RESEARCH PAPER | Engineering | Volume - 5 | Issue - 1 | Jan Special Issue - 2015 | ISSN - 2249-555X

Runoff Simulation of Hathmati watershed Using SWAT model- A real life case study of Sabarmati Basin

KEYWORDS: Hydrologic Modelling, Runoff, SWAT, Sabarmati Basin

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ABSTRACT Runoff is a phenomenon representing the hydrologic response of a watershed to precipitation. Soil and Water Assessment Tool (SWAT) is a physically based distributed parameter model which has been developed to predict runoff, erosion, sediment and nutrient transport from agricultural watersheds under different management practices. For the present study, Sabarmati basin Hatmati watershed in Gujarat has been selected as the study region. By providing all the inputs for model set up, SWAT model was simulated for the period of thirty years (year 1998–2005). A study is divided in 29 sub-watersheds with help of the SWAT model and find out Surface runoff of each sub-watershed. The results obtained showed that WS-22 watershed has maximum runoff potential while WS-25 as least. Further, this model can be utilized as a potential tool for water resource management of the Sabarmati basin.

I. INTRODUCTION

Water and soil management is challenges for developing country for sustainable developments. It is necessary for social and economical grow of country like India. Traditional method is not efficient to provide the sustainable solution of the problem so the watershed is considered to be the ideal unit for management of the natural resources .

Extraction of watershed parameters using Remote Sensing and Geographical Information System (GIS) and used of mathematical models is the current trend of hydrologic evaluation of watershed. Several physically based distributed parameter models like AGNPS , SHE —, HEC-HMS , HEC 2000), SWRRB and SWAT have been developed to predict runoff, erosion, sediment and nutrient transport from rural and agricultural watersheds under various management regimes.

The SWAT (Soil and Water Assessment Tool) is one of the most recent models developed jointly by the United States Department of Agriculture - Agricultural Research Services (USDA-ARS) and Agricultural Experiment Station in Temple, Texas . It is a physically based, continuous time, long-term simulation, lumped parame-ter, deterministic, and originated from agricultural mod-els. The computational components of SWAT can be placed into eight major divisions: hydrology, weather, sedimentation, soil tempera-ture, crop growth, nutrients, pesticides, and agricultural management. The SWAT model uses physically based inputs such as weather variables, soil properties, topography, and vegetation and land management practices occurring in the catchment. The physical processes associated with water flow, sediment transport, crop growth, nutrient cycling, etc. are directly modeled by SWAT . Some of the advantages of the model include: modeling of ungauged catchments, prediction of relative impacts of scenarios (alternative input data) such as changes in management practices, climate and vegetation on water quality, quantity or other variables. SWAT has a weather simulation model also that generates daily data for rainfall, solar radiation, relative humidity, wind speed and temperature from the average monthly variables of these data. This provides a useful tool to fill in missing daily data in the observed records. The hydrologic cycle as simulated by SWAT is based on the water balance equation:

$$SW_t = SW_o + \sum_{i=1}^{n}(R_{day} - Q_{surf} - E_a - w_{seep} - Q_{gw}) \quad (1)$$

where, *SWt* is the final soil water content (mm H_2O), *SWo* is the initial soil water content (mm H_2O), *t* is time in days, *Rday* is amount of precipitation on day *i* (mm H_2O), *Qsurf* is the amount of surface runoff on day *i* (mm H_2O), *Ea* is the amount of evapotranspiration on day *i* (mm H_2O), *wseep* is the amount of percolation and bypass exiting the soil profile bottom on day *i* (mm H_2O), *Qgw* is the amount of return flow on day *i* (mm H_2O).

In SWAT, a basin is delineated into sub-basins, which are then further subdivided into hydrologic response units (HRUs). HRUs consist of homogeneous land use and soil type (also, management characteristics) and based on two options in SWAT, they may either repre-sent different parts of the sub-basin or sub-basin area with a dominant land use or soil type (also, management characteristics). With this semi-distributed (sub-basins) set-up, SWAT is attractive for its computational efficiency as it offers some compromise between the constraints imposed by the other model types such as lumped, conceptual or fully distributed, physically based models. A full model description and operation is presented in Neitsch *et al.* [4,5]. SWAT uses hourly and daily time steps to calculate surface runoff. The Green and Ampt equation is used for hourly and an empirical SCS curve number (CN) method is used for the daily computation.

The soil and Water Assessment tool (SWAT) having an interface with ArcView GIS software (AVSWAT2000/X) was utilized for estimation of runoff from the Hathmati water-sheds, Sabarmati basin. The watershed is divided in 29 sub-watersheds and runoff of each watershed carried out.

II. STUDY AREA

For the present study, Sabarmati River is one of the major Wests flowing Interstate Rivers in India, draining into the Gulf of Khambhat. The basin is bounded by Aravalli hills in the

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North and North-East, by ridge separating it from basins of minor streams and draining into Rann of Kachchh and Gulf of Khambhat in West and by Gulf of Khambhat in the South. The basin has a maximum length of 300 km and maximum width of 105 km. It is triangular in shape with the main river as the base and the source of the Watrak as the apex point. It originates in the Aravalli hills at latitude 240 40' N and longitude 730 20' E in the Rajasthan State at an elevation of 762 m above m.s.l. The Sabarmati River has a length of 371 kms and the drainage area is of 21674 sq km.

The Sabarmati River with its origin in Rajasthan flows generally in South - West direction. It enters the Gujarat State and passes through the plains and continues to flow in the same direction and joins the Gulf of Khambhat in the Arabian Sea. At the 51 km of its run, the river is joined by the Wakal on the left bank near village Ghanpankari. Flowing generally in the South - West direction at 67th km of its run, it receives the Sei on the right bank near Mhauri and then the Harnav on the left bank at about 103 km. From respective sources beyond this confluence, Sabarmati flows through the Dharoi gorge. Emerging from the gorge it passes through the plains and is joined on its left bank at about 170 km from its source by the Hathmati, which is its major tributary. Continuing to flow in South - West direction, the river passes through Ahmedabad and about 65 km downstream, another major tributary, Watrak joins it on the left bank, flowing for a further distance of 68 km, the river outfalls in the Gulf of Khambhat in Arabian Sea.

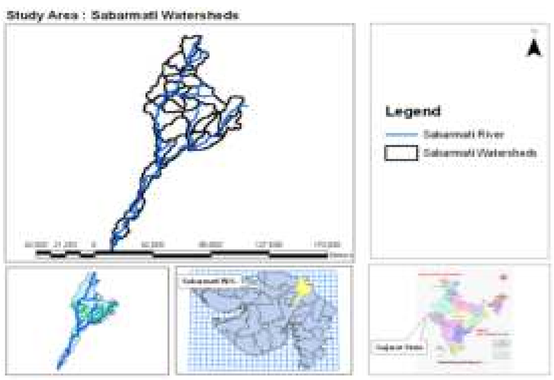


Fig.1Location map of Hatmati Watersheds, Sabarmati Basin

III. METHODOLOGY TO RUN THE MODEL

The SWAT model is used for find out the runoff from the Hatmati watersheds. The step by step methods to simulate SWAT model is describe here:

1) Delineation of watershed

Step1: Automatic delineation of micro-watershed with the input of DEM (SRTM data is used), Digitized drainage network, and area of interest in the grid (mask) format.

Step2: Next the system default threshold value for delineating the drainage tributaries is adjusted.

Step3: Next is to identify the outlet pour point on the drainage.

2) Overlaying of Landuse and soil map

Step4: Landuse map in shapefile/grid format has to be provided.

Step5: File containing re-codified land use classes as per SWAT model requirement are provided.

Step6: The soil map is also given in shapefile/grid format.

Step7: Soil classes are re-codified and file containing re-codified soil classes is provided.

Step8: Land use and soil map are overlaid with micro-watershed.

3) Hydrological response unit

Step9: Hydrological response units for the study area are also delineated by the system.

4) Weather input

The different input given in the weather input file (wgn file) is

Step10: Identification of path to the Rainfall station file (dbf/text format).

Step11: Identification of path to the Temperature station file (dbf/text format).

Step12: The model itself then simulates Weather station file-using values provided as well as default values based on look up table available with the model for the region.

Step13: The model itself has simulated solar radiation file.

Step14: The model itself has simulated wind station file.

Step15: Identification of path to the Relative humidity station file (dbf/text format).

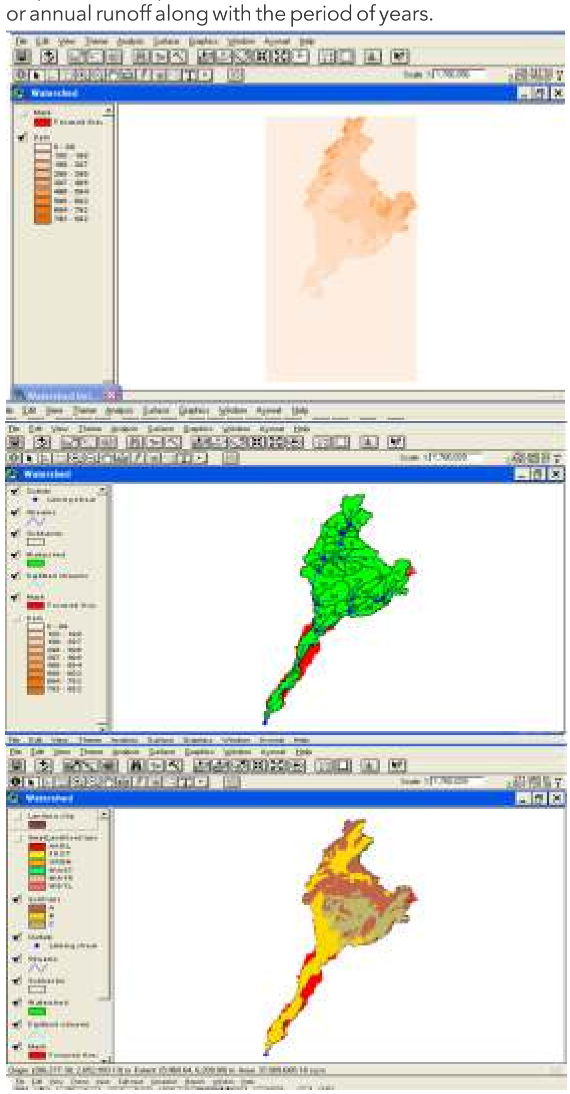
5) Write input file

Step17: In this step, the model itself will extract the required inputs from the provided files and generate the different input parameter as per its requirement.

6) Model - Simulation

Step18: After writing all required input files the final stage is the running the simulation model.

Step19: The output file format is identified as daily, monthly or annual runoff along with the period of years.



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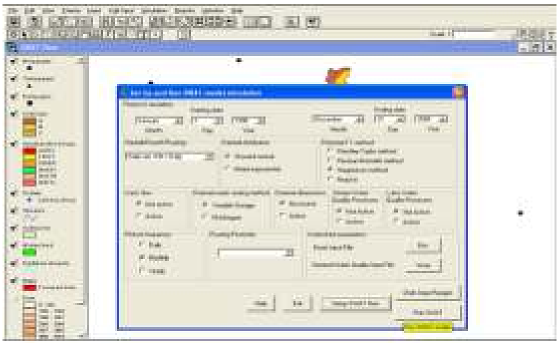

Fig.2 Steps to run the SWAT Model

IV. RESULTS AND DISCUSSION

Concept of hydrological modeling is applied in the present work. "Soil And Water Assessment Tool" (SWAT) the hydrological model is used to estimate runoff resulting from Monthly rainfall. Various thematic maps such as Landuse/Landcover, Drainage, soil, etc., are prepared from IRS-1B (LISS-III) digital data, SOI toposheets of 1:50000 scale and other reference maps. The generation of database for thematic layer is made using ArcGIS 9.1, ArcView 3.1. The model thus indicates the runoff of Sabarmati catchments consisting 29 Sub-watersheds which discharge into the river Sabarmati. Highlights of the results obtained as an output of the work are as follows:

As a part of study the SWAT MODEL is used for estimating the water accumulated due to precipitation and discharge runoff at Vasna barrage down stream side of the Ahmedabad city. Sabarmati River is passing through Sabarkhantha district, Mahesana district, Gandhinagar district and Ahmedabad district. In the study area 14 rain gauge station and 4 temperature Station are used. The rainfall data are used from the year 1998 to 2005 for the research. The average rainfall of the study area is 669.9 mm.

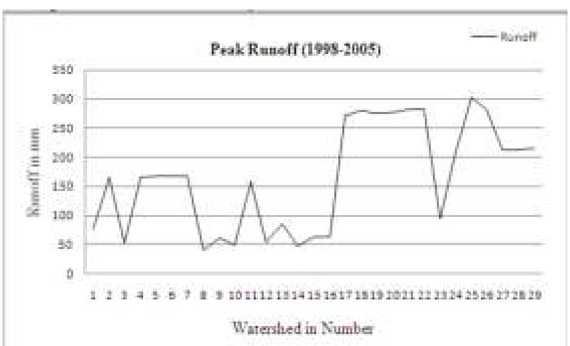

Fig. 3 Peak runoff from 1998-2005

SWAT Model divide watershed area in to 29 HRU. The HRU is considered to be homogeneous, having distinct hydrological response. The distinction can be made on the basis of vegetative cover, soil type, slope and aspect and useful for watershed management. Model simulates all HRU and gives a surface runoff of each 29 HRU. Surface runoff might be changed when the rainfall intensity changed and also prediction of flood and change of vegetation cover and soil erosion of HRU.

It was observed that watershed 25 leads 302.6 mm runoff where as the watershed 8 leads 38.93 mm runoff which the least among other watersheds.

V. CONCLUSION

This study demonstrates the integrated use of remote sensing and GIS for development of a watershed and for evaluation of its hydrologic response, to various land use and management changes. The spatial analysis of thematic information, which can be derived from remote sensing helps in the assessment of development plans before they are implemented in the field. This approach is thus an effective tool for selection of the best management plan to be implemented.

The SWAT model used on Sabarmati River to calculate the flow at Vasna Barrage. The SWAT hydrological model successfully used to calculate surface runoff of each HRU individually of study area. SWAT model generate automatically delineate the watershed and 29 HRU was generated. The effect of various method of PET like Hargreaves Method, Panman-Monteith Method and Priestley-Taylor Method are seen through various run made by changing the appropriate option. The sensitivity analysis was done by changing the number of rain gauge station in the catchments area. Model is found very sensitive to this change and responded very sharply.

The study is useful to predict surface runoff at Vasna barrage if there is any change in rainfall intensity or watershed management practices with respect to change in land cover or soil erosion which can be monitored on sub watershed basis or HRU basis.

IV. ACKNOWLEDGEMENT

Authors wish deepest gratitude to Mr. Yogesh Patel, PG scholar, LDCE for providing the valuable help in computing work and also thanks to Dr P. P. Lodha for their continuous guidance for modeling work. Also thanks to Prof. M. B. Dholakia, Principal, LDCE for the necessary software and utility support through out the work.

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