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Flood Modelling and Water Harvesting Plan for Paravanar Basin

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Abstract : Water is one of the most important resources on this planet. Almost half a billion people live in countries where water is scarce. To overcome this situation, Water harvesting is the only solution. In this project, the plan for water harvesting in a sub-basin is developed with the assistance of HEC-HMS model and Remote Sensing and GIS techniques. HEC-HMS is a conceptual and semi-distributed model designed to simulate the rainfall-runoff processes in a wide range of geographic areas such as large river basin to small urban and natural watershed runoff..The objectives of this study are to carry out the flood modeling using HEC-HMS and also to develop flood water harvesting plan using GIS. This is an attempt, made to identify favorable zones for the application and adaptation of site specific artificial recharge techniques for the augmentation of groundwater through a Geographical Information System (GIS) based hydro-geomorphic approach in a Sub-basin. An extreme event for the year 2015, flood was simulated in the HEC-HMS model and the runoff potential map was arrived, which can be used for the development of rainwater harvesting plan. The harvesting plan is finally created using Remote Sensing and GIS Techniques. The study area chosen is Paravanar basin of Cuddalore district, Tamilnadu, India.
Key words : Flood modelling, HEC-HMS, GIS, Water harvesting plan.

Introduction:

A flood is an overflow of water that submerges land which is usually dry. Flooding occurs most commonly from heavy rainfall when natural watercourses do not have the capacity to convey excess water. RWH is the technique of collecting, storing and distributing rainwater for multiple uses. The collected water can be stored for direct use or diverted for bore well /groundwater recharge. In simple terms it is a way to capture the rainwater when it rains, for later use. India receives high annual rainfall, but it faces a severe shortage of water. This is primarily due to excess runoff and lack of water conservation practices

Hydrological modeling is a commonly used tool to estimate the basin’s hydrological response due to precipitation. It allows to predict the hydrologic response to various watershed management practices and to have a better understanding of the impacts of these practices. The Hydrologic Engineering Centers Hydrologic Modeling System (HEC-HMS) is a popularly used watershed model to simulate rainfall-runoff process.

Study Area:

Paravanar river basin lies between Pennaiyar river basin on the north and Vellar river basin on the south within the following coordinates.

Latitude: 11^{0} 27' 00" - 11^{0} 43' 00" N

Longitude: 79^{0} 23' 00" - 79^{0} 47' 00" E

The map of Paravanar river basin can be found in the toposheets of Survey of India, 58 M06, M07, M10, M14 and M11 of 1:50,000 scale. It is a small basin covering an area of 879.462 sq.km.Paravanar and Uppanar are the two main rivers in this basin. There are two major tanks namely Wallajah tank and Perumaleri. Apart from this, there are number of rainfed tanks and small streams in this basin. Chidambaram, Cuddalore, Panruti and Vridhachalamtaluks are covered by this basin area.

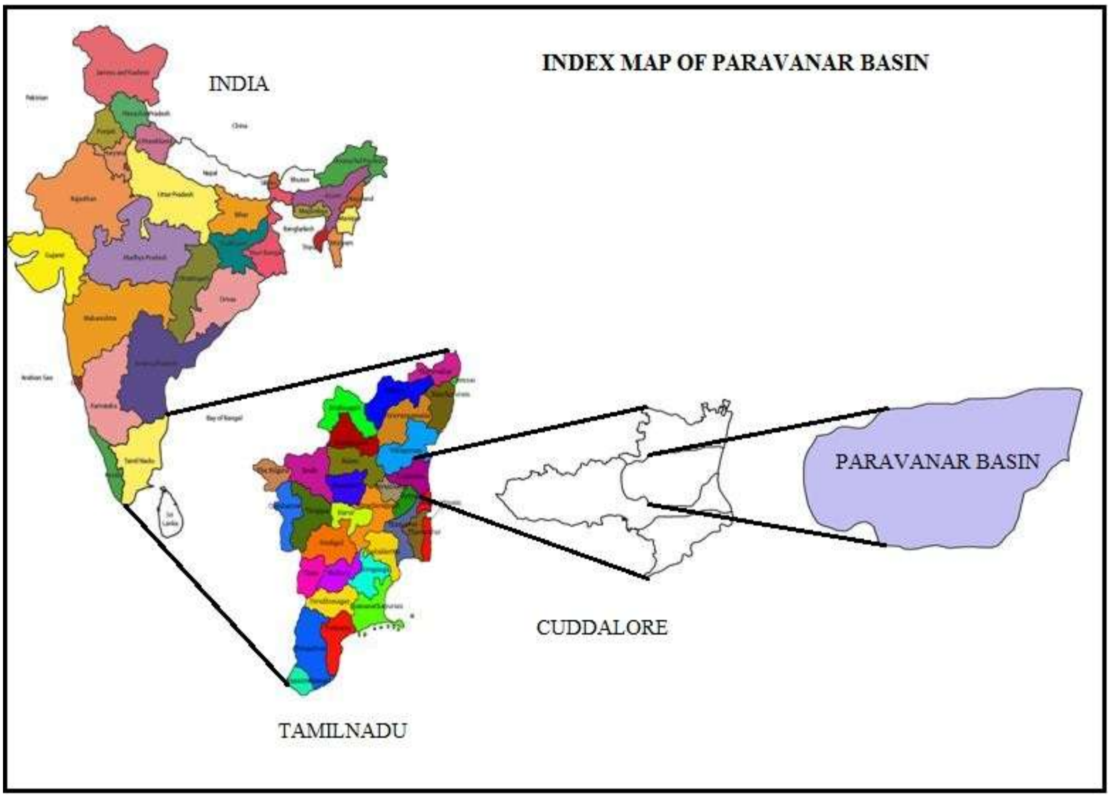


Fig 1: Index map of Paravanar Basin

Data Collection

Thematic maps such as Landuse map, Soil map, Geomorphology map and also monthly rainfall data were acquired for the period of 10 years, from 2002-2012 for the Cuddalore district.

Digital Elevation Model:

SRTM (Shuttle Radar Topography Mission) has been interpolating with our concerned boundary and it is helpful to create digital elevation model to the required boundary with the interface of Arc-GIS.

Land Use Map:

Land use map depicts the pattern of land use in the study area and is an important input for preparation of the other theme maps which is shown in the figure 4.2. The built up land is composed of 41.87 sq.km, agricultural land of 634.10 sq.km and wasteland category of about 194.57 sq.km. Especially mining area accounts to be 45.5 sq.km.

Soil Map:

Soil map is a map showing distribution of soil types and/or soil properties (soil pH, textures, organic matter, depths of horizons etc.) in the area of interest and it is showed in the figure 4.3. It is typically the end result of a soil survey inventory, i.e. soil survey.

Rainfall and discharge data:

Analysis of historic rainfall and discharge data is necessary to find the occurrence of flood (extreme events) in the past. The rainfall event is said to be an extreme event when it exceeds 244 mm/day as per Indian Meteorological Department. By using this data, model calibration and validation were carried out.

Methodology

The DEM from SRTM is used for delineating the basin boundary and drainage pattern of the study area. HEC-GeoHMS is the pre-processor of HEC-HMS and it is an extension of ArcGIS, which aids in the delineation process. Some other basic parameters of the basin and rivers are also obtained in HEC-GeoHMS. The land-use and soil map obtained are clipped to the area of the basin and are used for the estimation of Curve Number in ArcGIS. Intersection of three files forms a composite file with polygons of unique land use and soil combination, for which the CN's are assigned. The appropriate methods for the simulation of-various hydrologic components are chosen and the model is set-up. Using the historical flood data of the study area, the model is calibrated.

The model is then validated. In case the validated model is of low efficiency, the model is to be calibrated again till the acceptable efficiency is obtained. Hence calibration is done by trial and error method. An approximate value of the calibrated parameters for the given rainfall and runoff, can be obtained through optimization trials. When the validation is over, the model becomes ready for simulation of runoff resulting from rainfall for the topographical and geological condition of the study area. The model results consists of flood hydrograph and peak discharge for the given storm.

Results and Discussions

Flood modelling was carried out using HEC-HMS. GIS overlay analysis was carried out and the water harvesting plan for Paravanar basin is developed.

The sub-basins are delineated around each stream segment as grids by joining the high elevation points around each segment and then a vector layer of sub-basins is formed.

Fig 2: Delineated Sub basin map

Theissen polygon is created using the analysis tools of ARCGIS. After construction of polygons, the area of each sub-basin covered within various polygons is measured

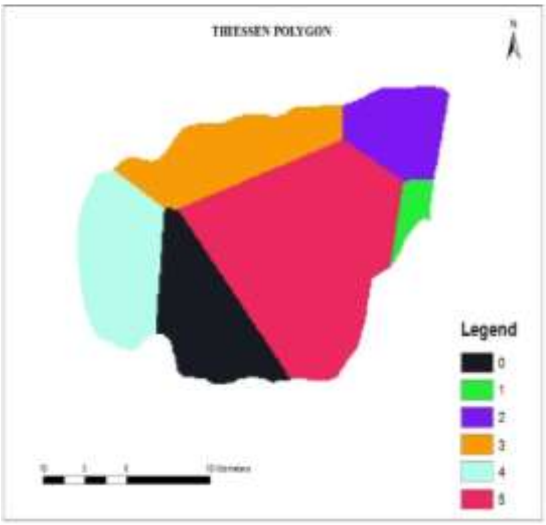


Fig 3: Thiessen polygon of Sub basin **Fig 4 : Drainage map of Paravanar basin**

The CN is to be estimated for each sub-basin as the simulation is semi-distributed; the CN is lumped within the sub-basin. Land use/land cover and hydrological soil group decides the CN.

Basin model file:

The basin boundary and drainage line layers prepared as background files for HEC-HMS were imported into the model. Fig 5 shows the basin model file of Paravanar basin.

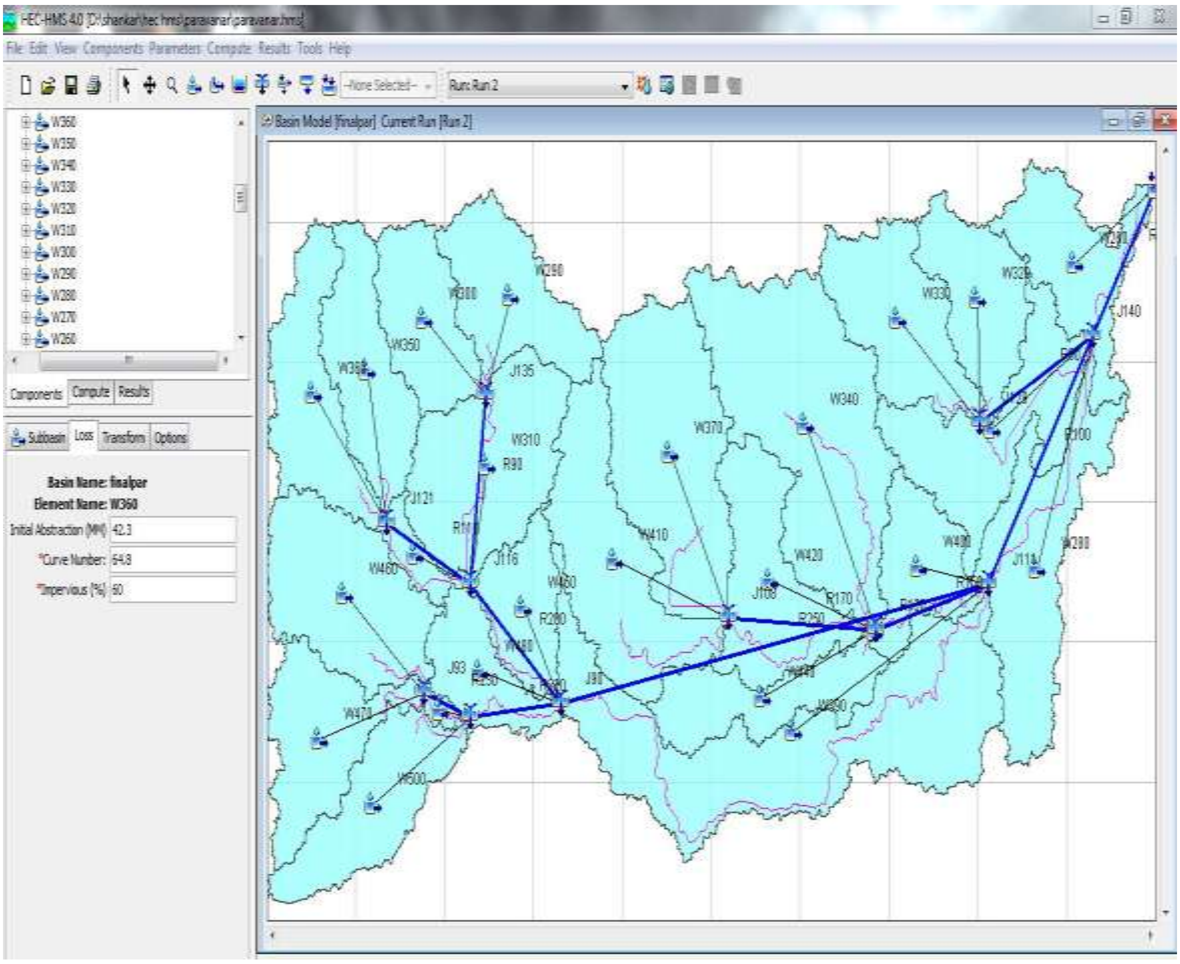


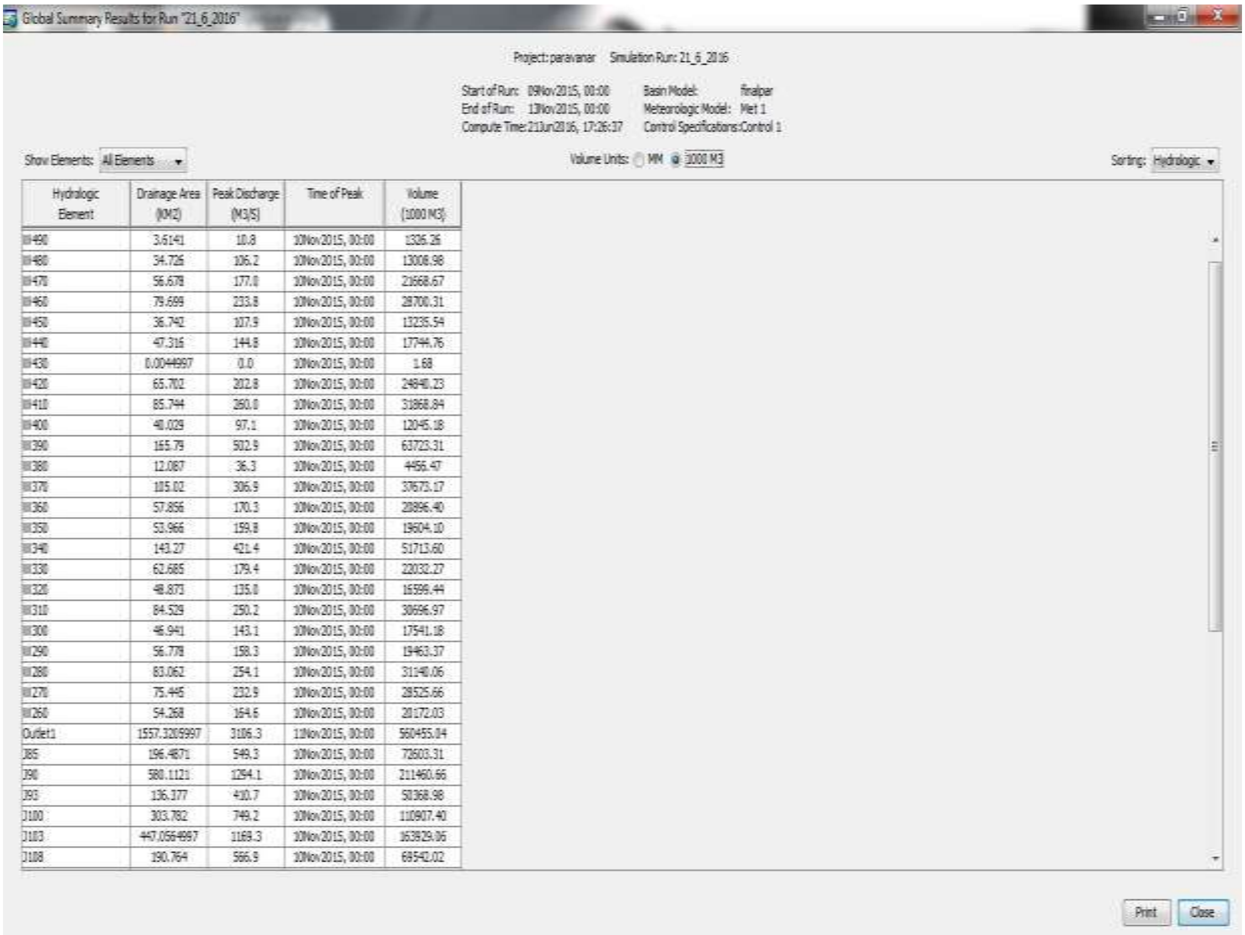
Fig 5Basin model file of HEC- HMS

Simulations run:

The model files and data are made ready, after which the estimated parameters are given into the model. The simulation run is then created, the required control specification is selected and the model is run. The results consist of hydrograph, hyetograph, summary table and time-series table for the elements.

Calibration:

It is an iterative process of comparing the model to actual system behaviour and using the discrepancies between the two, and the insights gained, to improve the model. This process is repeated until model accuracy is judged to be acceptable.After calibration, thus the model becomes ready to simulate the discharge resulting from any other rainfall events of the basin, with the appropriate parameters. In this study calibration is done for the past flood events of 2005 and 2008. The parameters calibrated are Curve Number and lag time.


Global Summary Results for Run "21_6_2016"

Project: paravanar Simulation Run: 21_6_2016

Start of Run: 09Nov2015, 00:00 Basin Model: finalper
End of Run: 13Nov2015, 00:00 Meteorologic Model: Met 1
Compute Time: 21Jun2016, 17:26:37 Control Specifications: Control 1

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

Hydrologic Element	Drainage Area (KM2)	Peak Discharge (M3/S)	Time of Peak	Volume (1000 M3)
W490	3.6141	10.8	10Nov2015, 00:00	1326.26
W480	34.726	106.2	10Nov2015, 00:00	13008.98
W470	56.678	177.0	10Nov2015, 00:00	21668.67
W460	79.699	233.8	10Nov2015, 00:00	28700.31
W450	36.742	107.9	10Nov2015, 00:00	13235.54
W440	47.316	144.8	10Nov2015, 00:00	17744.76
W430	0.0044997	0.0	10Nov2015, 00:00	1.68
W420	65.702	202.8	10Nov2015, 00:00	24840.23
W410	85.744	260.0	10Nov2015, 00:00	31868.84
W400	40.029	97.1	10Nov2015, 00:00	12045.18
W390	165.79	502.9	10Nov2015, 00:00	63723.31
W380	12.087	36.3	10Nov2015, 00:00	4456.47
W370	105.02	306.9	10Nov2015, 00:00	37673.17
W360	57.856	170.3	10Nov2015, 00:00	20896.40
W350	53.966	159.8	10Nov2015, 00:00	19604.10
W340	143.27	421.4	10Nov2015, 00:00	51713.60
W330	62.685	179.4	10Nov2015, 00:00	22032.27
W320	48.873	135.0	10Nov2015, 00:00	16599.44
W310	84.529	250.2	10Nov2015, 00:00	30696.97
W300	46.941	143.1	10Nov2015, 00:00	17541.18
W290	56.778	158.3	10Nov2015, 00:00	19463.37
W280	83.062	254.1	10Nov2015, 00:00	31140.06
W270	75.445	232.9	10Nov2015, 00:00	28525.66
W260	54.268	164.6	10Nov2015, 00:00	20172.03
Outlet1	1557.3209997	3106.3	11Nov2015, 00:00	560455.04
J85	196.4871	549.3	10Nov2015, 00:00	72603.31
J90	580.1121	1294.1	10Nov2015, 00:00	211460.66
J93	136.377	410.7	10Nov2015, 00:00	50368.98
J100	303.782	749.2	10Nov2015, 00:00	110907.40
J103	447.0564997	1169.3	10Nov2015, 00:00	163929.06
J108	190.764	566.9	10Nov2015, 00:00	69542.02

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Fig 6 Calibration for the Event – 2015

Validation:

Once satisfactory estimates of the parameters for all models have been obtained, the models must be checked to assure that they adequately perform the functions for which they are intended.

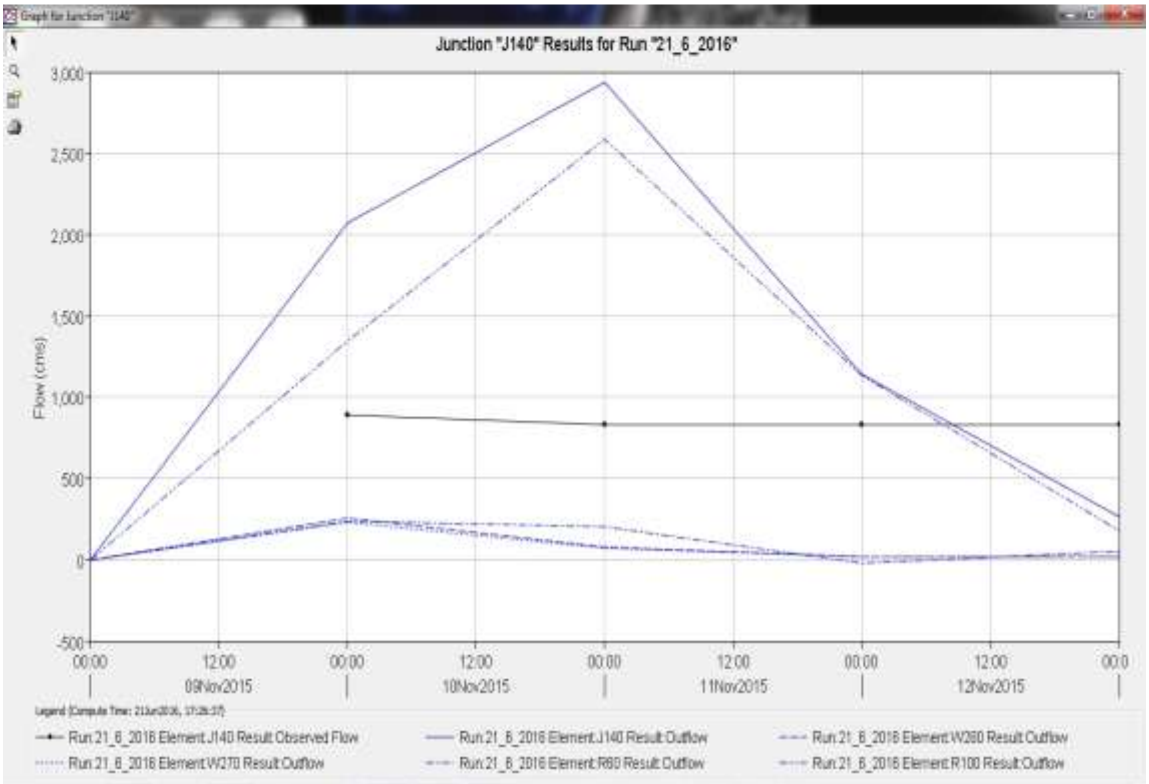

Fig 7 Outflow Graph for Perumal tank

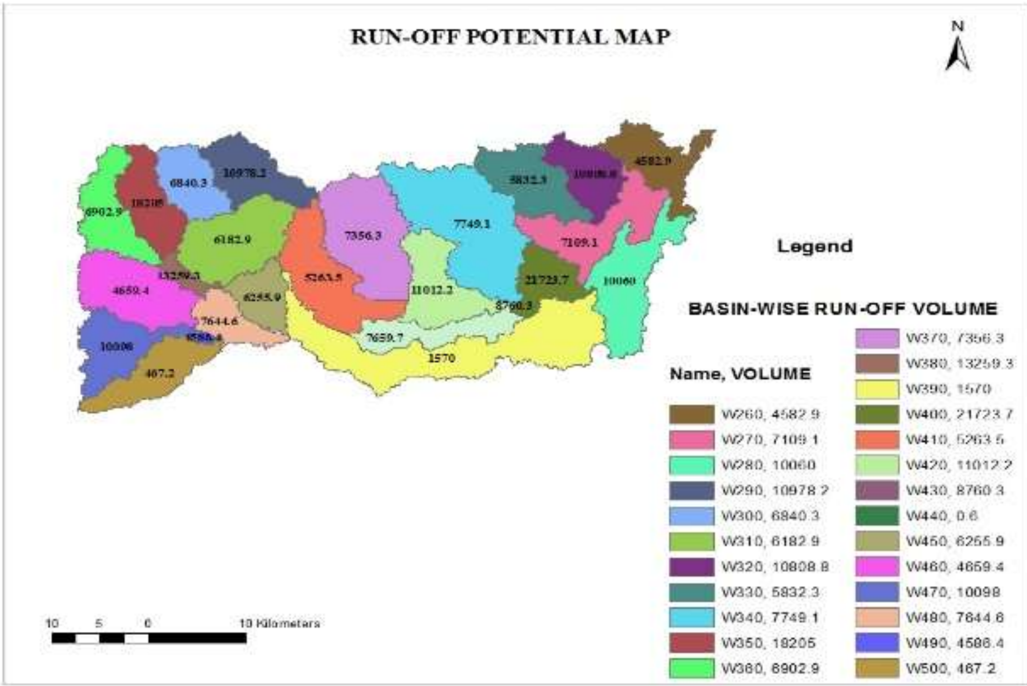

Fig 8 Runoff Potential map

The Runoff potential map is generated using HEC-HMS as shown in the figure 8. The attribute table contains the volume of runoff and slope of each basin as shown in figure 9. Finally the suitable structure is recommended. Figure 10 shows the water harvesting plan for Paravanar basin.

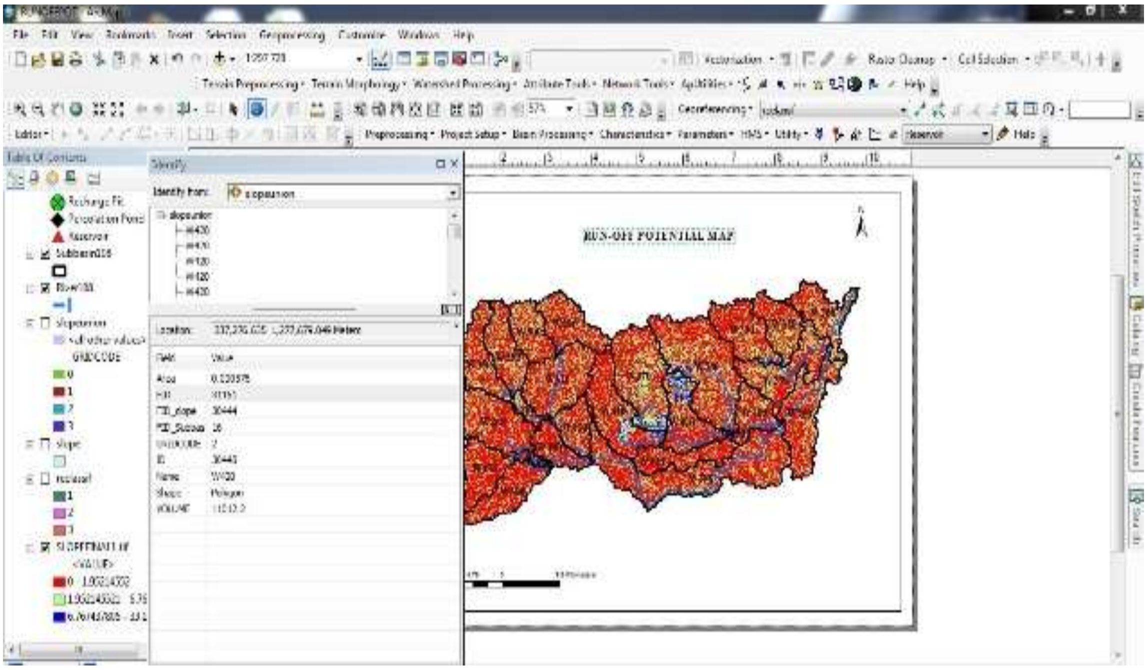

Fig 9 Data Acquisition from runoff potential map

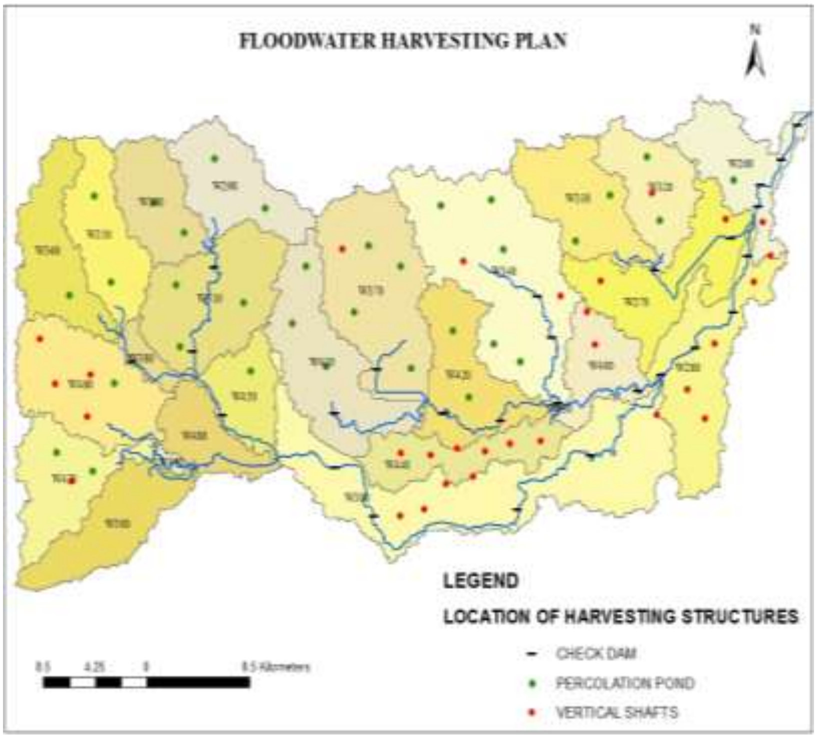

Fig 10Water harvesting plan for Paravanar basin

Conclusion

Attempts were made since early days to reduce the impact of flood and to forecast future floods. Each attempt had their own advantages and dis-advantages, giving rise to the innovation of new methods. Flood modeling though practiced for many years has now been increasingly used because of its efficiency and accuracy.

This study shows that the model is efficient enough to simulate the real time conditions of the basin, proving that its results about flood estimation are acceptable. The presence of reservoirs in the basin affects the amount of flow at the downstream considerably. Hence their inclusion in the model is necessary to improve the efficiency of simulation. Remote sensing and GIS have proved to be of great help in this study by providing the required thematic layers for boundary delineation and parameter estimation and development of flood water harvesting plan. This project describes about suitable rainwater harvesting methods for various land-uses based on the generated runoff. The results of this project can be used for the design of flood water harvesting structures.

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