CS—53

GEOMORPHOLOGICAL CHARACTERISTICS OF WESTERN GHATS

PART-II : GHATAPRABHA & MALAPRABHA BASINS

NATIONAL INSTITUTE OF HYDROLOGY
JAL VIGYAN BHAWAN
ROORKEE—247 667 (U.P.)

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ABSTRACT

Geomorphology is science of landforms. It describes landforms and attempts to explain the evolution of landform in terms of lithology,. structure, climate and geomorphology. The advance knowledge of geomorphology of the region is of importance in the field of flood control measures and engineering projects, since the geomorphological characteristics of river basins in mountainous areas affect runoff process and formation of flood in these areas.

Parameters of Hydrologic models describing rainfall-runoff process may be estimated either by optimisation technique using rainfall-runoff data or using topographical and climatic information of the basin. Since most of the locations in mountainous areas are either ungauged or sufficient data is not available for them, the study of geomorphological characteristics of such areas become much more important and significant. Thus 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 Aspect of Channel System (2) Areal Aspect of Channel System and (3) Relief Aspect of the basin.

The river systems of western ghats region are non-snowfed. Since the rain falling over these basins is directly converted into overland flow and channel flow, it becomes all the more important to have clear idea of geomorphological characteristics of these basins.

This study is continuation of the earlier studies that are undertaken in the western ghats region. Some of the widely used geomorphological parameters of Ghataprabha watershed upto Daddi and Malaprabha watershed upto Khanapur are evaluated in this exercise. The study may be useful at finding out effect of geomorphology on watershed runoff response and identifying those parameters which are more closely related to runoff in western ghat region.

.0 Introduction

Geomorphology, the study of 'terra firma' holds a unique position among a host of geosciences. The various parameters under the investigation of Geomorphologist are the land forms, the slopes, the stream network and the natural processes. It is very much possible to apply the geomorphological data, which was painstakingly collected by a geomorphologist, for different prospective areas just because of the strong relations which geomorphology has with the other disciplines like geology, pedology, hydrology, forestry, civil engineering, land use, archaeology etc. Such application can be for surface hydrological problems or for ground water prospecting.

Geomorphology being the study of landforms has direct influence on the flow processes. Geomorphological studies become much more important in the ungauged catchments since different geomorphological parameters help in regionalization of hydrological models dealing with the runoff estimations.

When the rainfall occurs over any part of the earths surface, a part of it runs over the ground as surface runoff while the portion which enters the earth's surface, either becomes subsurface water and joins the main stream after some time or percolates into the bottom layers and becomes ground water. This apportioning of the precipitation to surface runoff which collects in the streams and infiltration which contributes to the water table is effected primarily by the form of the earth's surface, which is accountable through various geomorphological aspects like linear, areal and relief parameters. Parameters like channel gradients, circularity ratio, elongation ratio, length of overland flow play important role in the runoff process and effecting peak runoff. The larger the drainage area the greater the amount of rain intercepted and the higher the peak discharge that results. Drainage density expresses the number of kilometers of channel maintained by a square kilometer of drainage area. Basin shape is very important factor influencing the peak flow and other hydrograph characteristics such as steepness of rising and recession limbs, the time spread of hydrograph etc.

Variables involving relief aspects of the basin are the most significant parameters in the hydrological studies of the watershed. The slope is related to the rate at which the potential energy of the waters at high elevations of the catchments is converted into kinetic energy. Losses in various forms occurs in the process. Water is held in storage and the travel time in the hydrologic system is in general inversely related to the slope.

The western ghats area is the origin of the major river systems like Godavari, Krishna and Cauvery. Since major portion of the discharge of these river systems is contributed by the overland flow of the rainfall, it becomes all the more important to have a clear idea of the landform characteristics of the catchments in this area.

The present study is aimed at establishing geomorphological parameters in the upper reaches of Ghataprabha and Malaprabha two important tributaries of the Krishna drainage system. The study area is located in the Western Ghats region.

2.0 Review

The collection of morphometric data involves such tedious laborious and time-consuming procedures that there is no unanimity among those who choose to undertake this exercise over the ultimate value of the same. Some like Hettner (1921) and others seem to be sceptical about the final outcome and are not quite sure if the results are commensurate with the time and labour spent on such a strenuous analysis. Strahler (1953) and others who have contributed constantly with methodology felt the analysis worthwhile. However, Subramanyan (1991) opines that the methodology seem (i) to minimize the subjective factor in land form treatment being more objective in approach (ii) to permit mathematical manipulation and statistical analysis of descriptive data and quantitative comparisons of drainage basins, (iii) to focus attention on details and aspects of basin configuration apt to be overlooked in a purely qualitative description and (iv) to help in establishing the denudation chronology of a region.

The drainage basin is quite clearly a fundamental geomarphic unit, having a number of streams, each having its own length, area of jurisdiction and channel slope. No analysis will be complete without dealing with these parameters and Horton (1945) has only projected the stream order as basic, independent variable that has exponential relations to all these. Horton modestly stated, "What has been given is a framework or outline of drainage basin development along hydrophysical lines rather than the completed picture. It is hoped that the reader will find that a new, more definite and more quantitative measuring has been imported to playfairs law and the Davis concept of the stream erosion cycle".

Playfair's law states, "Every river appears to consist of a main trunk, fed from a variety of branches each running in a valley proportional to its size and all of them forming a system of valleys communicating with one another and having such a nice adjustment of their declivities that none of them join the principal valley either on too high or too low a level"

Overland flow is one attribute of the basin which is very significant in hydrological studies. This is half the reciprocal of the drainage density and represents the distance from the water divide over which surface runoff takes place before getting localized in stream channels. It is during this overland flow as unconcentrated runoff that the precipitation manages to infiltrate through the soils to add to the groundwater, gets held up as depression storage or is lost by evapotranspiration. Howe (1960) has given the following equation for calculating the runoff,

$$q = c * a * i$$

where q is runoff; a is the drainage area; i is precipitation and c is a runoff coefficient.

A direct linear correlation between the drainage density and surface runoff was established by Hadley and Schumm for many basins in Wyoming.

Carlston (1963) found a significant relationship between the mean annual flood discharge for square mile (q) and the drainage density (d) expressed by the equation $q = 1.3\ d2$ for some basins in the eastern USA. Using the same data, an inverse relationship between the drainage density and the groundwater discharge (base flow) was shown.

Smith and Atkinson (1976) have shown that a direct linear relationship exists between the mean annual surface runoff and the mean annual solutional removal for lime stone regions with a continuous soil and vegetative cover.

The drainage texture-basin slope index has a direct correlation with the mean annual runoff In small areas with uniform geology, climate, land use and vegetation, a direct linear regression exists between the relief ratio and the annual sediment yield. The texture-slope ratio has also a similar linear relationship with the mean annual sediment-yield. Schumn (1977) observes that these relations provide a ready means for the delineation of high-sediment producing areas within a large drainage systems. If check dams are constructed across channels draining basins with both a high relief ratio and a high incised-channel density, it may be possible to prevent as much sediments from leaving the area. Whereas dams in basins with moderate runoff and low sediment yield may be good for water supply purposes.

A 'T' factor defined as largest length of the principal stream divided by the square root of the average channel slope, has been closely correlated with the basin area, rainfall intensity and frequency.

A modified 'T' factor defined as the product of relief ratio, circularity ratio and the frequency of the first order streams - has been found to have a high correlation with the peak intensity of runoff. Likewise, average runoff and peak runoff were found to be related to the stream length, relief ratio and shape ratio.

Maxwell and Marston (1980) derived area-yield indices of hydrologic characteristics, using physically sound relationships with geomorphic factors. Seven geomorphic variables are diversely combined into four geomorphic "factors" to produce statistically significant correlations with mean annual runoff, base flow, mean annual peak flow and mean annual sediment yield for six small research watersheds in the forested mountains of western Oregon. The derived correlations demonstrate the importance of channel density and relief, basin and channel network steepness and basin shape to hydrologic processes. They felt that the geomorphic factors should be used as relative indices, when applying to basins with no available hydrologic data.

National Institute of Hydrology (1988) commenced study on Geomorphological characteristics of Western Ghats region, and carried out studies for the Upper Krishna basin, which contributes predominantly to the flows in the Krishna drainage system. The objective of the studies were to evaluats some of the widely used geomorphological parameters for the mountainous catchments in the Western Ghats, which are mostly ungauged. The different geomorphic variables, their evaluation involving the linear, areal and slope aspects are brought up in detail in the report. The report has been referred in evaluating the different geomorphic parameters in the current report.

3.0 Description of the Study Area

The present area of study shown in fig. 1 is located in the Western Ghats. The two subbasins of Krishna are briefly described below (MOWR, 1972).

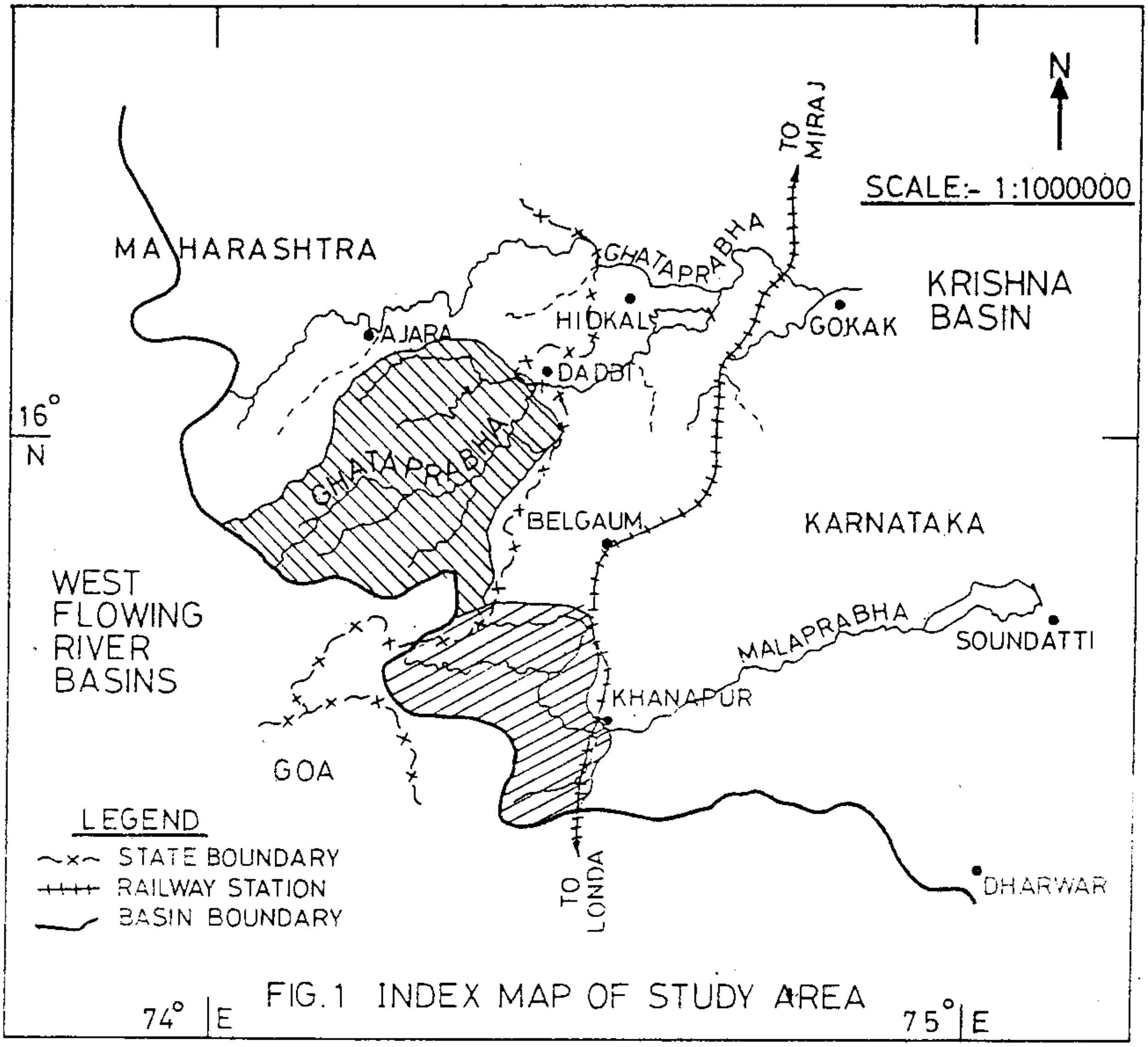
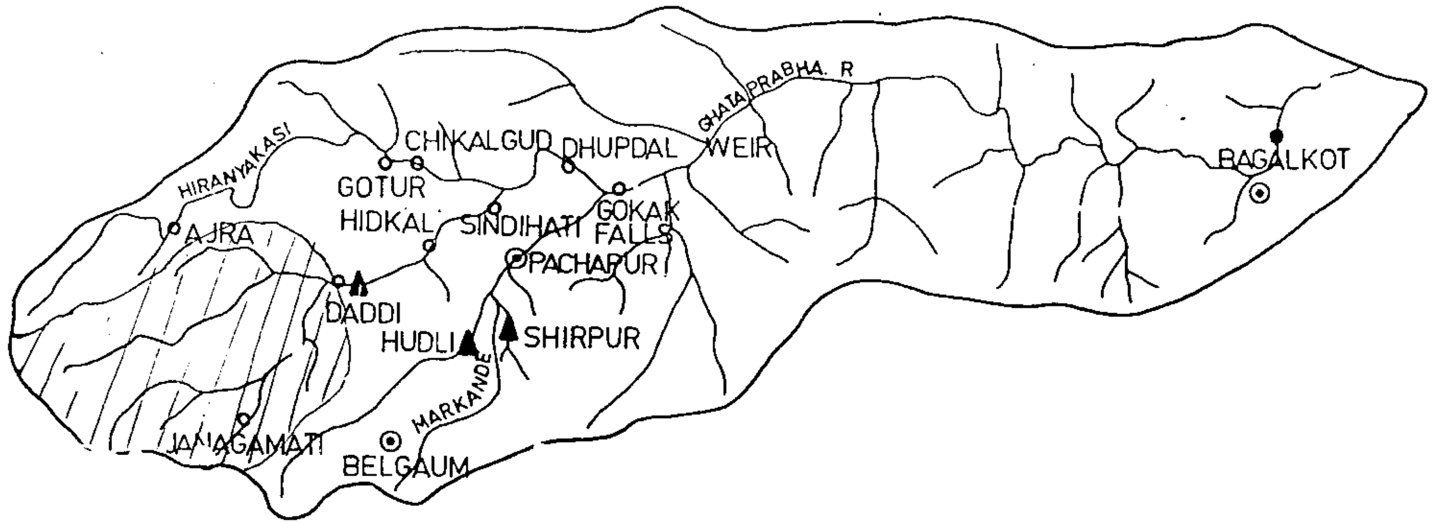


FIG.1 INDEX MAP OF STUDY AREA

The Ghataprabha rises in the Western Ghats at an altitude of 884 m and flows eastwards for a length of 283 km before joining the Krishna at Kudlisangam about 35 km north-east of Kaladgi at an elevation of 500 m. The river flows for about 60 km in the Ratnagiri and Kolhapur districts of Maharashtra before entering the Belgaum district of Karnataka. Two of its tributaries, the Hiranyakshi and the Markandeya also rise in Western Ghats and flow through Maharashtra and Karnataka. The total catchment area of Ghataprabha is 8,829 sq.km. The principal source of supply is an area of about 64 km of length along the Westernghats and about 64 km in width to the east of these hills. With in this area the annual rainfall decreases from about 3,048 mm to about 1016 mm. The basin map of Ghataprabha along with the location of the area of study is shown in Fig. 2. The area of study on Ghataprabha is the watershed upto Daddi, which is the first gauge - discharge site on the stream. At this place the measurements are being done using the boat and the current meter by the Central Water Commission.

The Malaprabha rises in the Western Ghats, at an altitude of about 793 m about 16 km west of Jamboti in Belgaum district of Karnataka. The river flows first in an easterly and then in a north easterly direction and joins the Krishna at an elevation of about 488 m about 306 km from its source. The total catchment area of the Malaprabha is 11,549 sq.km. Its principal source of supply is, however, only about 32 km along the Western Ghats and a small area east of it. The basin map of Malaprabha alongwith the location of the area of study is given in Fig.3. The area of study on Malaprabha consisted the watershed upto Khanapur which is the first gauge - discharge site on the stream. Here the measurements are being done by the state government agency near a road bridge.

FIG 2
MAP SHOWING GAUGE DISCHARGE AND
SILT SITES IN GHATAPRABHA SUB-BASIN
SCALE = 1 : 1,000,000



▲ GAUGE SITE
○ GAUGE DISCHARGE SITE
● GAUGE DISCHARGE & SILT SITE
AREA OF STUDY

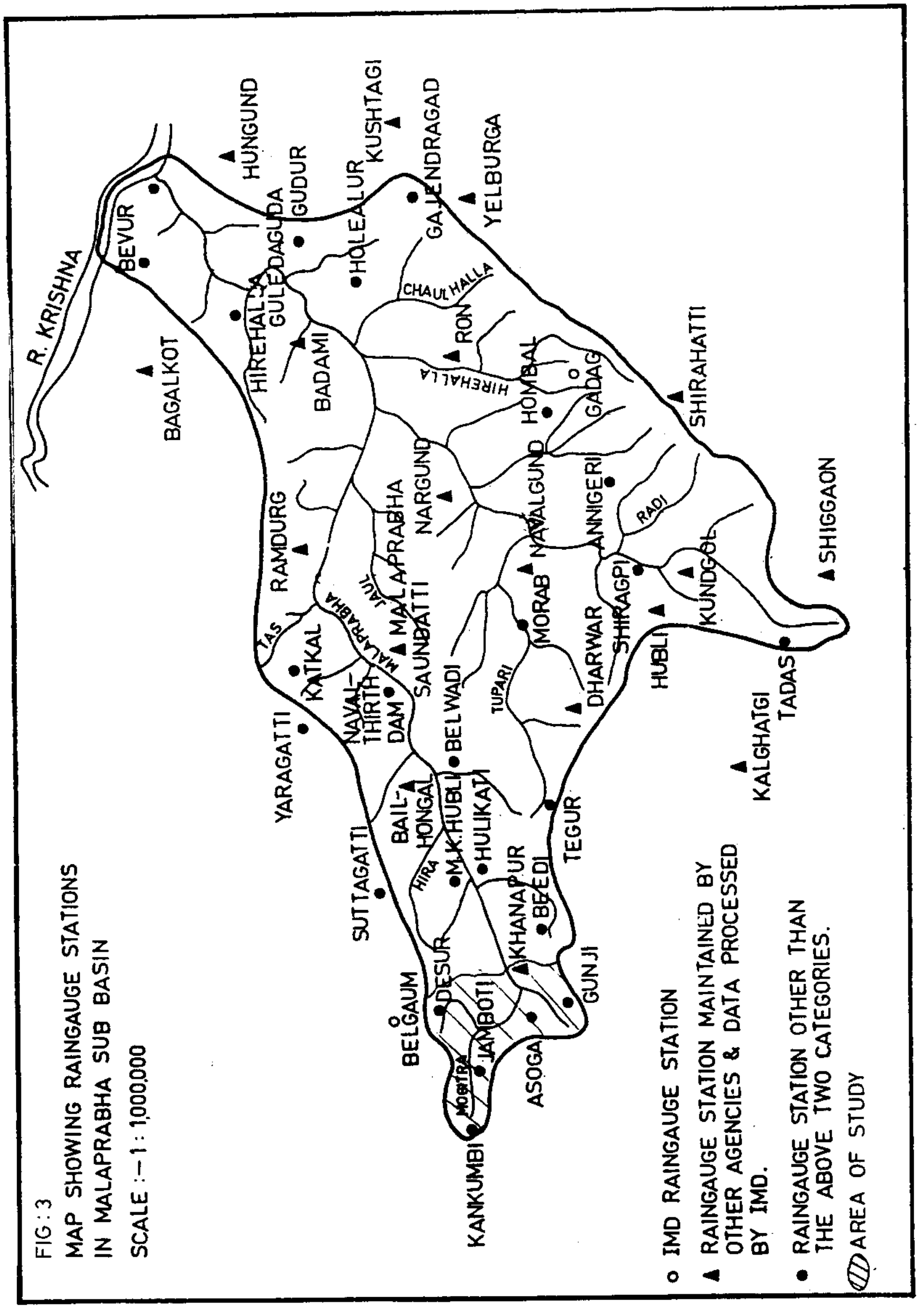


FIG: 3
MAP SHOWING RAINGAUGE STATIONS IN MALAPRABHA SUB BASIN
SCALE :- 1 : 1,000,000

3.1 Location

The location of the area over which geomorphological studies are conducted is between 74° E-75° E longitude and around 16° N latitude. The area of study lies along the border of the states of Maharashtra and Karnataka (Fig.1).

3.2 Climate

Four distinct seasons occur in the basins in the year. They are (i) the cold weather (ii) the hot weather (iii) the south-west monsoon and (iv) the post-monsoon.

The cold weather from mid October to mid February is generally pleasant in the entire basin. The Western and the North-Eastern regions are colder than the rest. The summer is pleasant in the Western parts of the basin, which is under study. The South-West monsoon sets in by mid June and ends by mid October. During this period, the basin receives about 80% of its total annual rainfall.

3.3 Soils

The principal soils found in different districts of the present area of study are listed below in Table 1.

Table 1: Soils in the Study Area

S.No	State	District	Basin	Type of soil
1.	Maharashtra	Kolhapur	Ghataprabha	Laterite, medium black and deep black
		Ratnagiri	- do -	Laterite
2.	Karnataka	Belgaum	Malaprabha	Red, Black and laterite

The areas under study in the present report are the higher reaches of Malaprabha and Ghataprabha, which are tributaries to river Krishna. The catchment area upto Daddi on the Ghataprabha is considered for the present study as shown in Fig.2. The area of study on the Malaprabha analysed in the present report is shown in Fig. 3. The catchment area upto Khanapur on the Malaprabha is studied. The data used to carry out the Geomorphological studies is shown in the Table 2.

Table 2 : Data Used for Study

S.No.	Area of Study	Data used	Scale
1.	Ghataprabha up to Daddi	Blue print from topo sheets 47 L/4, 47L/8, 48 I/1, 48 I/5	1"=1 mile
2.	Malaprabha up to Khanapur	Blue print from toposheets 48 I/1 48 I/5, 48I/2, 48 I/6	1"=1 mile

4.0 <u>Methodology</u>

The morphometric studies of the two basins namely Malaprabha upto Khanapur and Ghataprabha upto Daddi was carried out using the maps prepared from Survey of India toposheets on the scale of 1"=1 mile (1:63,360). There was no field verification of the drainage pattern changes. The lengths of the streams are measured using the digital techniques and areas using the planimeter.

The linear aspects were studied using the methods of Horton (1945), Strahler (1953) and Chroley (1957). The areal aspects using those of Schumm (1956), Strahler (1956, 1968), Chroley (1957), Miller (1953) and Horton (1932) and the relief aspects employing the techniques of Horton (1945), Schumm (1954) and Strahler (1952).

Various parameters to be studied and established in the study can be broadly classified into three categories :

i) Linear Aspects of the channels

ii) Areal Aspects of the basin

iii) Relief Aspects of the catchment and channel network.

4.1 Linear Aspects

Various parameters which involve length of channels in different ways are grouped under this category. Linear aspects of channel network are listed and explained below :

a) Length of the Main Channel (L)

b) Length of the channel between the outlet and a point nearer to C.G. (Lc)

c) Total length of channels

d) Wandering Ratio

e) Basin Perimeter

f) Fineness Ratio

g) Watershed Eccentricity

a) Length of the main channel (L) :

This is the length along the longest water course from the outflow point of designated sub-basin to the upper limit to the catchment boundary.

b) Length of channel between the outlet and a point nearer to Centre of gravity (Lc) :

It is the length of the channel measured from the outlet of the catchment to a point on the stream nearest to the centroid of the basin.

c) Total length of Channels :

Total channel length is the sum total of the lengths of channels of all the orders in the basin. This parameter is important as it gives an idea of over land flow and channel flow in the basin. Channel storage also varies with stream length as a simple power function.

d) Wandering Ratio :

Wandering ratio is defined as the ratio of the main stream length to the valley length. Valley length (Lv) is the straight line distance between outlet of the basin and the farthest point on the ridge.

e) Basin Perimeter:

It is measured along the divides between basins and may be used as in indicator of basin size and shape.

f) Fineness Ratio :

The ratio of channel length to the length of the basin perimeter is fineness ratio, which is a measure of topographic fineness.

g) Watershed eccentricity :

The watershed eccentricity is given by the expression :

$$\tau = \frac{|(Lc^2 - Wc^2)|^{0.5}}{Wc}$$

where τ = Watershed eccentricity, a dimensionless factor

Lc = Length from the watershed mouth to the center of mass of the watershed in the same unit

Wc = Width of the watershed at the centre of mass and perpendicular to Lc.

4.2 Areal Aspects of the Basin

The parameters which are governed mainly by the area of the drainage basin are classed as Areal aspects of the basin. Following areal aspects have been considered for the present study :

a) Drainage Area

b) Drainage Density

c) Constant of Channel Maintenance

d) Channel Segment Frequency

e) Circularity Ratio

f) Elongation Ratio

g) Watershed Shape Factor

h) Unity Shape Factor

These parameters have been discussed in detail and are explained below :

a) Drainage Area:

Drainage area is defined as collecting area from which water would go to a stream or river. The boundary of the area is determined by ridge separating water flowing in opposite directions. This parameter is hydrologically important because it directly affects the flood hydrograph and the magnitude of flood peaks in mountainous areas. The larger the size of the basin, the greater is the amount of the rain intercepted and higher the peak discharge that results.

b) Drainage Density :

Drainage density is defined as the ratio of the total length of channels of all orders in a basin to the area of the basin. It should therefore be measured on the topomaps of large scales (1:50,000) so that first order streams can also be taken into account. Drainage density is a textural measure of a basin which is generally independent of basin size. It is considered to be a function of climate, lithology, and stage of developement . Numerically this ratio expresses the number of kilometers of channel maintained by a square kilometer of drainage area.

c) Constant of Channel Maintenance

Constant of channel maintenance is defined as the ratio between the area of a drainage basin and the total length of all the channels expressed in square feet per foot or square meters per meter. It is virtually the reciprocal of drainage density.

The importance of this constant is that it provides a quantitative expression of the minimum limiting area required for the developmental of a length of the channel.

d) Channel Segment Frequency

Channel segment frequency or stream frequency is defined as the number of streams per unit area in a drainage basin. Horton suggested that the composition of a drainage basin provided a more adequate characterization of a stream, than did drainage pattern. His "composition" was completely described using the two textural measures of drainage density and stream frequency.

e) Circularity Ratio

Basin circularity ratio is defined as the ratio of the basin area to the area of a circle having a circumference equal to the perimeter of the basin. The value of this ratio approaches unity as the shape of a drainage basin approaches a circle.

f) Elongation Ratio

Elongation ratio of a basin is defined as the ratio between the diameter of a circle with the same area as the basin and basin length. The value of the elongation ratio approaches unity as the shape of drainage basin approaches a circle.

g Watershed Shape Factor

Watershed shape factor is defined as the ratio of main stream length to the diameter of a circle having the same area as the watershed.

h) Unity Shape Factor

Unity shape factor is defined as the ratio of the basin length to the square root of the basin area.

The indices such as Circularity Ratio, Elongation Ratio, Watershed Shape Factor and Unity Shape Factor are the measures to compare basin shapes. Basin shape is very important factor influencing the peak flow and other hydrograph characteristics such as steepness of rising and recession limbs, the time spread of hydrograph etc.

4.3 Relief Aspects of Catchments and Channel Networks

Relief Aspects are the functions of the elevation or elevation difference at various points in a catchment or along the channels. Contour lines on a toposheet are made use of while determining the relief aspects. Various parameters involving the relief aspects are as follows :

a) Basin Relief

b) Relief Ratio

c) Relative Relief

d) Ruggedness Number

e) Nash's measure of slope

Variables involving relief aspects of the basin are the most significant parameters in hydrological studies of the watershed. The slope is related to rate at which the potential energy of the water at high elevation in the headwaters of the catchment is converted into kinetic energy. Losses in various forms occur in the process. Water is held in storage and the travel time in the hydrologic system is in general inversely related to the slope. Mountainous catchments (as under study) are characterised by the steep slopes and hence these parameters become still more important for mountainous catchments. These parameters, therefore, have been discussed in the following text.

a) Basin Relief

Relief of a basin is the maximum vertical distance from the stream outlet to the highest point on the dividing ridge. The total relief of a basin is a measure of the potential energy available to move water and sediment downslope.

b) Relief Ratio

The relief ratio is defined as the ratio between the basin relief and the basin length. In normally shaped basins the relief ratio is a dimensionless height length ratio equal to the tangent of the angle formed by intersection at the basin mouth of a horizontal plane with a plane passing through the highest point on the divide. This parameter permits comparison of the relief of two basins without regard to the scale of the topomaps used.

c) Relative Relief

Relative relief is defined as the ratio of the basin relief expressed in units of miles to the basin perimeter. Relative relief is an indicator of the general steepness of a basin from summit to the outlet. It has an advantage over the relief ratio in that it is not dependent on the basin length which is questionable parameter in spreaded basins. When the main channel consists of two branches more or less of equal catchment the channel slopes are taken as the mean of the two values calculated separately and weighted with the appropriate catchment area.

d) Ruggedness Number

The product of drainage density and relief (in the same units) is termed as the ruggedness of a basin. Areas of low relief but high drainage are, therefore, as ruggedly textured as the areas of higher relief having less dissection.

e) Nash's Measure of Slope

Nash (1960) defined another measure of slope where the profile of the main channel having been plotted from the gauging site to the catchment boundary, a straight line was drawn through the gauging station and the vertical through the highest point of the main channel. Further the slope of the line being so chosen that the area of the triangle was equal to the area contained below the channel profile.

5.0 Results & Discussions

The topomaps were used to find out the various geomorphological characteristics covering the linear, areal and relief aspects. Most of the characteristics are measured using digital techniques. The results are presented in different Tables in the following sections.

5.1 Parameters based as Linear Aspects

The different parameters based on linear aspects are found using the digital techniques. The values for both the study areas are presented in Table 3.

Table 3 : Geomorphological parameters Based on linear aspects

S.No.	Parameter	Ghataprabha upto Daddi	Malaprabha upto Khanapur
1.	Length of Main Channel (L)	63.485 Km	48.392 Km
2.	Length upto Centroid (Lc)	22.809 Km	11.104 Km
3.	Length of the Valley or Basin Length (Lv)	47.519 Km	33.892 Km
4.	Total length of Channels (LT)	1403.354 Km	1186.022 Km
5.	Basin parimeter (P)	155.101 Km	152.594 Km
6.	Wandering Ratio(L/Lv)	1.336	1.428
7.	Fineness Ratio (L/P)	0.409	0.317
8.	Watershed Eccentricity	0.541	0.861

5.2 Parameters based on Areal Aspects

Areas of the study areas are measured using the planimeter. Different parameters based as areal aspects are presented in Table 4.

Table 4 : Geomorphological parameters based on Areal Aspects

S.No.	Parameter	Ghataprabha upto Daddi	Malaprabha upto Khanapur
1.	Drainage Area (A)	1055.0 Sq.Km	540.0 Sq.Km.
2.	Drainage Density (L/A)	0.0602 Km/Sq.Km.	0.0896 Km/Sq.Km.
3.	Constant of channel Maintenance (A/L)	16.6181 Sq.km/km.	11.1589 Sq.Km/Km
4.	Circularity Ratio	0.5511	0.2914
5.	Elongation Ratio	0.7713	0.7737
6.	Watershed shape factor	1.7321	1.8455
7.	Unit shape factor	1.4630	1.4585
8.	Channel segment frequency	1.6948/Sq.Km.	1.9315/Sq.Km.

5.3 Parameters based on relief aspects

Some of the parameters based on the relief aspects of the watersheds have been computed. The values of different parameters are presented in Table 5.

Table 5 : Geomorphological Parameters based on relief aspects

S.No.	Parameter	Ghataprabha upto Daddi	Malaprabha upto Khanapur
1.	Basin Relief (Rb)	304.80 m	182.88 m
2.	Relief Ratio (Rb/Lv)	6.414	5.396
3.	Relative Relief (Rb/P)	1.965	1.198
4.	Ruggedness Number	0.01835	0.01639

5.4 Relationships of Some stream characteristics

The studies conducted revealed that the Malaprabha and Ghataprabha both are of sixth order. The number of streams and stream lengths for each order for Ghataprabha and Malaprabha are tabulated in Table : 6 and Table : 7 respectively.

Table 6: Stream Orders-Stream Numbers-Stream Lengths for Ghataprabha upto Daddi.

Stream Order	:	1	2	3	4	5	6
Stream Number	:	1402	284	82	15	4	1
Stream Length (Km)	:	753.140	293.444	152.472	81.415	85.565	37.318

Table: 7: Stream Orders-Stream Numbers-Stream Lengths for Malaprabha upto Khanapur.

Stream Order	:	1	2	3	4	5	6
Stream Number	:	784	198	50	8	2	1
Stream Length (km)	:	651.155	329.295	97.459	58.144	47.619	2.350

For both the basins exponential relation between Stream Order versus Stream Number and Stream Order versus Stream length is brought out. These relationships are described in Fig. 4 and Fig. 5 for Ghataprabha and in Fig. 6 and Fig.7 for Malaprabha.

FIG .NO 4 : SEMI LOG PLOT FOR STREAM ORDER Vs STREAM NUMBER FOR GHATAPRABHA

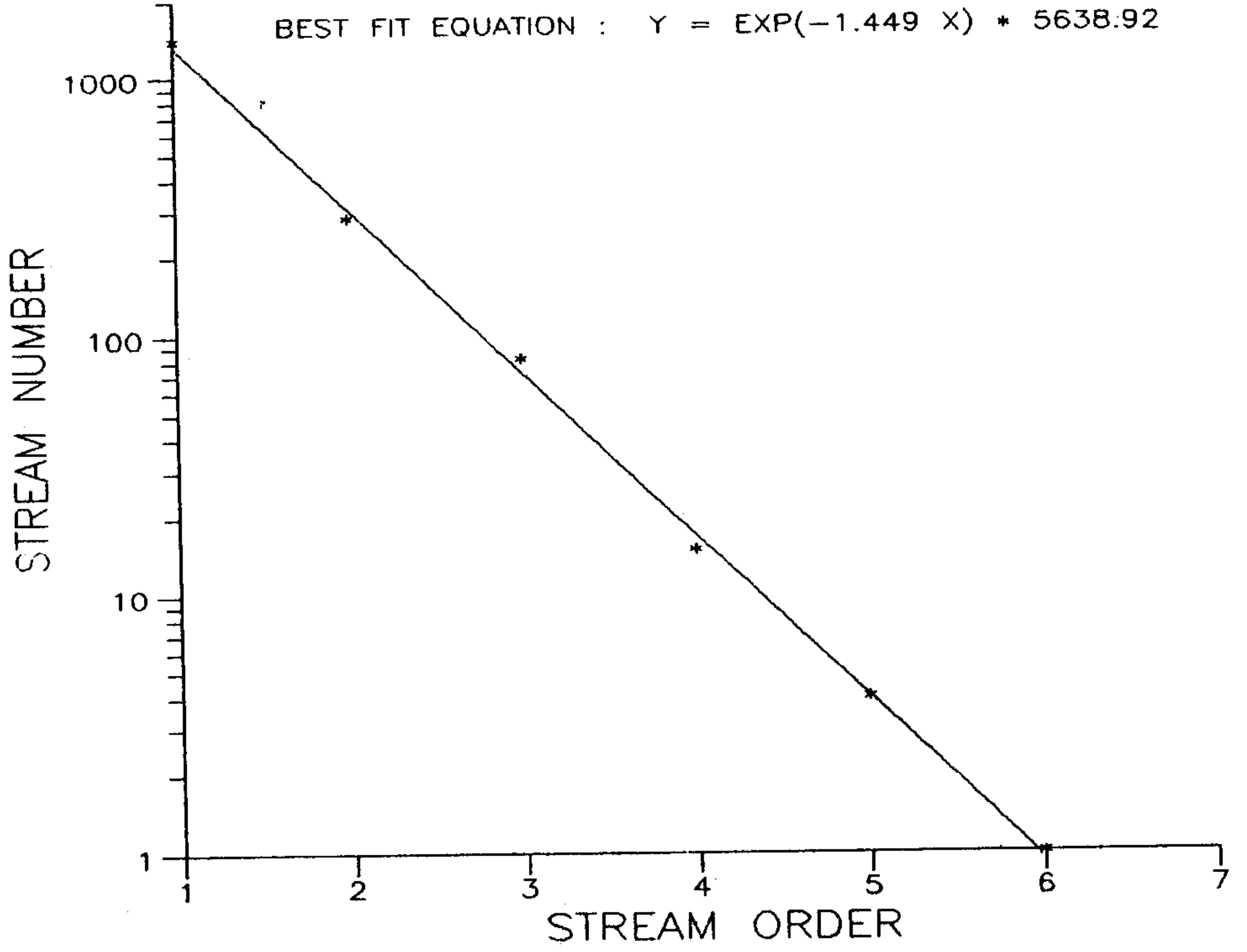


FIG NO 5: SEMI LOG PLOT FOR STREAM ORDER Vs STREAM LENGTH FOR GHATAPRABHA

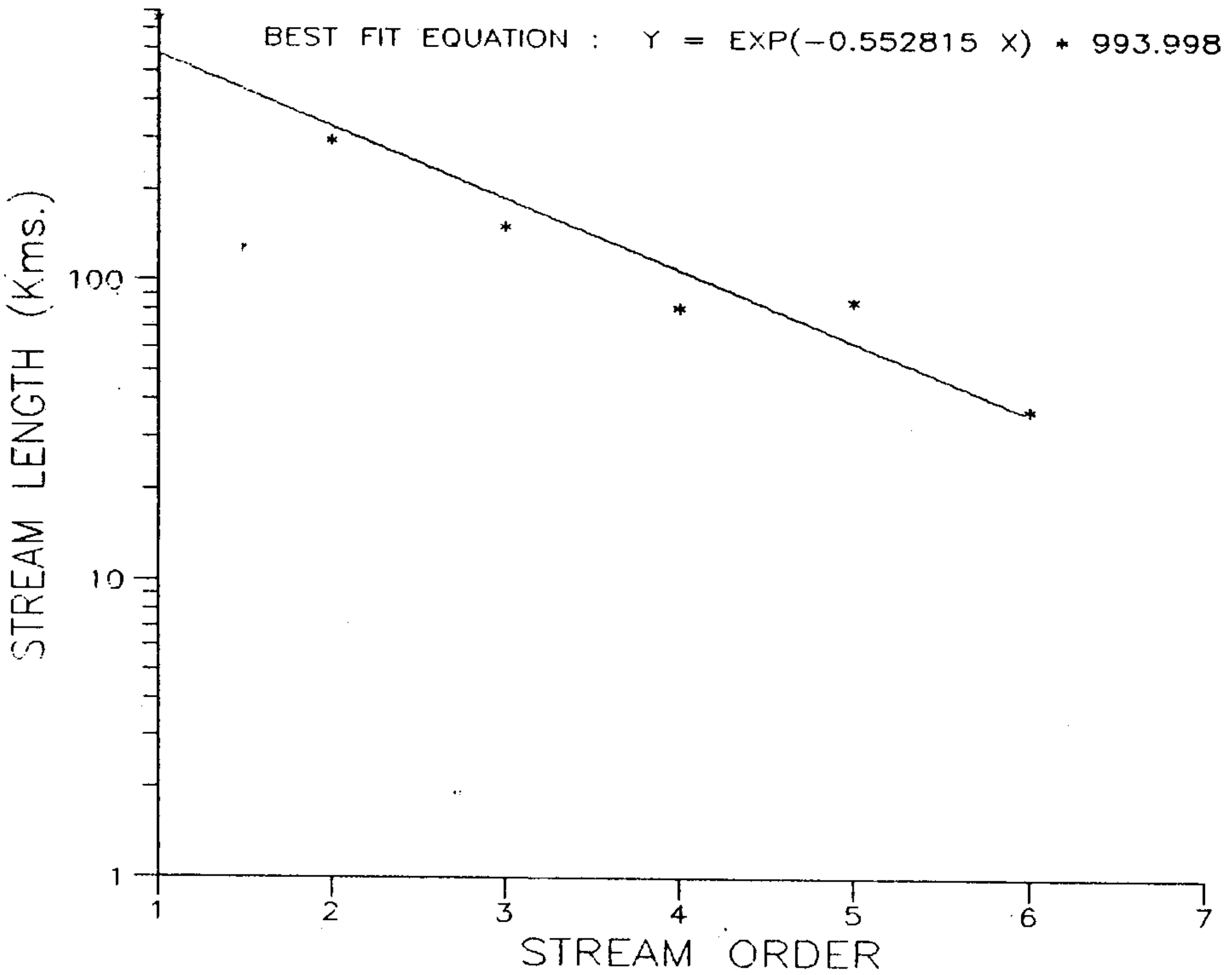


FIG NO.6: SEMI LOG PLOT FOR STREAM ORDER Vs STREAM NUMBER FOR MALAPRABHA

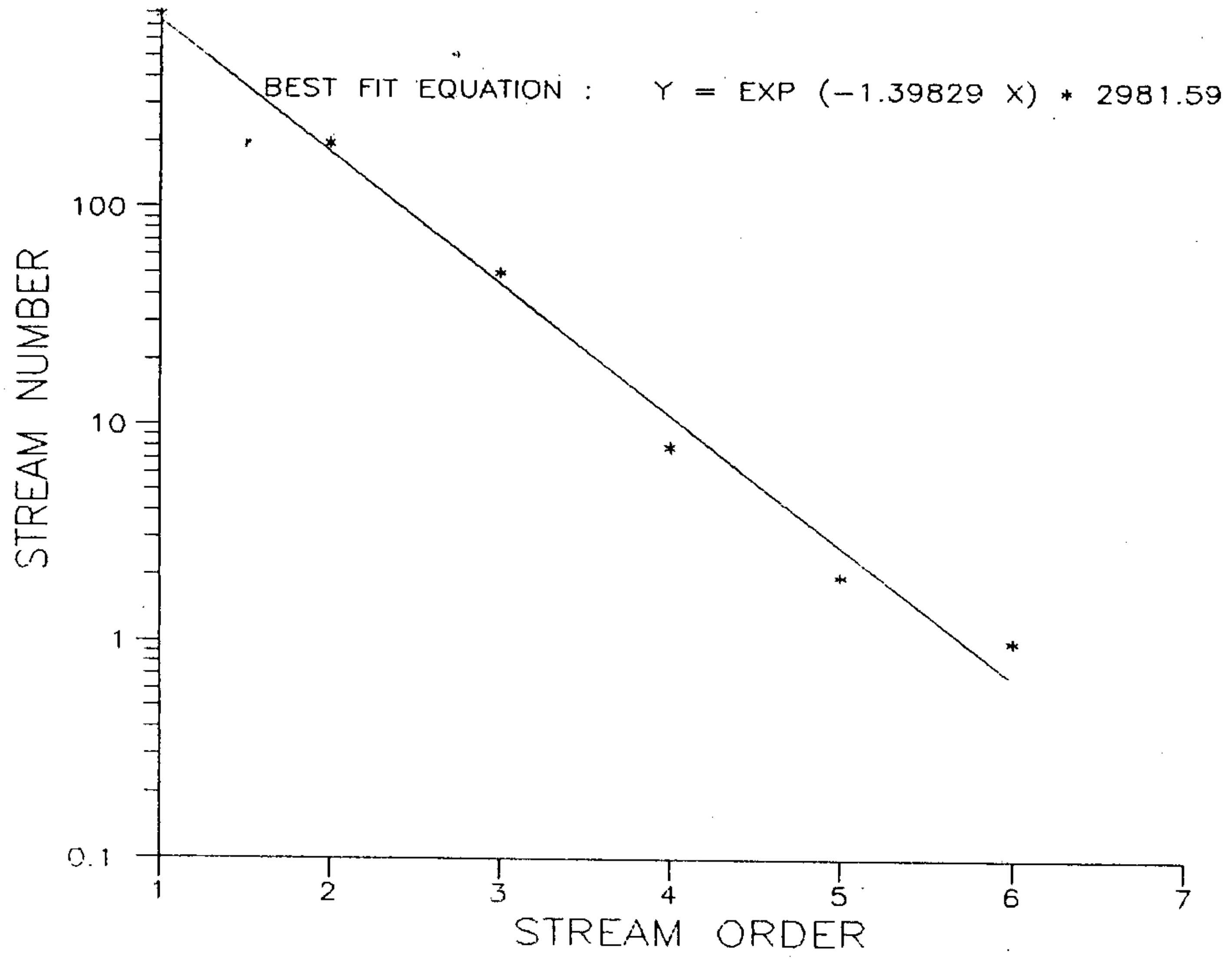
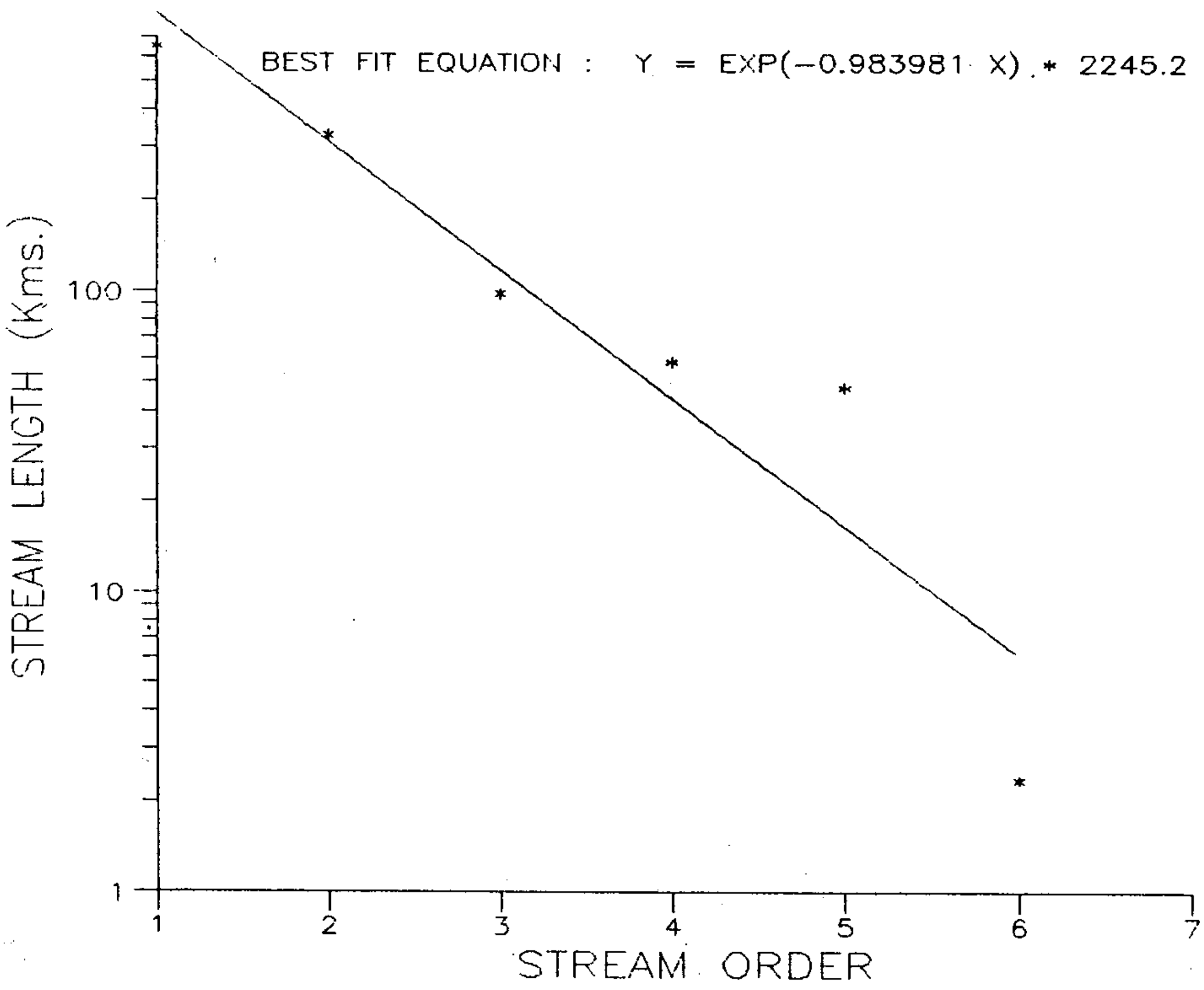


FIG NO 7: SEMI LOG PLOT FOR STREAM ORDER Vs STREAM LENGTH FOR MALAPRABHA



Elevations along the main streams for both the rivers are found the cotours . The slope maps for Ghataprabha and Malaprabha are shown in Fig. 8 and Fig. 9 respectively.

6.0 Conclusions and Recommendations

The studies conducted on the two basins namely Ghataprabha upto Daddi and Malaprabha upto Khanapur led to the following conclusions on the difference of hydrological regimes of the two streams. The experiences of conducting these studies on the blueprints (made from toposheets) necessitated in making some important recommendations for future studies.

6.1 Conclusions

It is observed from the geomorphological parameters based on linear aspects that the Ghataprabha is more compact and well shaped compared to Malaprabha. The low wandering ratio of Ghataprabha shows the travel time of runoff is less compared to that of Malaprabha. This can be observed from the watershed eccentricity point of view. The lower values of watershed eccentricity for Ghataprabha upto Daddi indicate the greater compactness of the watershed and higher flood peaks in this portion are attained earlier than in Malaprabha at Khanapur for any given event of rainfall.

The areal aspects found from the study reveal that constant of channel maintenance, which provides a quantitative expression of the minimum limiting area required to form unit length of the channel, is very high and is about 50% more than that for Malaprabha. This indicates that the channel capacities of Ghataprabha should be large enough to carry higher discharges resulting from the bigger drainage areas. The equality of fig no: 8 Slope map of Ghataprabha

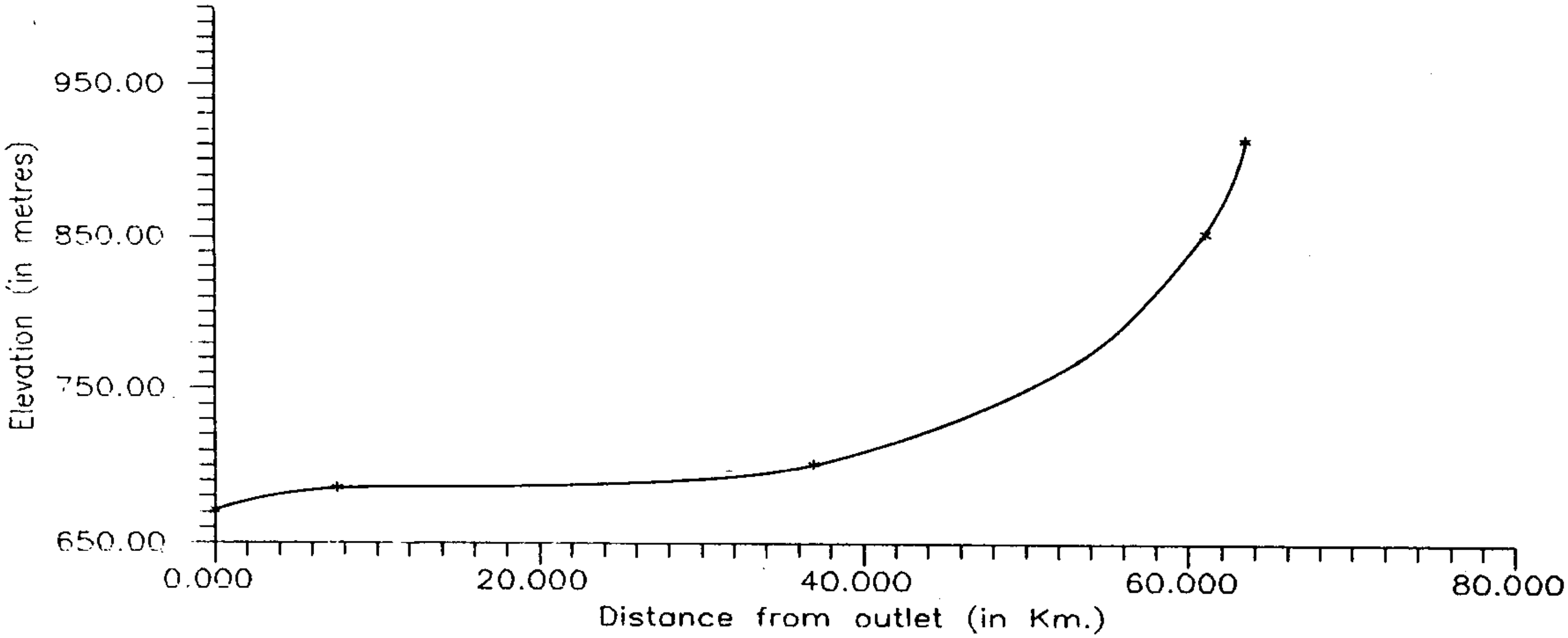
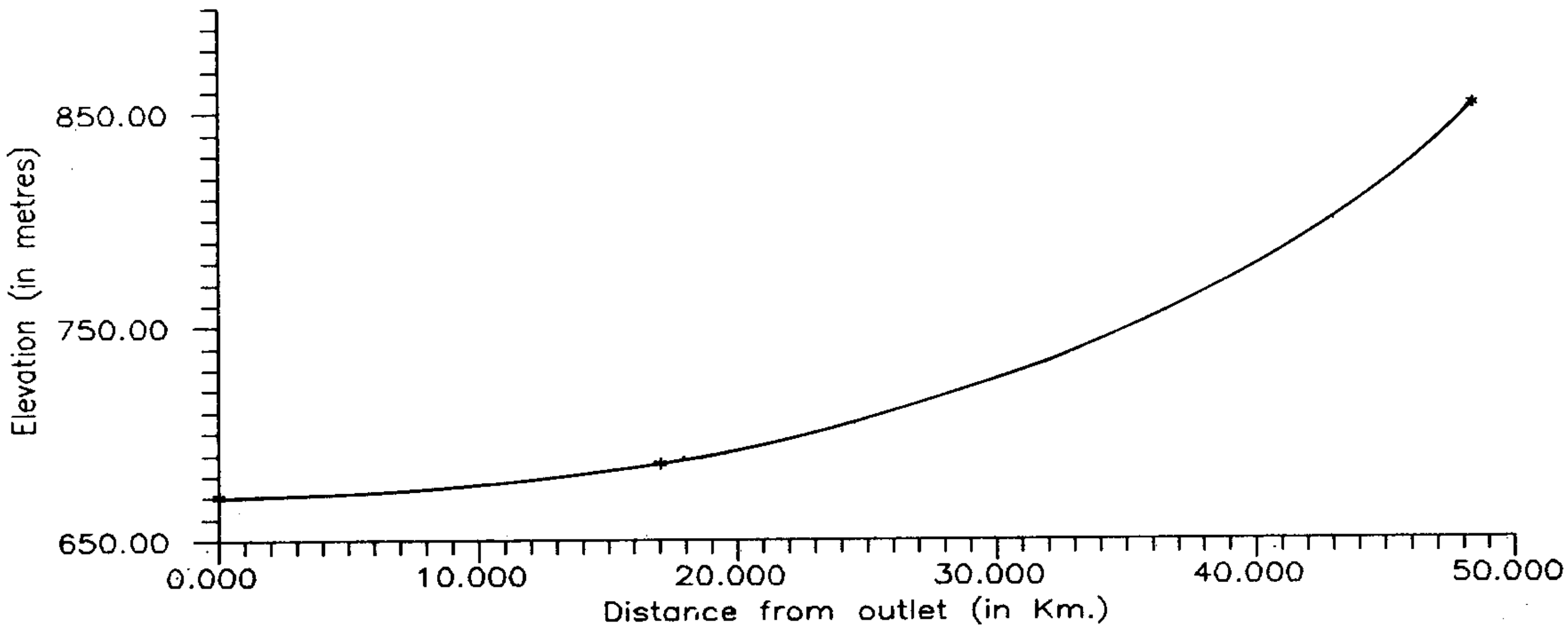


fig no:9 Slope map of Malaprabha



elongation ratios for both the catchments and higher circularity ratio for the Ghataprabha also indicate the larger amounts of flows in Ghataprabha than in Malaprabha.

The parameters based on relief, which are most important in influencing the runoff and other hydrological process, indicates that the Ghataprabha catchment is steeper than the Malaprabha. The high basin relief of Ghataprabha is a measure of the higher potential energy available to move water and sediment downstream.

6.2 Recommendations

The report is in continuation of the Geomorphological studies that are being carried out in Western Ghats. As suggested in the earlier report on Upper Krishna Basin the studies were conducted on higher scale maps of 1"=1 mile. The slope aspects could not be found more satisfactorily due to the limitation that the studies are conducted using the blue prints. The blue prints as such are not the first hand media to rely upon to conduct the geomorphological studies. It is suggested that further studies should be conducted on toposheets, which are the media giving first hand and detailed information of the geomorphology.

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Reporting Group

Prepared by	S V VIJAYAKUMAR Scientist 'B'
Guided by	K S RAMASASTRI Scientist 'F'
Assisted by	Kamal Kumar, SRA, U.K. Singh, RA Narendra Kumar, N.K. Varshney, Draftsmen
Typed by	Kiran Ahuja