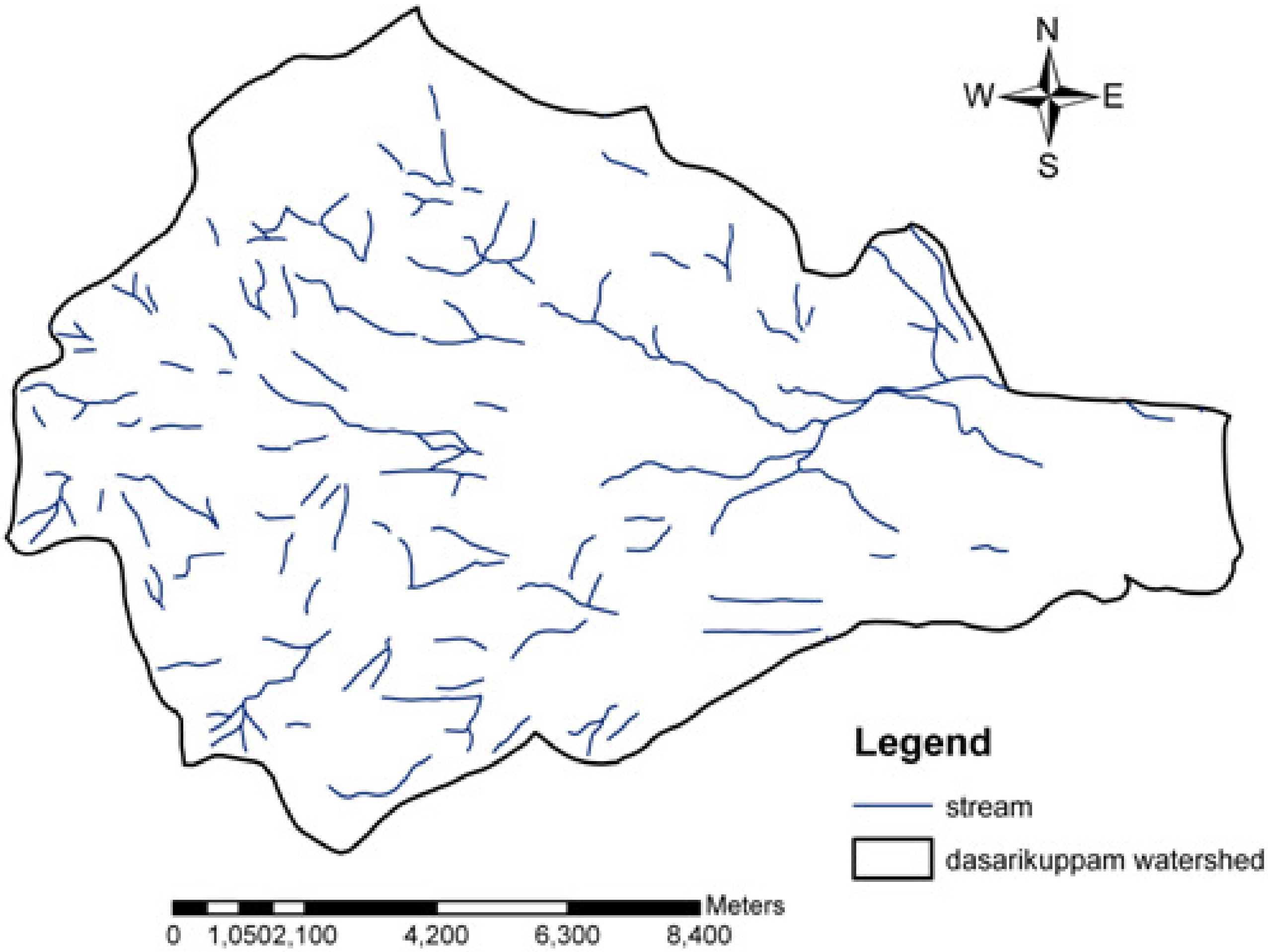


Sub and micro watersheds of Adayar river



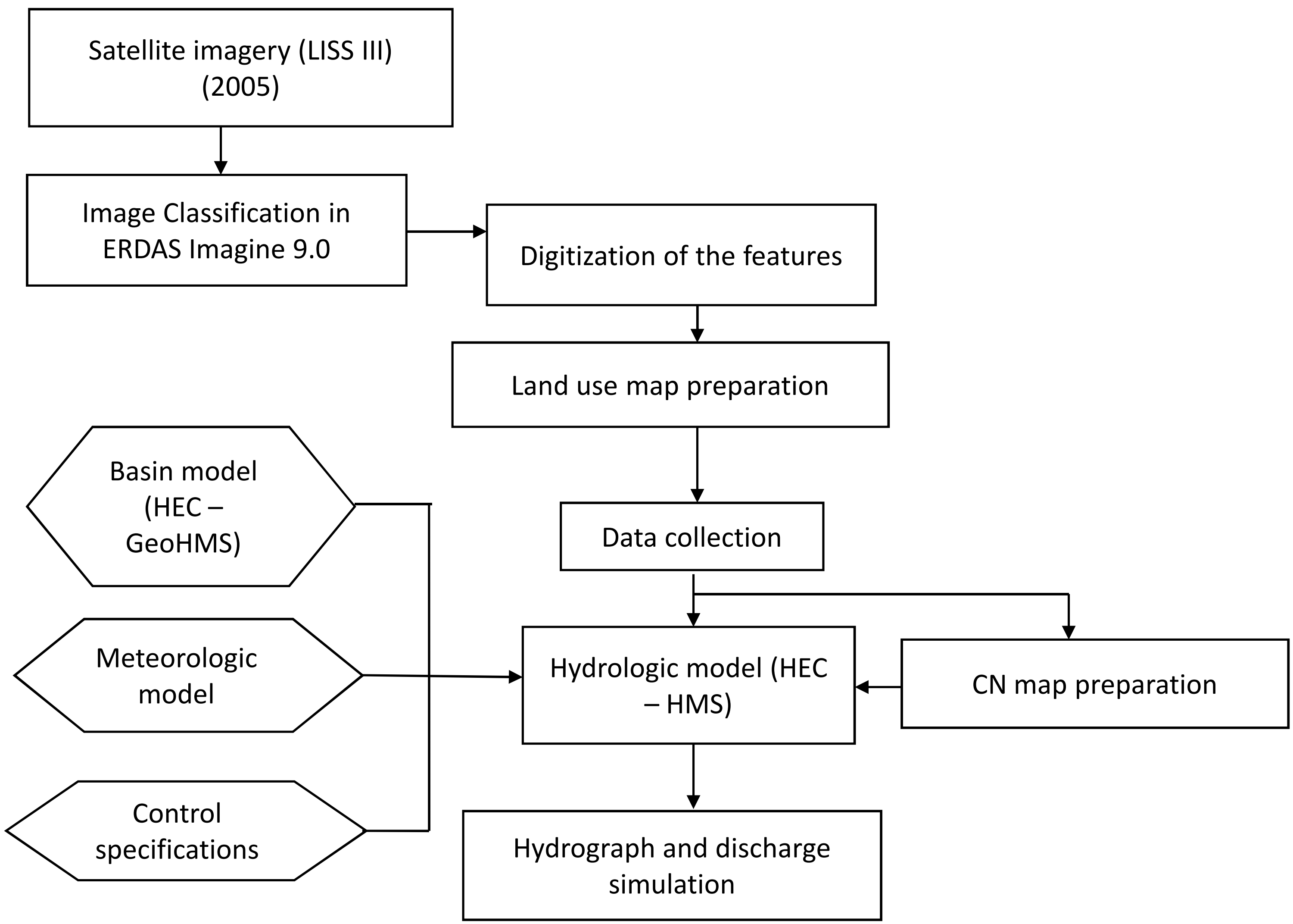
Dasarikuppam watershed

- The Dasarikuppam watershed is the sub watershed of the Adayar watershed.
- This watershed is a rural watershed.
- The study area is a flat and slightly undulating terrain with a general slope of 3°-5° toward the E-ENE direction (Ramesh, 1994).
- The total area is about 146.99 sq km.



Index map of the study area

Methodology flow chart

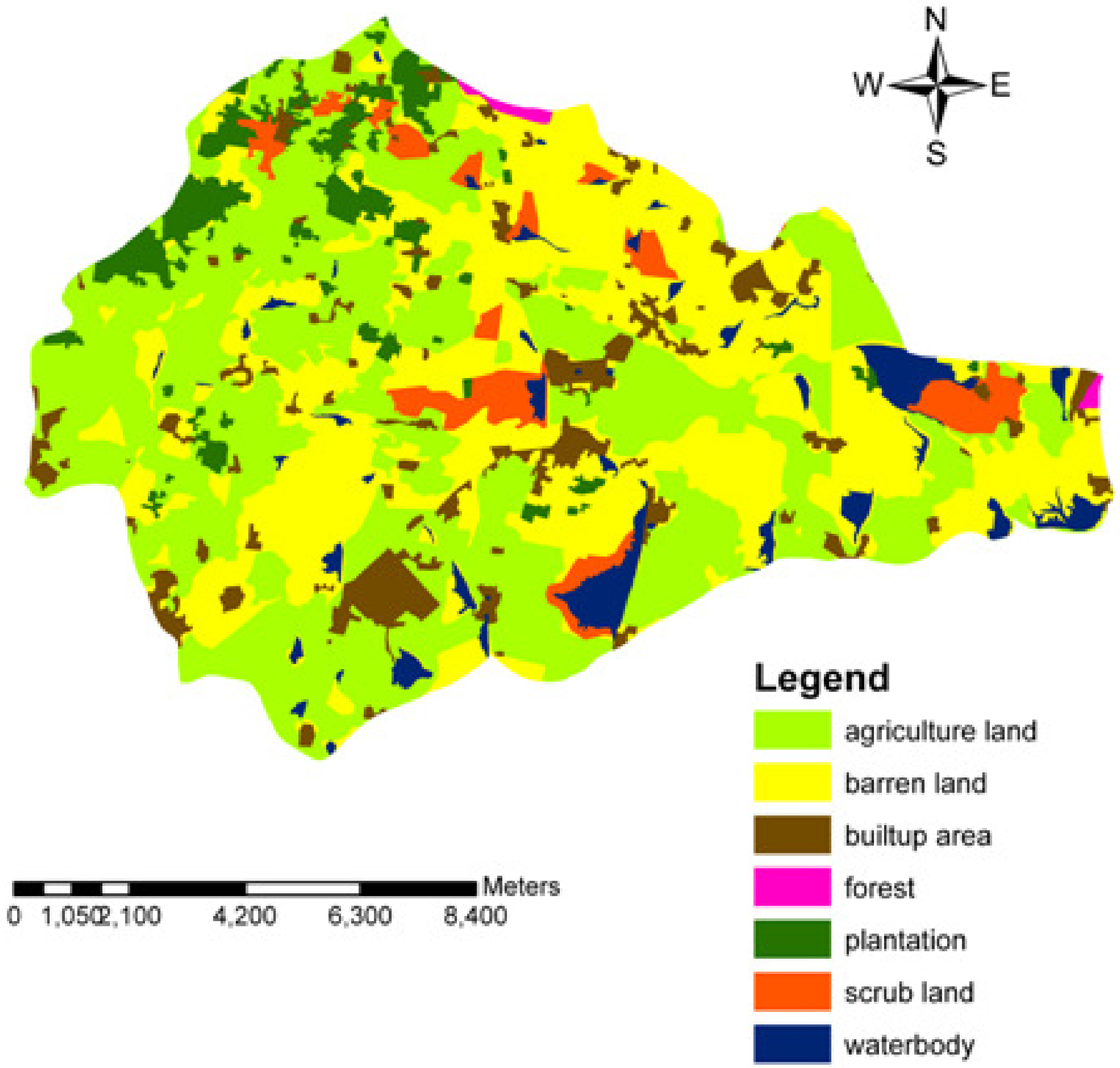


Land use classification

- LISS III imagery taken in December 8, 2005 was processed and classified using Maximum Likelihood method in ERDAS Imagine 9.0 and digitized in ArcMap platform to produce land use map of 2005.

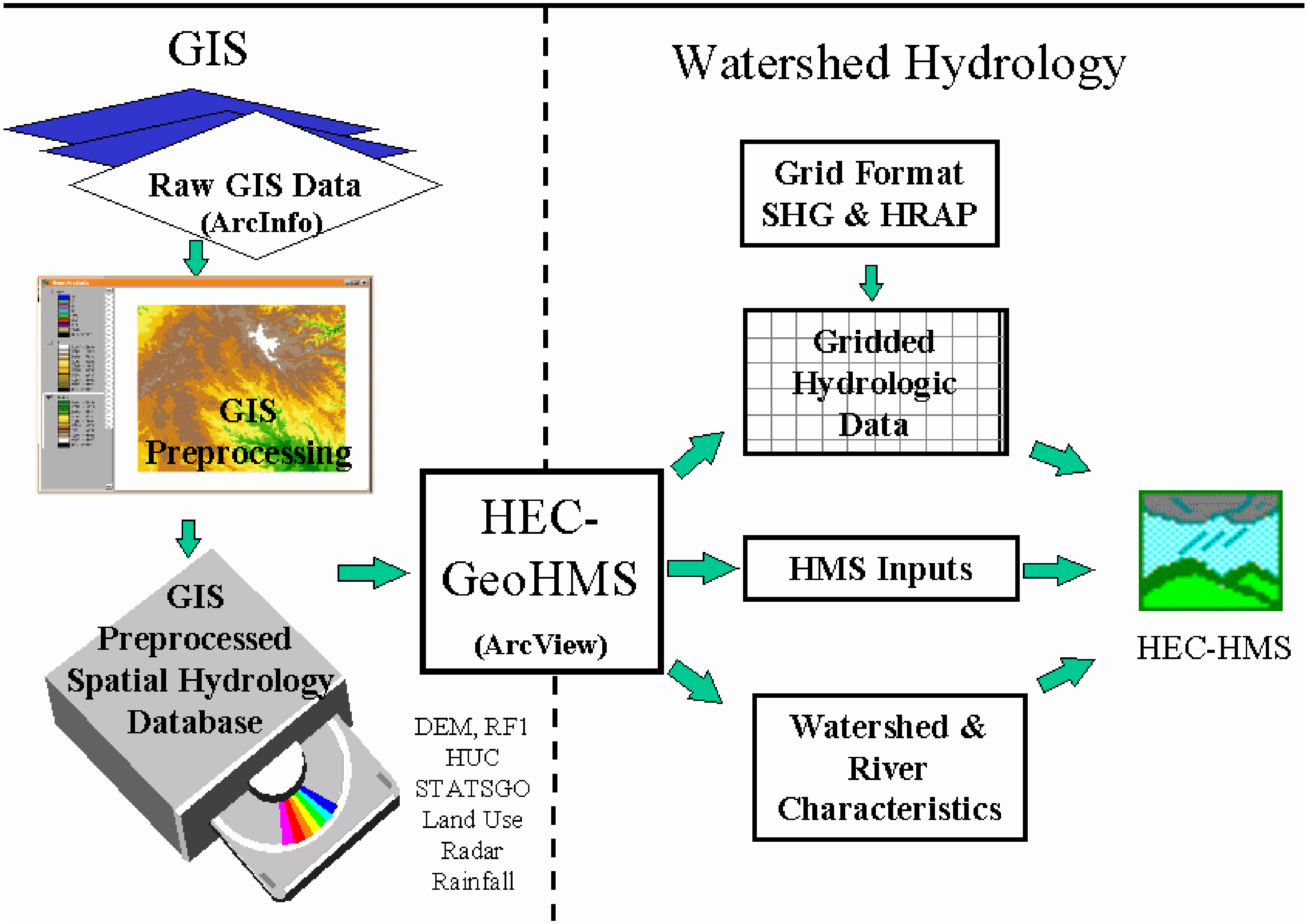
Land use classification

Sl.No	Land use pattern	Area (sq km)	Percentage
1.	Agricultural land	58.70	39.93
2.	Barren land	29.40	20.00
3.	Built up area	21.21	14.43
4.	Forest	0.73	0.50
5.	Plantation	11.10	7.55
6.	Scrub land	5.58	3.80
7.	Water body	20.27	13.79

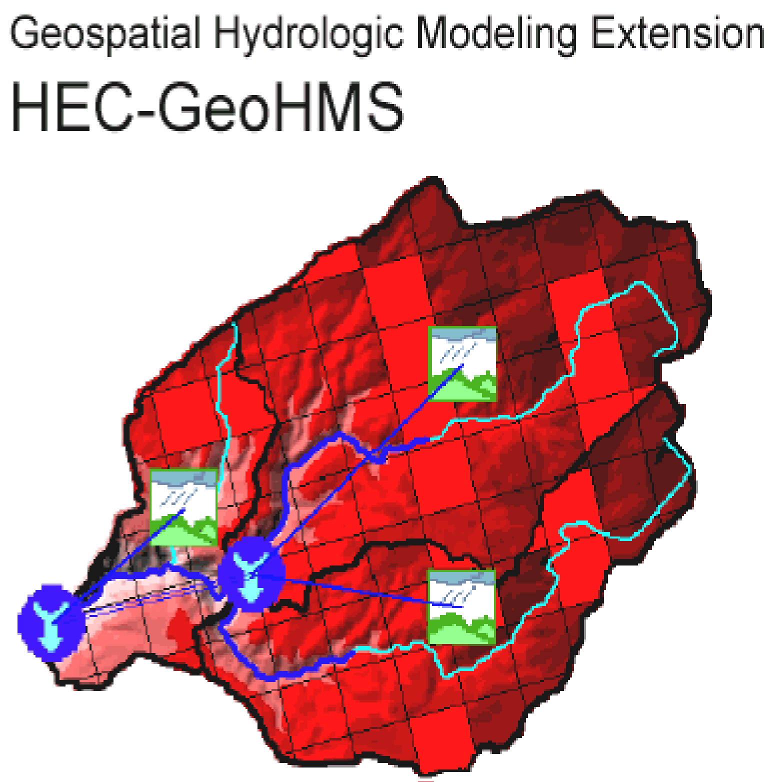


Land use map of Dasarikuppam subwatershed

Overview


GIS
Watershed Hydrology
Raw GIS Data
(ArcInfo)
GIS
Preprocessing
GIS
Preprocessed
Spatial Hydrology
Database
DEM, RF1
HUC
STATSGO
Land Use
Radar
Rainfall
HEC-
GeoHMS
(ArcView)
Grid Format
SHG & HRAP
Gridded
Hydrologic
Data
HMS Inputs
Watershed &
River
Characteristics
HEC-HMS

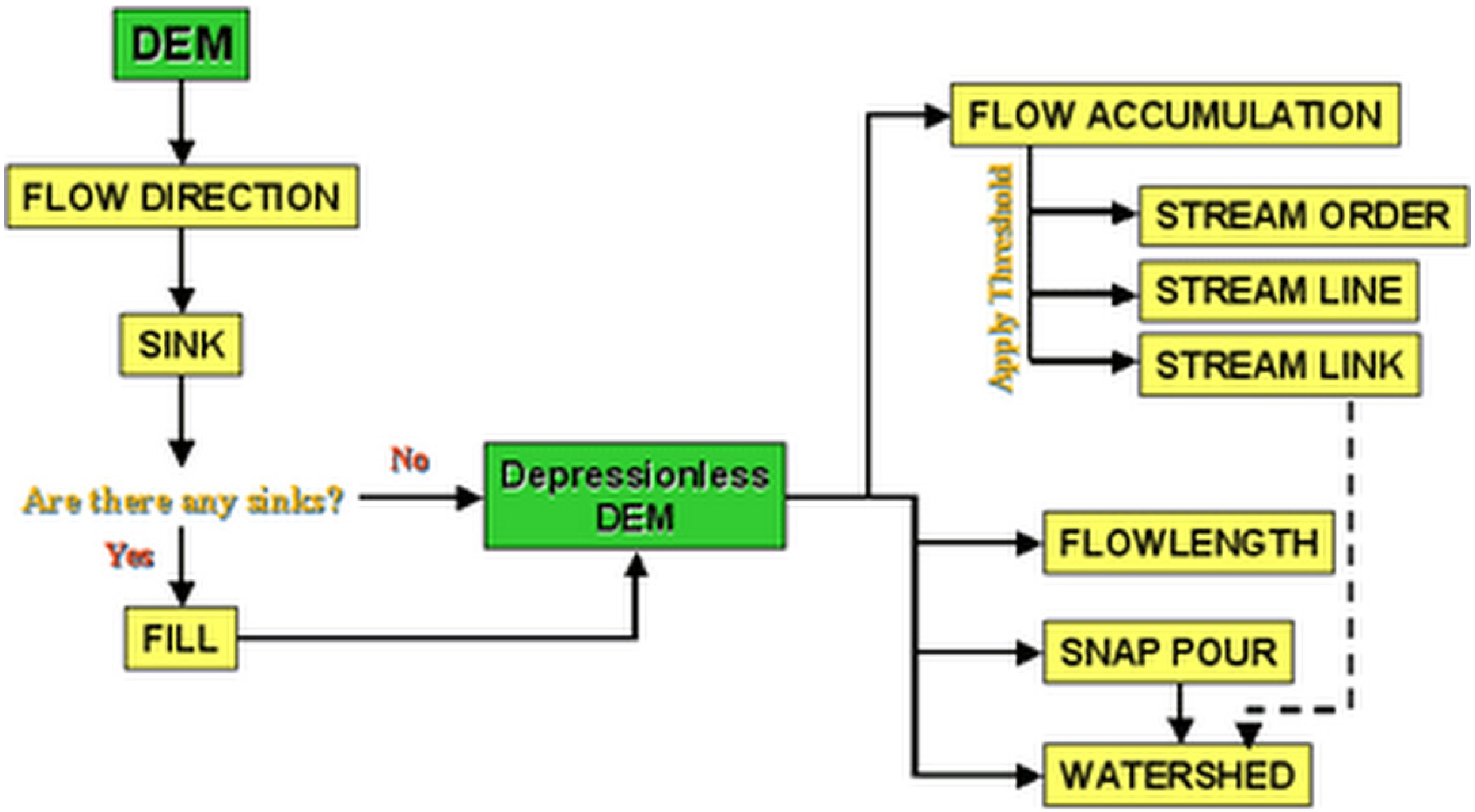
HEC-GeoHMS



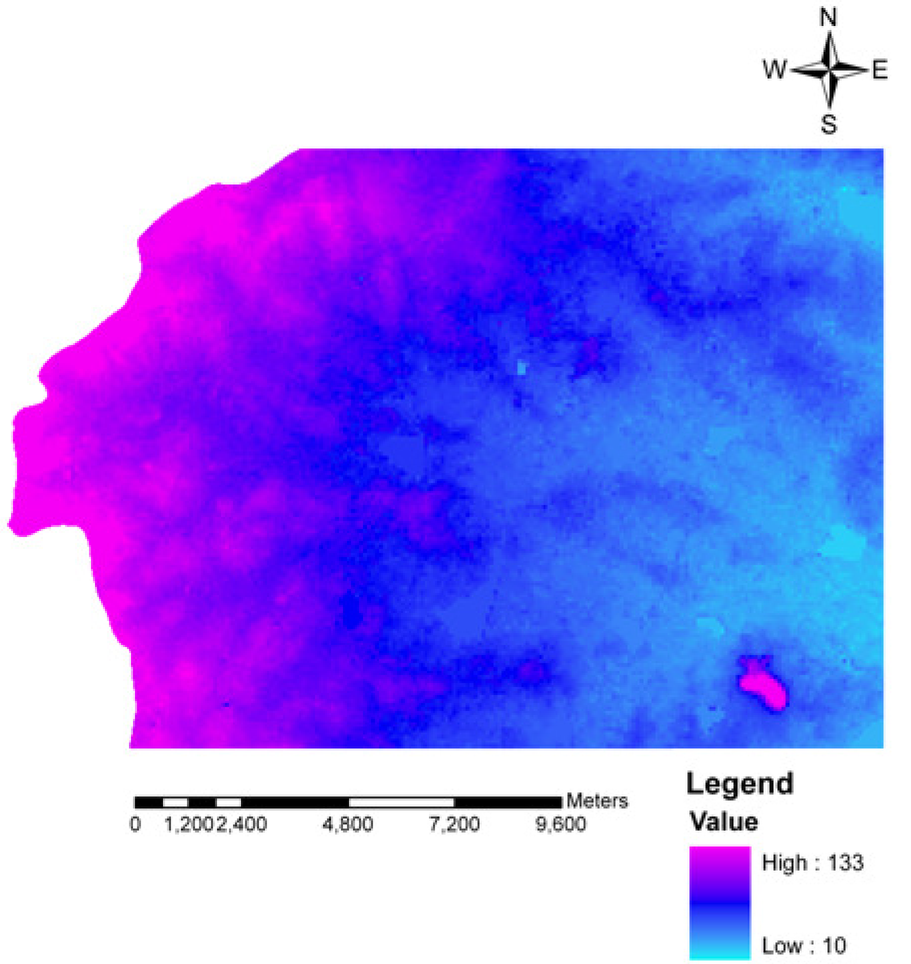
- Delineate subwatershed
- Lumped or grid-based hydrologic parameter estimation
- HEC-HMS model input (development of basin model)

ArcView

- Terrain Preprocessing
- Basin Processing
- Basin Characteristics
- Hydrologic Parameters
- HMS


DEM
FLOW DIRECTION
SINK
Are there any sinks?
No
Yes
FILL
Depressionless DEM
FLOW ACCUMULATION
Apply Threshold
STREAM ORDER
STREAM LINE
STREAM LINK
FLOWLENGTH
SNAP POUR
WATERSHED

SRTM DEM of Dasarikuppam watershed



Flow direction

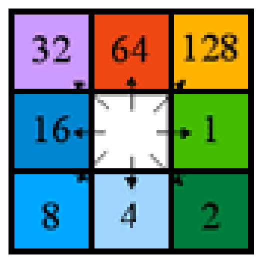
78	72	69	71	58	49
74	67	56	49	46	50
69	53	44	37	38	48
64	58	55	22	31	24
68	61	47	21	16	19
74	53	34	12	11	12

Elevation surface

→

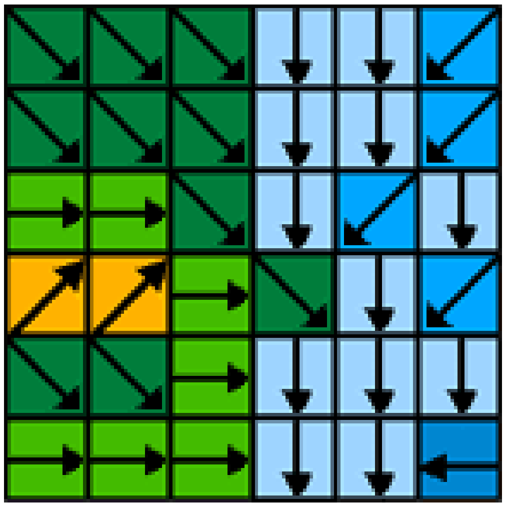
2	2	2	4	4	8
2	2	2	4	4	8
1	1	2	4	8	4
128	128	1	2	4	8
2	2	1	4	4	4
1	1	1	1	4	16

Flow direction



Direction coding

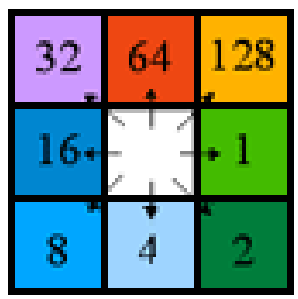
Flow accumulation



Flow direction

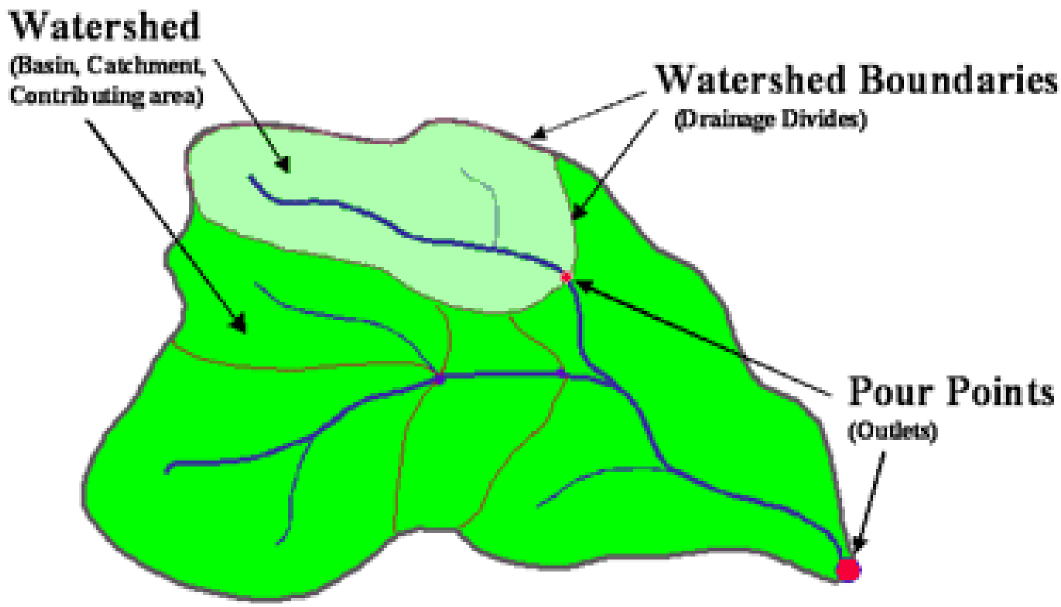
0	0	0	0	0	0
0	1	1	2	2	0
0	3	7	5	4	0
0	0	0	20	0	1
0	0	0	1	24	0
0	2	4	7	35	2

Flow accumulation



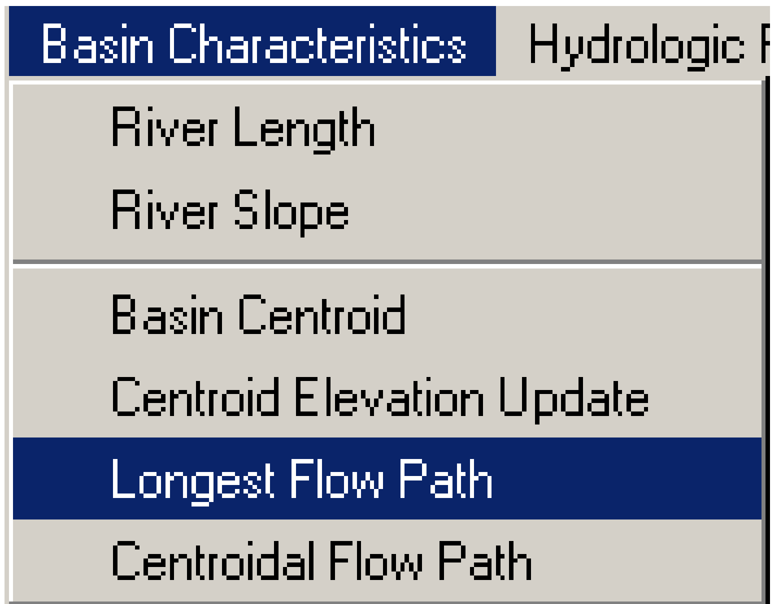
Direction coding

Watershed delineation



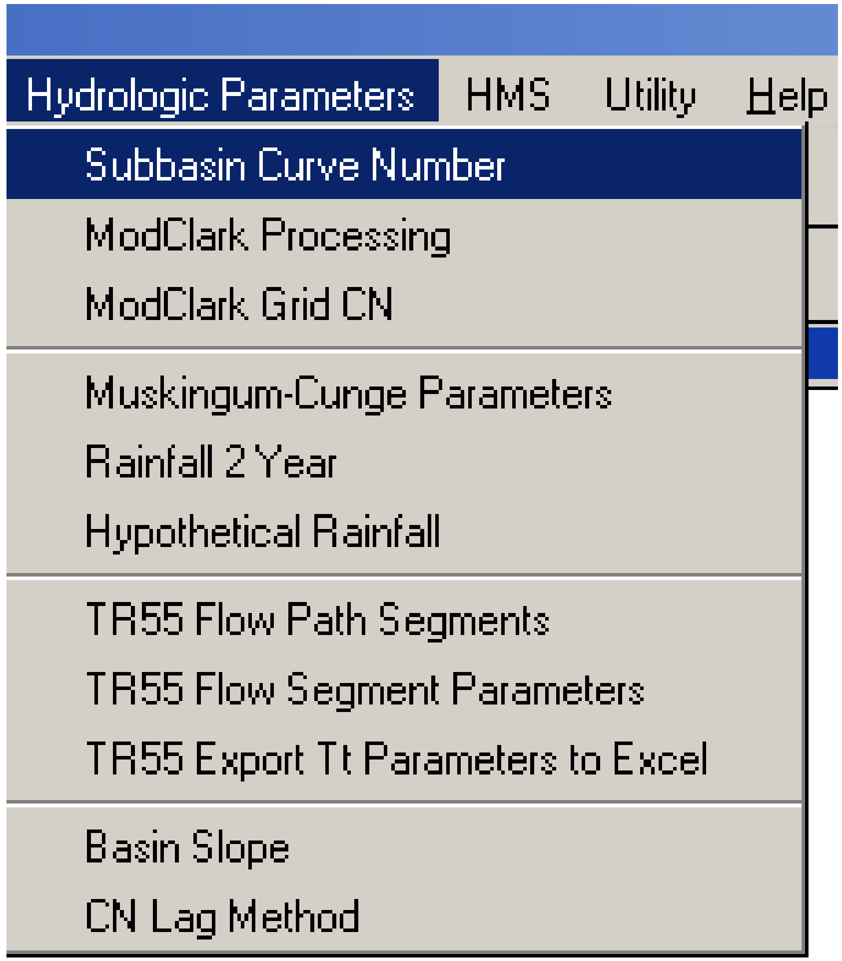
- Stream links are created
- Specify the pour points and the watershed is delineated.

Basin Characteristics



Calculate physical attributes such as stream length, subbasin centroid, and subbasin longest flow path

Hydrologic parameters



SCS CN method

- Jang et al (2007) stated that the Disaster Impact Assessment Manual (2005) suggests the use of synthetic hydrograph techniques such as the Soil Conservation Service (SCS) method for ungauged areas, while the Storm Water Management Model (SWMM) is useful for an area which is gauged.
- The SCS method was chosen for analysis as:

  (i) it is commonly used in different environments and provides good results;

  (ii) its calculation is made easier by the fact that only a few variables need to be estimated (hydrologic soil group, land use and slope); and

  (iii) despite its simplicity, it yields results that are as good as those of complex models (Lastra et al 2008).

- The modified SCS equations to suit Indian conditions (Kumar et al 1991) are as follows:

$$Q = \frac{(P - I_a)^2}{(P + 0.7S)} \qquad S = \frac{24500}{CN} \quad 254$$

$$CN_w = \frac{(\sum(CN_i * A_i))}{A}$$

Q is runoff depth, mm;
P is rainfall, mm;
S is potential maximum retention, mm;
I_a is 0.3 S (Initial abstraction of rainfall by soil and vegetation, mm);
CN is Curve Number;
CN_w is Weighted Curve Number;
CN_i is Curve number from 1 to number of land uses, N;
A_i is area with curve number CN_i;
A is total area of the watershed; and
i is index of the micro-watershed.

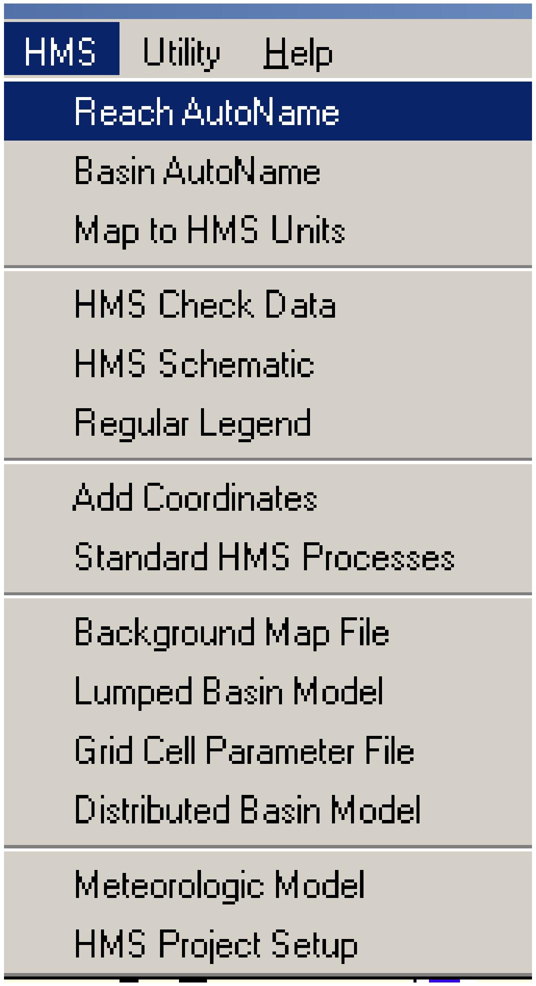
SCS curve numbers for Indian conditions

Sl No	Land use	Runoff curve numbers for hydrologic soil group			
		A	B	C	D
1.	Agricultural land	59	69	76	79
2	Barren land	71	80	85	88
3	Built-up area	77	86	91	93
4	Canal	100	100	100	100
5	Forest	26	40	58	61
6	Plantation	41	55	69	73
7	River	100	100	100	100
8	Scrub land	33	47	64	67
9	Tanks	100	100	100	100

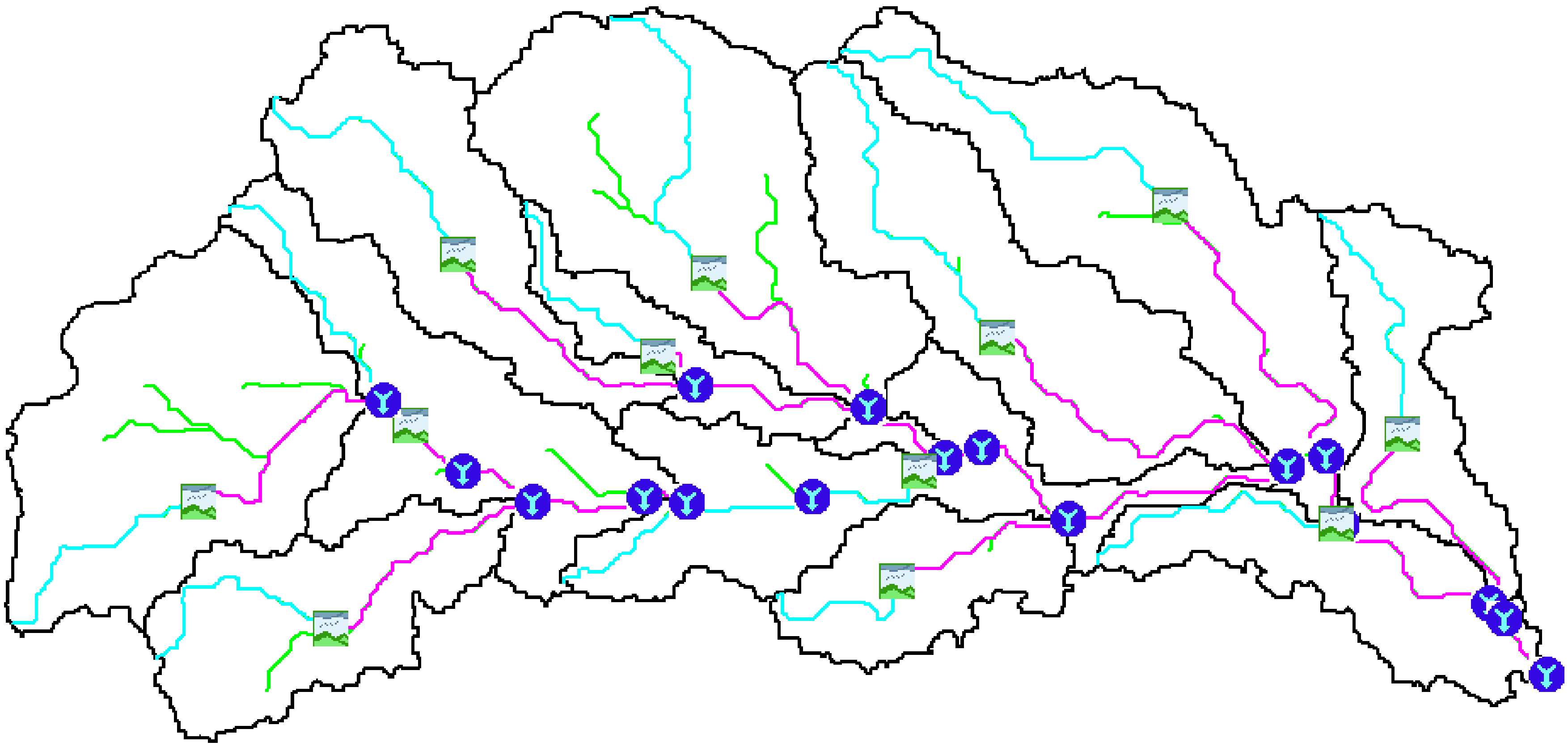
(Source Kumar et al 1991)

Note: Soil A – High infiltration
Soil B – Moderate infiltration
Soil C – Low infiltration
Soil D – Very low infiltration

HEC-HMS Model Generation



Basin model



HEC-HMS

Components

- Basin model
  - Elements of basin and their connectivity and runoff parameters
- Meterologic model
  - Rainfall data
- Control specifications
  - Start/stop timing

Meterorological model

- The meteorological model of the HEC-HMS handles the atmospheric conditions over the watershed.
- In this study, the gauge weight method was used for the meteorological data analysis.
- It was used for distributing the rain gauge station values over the watershed and the weights of each gauge was found using the inverse squared distance method given in Equation.

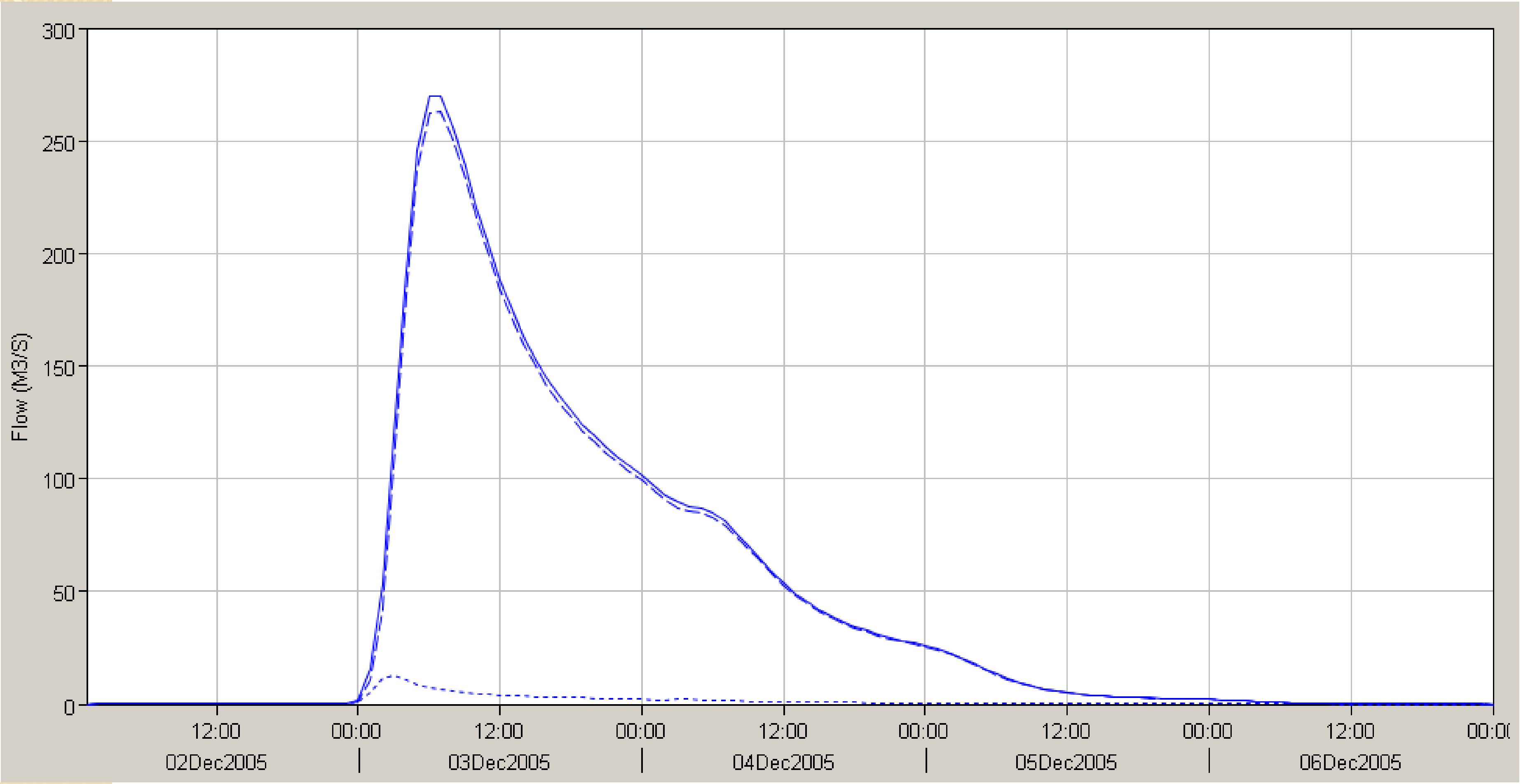
$$w_i = \frac{\frac{1}{d_i^2}}{\sum_{i=1}^{n} \frac{1}{d_i^2}}$$

w_i is weight of i^{th} rain gauge;
d_i is distance of i^{th} rain gauge to the centroid of the sub basin; and
n is number of gauges.

Discharge calculation

- Land use, hydrologic soil group and slope maps derived from SRTM DEM are overlaid and a complete GIS database is made.
- The runoff is calculated for each micro watershed and they are summed up to get the discharge at outlet.
- The peak discharge was estimated to be 256.4 cumecs.

Hydrograph



Flow (M3/S)
300
250
200
150
100
50
0
12:00
00:00
12:00
00:00
12:00
00:00
12:00
00:00
12:00
00:0(
02Dec2005
03Dec2005
04Dec2005
05Dec2005
06Dec2005

Conclusion

- The Geographic Information System adds a great deal of versatility to the hydrological analysis, due to its spatial data handling and management capabilities.
- With limited data available, the runoff can be quantified.
- It is evident from the study that the main role of HEC – GeoHMS is to devise a watershed data structure under the platform of GIS and that can be imported directly to HEC – HMS.
- The study clearly demonstrated the integration of remote sensing, GIS and hydrological model HEC – HMS provides a powerful assessment of peak discharge calculations.
- The starting point is comprehensive spatial planning, while sectoral and institutional aspects must be

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THANK YOU