Journal of Civil Engineering and Environmental Technology
Print ISSN: 2349-8404; Online ISSN: 2349-879X; Volume 2, Number 5; April-June, 2015 pp. 406-411

http://www.krishisanskriti.org/jceet.html

# Watershed Management of Rushikulya River using GIS

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**Abstract—***Intervention of nature by human activities in the form of development and encroachment of forest land due to increase in population has lead to increase of natural calamities. The present study is done with the aim of addressing the causes of draught and flood in state of Odisha, India with respect to existing watershed management. GIS technology affords the basis to solve these problems where distributed data were collected, simulated and used to prepare model input files and estimate model results. GIS-based tools(Arc-SWAT) could be used successfully to illustrate the effects of land use practices on runoff, and to support watershed land use management judgments. The technique systematizes the process of converting frequently available GIS data to input parameter files for the SWAT hydrologic model. Input parameters for this model were achieved using GIS-SWAT in combination with available topographic, land cover and soil data. In this work a simple application of above technology is applied for RushikulyaRiver of Odisha. Modelling result reveals that during month of July-October the flow is maximum due to monsoon weather causing flood and for the remaining period the flow is very less causing draught. Simulation gives good results with coefficient of determination ($R_2$) as 0. 86and Nash-Sutcliffe Index (NSI) as -0. 27. We anticipate that the result obtained here will help investors and decision makers for better planning and management of watersheds in Odisha.*

**Keywords:** *SWAT modeling, Runoff,Rushikulya River Watershed.*

## 1. INTRODUCTION

Soil and water are both indispensable components in a watershed for balancing ecosystem, Approach for the effective management of watershed regions for controlling flood, irrigation, electricity, drinking water, rehabilitation of deteriorating land, to manage and utilize run-off waters,improving and increasing the production of timbers, fodder and wild life resources,checkingsoil erosion and reducing the effect of sediment yield is urgently needed. Watershed management in the developing countries is in state of deprivation due to their mismanagement and underprivileged technology. Soil and Water are two basic necessary assets of a watershed for the sustaining of ecosystem and controlling its social and economic life. Designing and implementing environmentally friendly, socially and financially sound watershed resource management requires long-term, reliable hydrologic information. Effective watershed management requires the integration of knowledge, data, simulation models, and expert judgment to solve practical problems. Poor availability of comprehensive and good quality hydrologic data leads to unsound planning and inadequate design and operation of water resources projects.

Among the crush list, Watersheds of Odishaaregreatly mismanaged for which it is highly affected every year by flood and drought damaging many ecological life and economy of the state. Though many rivers are flowing through the different part of the Odisha and touches every corner of human life, but improper management of water and soil makes very hectic life of people. The watersheds could be widely used for the benefits of Odisha people for the purpose of drinking water, cultivation, irrigation, electricity, domestic/industrial use, fishing and transportation. The sustainable distribution of its resources and the process of creating and implementing plans, programs, and projects to sustain and enhance watershed functions that affect the plant, animal, and human communities within a watershed boundary is very important. Manyissues, such as sedimentation, ecological degradation, and pollution, are also associated with soil erosion, and may affect aquatic and coastal ecosystems as well (George & Leon, 2007). Land mismanagement can often be attributed to the lack of understanding of the impact of human activities on soil and water resources since watershed stakeholders do not have a tool to investigate the impact of proposed activities.

In recent years, distributed watershed models have been increasingly used to implement alternative management strategies in the areas of water resource allocation, flood control, impact assessments for land use and climate change, and pollution control. Many of these models share a common base in their attempt to incorporatethe heterogeneity of the watershed and the spatial distribution of topography, vegetation, land use, soil characteristics, rainfall, and evaporation. Such models include ANSWERS, agricultural nonpointsource (AGNPS) (Young et al. 1987), Hydrological SimulationProgram-Fortran (HSPF), European hydrological system(MIKE SHE) (Abbott et al. 1986), and Soil Water

Assessment Tool (SWAT). Among these models, the physically based distributedmodel SWAT is well established for analyzing the impacts ofland management practices on water, sediment, and agriculturalchemical yields in large, complex watersheds. SWAT has been successfullyused by researchers around the world for distributed hydrologic modelling and management of water resources in watersheds with various climate and terrain characteristics. In this work SWAT model has been applied in RUSHIKULYA river watershed to predict surface runoff under existing land management practices and also assessed

### 1. 1 SWAT Model Application

The major component of SWAT is Subbasin, Reservoir routing and Channel routing. The Subbasin component consists of following subcomponents, such nutrients, agricultural management, crop growth, hydrology, weather, sedimentation, soil moisture, and pesticides. The hydrology subcomponent, in turn, includes surface runoff, lateral subsurface flow, percolation, groundwater flow, snowmelt, evapotranspiration, transmission losses, and ponds. Detailed descriptions of the methods used in modeling these components and subcomponents can be found in Arnold et al. (1998), Srinivasan et al. (1998), and Neitsch et al. (2002/2005a).

Precipitation and stream flow data from three nested sub watersheds within the Little Washita River Experimental Watershed (LWREW) in southwestern Oklahoma were used to the capabilities of the model to predict stream flow under varying climatic conditions. Eight years of precipitation and stream flow data were used to calibrate parameters in the model and 15 years of data were used for model validation. SWAT was calibrated on the smallest and largest sub-watersheds for a wetter than average period of record. The model was then validated on a third sub watershed for a range in climatic conditions that included dry, average, and wet periods (Van Liew et al 2003b).

In another study, SWAT model has been successfully implemented to identify those areas of watershed prone to critical erosion for controlling the soil and nutrient losses (Tripathy et al, 2003, 2006). In that study, the model was used for a small watershed (Nagwan) and used for identification and prioritisation of critical sub-watersheds to develop an effective management plan. The topographical map, soil map, land resources data and satellite imageries of the study watershed were used.

SWAT 2000 (Arnold et al) watershed model was utilized to simulate the transport of flow, sediments and phosphorus to the Canyonville Reservoir in Upstate, New York. The available datasets for model development,particularly the phosphorus input and water quality calibration data, in this case study are unique because of the large amount of watershed specific, spatially and temporally varying data that are available for model development(Shoemaker et al 2007). The model has been implemented successfully to simulate all related processes affecting water quantity, sediment and nutrient loads. Their study provided excellent results for discharge and sediment yield.

The newest version of Soil and Water Assessment Tool (SWAT2005), coupled with a GIS interface (AVSWATX), was applied to Kosynthos River watershed located in North-eastern Greece (Tsihrintzis et al 2010). Using this model the runoff and nutrient concentrations measured at four monitoring sites located within the main tributaries of the Watershed has been studied. The validated model was also used to test the effect of several land use change and crop management scenarios in runoff and nutrient loadings. The study showed that SWAT model, if properly validated, can be used effectively in testing management scenarios in Mediterranean watersheds.

SWAT has been employed to model the amount and dynamics of nitrate leaching from a typical crop rotation in this watershed was studied. The objective of this study was to investigate the temporal and spatial variability of nitrate leaching in Hamadan–Bahar watershed (Abbaspourc et al 2010).

SWAT-IRRIG model has been calibrated and validated for the first time that reproduces well the irrigation return flows (IRF) when the irrigation source is outside of the watershed (Skhiri et al 2013). The application of this SWAT version in intensive irrigated systems permits to better evaluate the best management practices (BMPs) in such systems. This paper evaluates several BMPs on IRF, total suspended sediment (TSS), organic P (ORG_P), soluble P (SOL_P), and total P (TP) at the outlet Del Reguero stream watershed (Spain).

Distributed hydrological model “Soil and Water Assessment Tool” (SWAT), the freshwater availability is quantified for a 4-million $km^2$ area covering some 18 countries in West Africa (Yanga et al 2008).

## 2. MATERIALS AND METHODS

### 2. 1Background of Study Area

The Rushikulya is one of the major/important rivers of Odisha state and covers entire catchment area in the districts of Kandhamal and Ganjamof Odisha. The total catchment area is of about 8963 Sq. km. TheRushikulya originates at an elevation of about 1000 m from Rushimala Hills near Matabarhi village of Kandhamal district which lies within the geographical coordinates of 19. 07 to 20. 19 north latitude and 84. 01 to 85. 06 east longitude. It meets the Bay of Bengal at PurunaBandha of Chhatrapur block. Its tributaries are the Baghua, the Dhanei, theBadanadi.

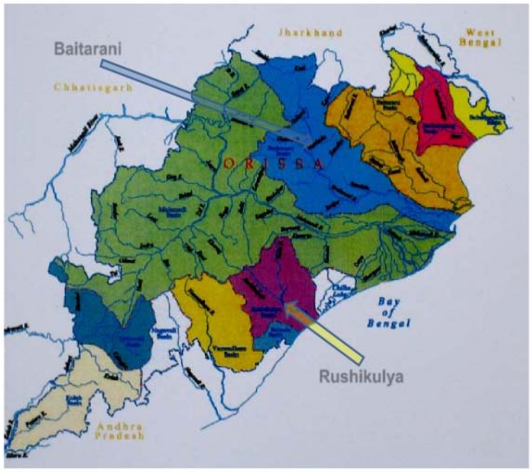


**Fig. 1: Rushikulya River Watershed**

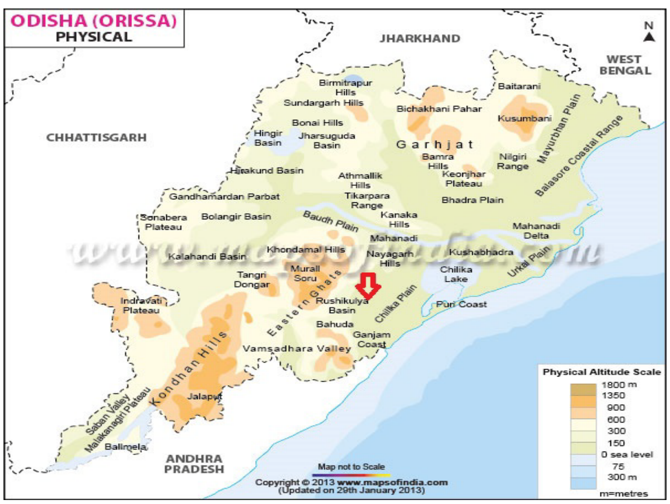


**Fig. 2: Geographical map of Odisha**

## 2. 2 Brief Description of SWATTheory

In SWAT, a watershed is divided into multiple sub basins or sub watersheds which are further discretized into units of unique soil/land use characteristics called hydrological response units (HRUs). These HRUs are defined as homogeneous spatial units characterized by similar geomorphologic and hydrological properties (Flugel 1995). In SWAT,HRUs are composed of a unique combination of homogeneous soil properties, land use, and slope. By partitioning the watershed into sub watershed, the user able to refer different areas of watershed to one another spatially. No matter what problem is studied with SWAT, water balance is the driving force behind everything what is happening in watershed. To accurately predict the movement of pesticide, sediment and nutrients the hydrological cycle as simulated by the model must conform what is happening in the watershed. Simulation of hydrology of a watershed can be separated into two major divisions. The first division is **the Land phase of hydrological cycle**and the second division is the **Routing phase of hydrological cycle.**

The land phase of hydrological cycle controls the amount of water, sediment, nutrients and pesticide loading to the main channel in each sub basin or sub watershed. The hydrologic cycle as simulated by SWAT is based on the water balance equation.

$$SW_t = SW_0 + \sum \sum_{i=1}^{i=t} (R_{day} - Q_{surf} - E_a - W_{seep} - Q_{lat} - Q_{gw})$$

Where;
$SW_t$= final soil water content (mm $H_2O$);
$SW_0$= initial soil water content on $i^{th}$day (mm $H_2O$);
t = time (days);
$R_{day}$ = amount of precipitation on day i(mm $H_2O$);
$Q_{surf}$= amount of surface runoffoni$^{th}$day (mm $H_2O$);
$E_a$= amount of evapotranspiration on $i^{th}$day (mm $H_2O$);
$W_{seep}$= amount of water entering the vadose zone from the soil profile on $i^{th}$day (mm $H_2O$);
$Q_{lat}$= lateral flow from soil to channel;
$Q_{gw}$= amount of return flow on $i^{th}$day (mm $H_2O$).

Once SWAT determines the loadings of water, sediment, nutrients and pesticides to the main channel, the loadings are routed through the stream network of the watershed using a command structure. In addition to keeping track of mass flow in the channel, SWAT models the transformation of chemicals in the stream and streambed. Channel routing is simulated by using the variable storage or Muskingum routing equation. For climate, SWAT uses the data from the station nearest tothe centroid of each subbasin.

Surface runoff from daily rainfall is estimated by using a modified soil conservation service (SCS) curve number method, which estimates the amount of runoff based on local land use, soil type, and antecedent moisture condition. Groundwater flow contribution to total stream flow is simulated by routing a shallow aquifer storage component to the stream (Arnold and Allen 1996). Three methods can be used to estimate potential evapotranspiration: the Penman-Monteith method (Monteith 1965), the Priestley- Taylor method (Priestley and Taylor 1972), and the Hargreaves method (Hargreaves and Samani 1985), depending on data availability

## 2. 2. SWAT Inputs

### 2. 2. 1. Digital Elevation Model

In order to delineate the watershed the measure input data include the digital elevation model (DEM) of the watershed by knowing the latitude and longitude of that area. The DEM was downloaded from source ASTER GDEM version -2 (Tachikawa et al. ,2011)(http://gdem. ersdac. jspacesystems. or. jp/search. jsp) with 30 meter resolution and was used for terrain analysis, including watershed and river network delineation.

### 2. 2. 2 Digitized drainage network.

The stream network was downloaded from Hydrosheds version-1. 0(http://hydrosheds. cr. usgs. gov/dataavail. php). In this work the stream network for the South Asia zone was downloaded first and then the Rushikulya river network was clipped from that entire network using Arc-GIS -10. 1.

### 2. 2. 3 Land Cover Data.

In this work the land cover data was downloaded from the USGS Land cover Institute (LCI)(A. Gutierrez,J. Seijmonsbergen,A. CDuivenvoorden 2012)(http://landcover. usgs. gov). First the land cover of whole South Asia zone was downloaded and the area of Rushikulya watershed was clipped from that zone by using the clip tool bar in Arc-GIS 10. 1 The area of the land classified into Tropical Semi Evergreen, Tropical Moist Deciduous, Tropical Dry Deciduous,Degraded Forest , Thorn Forest/Scrub (Southern), Irrigated Intensive Agriculture , Irrigated Agriculture ,Rainfed Agriculture and Barren . Further according crop databases of SWAT 2012 the land was reclassified into FRSE( Forest Semi evergreen),FRSD,( Forest Decidous),FRST(Forest mixed) ,AGRL( Agricultural land) and BARR( Barren) as per requirement of SWAT input file.

### 2. 2. 4 Soils Data

The Digital Soil Map of the World (DSWM) was used for modeling. The DSWM was acquired from the Food and Agriculture Organization (FAO) website (http://www. fao. org/geonetwork/srv/en/metadata. show?id=14116) (FAO, 2003). The FAO soil classification is well supported by the usersoils database of SWAT. The soil vector type was converted to raster carrying the SNUM code in the attribute data. SNUM is a sequential code, unique for each Soil Mapping Unit, which links the first level of soil information to the expansion data file (FAO, 2003). The soils of the Rushikulya Watershed belongs to the following classification of FAO: Ao1-2bc-3642 (SNUM: 3642); Lf95-1a-3795 (SNUM:3795); Ne58-1bc-3830 (SNUM: 3830) and Ne58-1bc-6670 (SNUM: 6670).

### 2. 2. 5 Climate Data

Climate data such as rainfall, temperature, wind speed, humidity, and solar radiation are the meteorological data inputs in SWAT. In this work climate data for the catchment was acquired from The National Centers for Environmental Prediction (NCEP) Climate Forecast System Reanalysis (CFSR)(Easton et al. ,2013) website (http://globalweather. tamu. edu). The CFSR dataset consists of hourly weather forecasts generated by the National Weather Service's NCEP Global Forecast System. This dataset contains historic expected precipitation and temperatures for each hour for any land location in the world. Moreover, as the precipitation is updated in near-real time every 6h, these data can provide real-time estimates of precipitation and temperature for hydrologic forecasting Four station data near to the watershed was downloaded from that global database and used as swat input file. The SWAT Model can simulate missing weather data values, which corresponds to a -99 value in the dataset. Missing values are needed especially in weather datasets of one year of less. The warm-up period or the number of years skip (NYSKIP) is essential for better prediction of results. Without the warm-up period, the model tends to overestimate the result during the initial model simulation. On the other hand, SWAT Weather Generator Program (WGEN –CFSR world) was used to generate climate data for the Rushikulya River Watershed.

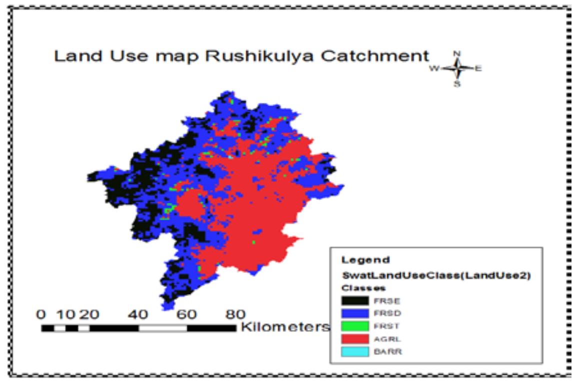


**Fig. 3: Land use map of Rushikulya River Catchment**

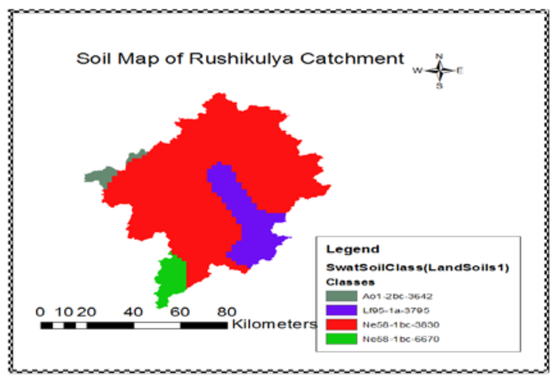


**Fig. 4: Soil map of Rushikulya River Catchment**

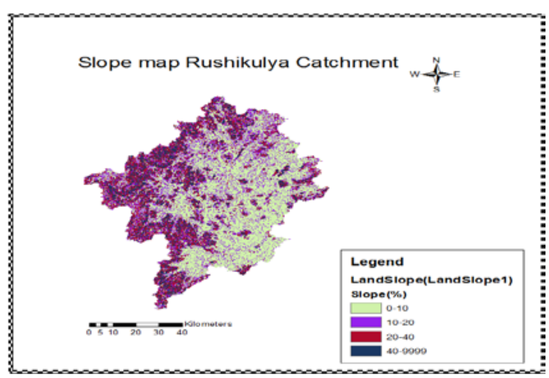


**Fig. 5: Slope map of Rushikulya River Catchment**

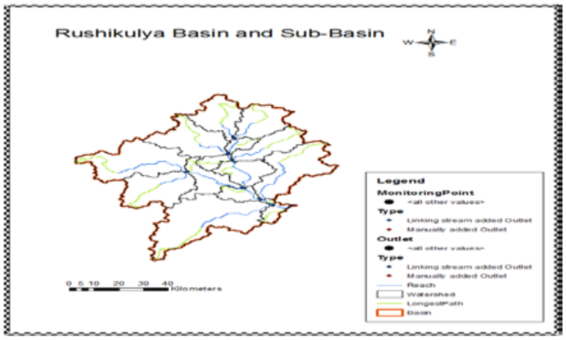


**Fig. 6: Map of Rushikulya basin and Sub-basin**

## 3. RESULTS AND DISCUSSION

In this work ArcGIS 10. 1 is used as framework for SWAT-2012. The first step of modeling process through Arc GIS 10. 1 is the watershed delineation. The key source is the DEM,(Fig. 7) which is used by the program to create the so-called flow direction and flow accumulation grids. They ensure the framework for the orientation of water movement through the basin and give the opportunity to delineate sub-basin from the user-defined point. Here Purushottampur station having 19. 506 N latitude and 84. 872 E longitudewas used as user defined point. Total surface runoff was calculatedat this point. We used DEM with 30 m cell size and digitized stream network for this whole watershed delineation. Based on its topography and existing stream network, the Rushikulyariver basinuptoPurushottampur Station was divided into 15 smaller hydro logically connected sub-watersheds The basin along with its sub-basins is shown in Fig. 8.

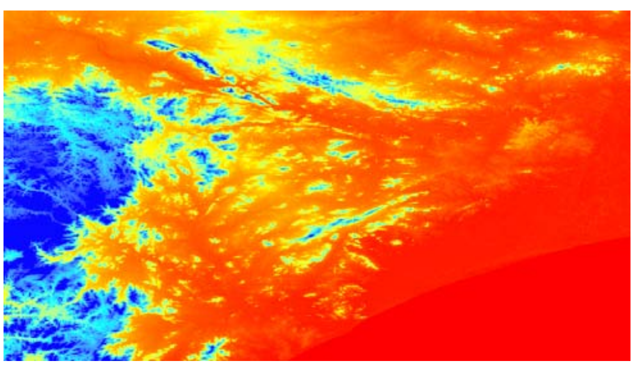

**Fig. 7: DEM Map of Rushikulya River**

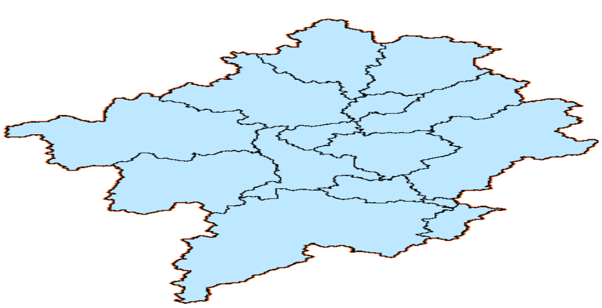

**Fig. 8: Delineated watershed with Sub basin of Rushikulya River**

In the second step, the basin is divided into model elements according to the land cover and soil properties. It requires availability of land cover and soil coverage with appropriate attribute data in order to be accepted by the program. A digitized soil information layer (FAO soil data base) and land cover data layer (the USGS Land coverdata base) were used for further sub-classification of areas in the watershed. All possible combinations of soil types and land use covering more than one percent area were included. Other model parameters such as length and slope of overland flow path andchannel geometry, which relate to physical dimensions of the watershed, were also calculated.

The third step of SWAT model, weather input file is prepared. Climate data such as rainfall, temperature, wind speed, humidity, and solar radiation data are used as inputs in SWAT. In this work climate data for the river catchment was collected from The National Centers for Environmental Prediction (NCEP) Climate Forecast System Reanalysis (CFSR), (Easton et al. 2013) The CFSR dataset consists of hourly weather forecasts generated by the National Weather Service's NCEP Global Forecast System. This dataset contains historic expected precipitation and temperatures for each hour for any land location in the world. Moreover, as the precipitation is updated in near-real time every 6h, these data can provide real-time estimates of precipitation and temperature for hydrologic forecasting. In this work four weather station was used nearest to the catchment for simulating the model. We used the Global weather generator(WGEN_CFSR world) to simulate the daily time-series of wind speed,solarradiation,and relative humidity. . The potential ET was computed using Penman-Monteith (Monteith, 1965) method. In the last step, the model was run fixing warm-up period 3 yeari. e, the number of years skip (NYSKIP). After running the model in monthly basis the following result was found. In this work the model has not been calibrated. But the simulated data is compared with the observed data.

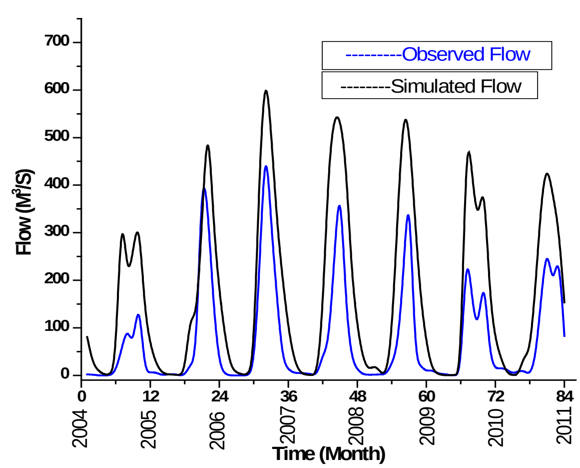


**Fig. 9: Monthly Flow from Year 2004 to 2010 at Purushottampur Station**

Since the model is not calibrated the simulated flow is higher than the observed flow. But the simulation gives good value of coefficient of determination (R2) which is about 0. 86, but Nash-Sutcliffe index (NSI) is -0. 27. So model needs to be calibrated for getting good value of NSI. From both graphs, it is observed that during the months of July, August, September and October the flow is generallyhigher and the flow for the remaining period is very less even some times remain dry. So from the above result we can reveal that Rushilukyariver needs good watershed management practices to avoid flood in coastal region during heavy flow and draught when flow is less or almost no flow. In the above analysis, the CFSR climate data is used.

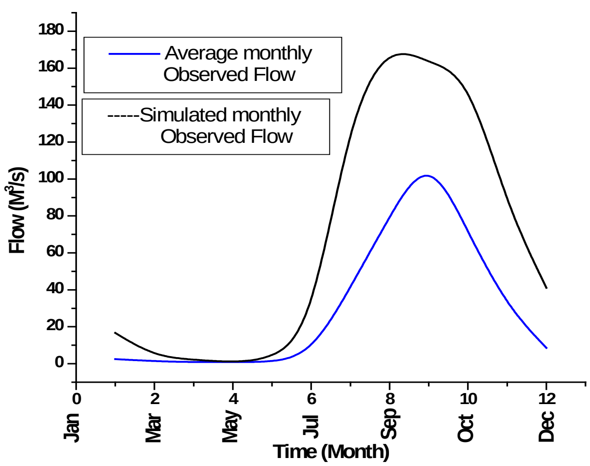


**Fig. 10: Average Monthly Flow from Year 2004 to 2010 at Purushottampur Station**

## 4. CONCLUSIONS

The SWAT model can be used as useful toolfor assessing magnitude of flood and draught expected in a catchment area based on climate data. The result of the present study showed that it is applicable in statesof Indian subcontinent like Odisha also. By using the model with available climate data, we can calculate the runoff from any river catchmentwhich is the major cause of flood. Accordingly, proper flood hazard management practices can be implemented in the catchment area. The obtained results of runoff of Rushikulya watershed simulation is acceptable. Further calibration, adjustment and validation would give more precise results and enhance the possibilities for floods and draught hazard assessment as well as their application in other fields of environmental investigations.

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