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SIMULATION OF RUNOFF FOR AN EXPERIMANTAL WATERSHED USING SWAT

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***Abstract*- Assessment of rainfall runoff for an event given is a challenging task due to various controlling factors. Many computer depended hydrological model have been developed for simulation of runoff in watershed and water resource studies. In this study, Soil Water Assessment Tool (ArcSWAT) an extension tool has been used to simulate runoff process in Walnut Gulch watershed located in Arizona, USA over sub hourly base. For computing infiltration, excess rainfall conversion to runoff and flow routing, methods like Green and Ampt method are adopted and the sensitive parameters that influence the model are identified. The model has been calibrated and validated for the five rainfall events. From the results obtained, we can assume that the ARCSWAT model has performed satisfactorily for the runoff simulations for differed rainfall events.**

***Index Terms* - GIS, ARCSWAT, Runoff Simulation.**

I. INTRODUCTION

Water is a mostly occupied and less available resource on the earth. Hydrology is a science which deals with the physical and chemical properties of water and their interaction with people, living things and their surroundings. Due to Increasing in the population leads to increase in the demand of natural resources such as water, land and forest. Among these water plays an important role in daily life. As the water resources are degrading day by day it essential to store and maintain the resource properly. In order to reach present demands and to attain sustainability systematic management techniques are to be used. A study on water resource plays an important role in solving the problem related to the water. Hydrology is a part of the water resource engineering which includes the study on quality, formation, transportation and accumulation of water on Earth, and also deal with all the sources of water present above and under the earth surface.

The formation and circulation of water is explained in terms of the hydrologic cycle, it is a continuous process. Hydrology cycle explains about the movement of water present on above and beneath on the earth's surface. The water availability on the earth surface is demonstrated in a cyclic order, mentioned as the Hydrology cycle. The Hydrology cycle is a combined classification of Evaporation, Precipitation, Condensation, Infiltration, Interception and Surface Runoff.

⇨ Green-Ampt method:

This method is developed to predict the process of infiltration in the region by assuming the excess of water present on the surface. This equation is developed by considering the soil profile is homogenous and the moisture is uniformly distributed over the wetting front. This model considers the wetting front saturated completely and there is a great break in the moisture content in the wetting front. The Green and Ampt method is used to determine the surface runoff by incorporating in to swat. This model requires the sub daily precipitation data of the event

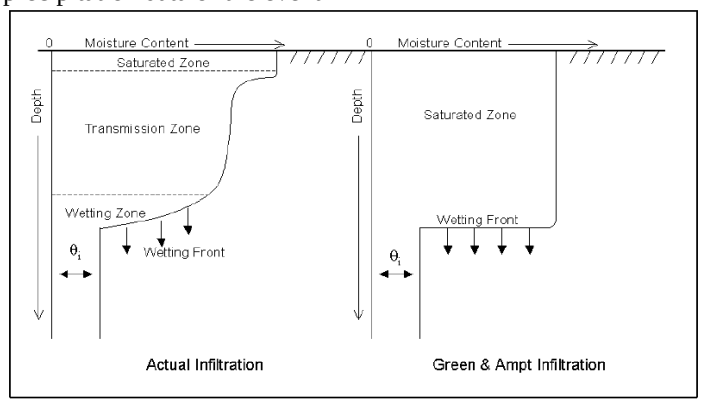


Figure 1- Infiltration process by Green and ampt method

The Green-Ampt Mein-Larson infiltration rate is defined as

$$f_{inf,t} = K_e \cdot \left(1 + \frac{\Psi_{wf} \cdot \Delta\theta_v}{F_{inf,t}}\right)$$

Where

- F_{int}= infiltration rate at time t(mm/hr)
- K_e = effective hydraulic conductivity (mm/hr)
- Ψ_{wf} is the wetting front matric potential(mm)
- $\Delta\ \theta v$ is the change in volumetric moisture content across the wetting front(mm/mm)
- $F_{inf=}$ is the cumulative infiltration at time (t)

⇨ **GIS and RS**

Remote sensing is an advanced surveying tool which is used to get information about the earth surface in the form of images with different resolutions. Remote Sensing works on the photogrammetric principles. One can obtain different sorts of information such as land use and land cover, soil and their textures, oceanography, stream networks, road networks and climatic data, based on the problem, the information will provided

GIS (geographical information system) is tool which is used to collect, store, manage and manipulate the spatially distributed data. Integration of GIS and remote sensing is used to determine problems related to the spatial data. Because of effectiveness and availability involved with spatial data analysis, GIS is making its way in different fields. It is used as decision making tool, management tool, analysis tool with respect to time and space. Hence it is a perfect tool to maintain and model the features related to the hydrology. Hydrological modeling consists of the ground water modeling and surface water modeling. Surface water modeling includes run off model, hydrological transport model, watershed model etc.

SWAT implies soil water assessment tool which is used to deal with the continuous process with specific time step. This tool effectively used for simulating rainfall and runoff, water quality, sediment yield and evapo-transpiration of a watershed region. Swat is used for validation purpose and to identify the sensitive parameters, which affect the runoff in the region. This process is based on water balance equations.

$$SW_t = SW_0 + \sum_{i=1}^{t} \left(R_{day} - Q_{surf} - E_a - w_{seep} - Q_{gw} \right)$$

- Where, SW_0= initial soil water content
- SW_t= final soil water content on the day i.
- t = time in days.
- R_{day}= water loss on day i from precipitation on the day i
- Q_{sur} =surface runoff
- E_a=evapotranspiration
- w_{seep}=loss to vadose zone
- Q_{gw}=return flow

II. STUDY AREA

Present study area is a sub watershed in an experimental watershed region called walnut gulch. South west research center conduct the real time experiments in prior to knowledge the technology to conserve water and soil in semi-arid regions. It is an Experimental Watershed which is the most densely gauged and monitored semiarid rangeland watershed in the world and is critical to improving scientific understanding of semiarid ecosystems. The Walnut Gulch Experimental Watershed spread over a area of 150 square kilometers in southeastern Arizona, U.S.A. that surrounds the western town of Tombstone (31º 42'N, 110º03'W). The watershed is locateded within the upper San Pedro River Basin which encompasses 7600 square kilometers in Sonora, Mexico and Arizona. The watershed represents approximately 60 million hectares of brush and grass covered rangeland found in and around the semi-arid southwest and is a transition zone lies within the Chihuahuan and Sonoran Deserts. Elevation of the watershed ranges from 1250 m to 1585 m MSL.

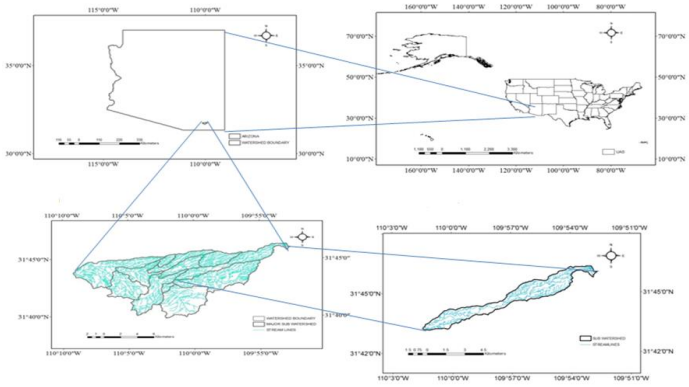


Figure 2- Study Area

III. METHODOLOGY

Present study is a simulation of the rainfall and runoff modeling of an experimental watershed using soil water assessment tool (SWAT) for a sub hourly time step. It explains about the micro level characteristics of the watershed features. It is used to estimate sensitive parameters which affects the runoff in the region and also helps to find the efficiency of the watershed.

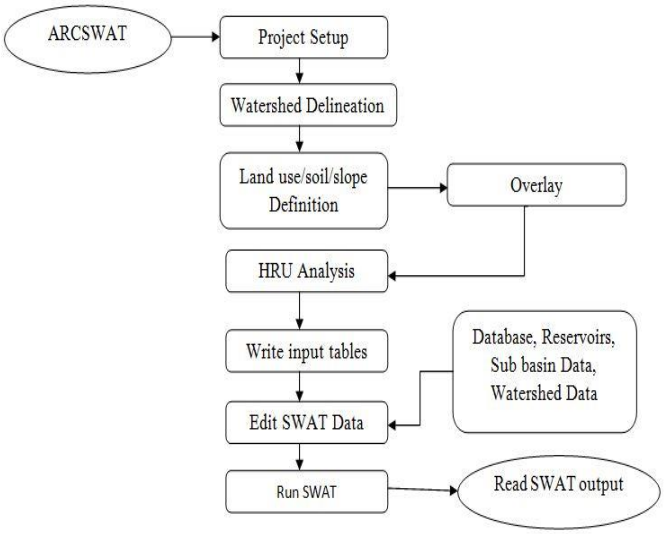


Figure 3-SWAT Methodology

Data sets required

- DEM (digital elevation model)
- Streamline data
- Vegetation data
- Soil data
- Hydrological data

In the starting step, a project setup file is created for the analysis work, for which we add data required such as base map of the study area, Dem map, vegetation map and soil map. Basic operations are done in this step according defined problem. Some of the operations are clipping, masking, conversions of vector to raster forms and some spatial analyst operations. This step is also called as pre processing.

Watershed is an area that allows water to the outlet during a rainstorm. Boundary of watershed-consisting of the line drawn across the contours connecting the highest elevations surrounding the basin. A common goal in hydrology is the watershed delineation with the help of a topographic map. This process can have be by using the computer based models and input files for this models are DEM. Digital Elevation Model (DEM) store topographic data in the form of grid cells. Genarally, these grids are having a resolution of 30 meters or less and with an elevation intervals of 1 meter. Using a DEM in a Geographical Information System (GIS), we can conduct digital terrain analysis (DTA) like calculating flow lengths, slopes, and can delineate watershed boundaries and stream networks.

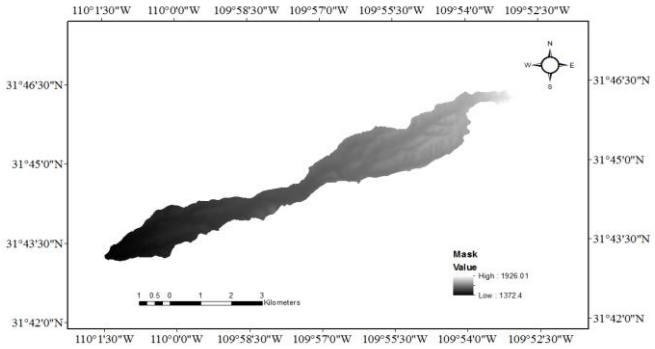


Figure 4- DEM map

In the present model water shed delineation is done by using the Dem map. In this process watershed region is sub divided to small catchments depending up on the elevation maps. This process streams, reach, monitoring points based on the Dem map and selected outlet. The output from this process creates a basic flow structure. This flow structure is an input of running simulations. The tool's functions are divided into five sections, namely:

- ⇨ Setup of DEM,
- ⇨ Definition of DEM,
- ⇨ Defining of Inlet and Outlet points,
- ⇨ Selection of Watershed Outlet(s) Definition,
- ⇨ Calculation of sub basin parameters.

After completion of all the steps it creates a basin around the delineated streams and also creates monitoring point at the intersection of the sub stream to the main stream. Sub basins are creating an in the basin according to the sub stream and outlet we selected.(fig.5).

- **HRU ANALYSIS**

HRU means hydrological response unit. It is a representation of the all the surface characteristics such as land use, soil data and slope in a single unit. In Each unit is all characteristics evenly distributed in order to improve the performance of the model. If the surface parameter is considered the separately we need to consider each and every properties of the parameters of the required area. It will increase the complexity of the model. Hence we combine all the parameters in to single which consists of lumped value of the all the parameter while simulation of it will consider the lumped value of the unit. Before preparing the HRU map we need to prepare the land map, soil map and slope map of the study area. These maps are prepared by using the vegetation data and soil data of the region. First we need to convert all the vector features to raster format. Then we need to reclassify the properties of the parameter according to our standards. By using the edit swat database. We need to create a separate data base of our standard. The behavior of the model mainly depends up on the hydrological parameters of the database. Hence all physical process in the hydrological cycle will depends of these parameters. The final output map(fig.6) of the HRU analysis will the input map for the simulation

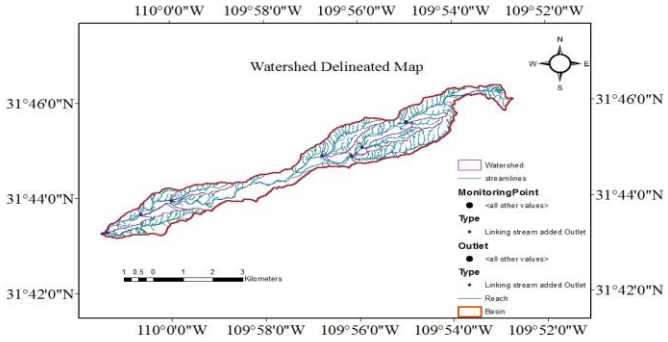


Figure 5- Watershed Delineation Map

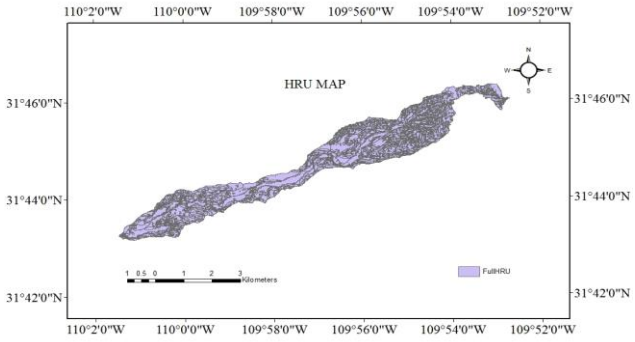


Figure 6-HRU Map

For rain fall and run off modeling basic input files are precipitations file. A rain fall runoff model explains the quantitative relation between the inlet of water and out flow.

This can be estimated by using the precipitation data.
We have chosen five events which are having continuous flume data. Because in the present study we are conducting the simulation on sub daily basis so in this case non continuous events may lead to the error in the simulation.
In swat input, files should be in a systematic way either this should be in the .txt format or in the form of the tables. If the input files are not in the format, then simulations cannot be processed. Two types of the txt files are to be created.

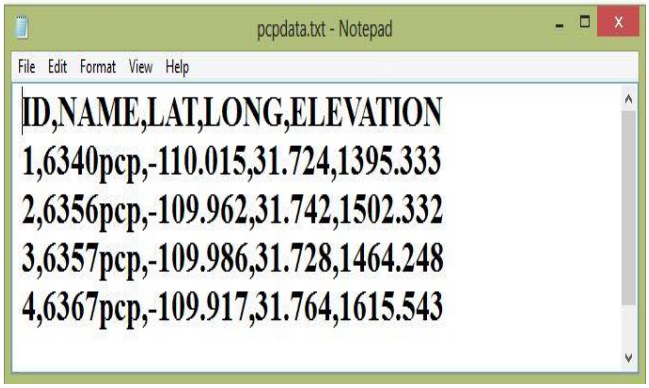


Figure 7- pcp text file

First consist of basic information such as latitude, longitude, and elevation of the rain gauge with a specified time step
Second file consist of date, time, year and precipitation data. These two files are inter linked with a relation .
In the above figure "1" indicates the Id of the rain gauge station, 6340pcp indicates precipitation values of the particular rain gauge and rest of information gives the details of latitude, longitude and elevation of the rain gauge.
The final step of the model is the SWATRUN. It deals with the date of simulation and on what time step basis the simulation is carried out. Simulations are by considering the delineation map, hydrological features in the HRU map and precipitation data. Swat model consider some of the default value which are not present in the data based. Hence the results of the simulation may on show the original values of the physical process. in order to correct the process or to reduce the error present of the model. It should be calibrated and validated. Calibration can be done by using manual calibrate helper in the swat run or by other techniques

IV.RESULTS AND DISCUSSIONS

Calibration is method of correction of model by considering the standard results. While processing the swat some data should be given as input files. This data base may or may not consist all the files required for the simulation. In this case SWAT consider some default value assign in the user define functions this may lead to the errors in output files. In order to get optimal parameters of the model calibration is by using manual calibration helper. This process is adopted to adjust parameter related to the hydrology of the catchment. The previous flume data is calibrating the model. Hydrological consists of many processes such as evaporation, condensation, infiltration and surface run off and these process are depends of the physical parameters of the watershed .by changing these values calibration can be done. These parameters have great influence on the result.
Walnut gulch sub water shed region is calibrated by using five continuous rain storm events over period of 2000-2015 on sub hourly basis. Continuous events are selected because as the simulations are done on micro level the discontinuity of the event may leads errors in results. This region is semi-arid land consist of grass land and shrub tress with mostly occupied by sandy loam and fine loam hence surface runoff or base flow is mainly relied on the surface properties. According to the surface texture of the region and their hydrological properties four parameters are adjusted to bring the simulated value close to the observed value. These parameters Effective hydraulic conductivity of the channel(CH_K1,2), saturation d hydraulic conductivity(SOL_K), Manning's value of main channel (CH_N1,2), Available water content((AWC). They are sensitive parameter of this model.

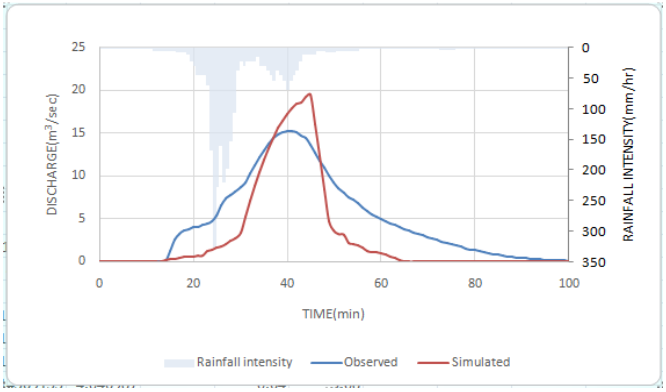
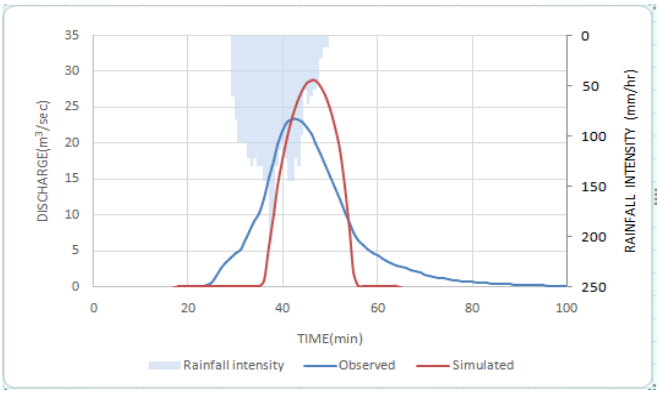


Figure-8(a)



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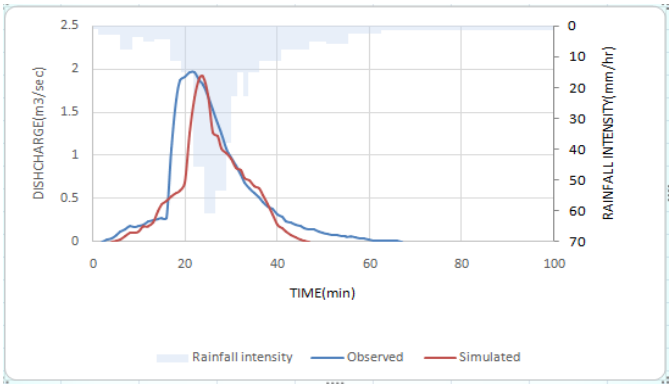

Figure-8(c)

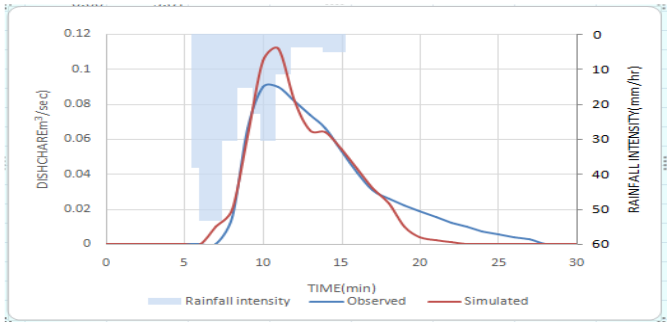

Figure-8(d)

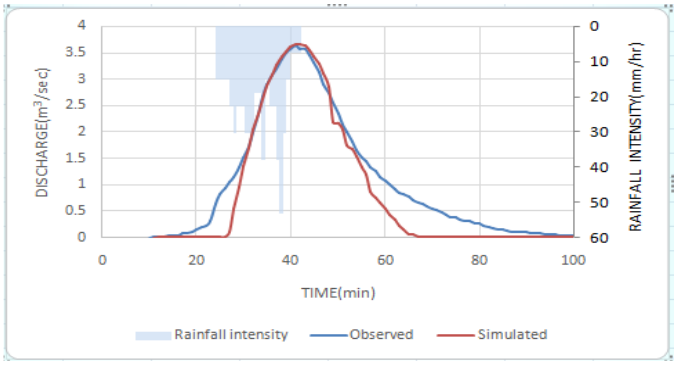

Figure-8(e)

Figure shows Observed and simulated hydrographs generated by using SWAT of walnut gultch watershed on (a)Aug 6, 2000, (b)Aug4,2002, (c)Aug 15,2006, (d)Aug 9,2008, (e)July30,2010,

Rain fall event	Volume of runoff mm		Error %
	Observed	Simulated	
08-06-2000	1.41	1.89	14.5
08-04-2002	1.42	3.08	36.8
08-15-2006	0.27	0.68	33.6
08-09-2008	0.012	0.016	14.2
07-30-2010	0.19	0.38	33.3

Rain fall event	Peak runoff m^3/sec		Error %
	Observed	Simulated	
08-06-2000	15.25	18.60	9.89
08-04-2002	22.95	28.4	10.6
08-15-2006	3.57	3.66	1.2
08-09-2008	0.089	0.11	2.1
07-30-2010	1.95	1.91	4
Rain fall event	Time to peak (min)		Error %
	Observed	Simulated	
08-06-2000	1216	1218	0.082
08-04-2002	793	797	0.25
08-15-2006	1128	1130	0.085
08-09-2008	1018	1021	0.14
07-30-2010	1131	1133	0.088

Table showing Simulated Results

V. CONCLUSION

Present paper focus on application of swat model on estimation of runoff on sub hourly basis and studying the efficiency of the model on micro level simulation and also identification of sensitive parameters of the model. A micro level simulation has been applied on the walnut gulch watershed, USA .The efficiency of the model is calculated by comparison of the simulated results with the observe values. Calibration and validation of the model is done with help of SWAT tool. Form the present study it is identified that the SWAT is less efficient on sub hourly basis when compared to the hourly, daily, monthly and yearly basis and more accuracy is required in the case of parameters, these parameters are very sensitive in the case of sub hourly basis runoff .minute variation of the parameters shall influence the entire process. This type of model can be useful to estimate the problem and parameters that influence the hydrological cycle on micro level.

IV. ACKNOWLEDGMENT

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