CS/AR-33/1998-99

GEOMORPHOLOGICAL STUDY OF DEVAK BASIN

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ABSTRACT

Geomorphology is the Science of evolution of landforms in terms of its lithology, stucture , basin geometry and other morphometric factors .The advanced knowledge of geomorphology of the region is of importance in the field of flood control measures and engineering projects, since geomorphological characteristics of river basin in mountanins areas affect runoff process and formation of flood in these areas.

Parameters of hydrologic models describing rainfall- runoff process may be estimated either by optimization technique using topographical and climatic information of the basin. Since most of the loction in mountainous areas is either ungauged or sufficient data is not available for them, the study of geomorphological characteristics of such areas become much more important and significant. This one of the main objectives of geomorphological studies is to regionalise the hydrologic models describing rainfall-runoff process.

Various geomorphological parameters, which have mostly been used by various investigators, can be broadly classified as those describing, 1. Linear aspects of channel system, 2. Areal aspects of channel system, and 3. Relief aspects of the basin

In this study the above mentioned aspects of the Devak Basin up to Gura Slathian are evaluated .The study may be useful at finding out effect of geomorphology on watershed runoff response and identifying these parameters which are more closely related to runoff.

1.0 INTRODUCTION

Drainage basins are created, shaped and structured by nature in some orderly manner and it exhibits interdependence of hydrogeoclimate factors and soil vegetation complexes. Hydrologists and Earth scientists in their effort to understand and synthesize hydrologic response of such basin have started looking into its morphologic and topographic features and establish connection of fluvial geomorphology to hydrology.

Geomorphology - the science of evolution of landforms in terms of lithology, structure, climate and other climate factors, had been mostly qualitative in its initial stage. Now, geomorphologic efforts have come out of past trend and with the rational relation between the "ensemble" average response of a basin with given geomorphologic properties established, greater need for quantitative information is felt for. To evaluate or predict the run-off response of river basin, hydrologists are faced with the vexed problem of non-availability of flow-precipitation data. Therefore, measurable basinal features of drainage network, which have been considered and shown to have potential to describe some of the hydrograph parameters of the ungauged system, have encouraged hydrologists for hydrological simulation and applying relationships developed for gauged basin at ungauged basins through hydrograph synthesis.

The geomorphologic characteristics which relate to hydrology, as suggested by many investigators, consists of linear aspect of stream system dealing with one dimensional overland flow lengths and length of the stream etc., areal aspect of catchment relating to basin shape, drainage, texture etc., and relief aspect of stream network/catchment describing elevation difference etc. The first two categories of measurement are planimetric (i.e. treat properties projected upon a hydrological datum plane) and the third category treats the vertical inequalities of the drainage basin form. Some typical catchment characteristics have also been identified which will be useful to derive unit hydrograph for the catchment. Some of the studies where quantitative geomorphological characteristics are used to describe hydrological properties are as follows:

- Development of empirical formula using geomorphological parameters.
- Regional unit hydrograph studies
- Regional flood frequency analysis
- Development of GIUH
- Hydrological modeling studies

The present study has been made to establish the various geomorphological characteristics of Devak river (a tributary of Ujh river in J&K State) in GIS environment with the help of established laws and procedures and using Survey of India (SOI) map of scale 1:50000. In absence of existing network of hydrological observation sites in the area, the geomorphological parameters derived for the basin may be used for further hydrological studies.

1.1 Importance of Geomorphology in Hydrology

A large number of studies have since appeared on synthesis of unit hydrographs in ungauged areas. Rodriguez-Iturbe et al (1982) employed bifurcation ratio, length ratio, area ratio, stream lengths and stream areas for synthesizing unit hydrograph. Ross (1970) gave relation between Nash model parameters and Horton's order ratios.

White (1975) classified 112 basins in Pennsylvania and surrounding states according to drainage density, Stream slope, shape factors, and geometric factors for the purpose of evaluating their flood potential. Ebisemiju (1979) used drainage density, stream number, steam lengths, and relief for identifying morphologically and hydrologically uniform basins. A study by Patton and Baker (1976) concluded that drainage density, stream magnitude and relief ratios are practical measures of flood potential in basins smaller than 100 mi^2 in area. Gurnell (1978) gave a comprehensive account of potential application of drainage density.

Zelazinski (1986) has applied the Geomophological Instantaneous Unit Hydrograph (GIUH) theory for the estimation of the parameters of two conceptual models: a linear cascade model and a Laurenson –type model. This model was successfully tested on the data of the Skawa River, a tributary of the upper Vistula. Pristachova (1990) has constructed flood waves for small basin in Czechoslovakia by evaluating bifurcation ratio, length ratio, area ratio, length of the highest order stream and a "velocity parameter" corresponding to average cross-sectional velocity at the out let for bankfull discharge. Yen et al (1997) has incorporated Horton-Strahler stream ordering laws in the GIUH model for Unit Hydrograph (UH) generation on two hilly basin in the eastern United States and two relatively flat-slope basin in Illinois (USA).

Wharton and Tomlinson (1999) has developed a relation between flood discharges, measured at gaging station, and a stream dimensions. This relation has been applied in four devoliping, tropical countries as part of hydrological investigations for road design and flood risk assessment (Java), irrigation and hydropower development (Burundi), design of all weather roads (Ghana), and rehabilitation of railway bridges (Tanzania). He demonstrated the benefits of the stream – geometry method in situation where data on the catchment characteristics are limited or may not offer the most appropriate basis for flood discharge estimation. Of all the indices, the basin area, drainage density, main stream length and main stream slope appears to have been utilized most frequently.

1.2 Problem Definition

Hydrological studies in drainage basins and sub basins often suffer setbacks due to lack of various long-term data. Then there is the need to extrapolate the results of few small sub systems to other hydrologically similar regions which mostly remain ungauged for want of enormous resource and time involved in instrumentation and monitoring them. In context of hydrology, geomorphological parameters provide reasonable scope to compare basins and transform the results of gauged basins to ungauged areas for its regionalization.

The network of hydrometeorological observation in Devak basin is not existing and data are not available for systematic hydrologic studies. Moreover, the stream networks of the basin is very complicated with most of the first, second and third order streams flowing on steep slopes. Even many of the major streams remain dry during non-monsoon period and experience flash flood during rainy days. There are no gauge discharge sites on these streams. Therefore, geomorphological parameters of the basin may provide an alternative to establish relationships describing flow process of the network.

In this study, various geomorphological parameters of Devak basin upto Gura Slathian (J & K State) are being evaluated. The parameters thus evaluated may be used to test hydrological models.

2.0 REVIEW

To understand the laws of runoff processes in a basin, hydrologists have been faced with many problems, especially in respect of ungauged catchment where hydrological data are rarely available. Many approximate formulae, usually crude empirical statements, have been developed to relate precipitation with flow. For ungauged basins it has been the endeavor of many hydrologists and earth Scientists to quantify and relate geomorphological parameters of naturally shaped river basins to its hydrologic response characteristics.

Horton (1945) pioneered the hydromorphometric analysis of drainage basin and provided a rational and systematic base, rather a framework of outline of geomorphological characteristics to relate them to various hydrological properties of the system. His works were pursued by many investigators. These works have brought forward many laws of fluvial geomorphology connected to hydrology and study of geomorphological characteristics of river basins has become a major area of scientific research for hydrologists throughout the globe.

Hydromorphometric studies in quantitative terms are very few in Himalayan Region where the present study was conducted. Singh (1990) studied the Geomorphology of the Tawi basin and concluded that "The Tawi basin, being part of Western Himalayas has been effected by intermittent tectonic events from Teritary upto Pleistocene and recent periods and their imprints are evidenced in the surface morphology. The region has also witnessed Pleistocene glaciation which has also played a significant role in shaping the geomorphic forms of the basin". Roohani and Gupta (1988) studied some relationships between hydromorphometric parameters like stream order Vs number, stream order Vs mean stream length, stream order Vs mean drainage area, stream order Vs stream slope etc. and inferred that the stream network lacked morphometric similarity or steady state for which the hydromorphometric relations exhibited deviations from the widely established and accepted norms.

2.1 Geomorphological Studies carried out by NIH

National Institute of Hydrology has taken up geomorphological studies of selected river basins spread over the entire country. Faced with the vexed problem of non-availability or inadequacy of data for the river basins, particularly in mountainous areas, the geomorphological studies have been taken up with the following objectives:

- Estimation of geomorphological parameters covering linear aspect of stream network, areal aspect and relief aspect of stream system.
- To study the relationships of drainage characteristics with stream flow.
- To regionalise hydrological models of runoff process.

Studies were conducted on estimation of geomorphological characteristics for the following river basins and details of these studies are summerised below:

1. Varna basin up to Samdoti
2. Krishna basin up to Karad (Western Ghats)
3. Krishna basin up to Arjunabad (Western Ghats)
4. Ghatapraba basin up to Daddi (Western Ghats)
5. Malaprabha basin up to Khanpur (Western Ghats)
6. Kolar sub-basin.
7. Hemavathi basin in karnataka
8. Sabarmati basin in Gujarat
9. Tawi basin up to Jammu (J&K)
10. Baira nalla sub-catchment (H.P)
11. Narmada basin up to Manot.

Geomorphological parameters of Kolar Subbasin of Narmada basin have been computed using a software, which was developed in Fortran-77 language by Singh (1990-91). The geomorphological parameters, thus estimated, will be utilized for testing hydrological models to simulate hydrological response of the basin. Jain (1993-94) has carried out various geomorphological parameters of Narmada basin upto Manot. Various geomorphological studies in subbasins of upper Krishana such as Krishna basin upto Kard, Varna basin upto Samdoli and Krishna basin upto Arjunwad have been carried out by Kumar and Singh (1988-89). Kumar (1990-91) has carried out geomorphological studies of Ghatprabha and Malprabha subbasins of Krishana basin. Geomorphological studies of Hemavati basin upto Sakleshpur in western ghat has been studied by Jain and Kumar (1991-92). Geomorphological parameters covering linear, areal and relief aspects have been estimated of the Sabarmati basin upto Dharoi. For study various geomorphological parameters, the basin is divided into various sub basin (Jain, 1992-93). Geomorphological parameters for Bagmati subbasin of Kosi basin up to Hayaghat have been computed. It is observed that the main Bagmati stream is a fifth order stream and the main stream is 346.60 km. long. Total relief of the basin was computed as 1453 meters. Various non dimensional geomorphological parameters of the basin were also computed. The geomorphological parameters, thus estimated, may be utilised for regional unit hydrograph studies, flood frequency analysis, instantaneous unit hydrograph study and simulation models (Lohani et al. 1992-93). Patwari and Kumar (1992-93, 1993-94) have carried out hydro-geomorphological studies of Tawi basin in Jammu and Kashmir and Baira nalla sub-catchment in Himachal Pradesh .

Recently, Jain et al. (1998) have estimated the geomorphological parameters required for developing GIUH using GIS (ILWIS). Rainfall losses were estimated using the Soil Conservation Services (SCS) run-off curve number (CN) method, and the developed GIUH was used for the transformation of rainfall into runoff on the data of the Kolar sub-basin in the Narmada basin, India.

3.0 METHODOLOGY

The methodology used to study the various parameters of linear, areal and relief aspects for the Devak basin is described below.

3.1 Linear aspects of the Basin

Linear aspect of the basin characteristics includes overland flow lengths of the streams of all orders. Usefulness of ordering stream system lies on the hypothesis that basin size, stream dimensions, and stream flows are proportional to the stream orders provided investigation is made for quite large number of basins. Among the various classifications, Horton-Strahler classification has been used to study the linear aspect of Devak basin. The following parameters (Table 1) under linear aspect of stream system were calculated directly or indirectly using the Vector-Network module of ILWIS 1.2 GIS. The details of different parameters of linear aspects are mentioned in the earlier NIH reports (Singh, 1990-91; Patwari and Kumar 1992-93; Jain,(1993-94).

3.2 Areal Aspects of the Basin

Areal measure of a drainage basin networks relates to many of its hydrologic characteristics. The various parameters (Table 2) of areal aspect of the basin defined by various workers are studied using the ILWIS GIS.

3.3 Relief aspects of the basin

Relief morphometry of river basin describes variation of elevation between the highest and the lowest point. This is significant to study the flow phenomena in the basin. The potential energy of flowing water from high altitude gets converted to kinetic energy, which is related to slope. Various losses of water like storage, infiltration, evaporation etc. and travel times are inversely related to slope. The various parameters (Table 3) defined by different workers are estimated by creating DEM and Slope map of the basin.

Table 1. Basin Linear Parameters

S.No	Parameters	Symbol	Definition.
1	Basin Perimeter	Lp	Length measured along the basin boundary
2.	Length of main stream	L	Length measured along the longest watercourse from the outlet point to upper limit to the basin boundary.
3	Length of Stream between the outlet and a point near to centre of gravity (Snyder, 1938)	Lc	Length of stream measured from the outlet of the basin to a point on the stream nearest to centroid of the basin.
4	Basin length or Valley length	Lb	Straight line distance between outlet of the basin and the furthest point on the ridge
5	Stream length of each order	L1	Total length of streams of first order.
		L2	Total length of streams of second order
		L3	Total length of streams of third order
		L4	Total length of streams of fourth order
		L5	Total length of streams of fifth order
6	Total stream length of all orders	Lw	L1+L2+L3+L4+L5
7	Mean stream length of each oredr	$\bar{L}1$	Total length of streams of first order / Total number of streams of first order
		$\bar{L}2$	Total length of streams of second order / Total number of streams of second order
		$\bar{L}3$	Total length of streams of third order / Total number of streams of third order
		$\bar{L}4$	Total length of streams of fourth order / Total number of streams of fourth order
		$\bar{L}5$	Total length of streams of fifth order / Total number of streams of fifth order
8	Number of streams of each order	N1	Total number of streams of first order.
		N2	Total number of streams of second order
		N3	Total number of streams of third order
		N4	Total number of streams of fourth order
		N5	Total number of streams of fifth order
9	Total number of streams of all order	Nw	N1+N2+N3+N4+N5
10	Wandering ratio (Smart and Surkan, 1967)	Rw	Mainstream length / Basin length.
11	Fineness ratio (Melton, 1957)	Rf	Stream lengths / length of the basin perimeter
12	Basin Eccentricity (Black, 1972)	τ	$[(Lc^2-W_L^2)]^{1/2} / W_L$, W_L =width if the basin at the center of mass and perpendicular to Lc.
13	Bifurcation ratio (Horton, 1945)	Rb	Ratio of number stream of lower order w to the number streams of order w + 1.
14	Stream-length ratio (Horton, 1945)	Rl	Ratio of mean stream segment length of order w to mean stream segment length of order w - 1.
15	Length of overland flow (Horton, 1945)	Lo	Half the reciprocal of drainage density.

Table 2. Basin Areal Parameters

S.No.	Parameters	Symbol	Definition
1	Total Drainage Area	A	Basin area
2.	Drainage Denisty	D	Total length of all streams / Basin area.
3	Constant of Stream Maintenance (Schumm, 1956)	C	Inverse of drainage density
4	Stream-Segment Frequency (Horton, 1945)	F	Number streams segments per unit basin area
5	Drainage area of each order	A1	Total drainage area of first order.
		A2	Total drainage area of second order.
		A3	Total drainage area of third order.
		A4	Total drainage area of fourth order.
		A5	Total drainage area of fifth order.
6	Average drainage area of each order	$\bar{A}1$	Total drainage area of first order / Total number of streams of first order
		$\bar{A}2$	Total drainage area of second order / Total number of streams of second order
		$\bar{A}3$	Total drainage area of third order / Total number of streams of third order
		$\bar{A}4$	Total drainage area of fourth order / Total number of streams of fourth order
		$\bar{A}5$	Total drainage area of fifth order / Total number of streams of fifth order
7	Area Ratio (Schumm, 1954)	Ar	Ratio of mean drainage area of basin of order w to mean drainage area of basin of order w - 1.
8	Circularity Ratio (Miller, 1953)	Rc	Basin area / Area of circle having circumference equal to the basin perimeter.
9	Elongation Ratio (Schumn, 1956)	Re	Diameter of a circle having the same area as the basin / Basin length.
10	Basin Shape Factor (Wu et al., 1964)	Rs	Main stream length / Diameter of a circle having the same area as the basin.
11	Unit Shape Factor (Smart and Surkan, 1967)	Ru	Basin length / $(\text{Basin area})^{1/2}$
12	Form Factor (Horton, 1932)	Rf	Basin area / $(\text{Basin length})^2$
13	Compactness coefficient (Strahler, 1964)	Cc	Basin perimeter / Perimeter of the circle having the same as basin area.

Table 3. Basin Relief Parameters

S.No.	Parameters	Symbol	Definition
1	Basin Relief (Schumm, 1956)	Rb	Altitude difference between highest point and outlet in the basin.
2.	Relief Ratio (Schumm, 1956)	Rh	Basin relief / Distance between the highest point and outlet in the basin.
3	Relative relief (Melton, 1957)	Rp	Basin relief / Basin perimeter.
4	Ruggedness Number (Melton, 1957; Strahler, 1958)	Rn	Product of the Basin relief and drainage density.

3.4 ILWIS GIS Software

The GIS software used in this stud,· is ILWIS (Integrated Land and Water Information System), developed at the Computer Center of International Institute of Aerospace Survey and Earth Sciences (ITC) Enschede, The Netherland. ILWIS provides user with state of art of data gathering, data input, data storage, data manipulation and analysis and data output capabilities, merging and integrating conventional procedures with image processing use with microcomputers and uses both vector and raster graphics data (Valenznela, 1990).

Complex modelling of features can be executed by the map calculation. Map calculation includes an easy to use modelling language and the possibilty of using mathematical functions and macros. It integrates tabular and spatial databases. Tabular and spatial data base can be used independently and on an integrated bases. Table calculator can perform calculation, queries and simple statistical analysis.

3.4.1 Creation of spatial database

The creation of a database for the basin through ILWIS involved the collection of relevant available data, the conversion of these data to digital format, digitization, error checking and correction, polygonization of segment files and, finally, conversion of the data acquired in vector structure to raster format. The primary source of information for geomorphological parameters (i.e. linear, areal, and relief aspects) was Survey of India toposheet No. 43 P/2. Basin boundary map, drainage map, and contour map at 20 m interval have been digitized through ILWIS and related attribute data entered.

3.4.2 Digital Elevation Model (DEM)

While digitizing contour lines of a basin, one should make sure to extend the digitized contour lines a little bit out of the study area, since artifacts may occur at the borders of the area in which interpolation takes place. The interpolation of contour lines will give wrong results for hilltops, which are enclosed on all sides by a contour line. They will appear as flat areas with the same altitude as the contour line surrounding it. To improve this, the raster segment map, containing the contour lines, and a raster point map, containing the altitude of the hilltops, wherever available, was combined. The combined raster map (pixel size 20 m) was then used as the basis for the interpolation. This interpolated map gives the ground surface elevation at each pixel point in the basin.

3.4.3 Slope map

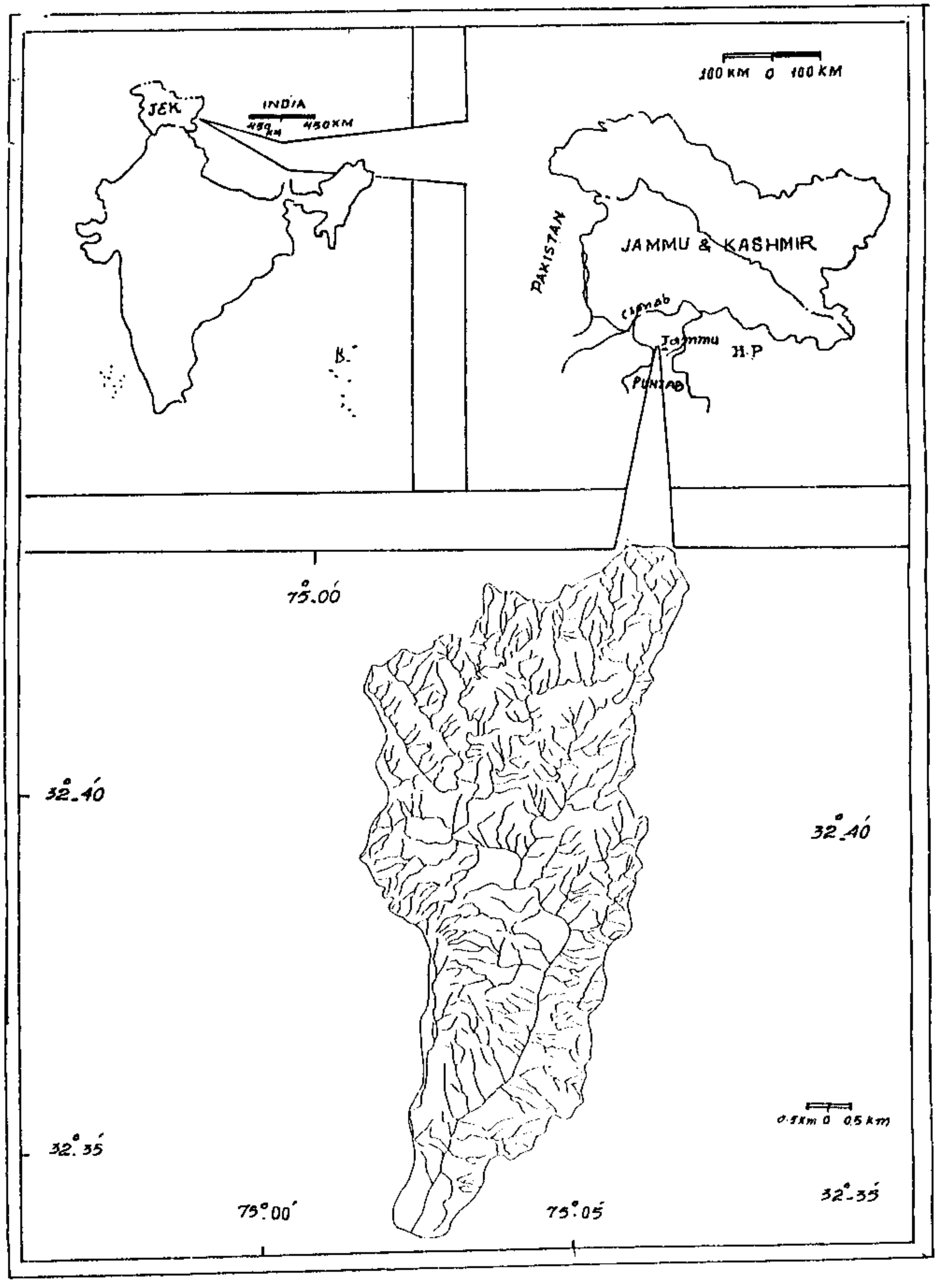
The slope in percentage has been generated calculating slope gradient in X and Y direction using a DEM, gradient filters (Dfdx and Dfdy) and a map calculation formula:

SLOPE = 100 * HYP(DX,DY)/ PIXSIZE(DEM)
HYP is an internal Mapcalc/Tabcalc function.
Function PIXSIZE returns the pixel size of a raster map
SLOPE is in percentages.

4.0 STUDY AREA

Devak is a small tributary of Ujh river (Ravi river basin) in the Western Himalayas and the catchment is located between latitude 32° 35′ to 32° 45′ N and longitude 75° 00′ to 75° 10′ E (Fig 1). The catchment is on the southern slope of lower Himalayas range in the Western Himalayas. The area of the catchment is 97.27 Km^2, with its elevation varying from 343.60 m at the outlet to 840 m at the peak above mean sea level. From the farthest point the river travels for a length of 27.47 Km up to the outlet near Gura Slathian. The major tributaries of the Devak river are Sangar wali khad, Plalaiwali khad and Karanalwali khad. No meteorological station is available in the basin for measurement of rainfall and temperature. The nearest meteorological station for the catchment is Jammu, where the average annual rainfall is about 1055 mm and average temperature varies from 4° to 40 ° Celsius. The temperature at higher altitudes in the northern part of the catchment is expected to be a little low. There are two rainy seasons: one from December to March, associated with the passage of western disturbances, and the other from mid - June to mid – September, due to southwest monsoon currents. The rainfall in October and November is generally small in amount. The western disturbances occasionally give very stormy weather. In April and May thunder storms are occasionally observed giving light to moderate showers of rain. The southwest monsoon is a predominant feature in this region.

Fig.1 Location map of Devak catchment Jammu(J&K)



4.1 Geology of the Area

According to Gupta and Verma (1988), Devak basin consists of Siwalik Group sequence of molassic sediments. The sequence is divisible into three subgroups, i.e., the Lower, Middle and Upper Siwalik, and further five mappable litho units, namely the Mansar, Dewal, Mohargarh, Uttarbaini and Dughor formations from the base to the top. The different units are traceable over long distances to the southeast and northwest throughout the extension of the foothills in J&K. On the basis of gross lithologies and physical characters of the sediments, the following stratigraphic successions in the study area are present:

Group	Subgroup	Formation	Member	Age
	Terraces (T1-T3)	Unconformity		Holocene
S	Upper Siwalik	Dughor (76 m)		Lower Pleistocene
I W A L I		Uttarbaini	Marikhui (1524m) Labli (1000 m)	Upper Pliocene
K		Mohargah(915 m)		Middle Pliocene
	Middle Siwalik	Unconfirimity Dewal (1753 m)		Lower Pliocene
	Lower Siwalik	Mansar (1977 m) (Base not exposed)		Upper Miocene

The oldest litho unit of Siwalik Group, the Mansar is present in upper reaches of the catchment. It consists of alternating layers of fine grained, hard and compact sandstone, silt stone, mudstone and clay (Gupta and Verma, 1988). The sandstone are buff, grey and light greenish gray in colour. The clays are purple, brown, red and yellowish red. The next litho unit, conformably overlying the Mansar Formation, is designated as the Dewal Formation. It mainly consists of grey (salt and pepper colour) to dull grey, comparatively fragile, fine to medium grained, occasionally pebbly sandstone and interbedded layers of reddish brown, orange, yellow, carbonaceous, grey and earthy grey clay. The sandstone/clay ratio is about 70/30 per cent. A gently but distinct angular unconformity is observed between the Dewal and the overlying lithounit, named as Mohargarh Formation, earlier known as Parmandal Sandstone (Rao et al, 1981).

Uttarbaini formation overlies the massive sandstone strata of the Mohargarh formation. Uttarbaini formation consists of a thick sequence of sandstone, variegated clay and conglomerate with a total thickness of 2524 m. The basal part of this unit is sandstone/red clay dominant facies. The formation as a whole is a red clay dominant unit and quite distinct from the preceding Mohargarh formation. The Uttarbaini formation is divisible into two members in this section, namely, the lower Labli and the upper Marikhui, both having considerable lateral extension. Dughor formation is a regional feature of the top most Upper Siwalik all over northwest India and is a significant landmark related to the palaeoclimate. The pebbles and boulders, embedded in an intense orange coloured matrix, constitute major part of this unit.

5.0 ANALYSIS AND DISCUSSION OF RESULTS

For evaluating the hydromorphological parameters of Devak basin, a topographic map of the area was drawn from the Survey of India Topo Sheet No. 43 P/2 (1:50000 scale). Boundary map, drainage map, and contour map at 20 m interval are digitized using ILWIS GIS in order to get the linear, areal and relief aspects of the basin. The stream network has been ordered by the Horton-Strahler method using network module in ILWIS 1.2.

It can be seen from the Table 4 that the mean lengths which were calculated as the ratio of total length of specific order stream to the number of stream segments are 0.59, 1.09, 2.85, 5.22 and 9.58 Km. for order 1, 2, 3, 4 and 5, respectively. It is observed that the basin is fifth order basin having 353 first order, 65 second order, 16 third order, 2 forth order and one fifth order streams contained in the drainage area of 97.27 Sq.Km. up to Gura Slathian. Since basin of a given order can be modeled as a collection of sub element, the number of streams of each order is an important concept in hydrology. Figure 2 shows that the number of streams of given order decreases with the increase in stream order and

Table 4. Linear parameters of the Devak basin up to Gura Slathian

S.No	Parameters	Symbol	Value
1	Basin Perimeter	Lp	53.58 Km.
2.	Length of main stream	L	27.47 Km.
3	Length of Stream between the outlet and a point near to centre of gravity (Snyder, 1938)	Lc	13.08 Km.
4	Basin length or Valley length	Lb	20.08 Km.
5	Stream length of each order	L1	208.76 Km.
		L2	71.13 Km.
		L3	45.65 Km.
		L4	10.43 Km.
		L5	9.58 Km.
6	Total stream length of all orders	Lw	345.55 Km.
7	Mean stream length of each oredr	$\bar{L1}$	0.59 Km.
		$\bar{L2}$	1.09 Km.
		$\bar{L3}$	2.85 Km.
		$\bar{L4}$	5.22 Km.
		$\bar{L5}$	9.58 Km.
8	Number of streams of each order	N1	353
		N2	65
		N3	16
		N4	02
		N5	01
9	Total number of streams of all order	Nw	437
10	Wandering ratio (Smart and Surkan, 1967)	Rw	1.37
11	Fineness ratio (Melton, 1957)	Rf	0.51
12	Basin Eccentricity (Black, 1972)	τ	1.42
13	Bifurcation ratio (Horton, 1945)	Rb	4.87
14	Stream-length ratio (Horton, 1945)	Rl	2.03
15	Length of overland flow (Horton, 1945)	Lo	0.14 Km.

the negative slope of the line confirms the law of stream numbers. The average Bifurcation ratio of the basin is 4.87, which is normally between 3 to 5, and can be used as an index of hydrograph shape for basins. Perimeter of the basin is found to be 53.58 Km. The length of main stream between basin mouth and a point near center of the drainage basin is 13.08 Km. The average stream length ratio of the basin is 2.03, it is useful in synthesizing hydrograph characteristics. Figure 3 shows stream length versus stream order. Figure 4 shows mean stream length versus order of streams. The plot shows the

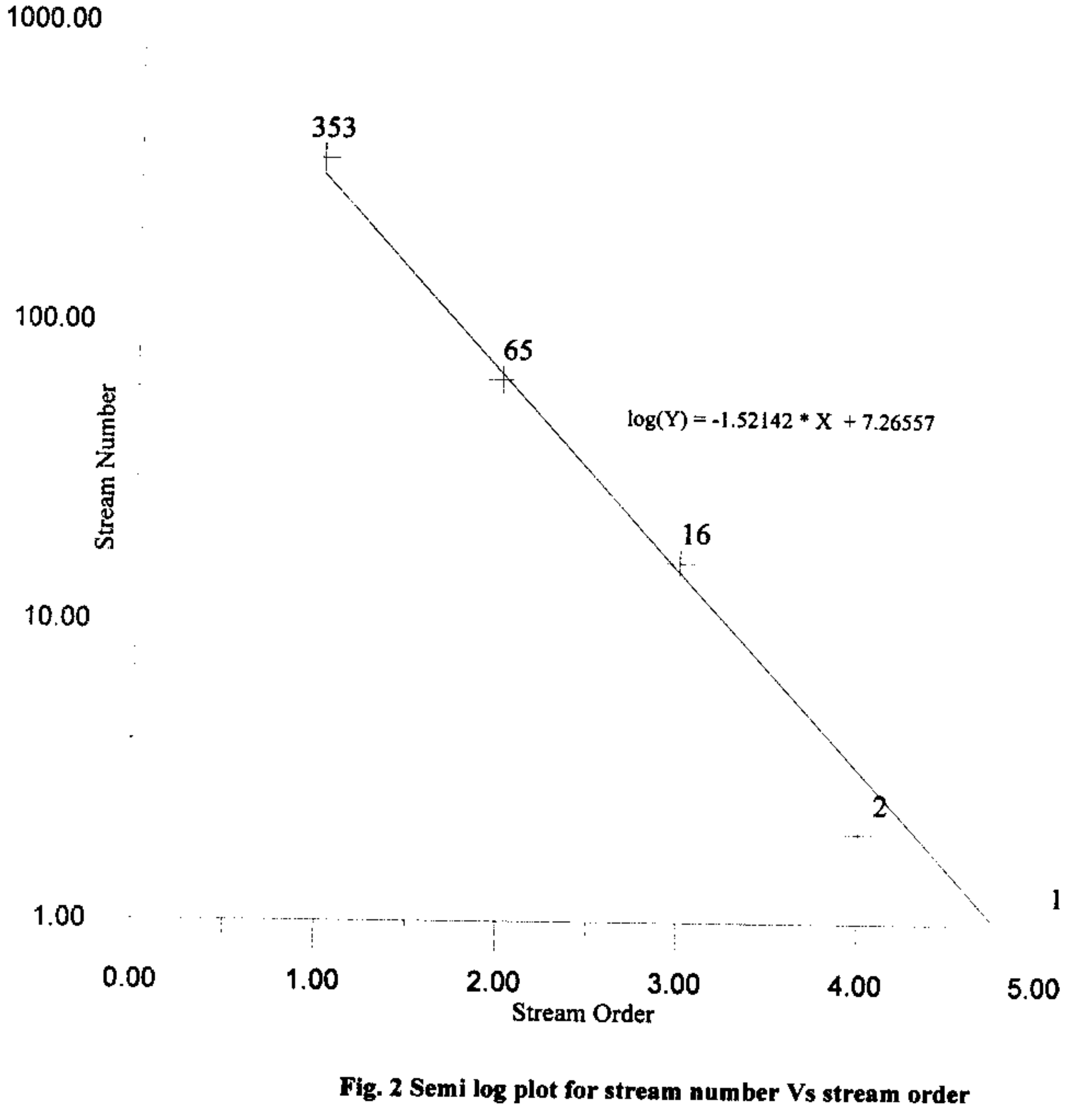


Fig. 2 Semi log plot for stream number Vs stream order

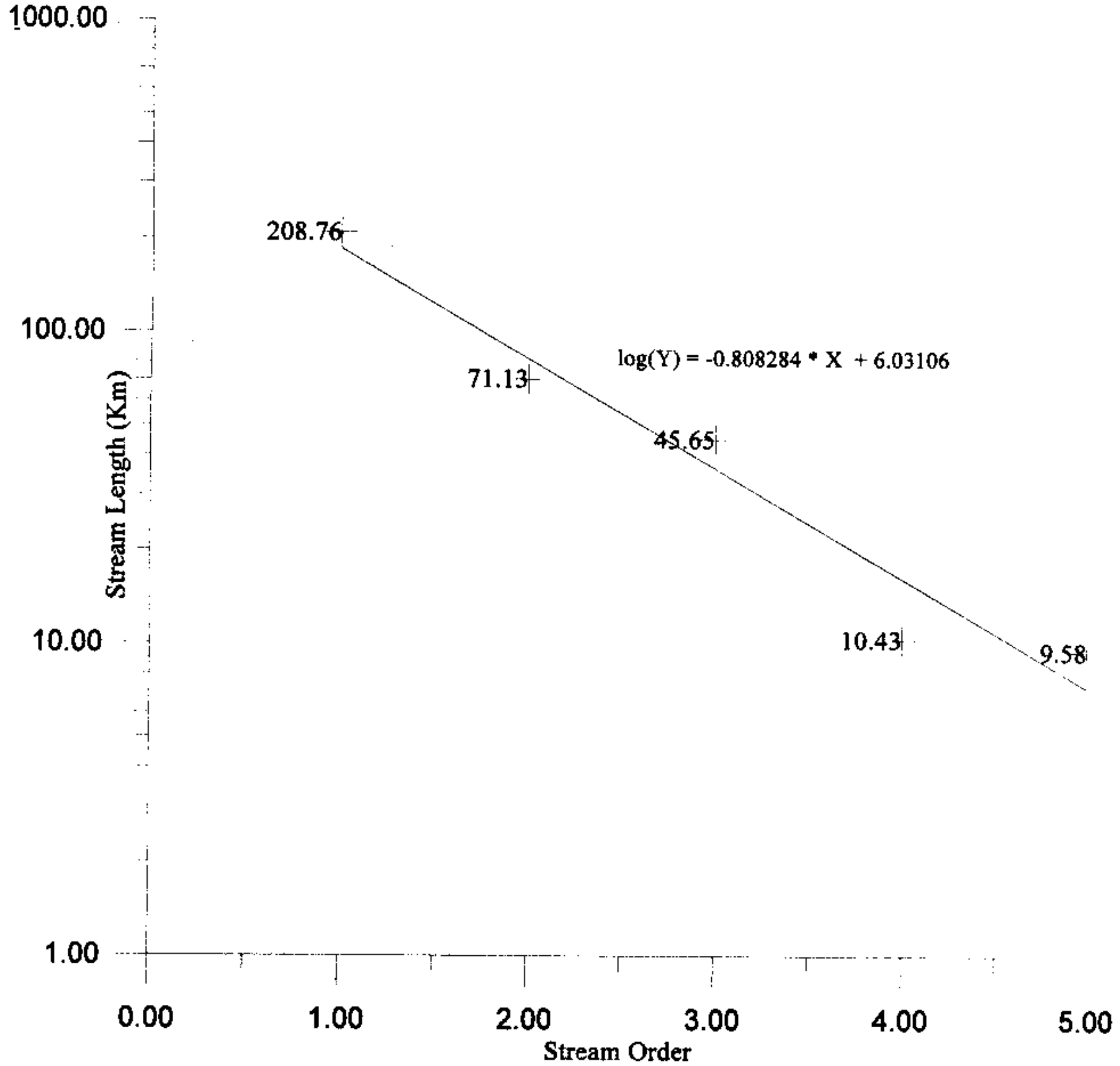


Fig.3 Semi log plot for stream length Vs stream order

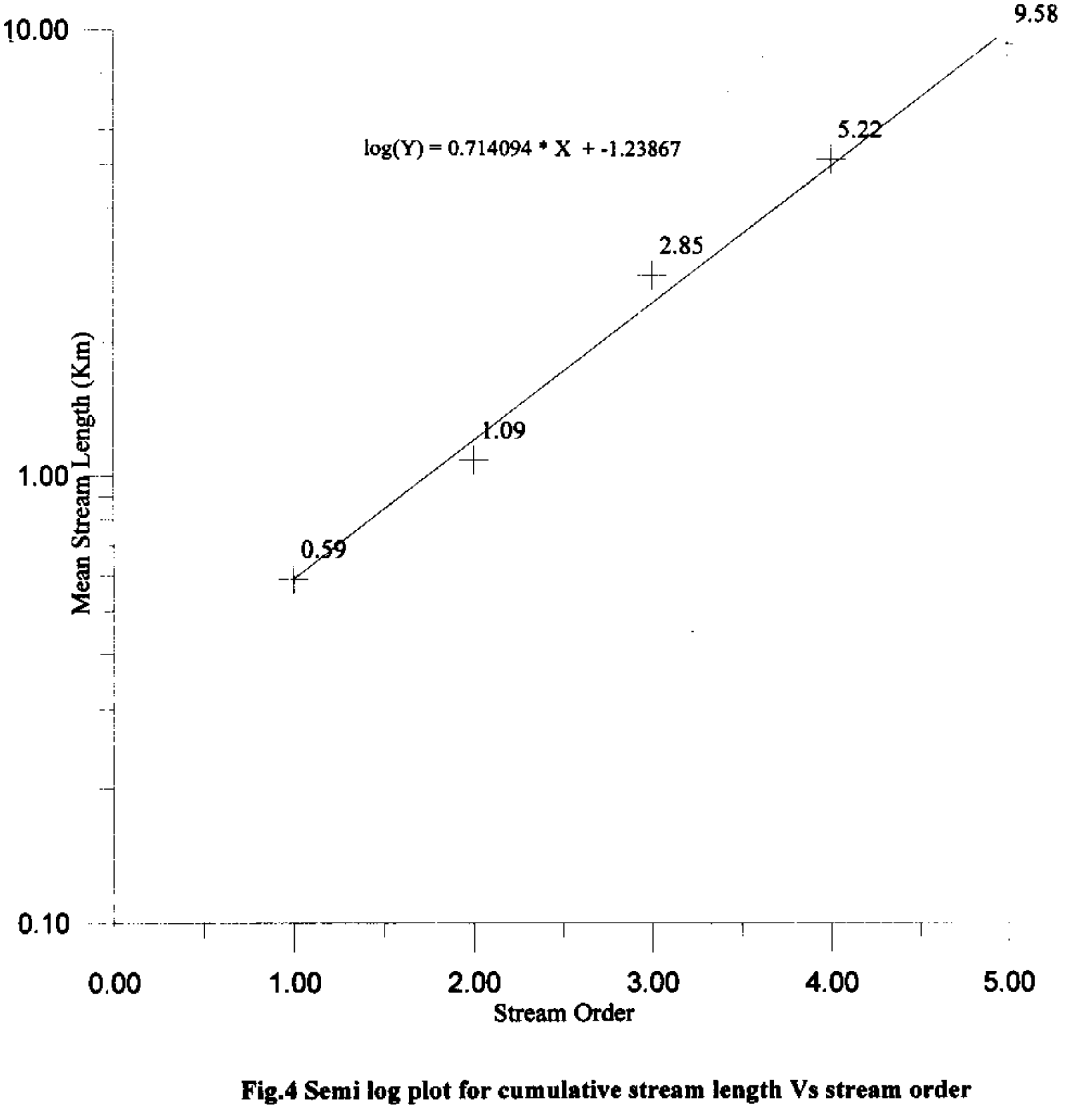


Fig.4 Semi log plot for cumulative stream length Vs stream order

increasing trend in average length of the streams and it follows Horton's law of stream length.

The various areal measures are presented in Table 5. In this table the total area covered by different order streams have been reported along with the mean areas. The mean areas as 0.16, 1.17, 5.64, 47.01, 97.27 Sq.Km respectively for order 1,2,3,4 and 5. The sub basin area is considered to be one of the important geomophological characteristic and has been used frequently in the various hydrological studies. Drainage density of the basin is found to be 3.55 Sq.km / Km. It is largely a function of climate, lithology, and stage of basin

Table 5. Areal parameters of the Devak basin up to Gura Slathian

S.No.	Parameters	Symbol	Value
1	Total Drainage Area	A	97.27 Sq.Km.
2.	Drainage Denisty	D	3.55 Km. / Sq.Km.
3	Constant of Stream Maintenance (Schumm, 1956)	C	0.28 Sq.Km. / Km.
4	Stream-Segment Frequency (Horton, 1945)	F	4.49 / Sq.Km.
5	Drainage area of each order	A1	56.48 Sq.Km.
		A2	75.98 Sq.Km.
		A3	90.38 Sq.Km.
		A4	94.02 Sq.Km.
		A5	97.27 Sq.Km.
6	Average drainage area of each order	$\bar{A1}$	0.16 Sq.Km.
		$\bar{A2}$	1.17 Sq.Km.
		$\bar{A3}$	5.64 Sq.Km,
		$\bar{A4}$	47.01 Sq.Km.
		$\bar{A5}$	97.27 Sq.Km.
7	Area Ratio (Schumm, 1954)	Ar	5.64 Sq.Km.
8	Circularity Ratio (Miller, 1953)	Rc	0.43
9	Elongation Ratio (Schumn, 1956)	Re	0.55
10	Basin Shape Factor (Wu et al., 1964)	Rs	2.47
11	Unit Shape Factor (Smart and Surkan, 1967)	Ru	2.04
12	Form Factor (Horton, 1932)	Rf	0.24
13	Compactness coefficient (Strahler, 1964)	Cc	1.53

development. The circularity and elongation ratio are found to be 0.43 and 0.55, respectively. The values of these dimensionless parameters approaches 1 as the shape of the basin approaches a circle and the computed value of elongation ratio indicates that the basin is having strong relief and steep ground slopes. Figure 5 shows that mean drainage area versus stream order. It can be seen from the plot that the drainage network follows the Horton,s law of stream areas.

A DEM (fig. 6) is prepared with pixel size of 20 m. Elevation of the basin ranging from 343.60 m at the out let and 840 m at the ridge of the basin, the average basin elevation is about 551.0 m. Slope map in percentage has been prepared using DEM and gradient filters. It has been classified into five categories i.e, 0-5 %, 5-15 %, 15-33%, 33-50 %, and more than 50 % (Fig.7). Results show that 33% of the total area falls under the 0-5%, 27% area under 5-15%, 22% area under 15-33%, 9% area under 33-50% and the rest of the total area under more than 50% slope. Figure 8 shows that the average slope of streams of given order decreases with the increase in stream order and the negative slope of the line confirms the law of stream slopes. A 3D View of the basin (Fig. 9) is also prepared using the DEM of the basin. The parameters based on relief are estimated using the DEM of the basin and given in Table 6. These parameters are most important in influencing the runoff and other hydrological process. The basin relief is found to be 496.4 m. The basin relief ratio, relative relief and ruggedness number are 0.025, 9.26, and 1.762 respectively. The relief parameters are mostly non-dimensional and have significant effect on overland flow governing the flow processes.

Table 6. Relief parameters of the Devak basin upto Gura Slathian

S.No.	Parameters	Symbol	Value
1	Basin Relief (Schumm, 1956)	Rb	496.4 m.
2.	Relief Ratio (Schumm, 1956)	Rh	0.025
3	Relative relief (Melton, 1957)	Rp	9.260
4	Ruggedness Number (Melton, 1957; Strahler, 1958)	Rn	1.762

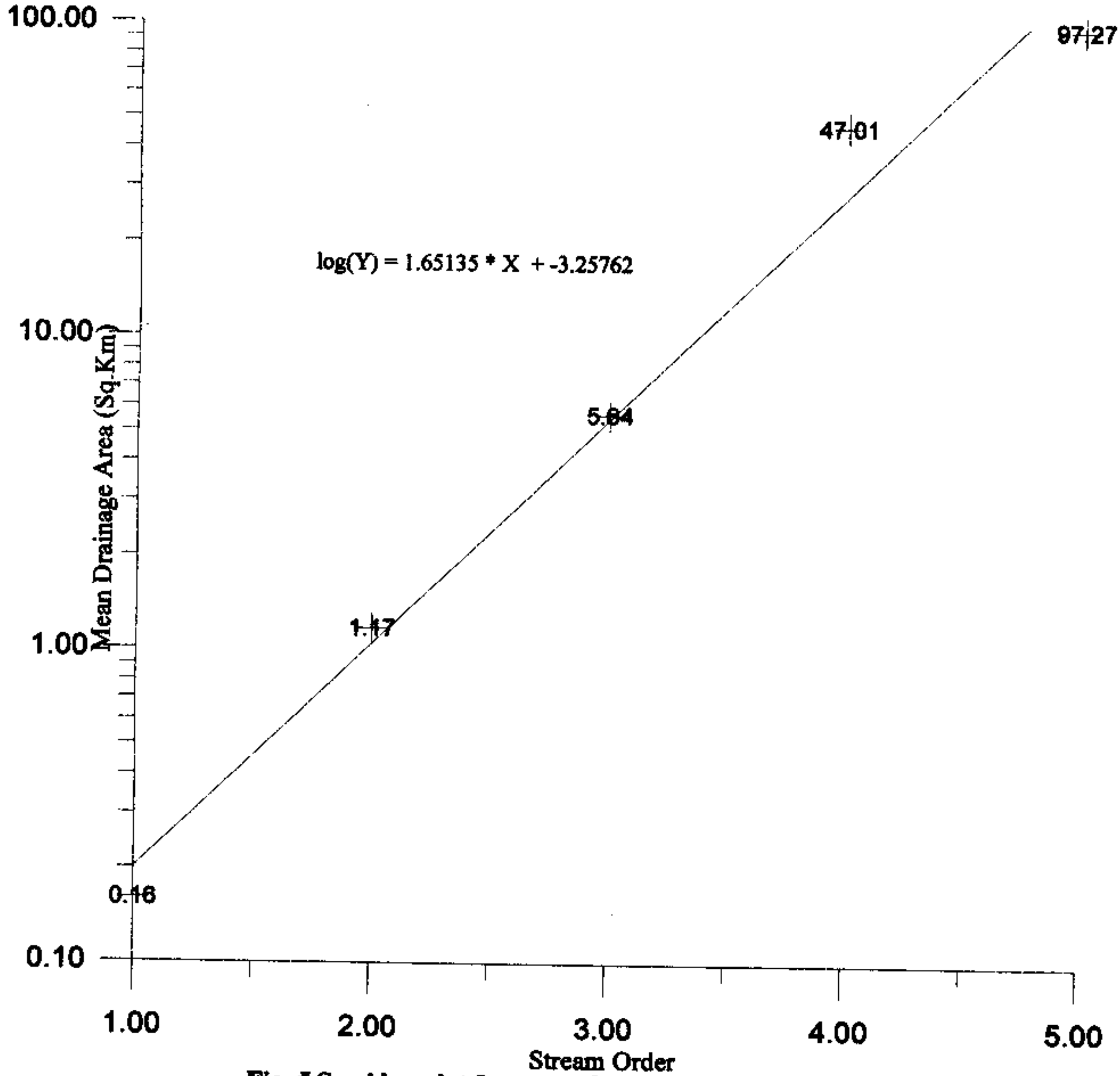


Fig. 5 Semi log plot for mean drainage area Vs stream order.

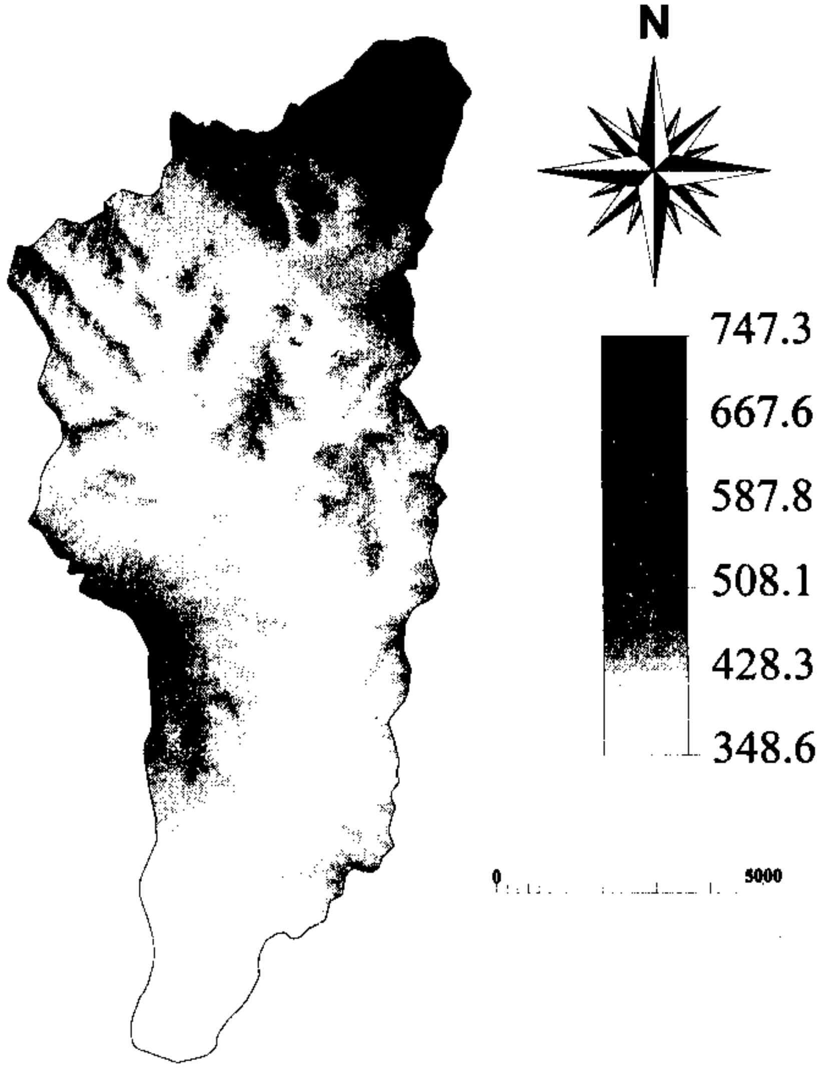


Fig.6 DEM of the Devak Basin

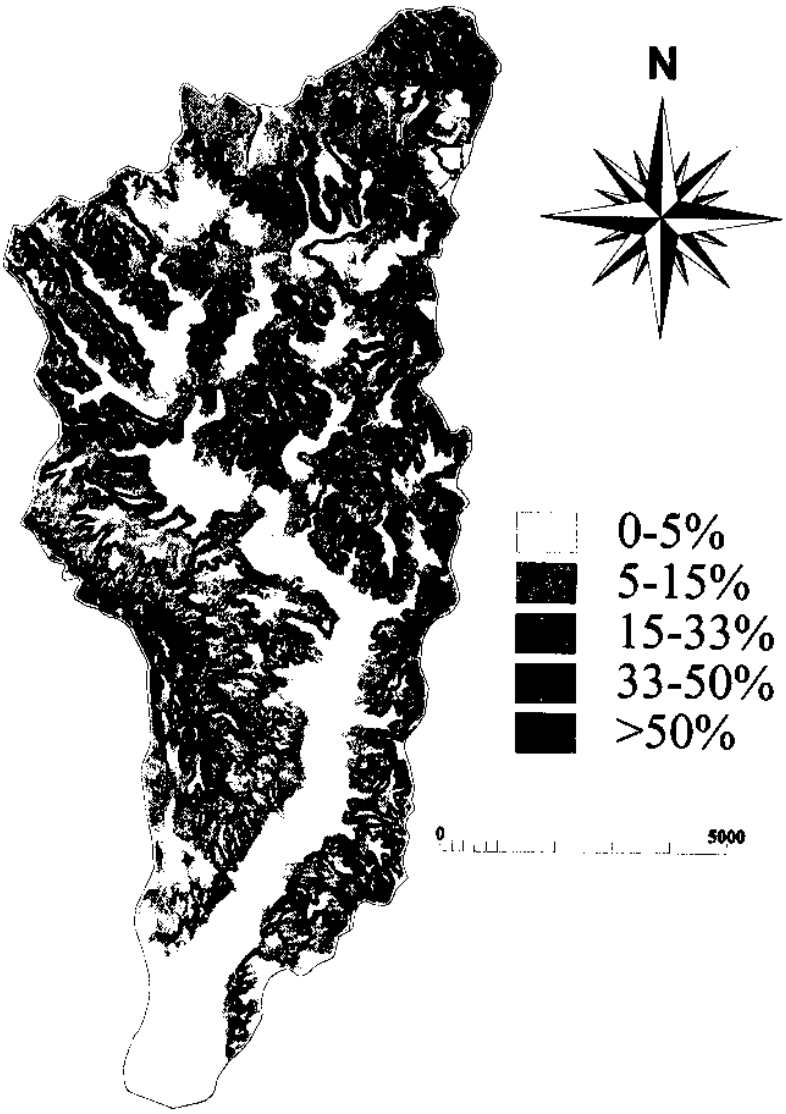


Fig. 7 Slope Map (%) of the Devak Basin

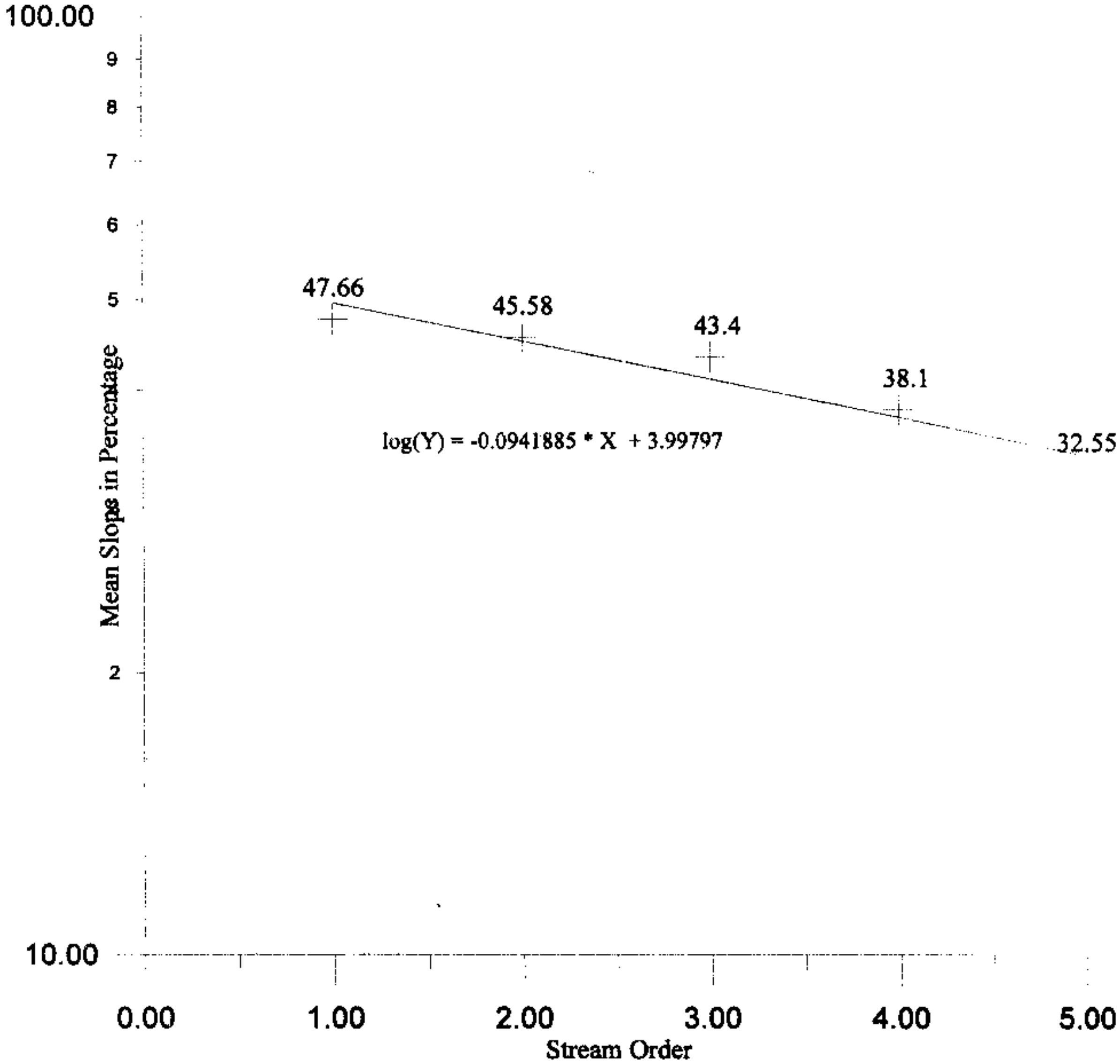


Fig.8 Semi log plot for mean overland slope Vs stream order

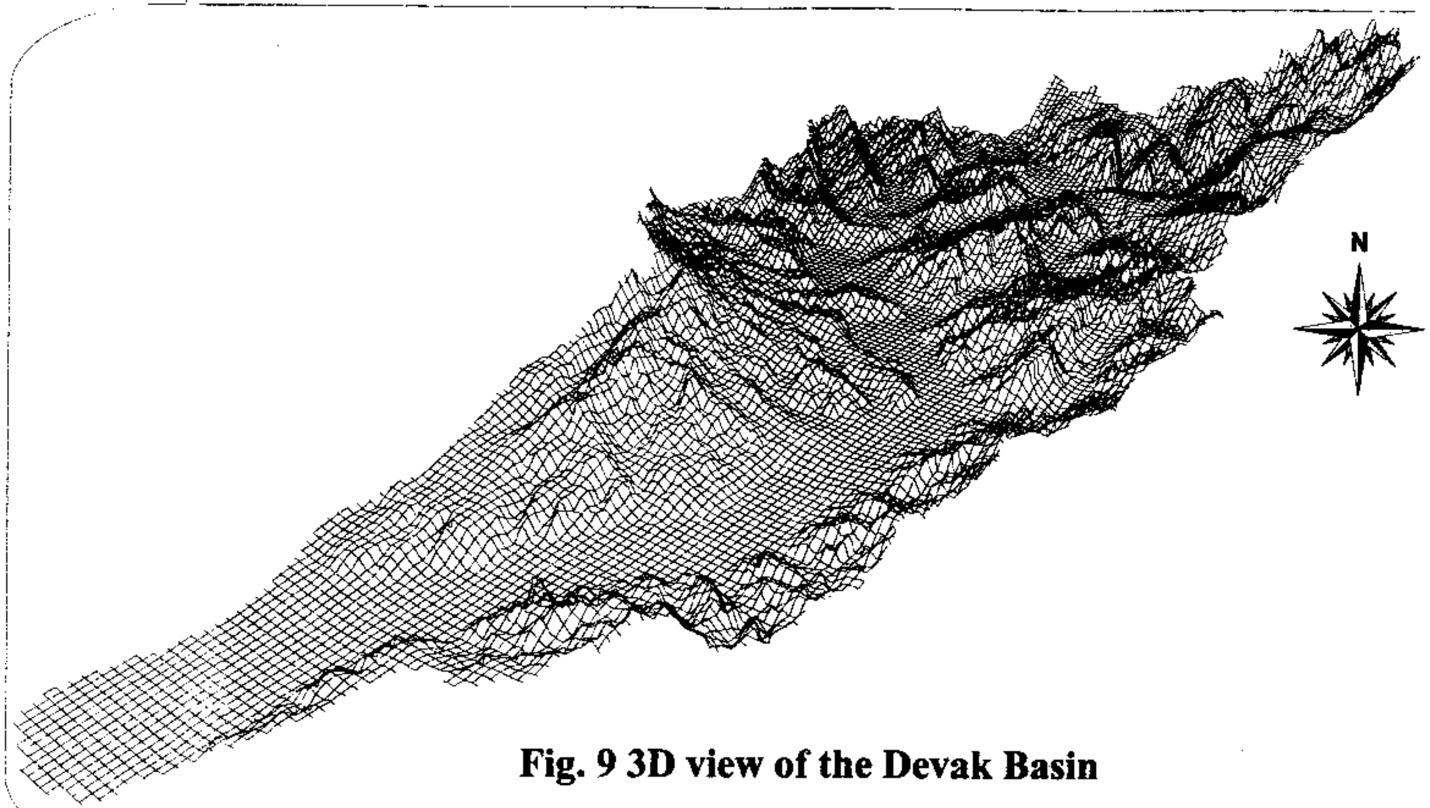


Fig. 9 3D view of the Devak Basin

6.0 SUMMARY AND CONCLUDING REMARKS

In absence of adequate data, especially in ungauged basins, the measurable geomorphological properties can be applied to synthesize the runoff response of a basin. However, in India, not enough successful applications of geomorphological characteristics to specific hydrologic studies in a basin, and subsequent transforming the results to other basins have yet been documented.

In this study, various geomorphological parameters, covering linear, areal and relief aspects, of Devak basin upto Gura Slathian have been evaluated. Devak is a tributary of Ujh river (Ravi Basin), originates from the Siwalik terrain of Jammu region. It is a fifth order basin, covering an area of 97.27 km^2. About 60% area of total basin falls within the 0-15% slope category while slope is very high (i.e., >50%) in its upper reaches. The geomorphological parameters estimated may be utilized for testing hydrological models to simulate hydrological response of the basin. Such models are very useful and are being widely used for simulating hydrological response of ungauged basin or basin with limited data.

In the Devak basin there is no existing network of hydrometerological observation. With the estimated geomorphological parameters of the basin it may be possible to develop synthetic Geomorphological Instantaneous Unit Hydrograph (GIUH) or evaluate important hydrologic model parameters, like that of Nash Model.

Reference:

Ebisemiju, F.S. 1979. An objective criteria for the selection of representative basin. Water Resources Research 15 (1): 148-58.

Gupta, S.S. and Verma B.C. 1988, Stratigraphy and vertebrate fauna of the Siwalik group mansar-utterbaini section, Jammu district, J&K journal of the palaeontological Society of India, vol.33, p.p. 117-124

Gurnell A.M. 1978. The dynamics of drainage network. Nordic Hydrology 9: 293-306.

Horton, R.E. 1932. Drainage basin characteristics, Trans. Am. Geophysics Union, vol.13,pp.350-361.

Horton, R.E.1945, "Erosional Development of streams and their Drainage Basins Hydrophysical Approach to Quantitative Morphology, Bull. Goel. Soc Am Vol-56.in Hand Book of Applied Hydrology by chow pp.4-47.

ITC, 1997. ILWIS User's Manual (Enschede, Netherlands, International Institute of Aerospace Aurvey and Earth Science).

Jain, M.K. and Kumar N., 1991-92. Geomorphological characteristics of Western Ghat region Part III- Hemavati basin upto Sakleshpur, National Institute of Hydrology, Roorkee, No. TR-127, 34pp.

Jain, M.K., 1992-93. Geomorphology of Sabarmati basin upto Dharoi, National Institute of Hydrology, Roorkee, No. TR-138, 27pp.

Jain, M..K., 1993-94. Geomorphological characteristics of Narmada (upto Manot) basin, National Institute of Hydrology, Roorkee, No.CS (AR)-128, 33pp.

Kumar, A. and Singh A.K., 1988-89 . Geomorphological characteristics of Western.Ghat region Part I- Upper Krishana basin, National Institute of Hydrology, Roorkee, No. TR-63, 24pp.

Lohani, A.K., Arora, M. and Kumar A., 1992-93. Geomorphological stidies of Bagmati basin of kosi river system, National Institute of Hydrology, Roorkee, No. TR-173, 68pp.

Melton, M.A. 1957. Geometric properties of Mature Drainage system and their Representation in an Ei phase space "-Geol, Vol. 66,pp- 35-54.

Miller, V.C 1953. "A Quantitative Geomorphic study of Drainage Basin characteristics in the clinch Mountain Area, "Virginia and Tennessee. Tech. Report. 3 columbia University, in hand Book of Applied Hydrology by Chow. P.4-51.

Patten, F.C and Baker, V.R., 1976. Morphometry and flood in drainage basin subject to diverse hydromorphic control. Water Resources Research 12: 941-52.

Patwari, B.C. and Kumar, K., 1992-93. Hydrogeomorphological study of Tawi catchment, J&K, National Institute of Hydrology, Roorkee, No. CS-114, 68pp.

Patwari, B.C. and Kumar, K., 1993-94. Hydrogeomorphological study of Baira nalla sub-catchment (HP), National Institute of Hydrology, Roorkee, No. CS (AR)-143, 65pp.

Pristachova G., 1990. Quantitative Geomorphology, Stream network and Instantaneous Unit Hydrograph. IAHS pub. No. 190, pp. 55-63.

Rao, R., Agarwal, R.P, Sharma, U., Bhalla, M.S. and Nanda, A.C., 1988. Magnetic Polar Stratigraphy and Vertebarte Palenthology of the Upper Siwalik Subgroup of Jammu Hills, India. Jour. Geol. Soc. of India, 31 (4): 361-365.

Rodrguez-Iturbe,I., 1982. The coupling of climate and geomorphology in rainfall-runoff analysis. In Rainfall-Runoff relationship, edited by V.P Sing, 431-48, Water Resources publication, Littelton,colo.

Roohani. M.S. and Gupta, R..P. 1988, Quantitative Hydrogeomorphic investigation in the Chenab cathment, Himalayas, Hydrology Journal of IAH vol. XI, No.4, pp. 25-43.

Ross, G.A., 1970. The Standford watershed model: the correlation of parameters values selected by computerized procedure with measurable physical characteristics of the watershed. Research report no.35, Water Resources Institute, University of Kentucky, Lexington, Kentucky.

Jain S.K., Jain S.K. and Ahmad T., 1998. Rainfall Runoff Modelling usin Geomorphologic Instantaneou Unit Hydrograph and GIS, Asian-Pasific Remote Sensing and GIS Journal, Vol 10, No.2, pp. 38-48.

Schumm, S.A., 1954. Evolution of drainage system and slopes in Badlands at perth Amboy, New Jersey. Department of Geology, Technical report no. 8, Columbia University, New York.

Schumm, S.A., 1956. Evolution of drainage system and slopes in badlands at Perth Amboy, New Jersey, Bull. Geol.Soc.Am., vol.67,pp.597-646.

Singh, V.P., 1983. A Geomorphic approach to hydrograph synthesis with potential for application to ungauged watersheds. Technical completion report, Louisiana Water resources Research Institute, Louisiana State University, Baton Rouge, La.

Singh, N., 1990. Geomorphology of Himalayan Rivers (A case study of Tawi basin), Jay Kay Book house, Jammu Tawi

Singh, R.D., 1990-91. Geomorphology of Kolar sub-basin for hydrological studies, National Institute of Hydrology, Roorkee, No. TR-99, 68pp.

Smart, J.S and A.J. Surkan 1967. The relation between main stream length and area in drainage basin. Water Resources Research, 3: 963-74

Snyder, F.F. 1938. Synthetic unit-graphs Transactions, American Geophysical Union 19:447-54.

Strahler, A.N. 1964. "Quantitative Geomorphology of Drainage Basins and Stream Networks", Section 4-11 in Hand Book of Applied Hydrology (1964) by Ven Te Chow. pp. 10-23.

Strahler, A.N .1958. Quantitative analysis of watershed geomorphology, Trans. Am. Geophys. Union, vol.38,pp.913-920.

Valenzuela, C.R. 1990. Introduction to Geographic Information System, ITC publication No.22. ITC, Enschede, The Netherland.

Vijay Kumar, S.V., 1990-91. Geomorphological characteristics of Western Ghat region Part II-Ghataprabha and Malaprabha Basins, National Institute of Hydrology, Roorkee, No. CS-53, 32pp.

Wharton. G and Tomlison. J.J, 1999. Flood discharge estimation from river stream dimensions: result of application in Java, Burundi, Ghana and Tanzania, Hydrological Science Journal, 44 (1), pp. 97-110.

White E.L 1975. Factor analysis of drainage basin properties: Classification of flood behavior in terms of basin geomorphology. Water Resources Bulletin 11(4): 431-434

Wu, I.P., J.W. Delleur, and M.H. Diskin. 1964. Determination of peak discharge and design hydrographs for small watershed in Indiana. Techinical report No. 7, Indiana Joint Highway research project, purdue University, West Lafayett, Indiana.

Yen, Ben Chie and Kwan Tun Lee, 1997. Unit Hydrograph Derivation for Ungaged Watershed by Stream-Oreder laws, Journal of Hydrological Engineering, January 1997. Pp. 1-8.

Zelazinski, Janusz. 1986. Application of the Geomorphological Instantaneous Hydrograph theory to development of forecasting model in Poland, Hydrological Science Journal, 31, 2, 6/1986, pp.263-70.

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