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HYDROLOGICALMODELINGWITHHEC-HMSINDIFFERENTCHANNELSECTIONSINCASEOFGANDAKIRIVERBASIN

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Er. Narayan Prasad Gautam

Abstract- The conceptual and physically based models can be categorized as lumped, semi-distributed and distributed. Lumped model treats the catchment area as one or more homogeneous land segments where the inputs are averaged. Distributed model explicitly represents the spatial variability by dividing the catchment into grids and modeling each grid cell individually. Semi distributed model is a conceptual model that bridge the gap between lumped and distributed models. It utilizes conceptual relationships for hydrological processes that are applied to several relatively homogeneous sub-areas of the catchment area. The main objective of this research paper is to assess the effect of channel geometry of basin at the outlet of basin in semi-distributed rainfall-runoff modeling and to determine performance of the different channel sections that will produce the best results for that basin. From study on the Gandaki river basin, the efficient section for routing depends upon the purposes of the simulating rainfall runoff process. Trapezoidal section is more efficient than other sections for determination of flood forecasting and both trapezoidal and triangular section is efficient for simulating to determine the total annual runoff volume.

Keywords: semi-distributed, geometry, modeling, simulation, Gandaki basin, trapezoidal section, routing.

I. Introduction

Hydrologic models have been developed to simulate the large river basin water supply, flood hydrograph and small urban or natural watershed runoff. The success of development projects (bridge, culverts and sewers) depends on the availability of accurate information describing the volume of runoff that a particular watershed will generate in response to a certain depth of precipitation falling on the basin. The aim of any watershed rainfall-runoff model is to provide a hydrograph showing the variation of volume flow rate of direct runoff over time at a particular point of interest, usually taken as the watershed outlet. Hydrographs produced by models are used directly or in conjunction with other software for the study of water availability, urban drainage, flood forecasting, future urban impact, flood damage reduction, floodplain regulation and systems operation[8] and the performance of hydrographs obtained in different channel section.

The conceptual and physically based models can be categorized as lumped, semi-distributed and distributed. Semi distributed models is a conceptual model that bridge the gap between lumped and distributed models. They utilize conceptual relationships for hydrological processes that are applied to several relatively homogeneous sub-areas of the catchment area[4]. Hydrological simulation could be performed using lumped to physically distributed hydrological models. Since lumped model has no physical meanings and distributed model is difficult and quite sophisticated as it requires large number of parameters, semi-distributed model with lesser set of available data is commonly used as it requires less number of parameters. Semi-distributed hydrological models generally have advantage of short calculation time, comparative low calibration needs and high model efficiency.

Spatial discretization either in terms of grid cell size or number of sub divisions of watersheds in hydrological modeling is an essential issue. The optimal spatial scale can be adapted to the modeling objectives for determination of the dominant hydrological processes (Dehotin and Brand, 2008). It has been observed that the sub basin scale have various effects on runoff simulation such as peak time, total runoff, temporal distribution of discharge, flow components and response processes [1]. Therefore, stabilized number of sub basin should be identified for the efficient simulation of hydrological behaviors of catchment using hydrological models. It is more cumbersome job to simulate the river basin considering the different geometries of channel section and various numbers of subdivisions of basin simultaneously and analyzing by semi distributed hydrological model. Definitely it increases the input data preparation effort and the subsequent computational evaluation[6]. The effect of watershed subdivision (or discretization) on the prediction accuracy of hydrological models on 12 watersheds was evaluated by Hromadka et al. (1988). They used a simple model based on the unit hydrograph method. Since most of rainfall runoff models achieve their greatest accuracy for smaller to medium sized watershed. It is beneficial to divide the main watershed into sub-watershed to increase the accuracy of model results.

Furthermore, stream flow may be significantly affected by the difference in soil, vegetation, land use or

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topography of the watershed and geometry of channel. The flow of water through soil and stream channels of watershed is a distributed process because the flow rate, velocity and depth vary in space throughout the watershed. Estimate of the flow rate or water level at important location in the channel system can be obtained using a distributed flow routing model. This type of model is based on partial differential equations (the Saint Venant equations for one dimensional flow) that allow the flow rate and water level to be computed as functional space and time.

Depending upon the drainage pattern, geometry of the channel and existence of dams, reservoirs, bridge etc. within the basin is to be routed during its journey to the watershed outlet to compute out flow hydrograph on the outlet reach. Stream flow may be significantly affected by the geometry of the channel of the stream. In this paper, Channel flow is simulated using a channel geometry relationship reflective of the natural channel shape. Alternative channels (Trapezoidal, rectangular and triangular) will be used to determine the output hydrograph of the given watershed at the end (outlet) of the basin. The simulated hydrographs will be compared with the observed hydrograph of the given basin at the outlet at different channel geometries (Rectangular, Trapezoidal and Triangular) on the routing process also finding the channel cross section of the stream give the best results.

II. Scope of the Study

The scope of this research paper, as per the objectives, contains application of the semi-distributed model to simulate the channel geometries on watershed. The study deals with pre processing and spatial analysis of the Digital elevation model (DEM) for the automated delineation of sub basins and river. GIS extension tools will be used for the extraction of physical characteristics of sub basin and rivers.

Required other model parameters such as daily precipitation, evapotranspiration are collected from department of hydrology and metrology of Nepal and analyze by thiessen polygon method. Hydraulic conductivity, suction head, initial moisture deficit and roughness coefficient are extracted on the basis of soil and land use map of the study area and these models parameters are used in HEC-HMS model simulation.

Hydraulic parameters are routed by using kinematic wave method for overland and Muskigum cunge method for channel routing. Simulated flow is compared with the observed flow at the outlet of the basin and analyzes the performance of the result to achieve the objective of the study[14].

III. Principle and Tools

a) Infiltration process

Infiltration is the vertical entry of the water into the soil surface and its subsequent vertical motion through the soil profile. It is the most important loss process. The major factors that influence the infiltration rates are soil texture, vegetation cover, the soil surface condition, land use, soil porosity, soil hydraulic conductivity and soil moisture content. Some of the popular infiltration models are the model developed by Green and Ampt (1911), Horton (1933, 1939), and Philip (1957).

Green and Ampt (1911) developed an infiltration loss model based on the physical theory in which the wetting front moves vertically downward. The wetting front is a sharp boundary dividing the soil with saturated moisture content from the underlying soil with lesser moisture content. The water moves vertically downwards from saturated soil to unsaturated soil. Horton (1933, 1939) developed an empirical equation for infiltration capacity based on the infiltration rate[15] begins at some rate fo and then decreases exponentially until it reaches a constant saturated infiltration rate fc Philip (1957) solved Richard's equation and proposed an equation to estimate the infiltration capacity.

b) Parameters for the Green & Ampt equation

Required parameters for the Green and Ampt model to estimate the excess runoff are the hydraulic conductivity of the soil at saturation, volumetric moisture deficit at the beginning of rainfall, and wetting front capillary action.

Table 3.1 : Green-Ampt infiltration parameter for various soil classes

Soil class	Porosity (η)	Effective porosity θ(c)	Wetting front soil suction head Ψ(cm)	Hydraulic conductivity K(cm/h)
Sand	0.437 (0.374-0.5)	0.417 (0.345-0.480)	4.95 (0.97-25.36)	11.78
Loamy sand	0.437 (0.363-0.506)	0.401 (0.329-0.473)	6.13 (1.35-27.94)	2.99
Sandy loam	0.453 (0.351-0.555)	0.412 (0.283-0.541)	11.01 (2.67-45.47)	1.09
Loam	0.463 (0.375-0.551)	0.434 (0.334-0.534)	8.89 (1.33-59.38)	0.34
Silt loam	0.501 (0.42-0.582)	0.486 (0.394-0.578)	16.68 (2.92-95.39)	0.65

Sandy clay loam	0.398 (0.332-0.464)	0.33 (0.235-0.425)	21.85 (4.42-108.0)	0.15
Clay loam	0.464 (0.409-0.519)	0.309 (0.279-0.501)	20.88 (4.79-91.10)	0.10
Silty clay loam	0.471 (0.418-0.524)	0.432 (0.347-0.517)	27.3 (5.67-131.5)	0.10
Sandy clay	0.43 (0.37-0.49)	0.321 (0.207-0.435)	23.9 (4.08-140.2)	0.06
Silty clay	0.479 (0.425-0.533)	0.423 (0.334-0.512)	29.22 (6.13-139.4)	0.05
Clay	0.475 (0.427-0.523)	0.385 (0.269-0.501)	31.63 (6.39-156.5)	0.03

Source: [1]

c) Routing

Routing is simply a method of translating the hydrograph in time and accounting for the hydrographs change in shape as it moves through the stream system. Hydrologic routing accounts for changes in the time distribution of volume and employs a relatively straightforward computation procedure. There are many methods available within the semi-distributed mode (HEC-HMS) as Clark unit hydrograph, Kinematic wave, Mod Clark, SCS unit hydrograph, Snyder hydrograph and User specified unit hydrograph. Among them kinematic Wave method is selected for both overland flow model and stream channel routing to accomplish the objectives of study.

For hydrograph routing, Kinematic Wave method is selected. Channel properties are extracted with the help of Geographical Information System (GIS) tool with the extension HEC Geo-RAS. Manning's roughness coefficient (n) is taken from the soil map.

d) Tools for model

i. *Arc view GIS*

GIS is a powerful tool for simulation and modeling of water resources engineering. Arc view GIS developed by ESRI that is equipped with excellent graphical user interface that enables visualization, exploring and the analysis of spatial data[2]. it has capable of displaying, viewing, editing vector dataset also the facility to display tables, charts, layouts associated with the shape files. The processing, modeling, visualization and interpretation of grid based raster data can be performed using the spatial analyst extension[2].

ii. *HEC-GeoHMS*

HEC-GeoHMS uses DEMs to determine watershed boundaries and flow path by analyzing the direction of steepest descent at each gird cell also watersheds are automatically defined by HEC-GEOHMS based on the user defined threshold for water shed size and at stream confluences. The user can manually add a watershed by defining an outlet on the stream network[3], and user can merge connected watershed. It creates the basic input for the HEC-HMS.

iii. *HEC-GEORAS*

For implementing the kinematic model in HECHMS the description of channel shape (triangular, rectangular or trapezoidal), principle dimension of channel cross section and channel side slope. HEC-GeoRAS is an ArcView GIS extension specifically designed to process geospatial data for use with the Hydrologic Engineering Center's River Analysis System (HEC-RAS). To create the import file, an existing Digital Terrain Model (DTM) of the river system in the TIN (Triangulated Irregular Network) format is required.

IV. Study Area

a) Description of Study Area

Gandaki river basin called also Narayani river basin of Nepal is situated in the Western and Central development Region between latitudes 27.63 N to 29.87N and 82.83 E to 86.79 E. It has the elevation from 73 m to about 7163 m which extends from the Himalayan range to the Nepal to India border.

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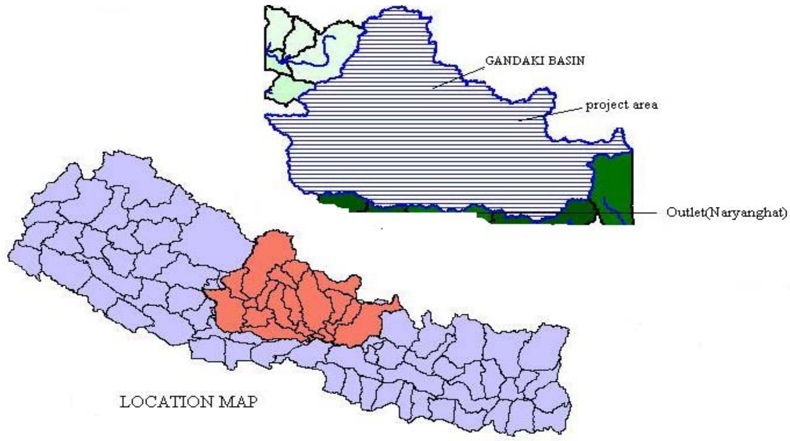

Fig. 4.1 : Location Map of the study

It covers 19 districts of Nepal and some area of China also. The catchments area of the basin is 30162 sq Km in Nepal and 10590 sq. Km in China. The Major river in this basin are Kali Gandaki river originated from Mustang district. The major tributaries forming the Sapta Gandaki in Gandaki river basin are Kaligandaki, Seti river, Modi river, Madi river, Budhi Gandaki, Marshyandi and Trisuli. Among them, three main confluences of the Trisuli, Seti and Kaligandaki are the narayani in east of the region, Downstream of the confluence, the river is named as narayani whereas in the upstream it is named after the name of three major tributaries namely Trisuli, Marsyandi and Seti. The location map of the studied basin is shown in fig: 4.1.

V. Methodology

The objective of the study is to assess the effect of channel geometries in semi-distributed rainfall-runoff modeling with the help of input data including precipitation, discharge, DEM (digital elevation model), soil, land use and metrological data. Kinematic wave method is used both catchment and channel routing. To fulfill this objective, the HEC-HMS Model is used. Finally, the output is compared with the observed discharge at selected gauging of the basin. The conceptual frame work for overall methodology is followed by GIS based processing and Rainfall runoff modeling.

a) *GIS Based Processing*

Topographical data, soil data and meteorological data are common inputs for GIS based processing. The type of data used in this study and their sources are shown in table 5.1.

Table 5.1 : Data used in the study

Data Type	Resolution	Source
DEM	100m Horizontal, 1m Vertical	STRM, U.S.A.
Soil and Landuse	250 m	DoS, Nepal
Rainfall-runoff	Average daily	DHM, Nepal
Temperature and Humidity	Average daily	DHM, Nepal

b) *Topographical Data (DEM) and its processing*

Before performing any spatial analysis of a river basin we should first prepare a three dimensional replica of the catchment. Digital elevation model (DEM) is one of such 3D model, which is prepared by generating a surface passing through the nodes of a triangular irregular network (TIN). DEM is a sampled array of elevations for a number of ground positions at regularly spaced intervals. DEM describes the elevation of any point in the study area in digital format and contains the information on drainage, crest and breaks of slopes. DEM is the primary spatial data source based on which GEOHMS extract catchments boundary, topographic variables such as basin geometry, stream networks, slope, aspect, flow direction, etc. The work was made simpler by the availability of 100m resolutions DEM of whole Nepal in free downloadable web site. The DEM for Gandaki basin was clipped out. Stream and watershed delineation has been conducted using HEC-GeoHMS Extension. This extension uses 8-Direction pour point Model to determine flow path.

c) *Hydro-Meteorological Data*

Hydro-Meteorological, vegetation and soil data of Gandaki watershed was collected from Department of Hydrology and Meteorology. Meteorological data used in this study includes precipitation, maximum and minimum temperature, maximum and minimum relative humidity data of daily duration.

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VI. Model Execution

a) Digital Elevation Model (DEM)

The DEM is the important input to describe the topography of the watershed on the based of semi distributed model. The DEM used in this study is of 100 meters resolution i.e. 100*100 m grid size. Stream map and stream network are also derived by imposing digitized stream network on the DEM.

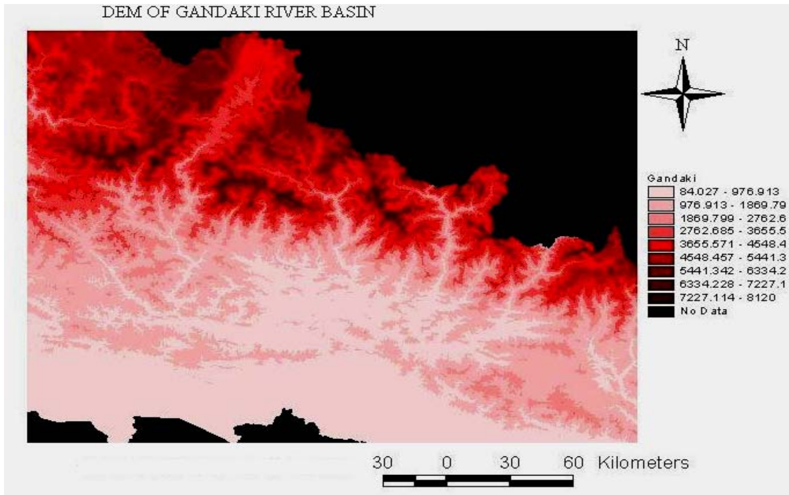

Fig. 6.1 : DEM of Gandaki Basin

b) Spatial Analysis (terrain processing)

Terrain processing is used to generate hydrologic parameters from a digital elevation model. Hydrologic derivatives include fill sink, flow direction, flow accumulation, watershed sub delineation and stream segmentation[9].

Flow accumulation: Drainage area to a given cell can be computed by multiplying the number of contributing upstream grid cells and cell size in the flow accumulation process.

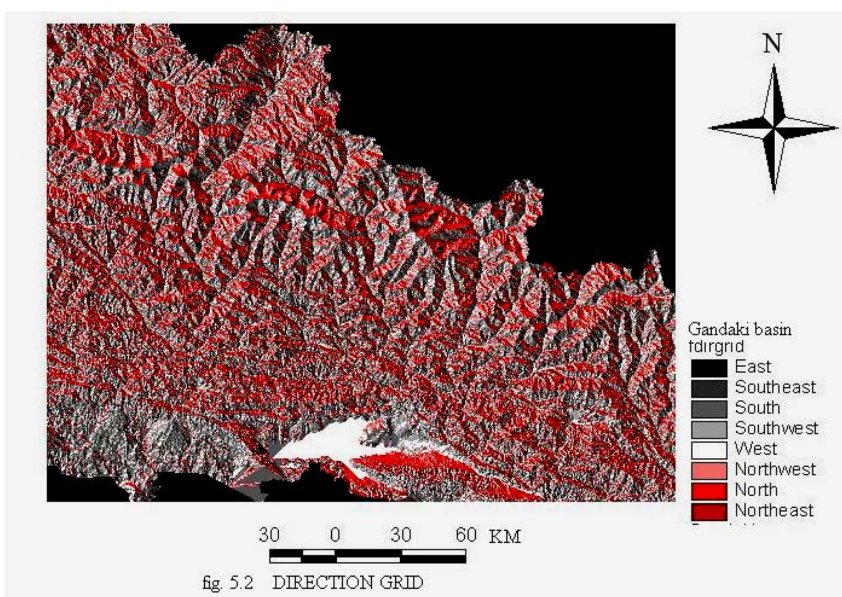

Fig. 6.2 : Direction Grid of Gandaki basin

c) Research input parameters

i. *Topographical (Spatial) data*

Digital elevation model (DEM) is required to describe the topography of the basin. DEM describes the elevation of any point in the study area in digital format and contains the information on drainage, crest and breaks of the slopes [7]. DEM is a primary spatial data source based on which Geo HMS extract the catchment boundary, stream networks files indicating stream properties are generated from the DEM using GIS.

ii. *Reach parameters extracted from HEC-GeoRAS*

Besides the movement of excess precipitation over the land surface, flow within a river channel and flood banks are required to predict the rate at which water will flow through a given point in the stream in the hydrologic stream routing. While there are many methods of predicting stream routing in HEC-HMS, the model in this study is the kinematic wave method.

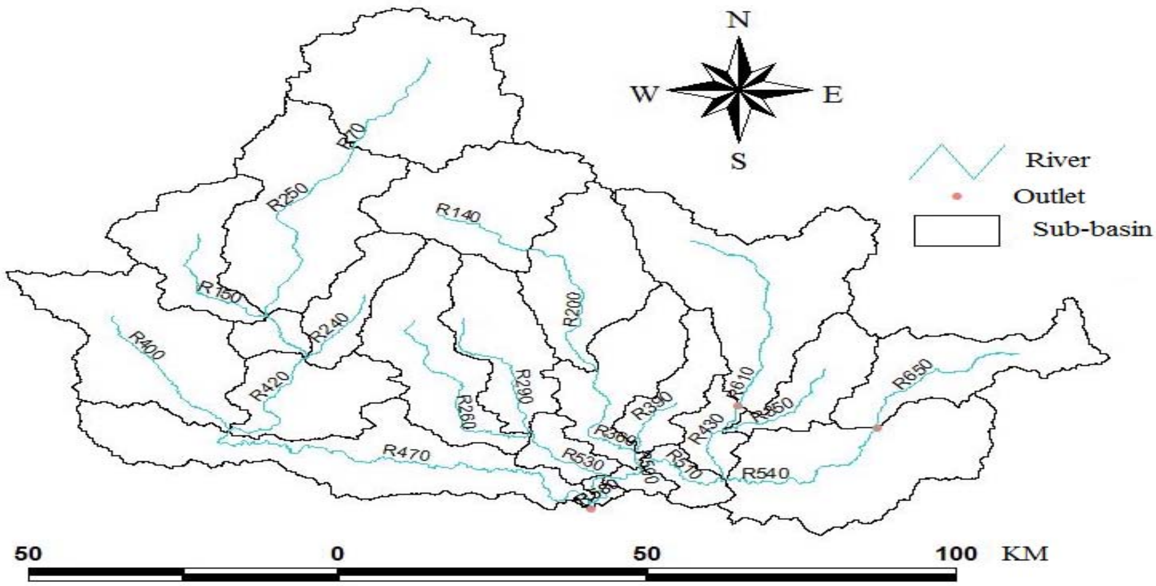

Fig. 6.5 : Delineation of river

The physical characteristics of watershed and river includes the sub basin area, river length, river slope, stream invert profile, sub basin centroid location, elevation, longest flow path for each sub basin and length along the stream path from the centroid to the sub basin outlet. In order to access such physical characteristics of the natural channel, the extension of Arc View GIS developed by USACE HEC-GEORAS can be used.

Table 6.3 : Stream reach parameters extracted from GeoHMS

S.No	Reach Name	Reach Length (M)	Energy Slope (m/m)	Cross section shape			
				Trapezoidal		Rectangular	Triangular
				Bottom width (M)	Slope(H:V)	Botom width (M)	Slope(H:V)
1	R70	45102	0.0128	40	37.5	71.667	65.33
2	R140	32586	0.0285	90.000	48.333	140.000	100.000
3	R250	77369	0.0262	61.667	43.333	85	71.667
4	R150	49206	0.0261	11.250	8.578	27.500	10.969
5	R270	23204	0.0055	20.000	18.540	43.750	26.250
6	R240	32251.9	0.0255	15.000	36.019	62.500	35.324
7	R200	64020	0.0316	56.667	143.333	170.000	186.667
8	R220	11691	0.0053	12.500	8.333	21.667	19.000
9	R350	43863.2	0.0182	24.000	28.000	45.000	65.567
10	R290	58737.8	0.0138	32.500	17.500	47.500	40.000
11	R400	61316.6	0.0102	20.000	27.833	41.667	45.833
12	R420	27829.1	0.0065	16.750	7.375	34.500	14.917
13	R260	78026.7	0.0104	31.250	59.375	100.000	87.500
14	R360	7718.4	0.0031	66.667	94.333	105.000	121.110

15	R390	25902.8	0.0089	36.250	29.167	80.000	46.667
16	R500	7718	0.0031	66.667	94.333	105.000	121.110
17	R530	29980.6	0.0028	32.500	12.500	42.500	30.000
18	R560	13301.2	0.0025	24.167	14.500	44.167	28.000
19	R430	22938	0.004	25.000	30.000	43.667	48.333
20	R540	60598.5	0.0042	18.333	20.333	32.500	30.833
21	R510	33843.4	0.0018	22.500	20.000	35.000	30.000
22	R470	150230.3	0.0021	40.000	32.667	80.667	53.833
23	R580	18458	0.0023	100.000	10.000	130.000	35.000
24	R600	2036	0	100	10	130	35
25	R610	81099	0.0316	12.500	8.333	21.667	19.000
26	R630	1631.4	0.0219	18.333	20.333	32.500	30.833
27	R650	74889.4	0.044	16.667	12.833	32.500	23.833

iii. *Overland flow parameter*

Watershed represents the two plane surfaces over which water runs until it reaches the channel. The water then flows down the channel to the outlet. The physical parameters used in this model are length, slope and area of each sub basin.

Table 6.4 : Plane overflow parameters extracted from GeoHMS

S.N	Reach Name	Basin Area (Sq km)	Plane1 (Right plane)				Plane2 (Left plane)			
			Length (Km)	Slope	Area (Sq km)	% Area	Length (Km)	Slope	Area (Sq km)	% Area
1	R140W120	1,620.23	8.88	0.21	1,242	77	29.52	0.09	377.66	23
2	R150W150	1,095.41	7.03	0.39	336.90	31	16.64	0.14	758.51	69
3	R200W170	1,406.8	15.51	0.29	712.96	51	11.93	0.26	693.88	49
4	R240W240	674.79	5.51	0.37	315.54	47	11.90	0.19	359.25	53
5	R250W90	2,204.18	16.71	0.18	1,256.7	57	17.70	5.27	947.46	43
6	R260W260	1,470.94	11.94	0.04	615.10	42	10.85	0.06	855.84	58
7	R270W270	258.17	6.53	0.25	94.98	37	12.94	0.12	163.19	63
8	R290W290	1,122.47	11.28	0.14	694.02	62	9.54	0.11	428.45	38
9	R350W350	748.26	9.78	0.22	418.95	56	7.61	0.21	329.31	44
10	R500W330	1,146.93	10.61	0.15	481.43	42	11.21	0.08	665.50	58
11	R430W220	379.15	4.96	0.11	114.20	30	7.89	0.11	264.95	70
12	R470W440	2,240.17	12.40	0.11	1,170.5	52	12.83	0.12	1,069.9	48
13	R400W310	1,994.20	14.86	0.11	758.61	38	18.75	0.10	1,235.6	62
14	R420W300	1,060.42	30.92	0.03	775.78	73	8.39	0.23	284.64	27
15	R530W530	353.27	6.69	0.10	226.06	64	7.33	0.11	127.21	36
16	R650W630	1,278.41	8.97	0.33	675.06	53	12.56	0.34	603.35	47
17	R540W280	2,129.80	11.58	0.12	558.99	26	5.90	0.21	1,570.8	74
18	R610W180	2,487.68	21.91	0.21	1,513.4	61	15.86	0.26	974.21	39
19	R510W510	286.36	5.09	0.20	114.20	40	6.87	0.08	172.16	60
20	R560W560	122.65	7.81	0.13	23.15	19	3.06	0.26	99.50	81
21	R600W580	66.72	2.05	0.09	41.26	62	1.88	0.12	25.46	38
22	R70W20	2,329.30	27.95	0.09	932.41	40	24.90	12.0	1,396.9	60
23	R390W390	611.25	5.86	0.24	342.36	56	5.57	0.16	268.89	44

VII. Result and Recommendation

The main objective of this paper was to find out the channel section of the study area which gives the best result. To achieve the main objective, the temporal variation of the flow by using different channel sections was analyzed and examined the result of different channel geometries at the outlet of the watershed at Narayanghat by considering the model's response of three-year separate precipitation.

a) Model calibration

The model is calibrated using 2004 and 2005 daily rainfall runoff data. Manual and automatic calibration techniques are applied to estimate values of parameters.

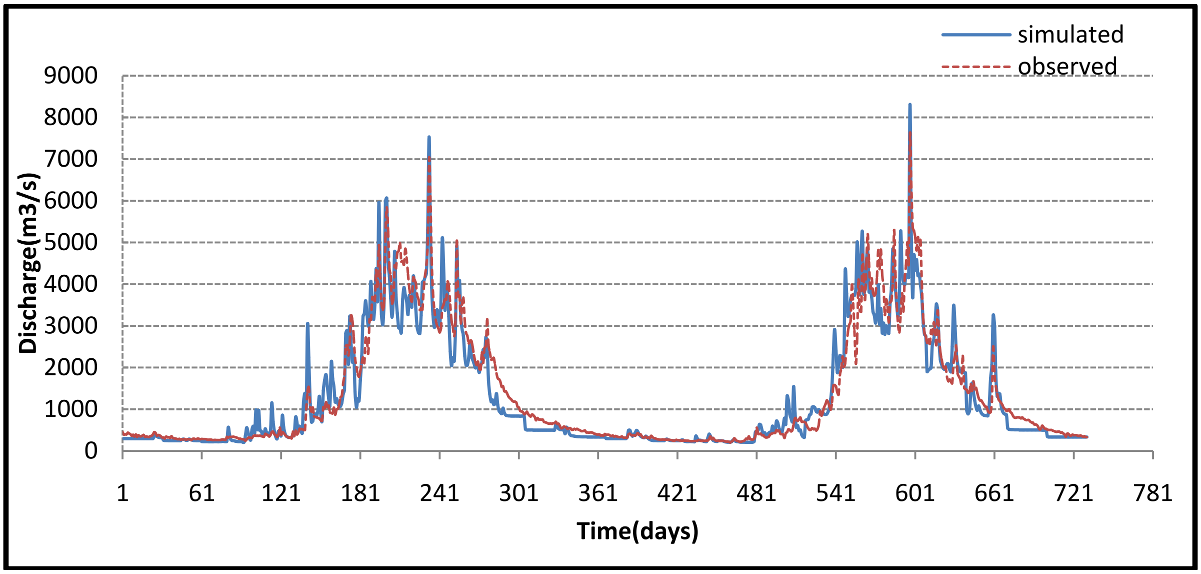

Fig. 7.1 : Simulated with observed hydrograph using trapezoidal channel section for calibration

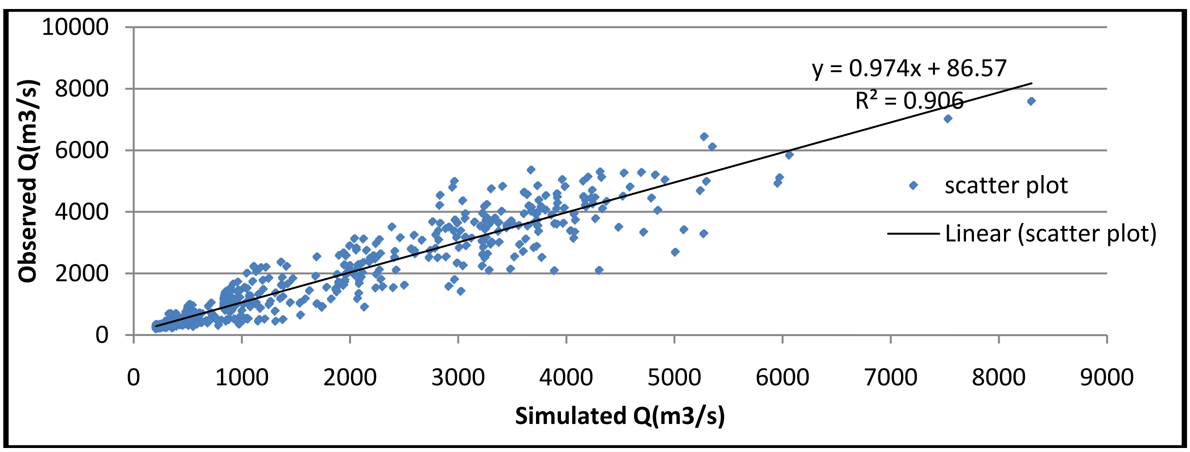

Fig. 7.2 : Scatter plot using Trapezoidal section for calibration period 2004 and 2005

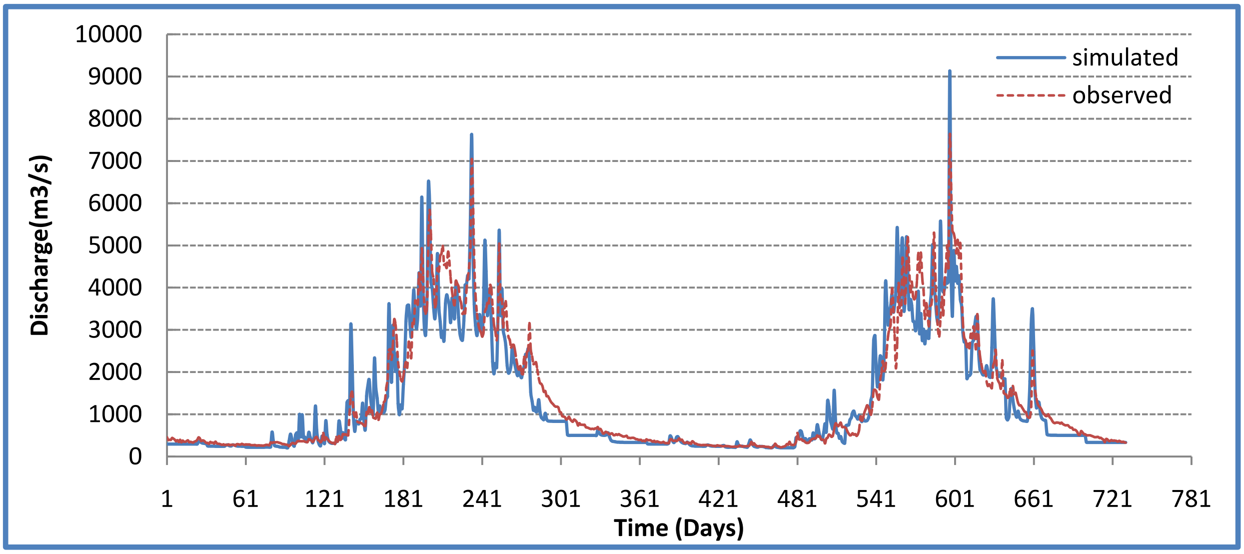

Fig. 7.3 : simulated and observed flow using triangular section

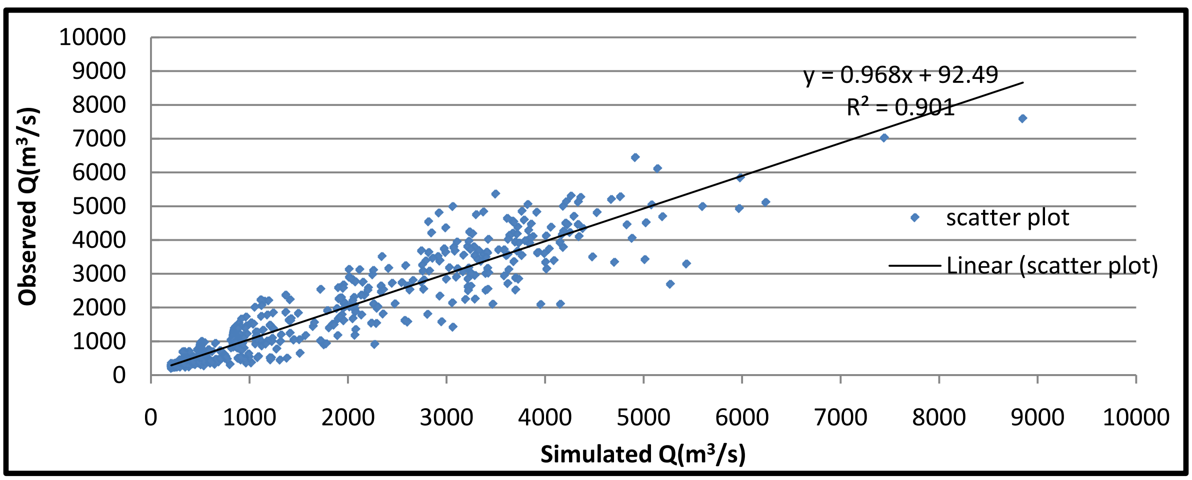

Fig. 7.4 : Scatter plot using triangular section for calibration

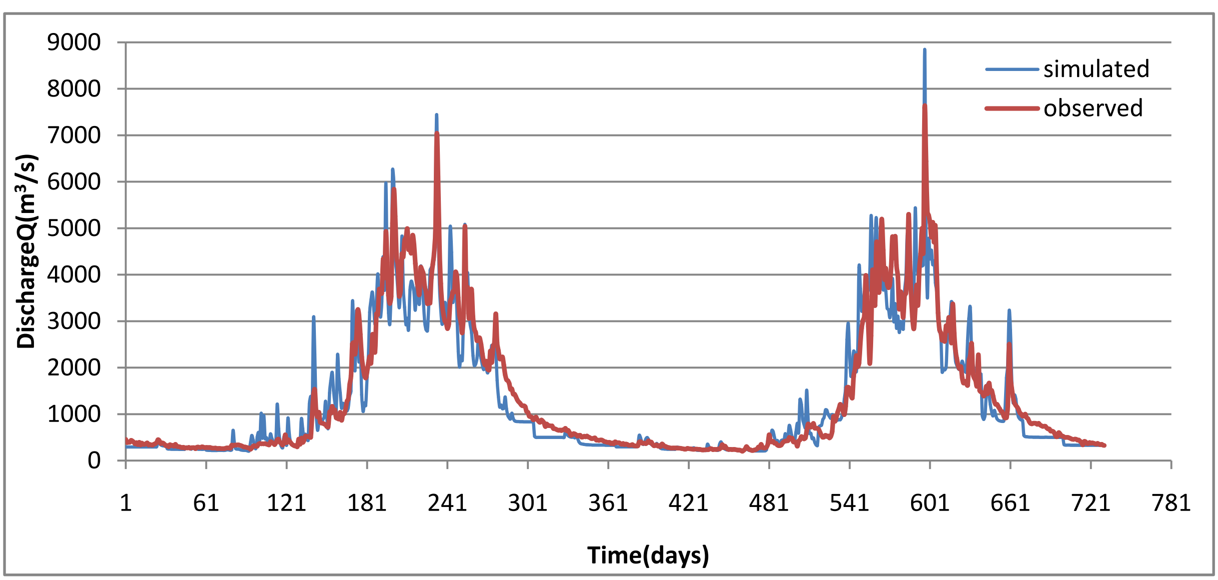

Fig. 7.5 : Simulated and observed hydrograph for rectangular section

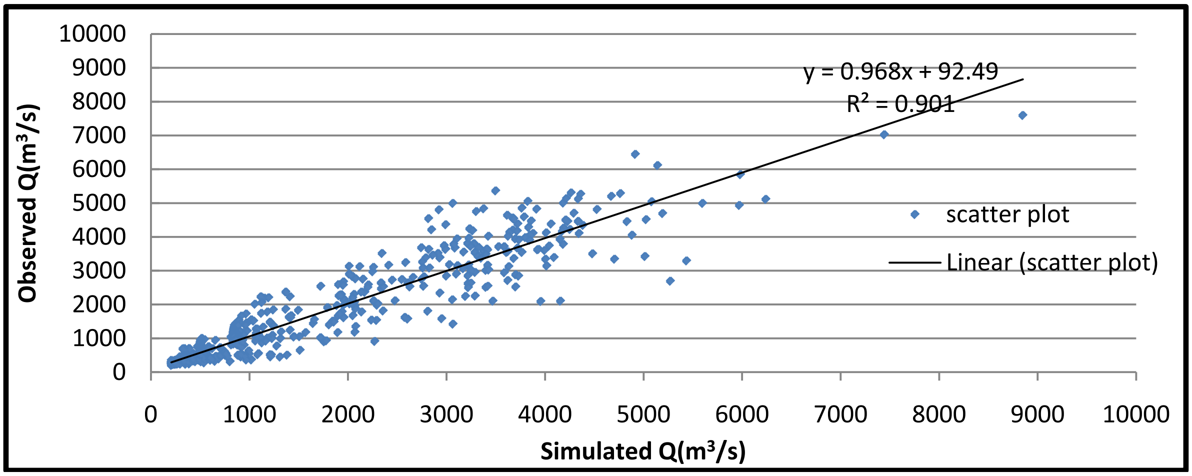

Fig. 7.6 : Scater plotter for rectangular section

b) Model validation

The model is run for one year's daily rainfall runoff data. The runoff is simulated using 2006 daily rainfall-runoff data in model validation. The calibrated model parameters are applied in model validation.

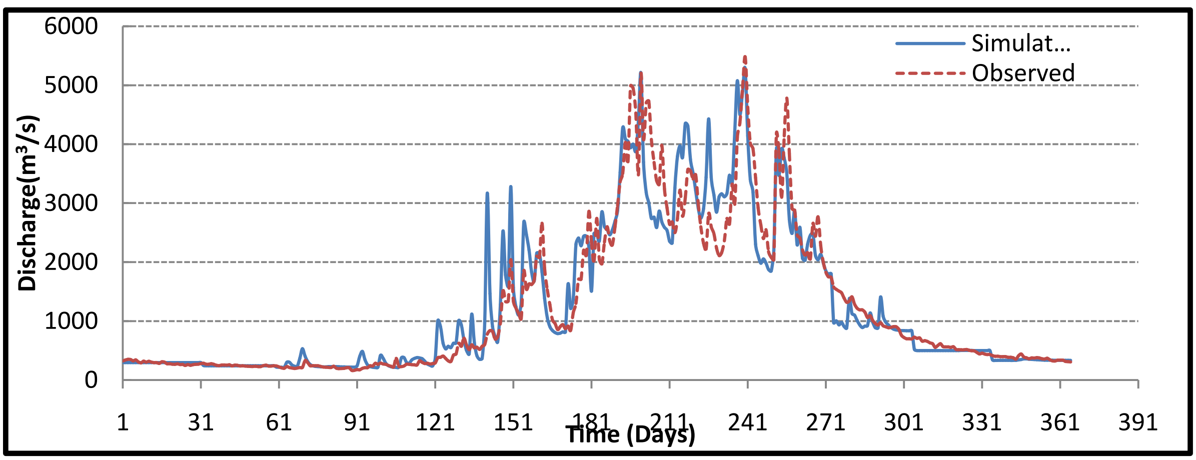

Fig. 7.7 : simulated and observed hydrograph for trapezoidal channel for validation period 2006

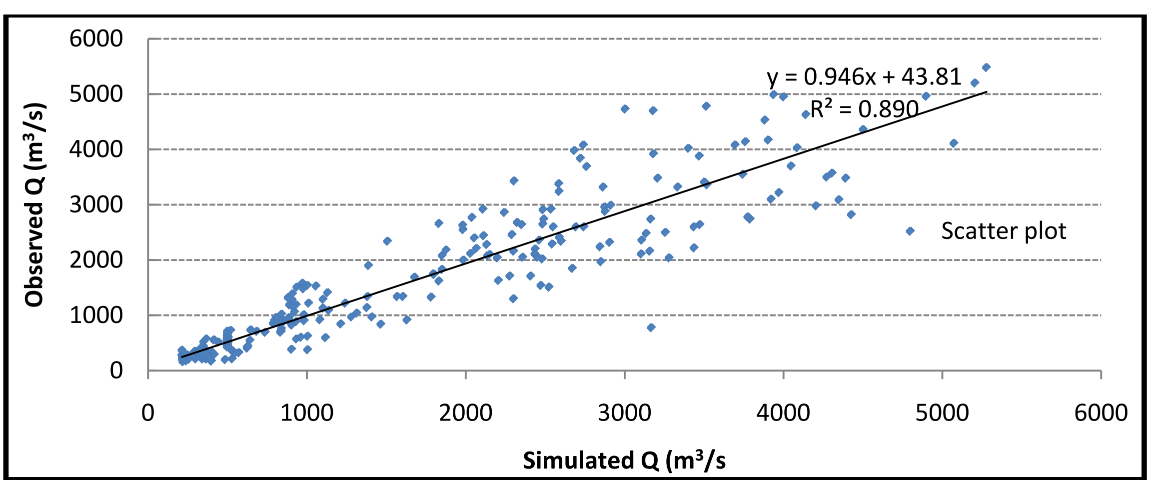

Fig. 7.8 : Scatter plot for validation period 2006 for trapezoidal section

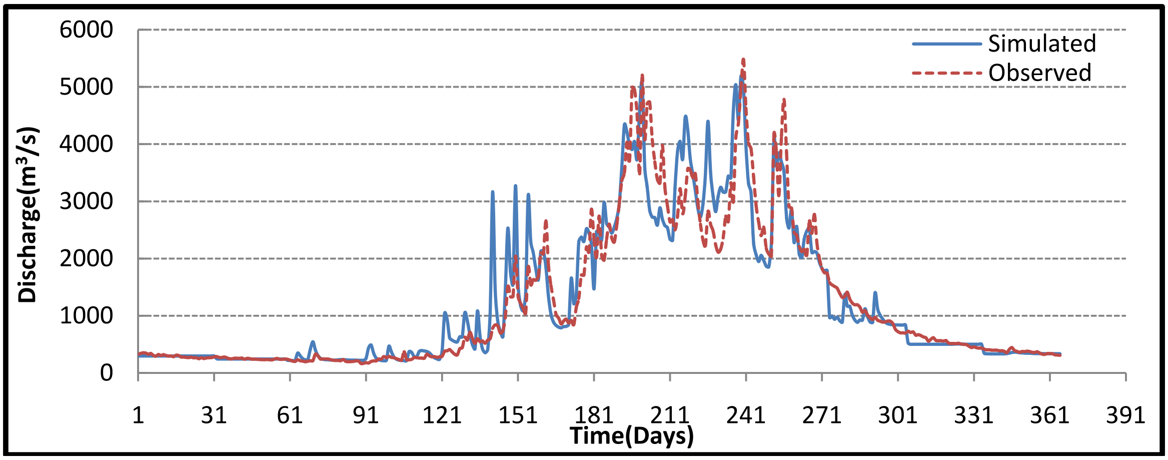

Fig. 7.9 : Simulated and observed hydrograph using Triangular channel for validation period 2006

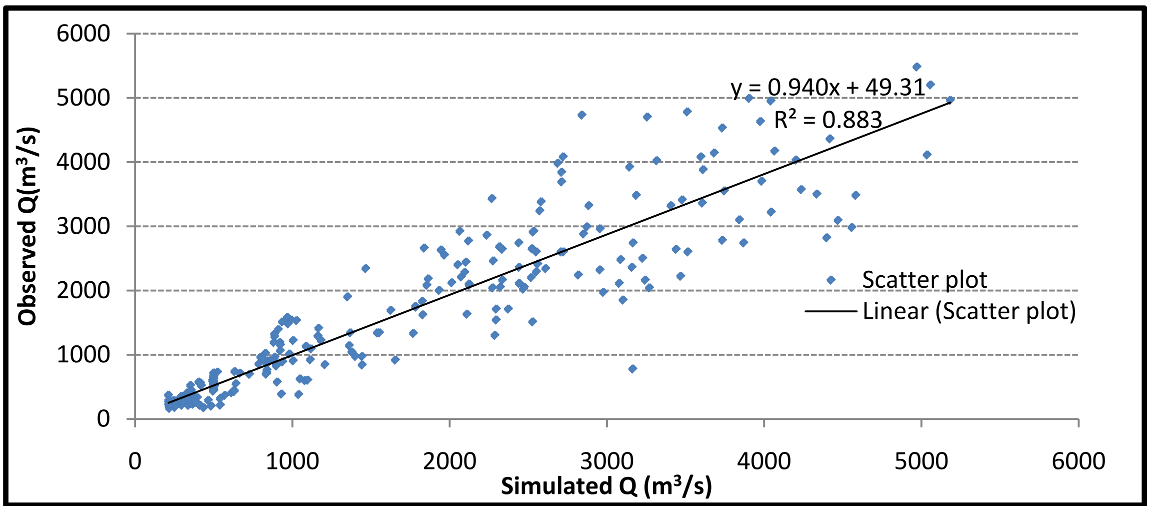

Fig. 7.10 : Scatter plot using triangular channel for validation period 2006

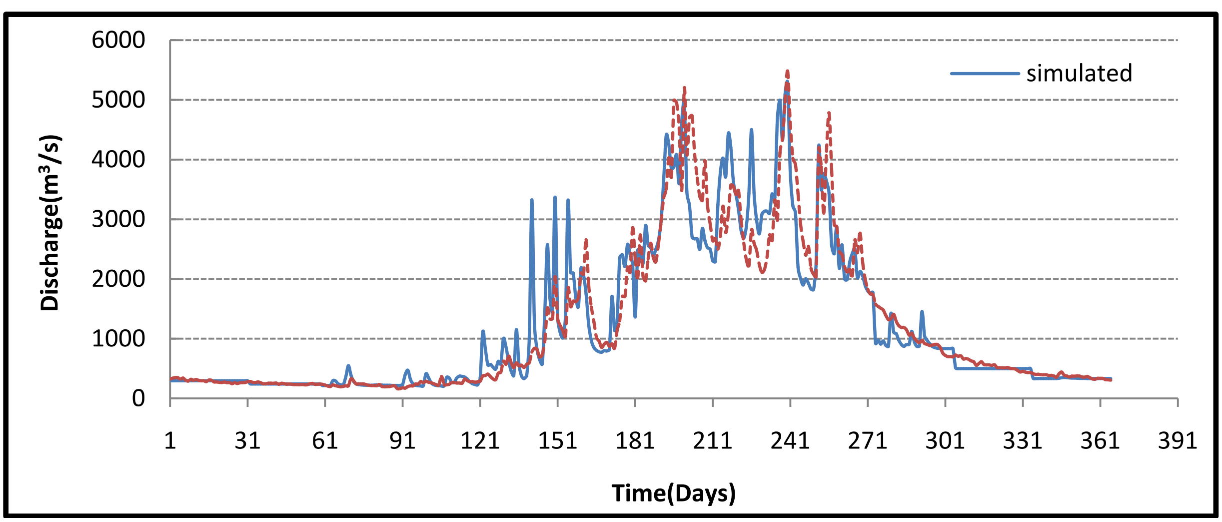

Fig. 7.11 : Simulated and observed hydrograph using Rectangular channel for validation period 2006

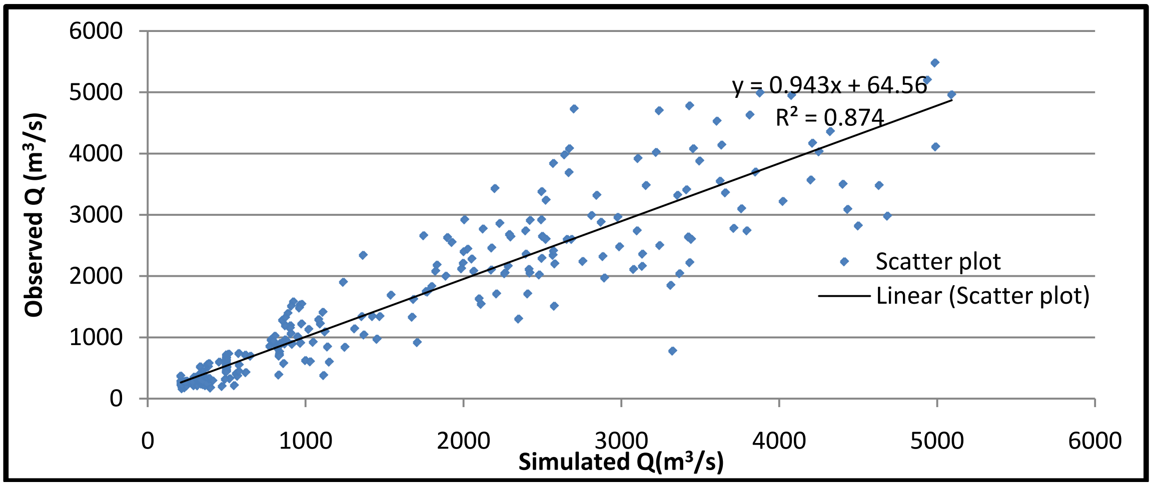

Fig. 7.12 : Scatter plot for rectangular section for validation 2006

c) *Performance analysis*

i. *Volume deviation using different channel section*

The simulated annual stream flow volume that occurred at the outlet of the basin in response to the channel geometries during calibration and validation period are presented in table 7.1 and fig.7.13.The volume deviation using trapezoidal and triangular section obtained almost similar but in rectangular channel the volume deviation is higher than other section

Table 7.1 : Annual stream flow volume at the outlet

Channel section	2004		2005		2006	
	Observed volume (10^7m^3)	simulated volume (10^7m^3)	Observed volume (10^7m^3)	simulated volume (10^7m^3)	Observed volume (10^7m^3)	simulated volume (10^7m^3)
Trapezoidal	4591.8	4264.458	4066.3	4060.03	3840.46	3909.9
Triangular		4276.44		4063.27		3916.41
Rectangular		4191.34		3998.9		3854.42

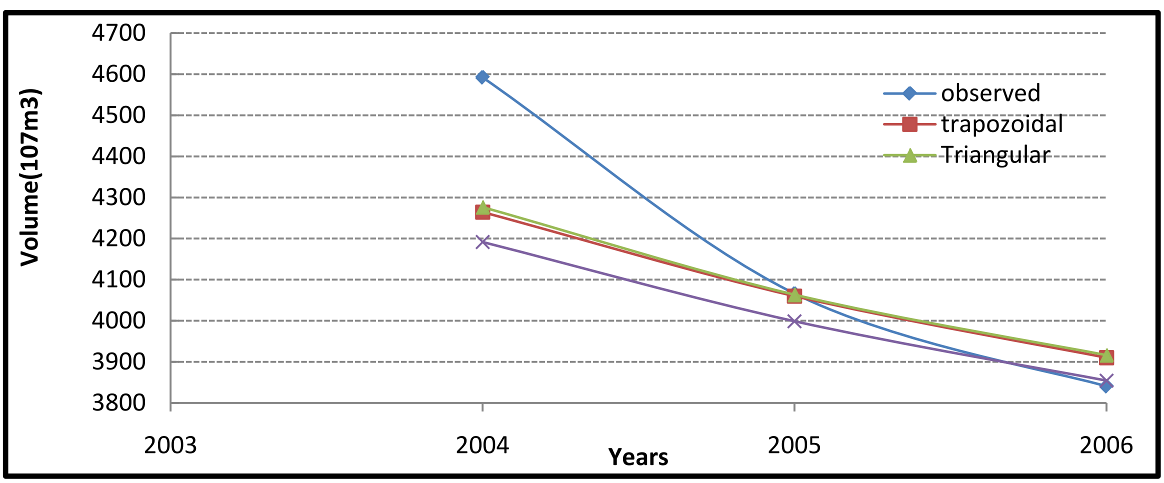

Fig. 7.13 : Annual stream flow volume using different channel section at the outlet

ii. *Annual mean flow using different channel section*

The simulated annual mean stream flow that occurred at the outlet of the basin in response to the channel geometries during calibration and validation period are presented in table 7.2 and fig.7.14.The annual mean flow using trapezoidal and triangular section obtained almost similar but in rectangular channel the annual mean flow is higher than other section.

Table 7.2 : Annual mean flow using different channel geometry at the outlet

Channel section	2004 Observed Peak flow (m^3/s)	2004 Simulated Peak flow (m^3/s)	2005 Observed Peak flow (m^3/s)	2005 Simulated Peak flow (m^3/s)	2006 Observed Peak flow (m^3/s)	2006 SimulatedPeak flow (m^3/s)
Trapezoidal	7020	7531.3	7590	8302.1	5480	5277.8
Triangular		7445.1		8850.5		5184.2
Rectangular		7621.7		9131.5		5093.3

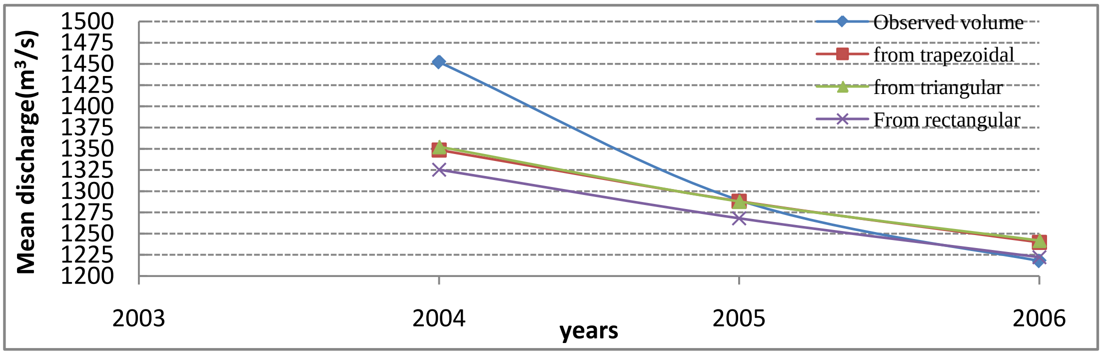

Fig. 7.14 : Annual mean stream flow using different channel section at the outlet

iii. *Peak flow using different channel section*

The simulated peak stream flow that occurred at the outlet of the basin in response to the channel geometries during calibration and validation period are presented in table 7.3 and fig.7.15.The peak flow using trapezoidal near to the observed flow but for triangular and rectangular section, the peak flow is higher than the observed peak. The time of peak using trapezoidal channel exactly same to the observed time of peak in calibration and validation period, but time of peak using triangular and rectangular section is same in calibration period and slightly different in validation period.

Table 7.3 : Peak flow using different channel geometry at the outlet

Channel section	2004 Observed Peak flow (m^3/s)	2004 Simulated Peak flow (m^3/s)	2005 Observed Peak flow (m^3/s)	2005 Simulated Peak flow (m^3/s)	2006 Observed Peak flow (m^3/s)	2006 Simulated Peak flow (m^3/s)
Trapezoidal	7020	7531.3	7590	8302.1	5480	5277.8
Triangular		7445.1		8850.5		5184.2
Rectangular		7621.7		9131.5		5093.3

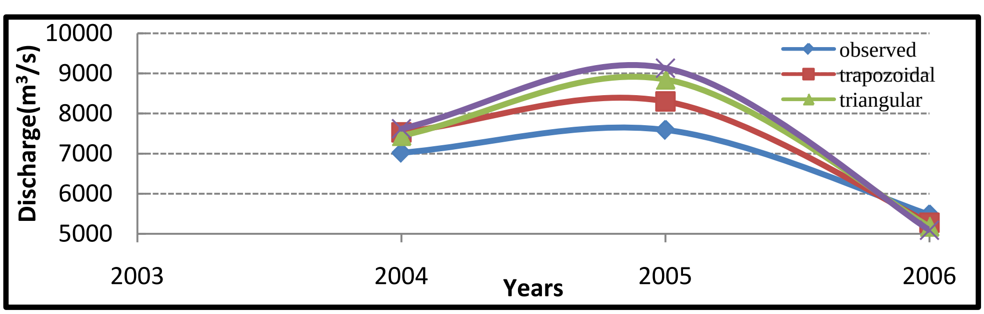

Fig. 7.15 : Peak flow volume using different channel section at the outlet

iv. *Efficiency using different channel section*

The Nash -Sutcliffe (1970), efficiency of stream flow that occurred at the outlet of the basin in response to the channel geometries during calibration and validation period are presented in fig.7.16.The efficiency of flow using trapezoidal channel is higher than the triangular rectangular section.

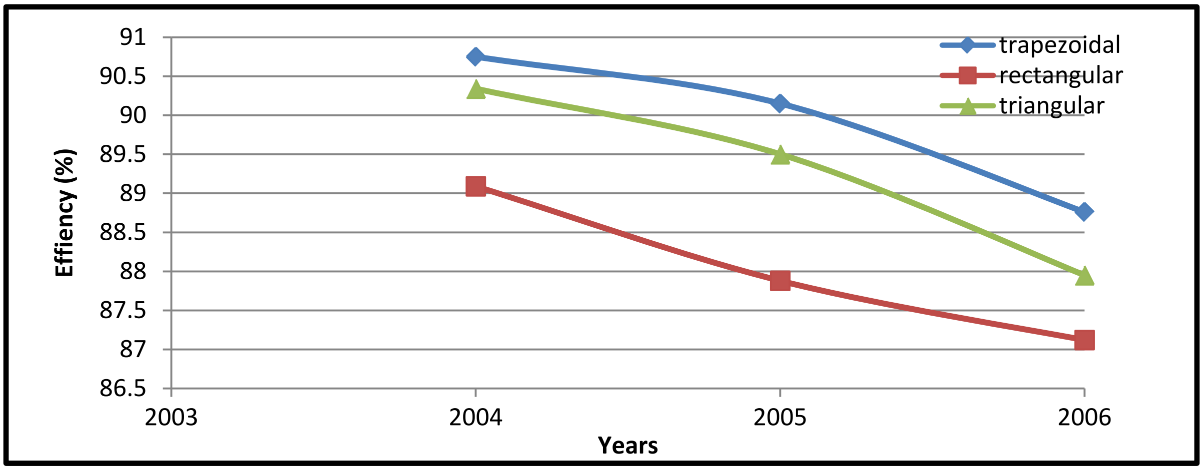

Fig. 7.16 : Efficiency using different channel section

It is clear from simulated hydrographs that different channel section show different degree of agreement between molded and observed discharge. Explanations for the results obtained can be pointed out in the following bullets.

- The precipitation, the infiltration parameters and channel routing method and parameters cause the difference in Peak flow, peak timing, and total volume, annual mean flow of observed and simulated hydrographs.
- Basins with a greater diversity of basin characteristics, including topography, soils and land use will produce poorer results than homogenous basins.
- Stream flow is affected by selection of channel geometry.
- Errors in peak flow due to inaccurate precipitation, inaccurate sub basin runoff parameters, incorrect timing of tributaries or the wrong amount of attenuation in channel routing.

VIII. Conclusion and Recommendation

The main objective of this research was to identify the efficient channel section in the computer-based rainfall runoff processes for Gandaki river basin. The GIS based semi-distributed model named HEC-HMS was used for this study. The response of channel geometry in simulating rainfall runoff was analyzed for the basin using DEM, Evapotranspiration soil type, and land use data. The GIS based extension tool HEC-GEOHMS and HEC-GEORAS were mainly used for preparation of inputs for HEC-HMS.

The model was calibrated for two years flow data and verification of the calibrated parameters for one year's flow data. For this study, especially trapezoidal, rectangular and triangular channel section were taken to account for the simulation. The result shows that using trapezoidal channel section is more efficient than triangular and rectangular section on the basis of Nash efficiency and degree of determination (R-squared value). The peak flow and time to peak at the outlet using trapezoidal channel section is nearly matched to the observed peak flow and time to peak for calibration and verification period than other sections. However the average annual flow and total annual volume at the outlet is nearly same using trapezoidal and triangular sections and slightly deviated from observed mean flow and annual volume respectively.

From the above result of this study which is the efficient section for routing that depends upon the purposes of the simulating rainfall runoff process. Trapezoidal section is more efficient than other for determination of flood forecasting and both trapezoidal or/and triangular section is efficient for simulating to determine the total annual runoff volume.

- Following are the specific conclusion from the analysis.
- The model provide the best result using trapezoidal channel section as a function of peak flow and time to peak.
- Hydrologic modal parameters can be derived from historic stream flow, precipitation and GIS database.
- The reasonable result were obtained using different channel sections for semi distributed model with efficiency ranging from 88.51% to 90.47% for calibration period and 87.12% to 88.76% for verification period respectively.

- Based on the result of this study, the trapezoidal channel section is most suitable for flood forecasting with continuous simulation.

a) Recommendations

From the study result, suitable channel section can be used for similar channel routing model. To develop capability of the model, following significant concepts are needed for further similar studies.

Digital elevation model plays vital role to enhance the capability of model. It is recommended to use high resolution digital spatial database for real replication of topography for the better performance of the model.

Channel cross sections are derived using HEC-GeoRAS extension of GIS. It should be checked by field surveys to get better result.

It is recommended to consider contribution of snow for better result.

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