CHAPTER I

PHYSICAL BACKGROUND OF THE BALASON WATERSHED

INTRODUCTION

The study area i.e. the Balason river basin, which includes the parts of the police stations of Kurseong, Mirik, Jorebunglow and Sukhiapokhri lies in the Darjeeling district of West Bengal. The basin is located between 26°48'50"N and 27°00'27"N latitudes and 88°07'10"E and 88°18'20"E longitudes. The basin is bordered in the north by the police stations of Pulbazar, Darjeeling, in the east lies by police stations of Jorebunglow and Kurseong along the length of the Hill Cart Road. The southern portion of the basin is bordered by the police stations of Naxalbari and Matigara.The western side of the Balason river basin coincides with the international boundary between India and Nepal. The study area covers an area of 229km^2. (Fig.1.1)

1.1 PHYSICAL BACKGROUND

The study area consists of a portion of the outlying hills of the lower Himalayas and a stretch of territory lying along their base known as the Terai. The hills rise abruptly from the Dudhia and Balason confluence (300m) and the elevation increases northwards and near Ghoom Simana Basti, the elevation is 2350m.Between these two heights, there is mosaic of micro topographic units. The complex physical environment in the region is due to different geomorphic processes, each of which has developed its own characteristic assemblage of landforms.

The physical configuration of the region is partly due to the direction of the main drainage, which is southerly and mainly due to geologic structure, which is the dominant controlling factor in evolution of landforms. The northern portion of the basin consists of hard gneissic rocks capable of resisting denudation to a considerable extent,

LOCATION MAP

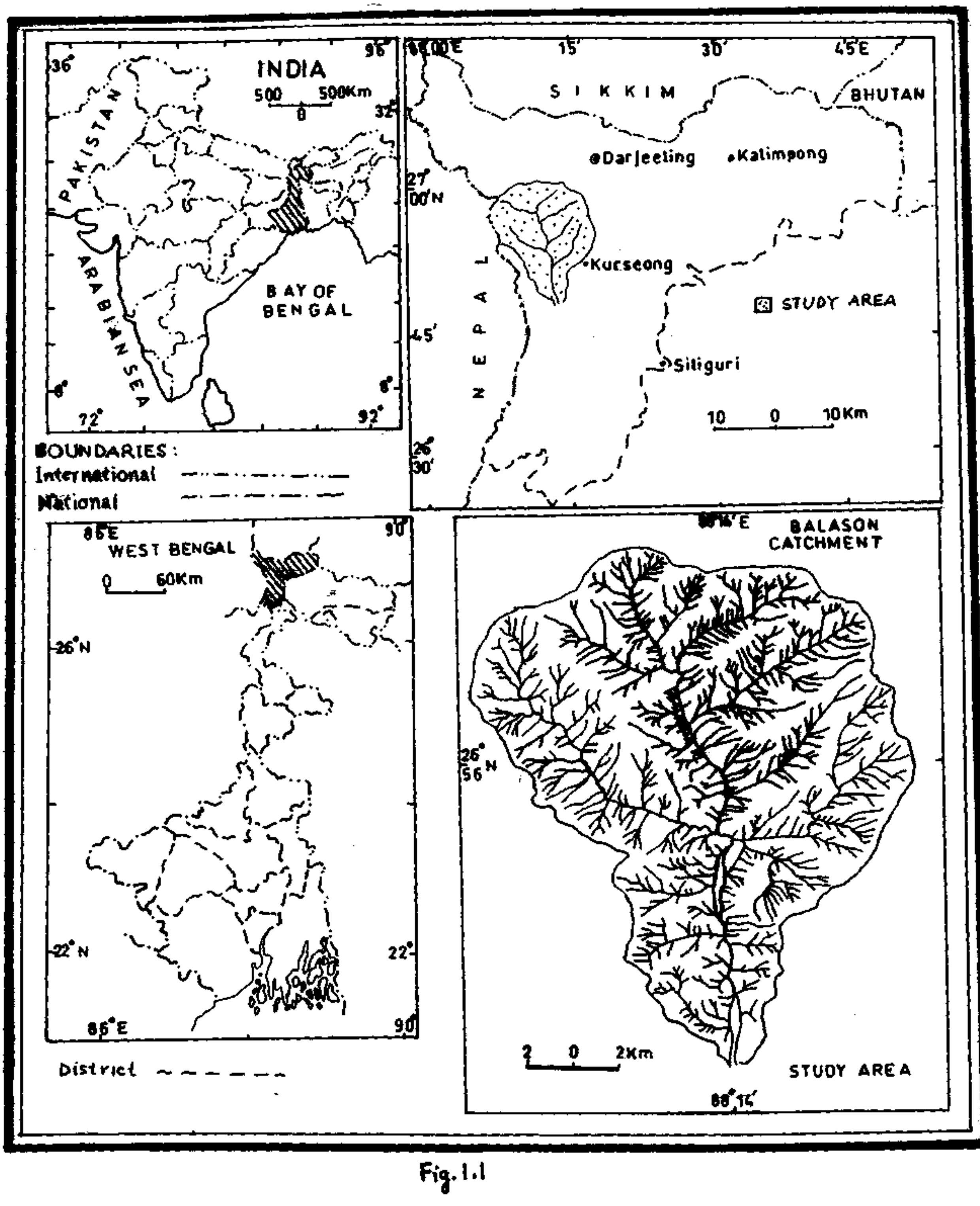


Fig. 1.1

while the southern portion comprises of comparatively soft, thin, salty and half-schistose rock, which are less resistant to erosion. There are no flat valleys, no plains, no sizable lakes, nor any cultured landscape except where virgin forests have yielded place to tea gardens or terraced fields. The main ranges wind and give off spurs of second and third orders in all directions. The valleys thus formed, present a great variety in climate and elevation.

Elevation of the Balason catchment varies from 2355m (at Ghoom Simana) to 267m (near Dudhia Bridge). Balason river flows down from north to south through a funnel shaped basin. The Balason watershed is delineated on its north side by a ridge emanating from the massive Singalila range and going almost straight to the east forming the Maneybhanjeng Ghoom ridge. This ridge throws smaller spurs having general direction south to southwest. From Ghoom, a complex system of ridges and spurs emanate, the longest of which is Tiger Hill – Dow Hill and marks the eastern boundary of the study area. From Dow Hill, this ridge dips down sharply taking a turn towards southwest and decreases its altitude from 2000m at Dow Hill to 1400m at Kurseong town within a distance of 4 kms. On the western side, a huge Nagri spur emanate from the main northern ridge, descends down sharply in the southeast direction from an altitude of 2350 m at Ghoom Simana on the Indo – Nepal border to 900 m in the bed of the river Balason. North of the Terai, the ridges stand out in a succession of bold spurs, the appearance of which has been compared with that of the weather beaten front of mountainous coast. The change from hills to plains is very abrupt and can be appreciated more vividly by observation on a clear day from above. From Kurseong and other view points of the basin, the observer looking southward will see the hills descending steeply below him and suddenly ending and from their foot the plains stretching away without any undulations to the southern horizon. On the southwestern tip of the Balason basin lies a huge colluvial deposit forming a flat terrain. The entire southern most width of this flattish part of the territory has been affected by notorious Ambootia landslide.

Photograph 1.1 Colluvial Deposits on Balason River

In the study area, the valley slopes are more flat and open towards the top but attain a steep gorge like character near the beds of the streams. The study area has spurs, ridges and ranges cut by rills, streams and rivers. For more detailed observations and analysis, the study area has been further divided into four physiographic divisions depending upon their heights. The four physiographic divisions are as follows: -

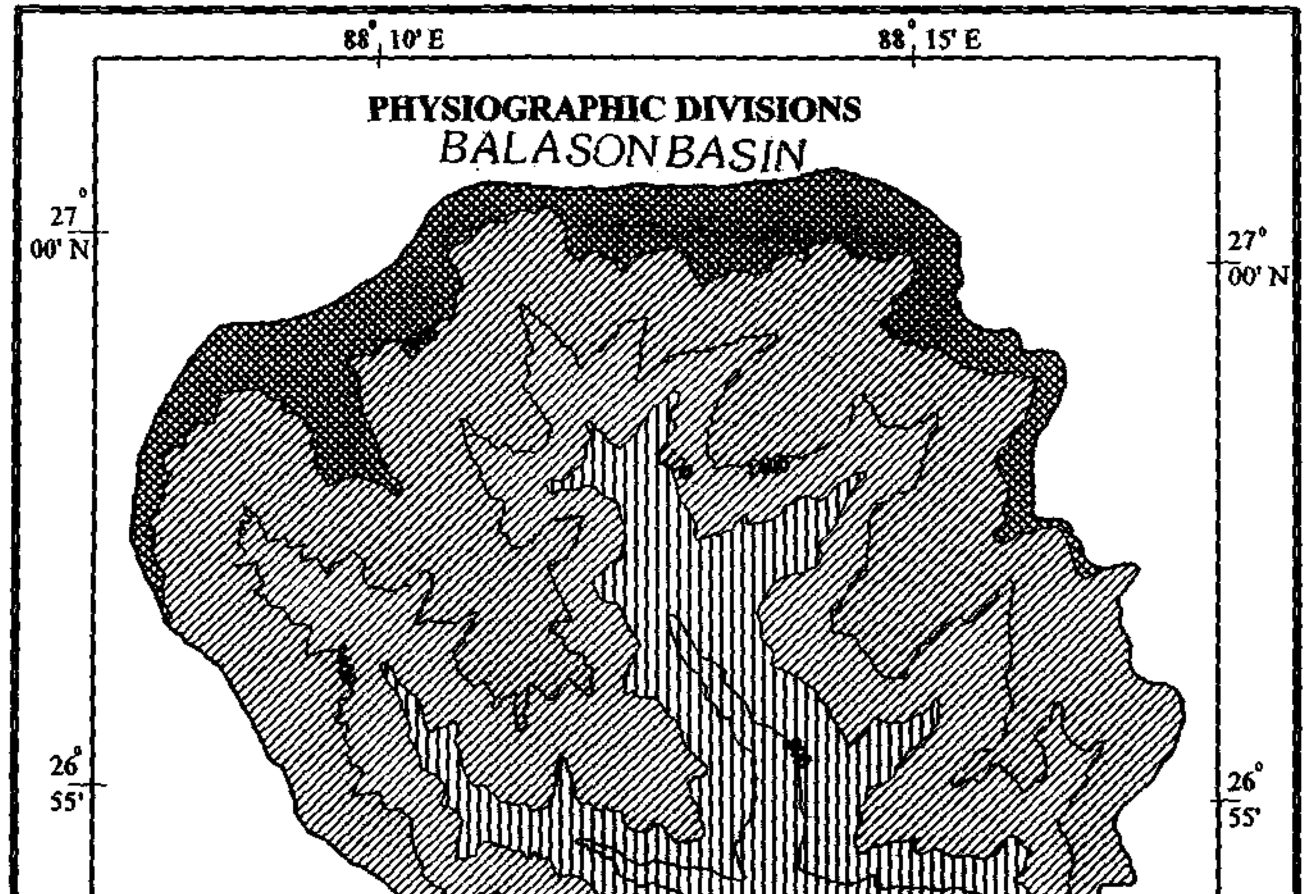
Table 1.1: Percentages of area under different physiographic units.

Division	Contour line in m	Area in km²	Percentage of area covered
i) Foothill	Below 500	10	4.37
ii) Rolling land	500 – 1100	65	28.38
iii) Steep slope	1100 – 1900	128	55.90
iv) Highland	Above 1900	26	11.35

1.1. a. Foothill: This region is present in the southern most part of the basin covering 4.35% of the total study area. The Longview T.G., Patong T.G., Jamadar Bhita Khasmahal and Manjha Forest occupy the entire zone. The Balason river flowing through this region has a very gentle gradient. The river flows in a southward direction with severely braided channel. Numerous river borne pebbles, boulders and sand is deposited on the riverbed and banks giving the area a flattish appearance. The colluvial deposits, south of the Dudhia bridge is of great economic importance (Fig.1.2).

1.1. b. Rolling Land: This region covers 28.38% of the total study area and can be further divided into two sub regions.

i) The first one lies between 500m and 800m.This region encompasses the lower segments of Makaibari, Longview, Ambootia, Singel, Moondakotee, Nahori, Dhajea,Marma, Singbulli T.G. and Punkhabari, Dhajea Khasmahal, Manjua Forest,Manjha Forest. This region has huge rock outcrops descending down vertically to the river Balason. The rock outcrops are massive particularly on the points where the river makes changes in the direction of its flow. Major parts of this zone are barren and inaccessible. Open scrubs and mixed jungle are the characteristic vegetation of this region.



88° 10' E
88° 15' E
PHYSIOGRAPHIC DIVISIONS
BALASON BASIN
27° 00' N
26° 55'
26° 50' N
27° 00' N
26° 55'
26° 50' N
LEGEND
HEIGHT IN METRES
Below 500 (Foot Hill)
500 - 1100 (Rolling Land)
1100 - 1900 (Steep Sloppy)
Above 1900 (High Land)
Scale
0 1 2
kilometers
88° 10' E
88° 15' E

Fig. 1.2

ii) The second sub region lies in between 800m and 1100m. This region has rolling terrain. Because of milder slopes, this part has well developed road networks and the beds of all the tributary rivers are approachable through motorable roads. The rolling slopes are clothed with tea bushes of high density. A number of *jhoras* flow through the tea gardens and have, on the most part, scrubby vegetation and open jungle on their banks. On account of lack of proper distribution of vegetal cover, for protection of steep *jhora* banks, which was not the case earlier, when tea gardens used to maintain such steep *jhora* banks under forests, cutting of stream banks is much in evidence.

1.1. c. Steep Slope: This region lies between the heights of 1100m and 1900m and cover 55.90% of the total study area. This is an area of spurs emerging from the ridge tops. This region has the maximum concentration of settlements. Several hamlets, whose size increases on spurs, like Kurseong, Kharia Basti, Sonada Khasmahal, Tung, Dilaram and Sepoydhura, are located along the Hill Cart Road in the western part of the basin. On the eastern part lies the settlement clusters like Mirik, Mirik Khasmahal, Saurini Basti. To the north lie Phulungdung Khasmahal and Rangbang Basti. Many tea gardens are spread all over the region.

1.1. d. Highland: This region lies above the height of 1900m. The northern part of the study area falls in this category. Steep rugged slopes having a concentric direction towards the center of the basin characterize this region. The terrain is quite rugged and has a complex system of smaller spurs emanating from the Manebhanjang – Ghoom ridge on the northern side and from the Nagri spur on the western and southwestern sides. The terrain being very steep, no tea garden is located in this region. Settlements like SimanaBasti,Sukhiapokhri,Jorebunglow are situated in this region. Most part of the land is occupied by Ghoom Pahari Forest, Mim Nagri Range and Dooteria Forest.

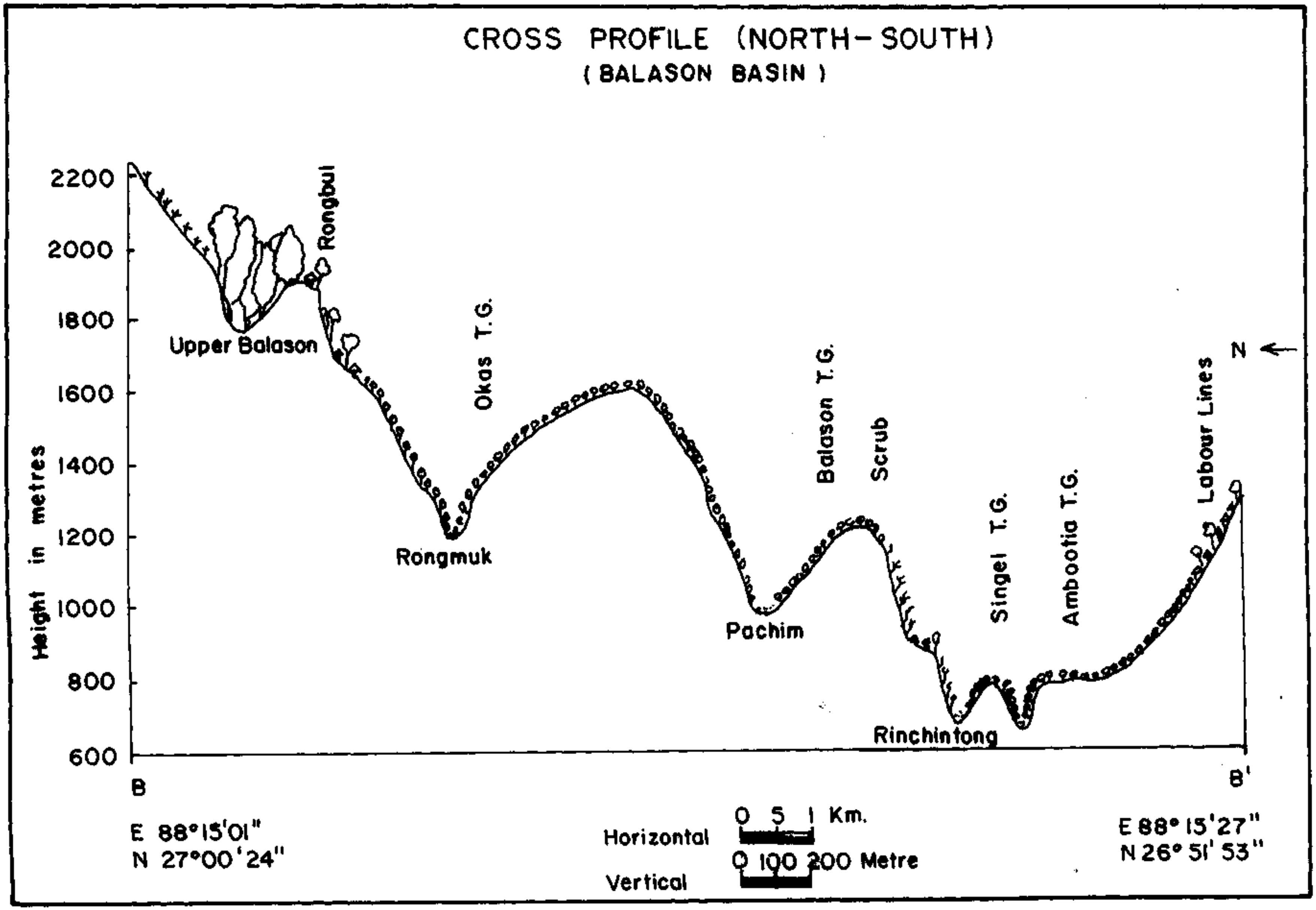
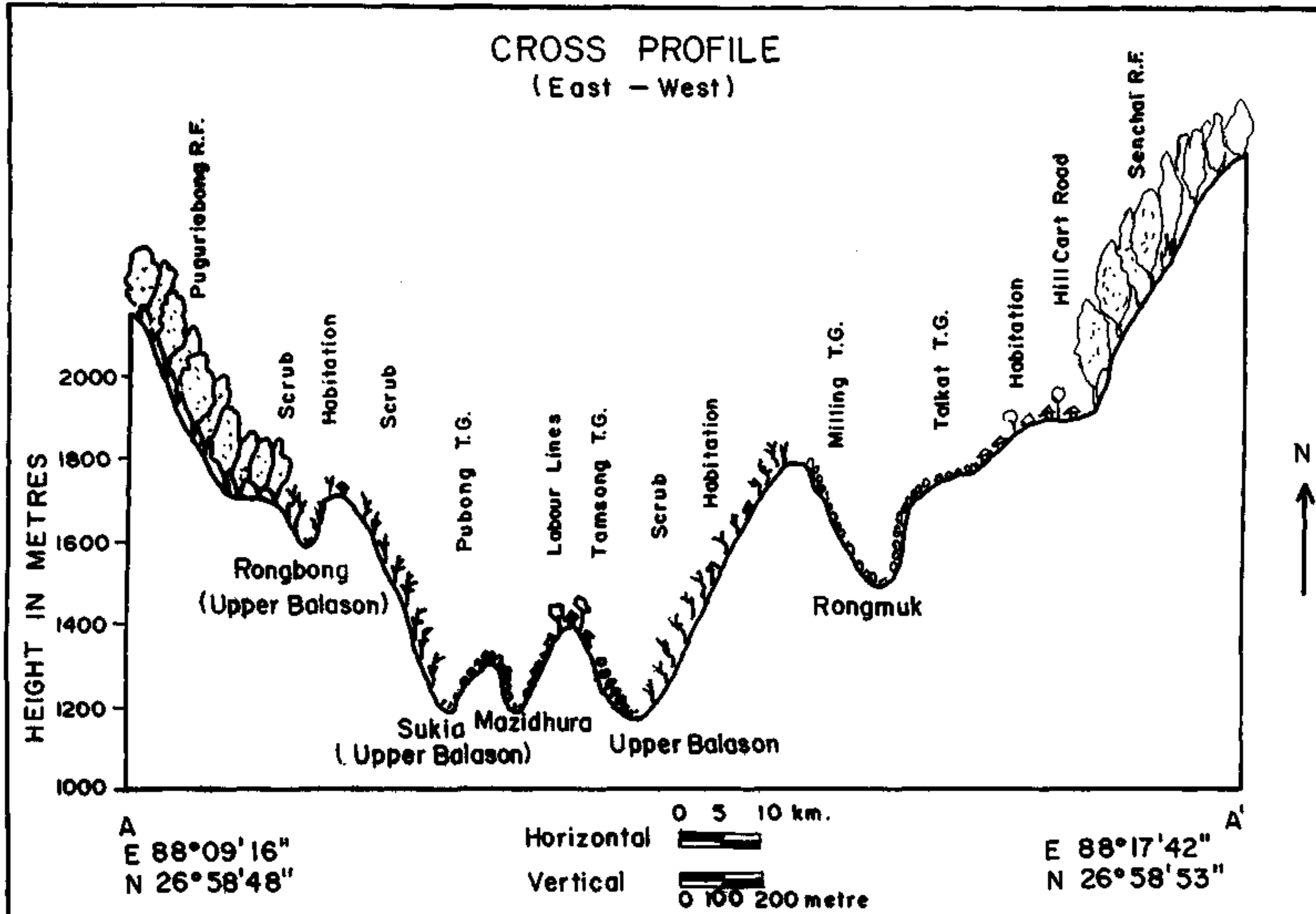

CROSS PROFILE (NORTH-SOUTH)
(BALASON BASIN)
Height in metres
2200
2000
1800
1600
1400
1200
1000
800
600
Rongbul
Upper Balason
Okas T.G.
Rongmuk
Balason T.G.
Scrub
Pachim
Singel T.G.
Ambootia T.G.
Rinchintong
Labour Lines
N
B
B'
E 88°15'01"
N 27°00'24"
Horizontal
0 5 1 Km.
Vertical
0 100 200 Metre
E 88° 15'27"
N 26° 51' 53"

Fig.1.3



CROSS PROFILE
(East – West)
Puguriabong R.F.
Scrub
Habitation
Scrub
Pubong T.G.
Labour Lines
Tamsong T.G.
Scrub
Habitation
Milling T.G.
Talkat T.G.
Habitation
Hill Cart Road
Senchal R.F.
HEIGHT IN METRES
2000
1800
1600
1400
1200
1000
Rongbong
(Upper Balason)
Sukia
(Upper Balason)
Mazidhura
Upper Balason
Rongmuk
N
A
E 88°09'16"
N 26°58'48"
0 5 10 km.
Horizontal
Vertical
0 100 200 metre
A'
E 88°17'42"
N 26°58'53"

Fig. 1.4

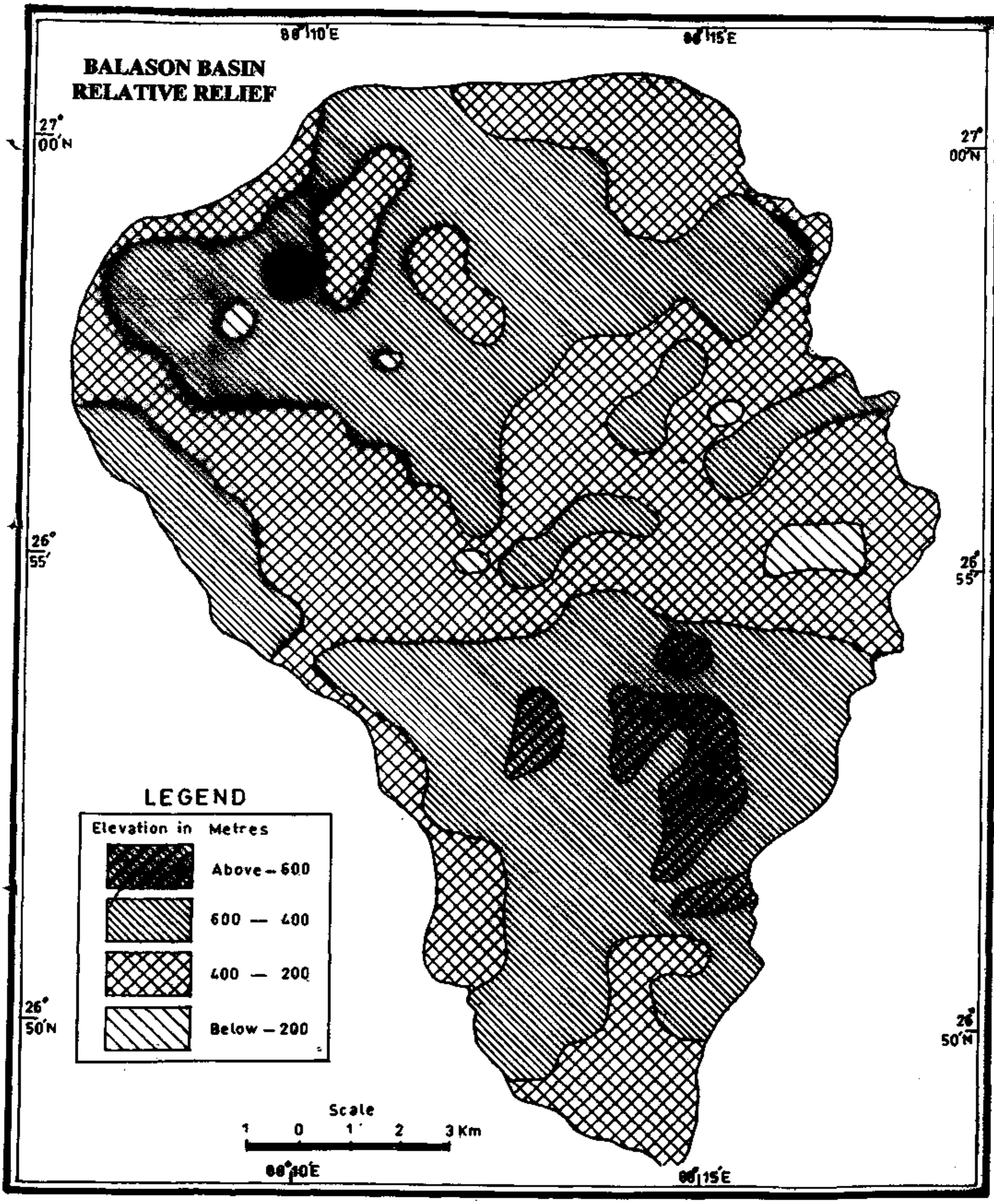
1.1.1. Relative Relief

The relative relief in the Balason basin ranges from below 200m to above 700m. Places having relative relief above 500m are regarded to have very high relative relief. These are found to the north of Dudhia *jhora* in Gayabari T.G., along upper Marina *nadi* to lower Rangbang *nadi* in the Marma T.G., upper Rangbang *nadi* and upper Phulugdung *nadi* in Ghum Simana Reserve Forest, upper Balason and middle Bhim *khola* stretching from Pubong T.G. to Tongsong T.G., upper Jore *khola* in Talkat T.G., in Okas T.G., lower Rinchingtong *nadi* north of Kurseong along Singell T.G., south of Ghatta *nadi* in the Makaibari T.G.

Extensive areas are under high relative relief (400 to 500m). On the north it sprawls over Chamong, Simripani, Pubong, Talkat and Cedar T.G. and parts of Ghoom Simana Reserved Forest. Whereas in the south high relative relief in encountered in Singbuli, Manjwa, Springside and Makaibari tea gardens and parts of Phuguri and Manjwa Reserved Forests. In general, the northern part of the study area has more area under high relative relief (400 to 500m) than the south (Fig. 1.5). Thus the former is more erosive and less productive than the latter. Medium relative relief is observed in isolated pockets in the upper Phulungdung basin, upper Manjwa basin, Thurbo T.G., Sangma T.G., Cedar T.G., south of the confluence of Manjwa *jhora* and Balason and to the north of confluence of Dudhia *jhora* and Balason. The low relative relief region is found all over the basin in a haphazard pattern. In general, the upper reaches of the rivers in the northwest are much steeper whereas the middle and lower reaches of the rivers in the eastern and southern part of the basin are steeper and hence the river basin is more eroded in different places.

1.1.2. Slope

One of the geomorphological factors influencing the erosion is the sloping of terrain. The greater is the steepness, the greater is the velocity, and higher are the carrying capacity, greater kinetic energy and erosivity of run off. In natural landscape, before the soils were used, water influenced the soil directly by erosion. Of the four eroding



BALASON BASIN
RELATIVE RELIEF
88°10'E
88°15'E
27°00'N
26°55'
26°50'N
LEGEND
Elevation in Metres
Above – 600
600 — 400
400 — 200
Below – 200
Scale
1 0 1 2 3 Km

Fig. 1.5

agents – water, wind, ice and gravity – the first is the most potent one and its erosivity is affected the most by the degree of slope (Smith et al, 1969). Slope, which is conventionally known as the angular inclination between different elevations, is a very important morphometric property since it explains the stages of development of a particular landscape. Various procedures of slope analysis based on contours of topographical maps have been evolved by a number of prominent geomorphologists. The present investigator, however, has chosen Wentworth's (1930) method of slope determination, which is very useful for explaining the spatial distribution of average slope of a particular area. The computation of average slope is based on 2cm grid square area instead of Wentworth's grid based on the British system.

The average slope of the study area varies from 15° to 30°. Slope above 30° is found in small-scattered pockets all over the basin. Slope above 30° is encountered along the left bank of the middle Dudhia *jhora* near Gayabari T.G., right bank of the middle reaches and lower reaches of Rangbang *nadi,* Tomsong T.G., in the middle reaches of Bhim *khola,* upper Jore *khola,* lower Rinchington T.G, interfluve between the Ghatta and southern tributaries of Balason. In the study area, one of the most conspicuous slope assemblages is that comprising a bare rock face followed by a substantial accumulation of talus. Development of talus slope is an interesting phenomenon. Weathering of rocks affects their shear strength, bulk density and permeability it penetrates rapidly when rocks are foliated, jointed or crushed (Gerrard, 1991). Extensive area has medium slope ranging from 25° to 30° (Fig. 1.6). These are also found in isolated pockets but cover more area than the high slope zone. Such pockets occur in north west corner in the upper Rangbang basin and Pussimbing T.G. in the northern part in upper Balason and middle part Bhim *khola* basin, in the north-eastern corner in the Jore *khola* basin in the Talkat T.G in the central part of the basin, a large part along the lower reaches of Ragbang, Pachhim, middle Balason.

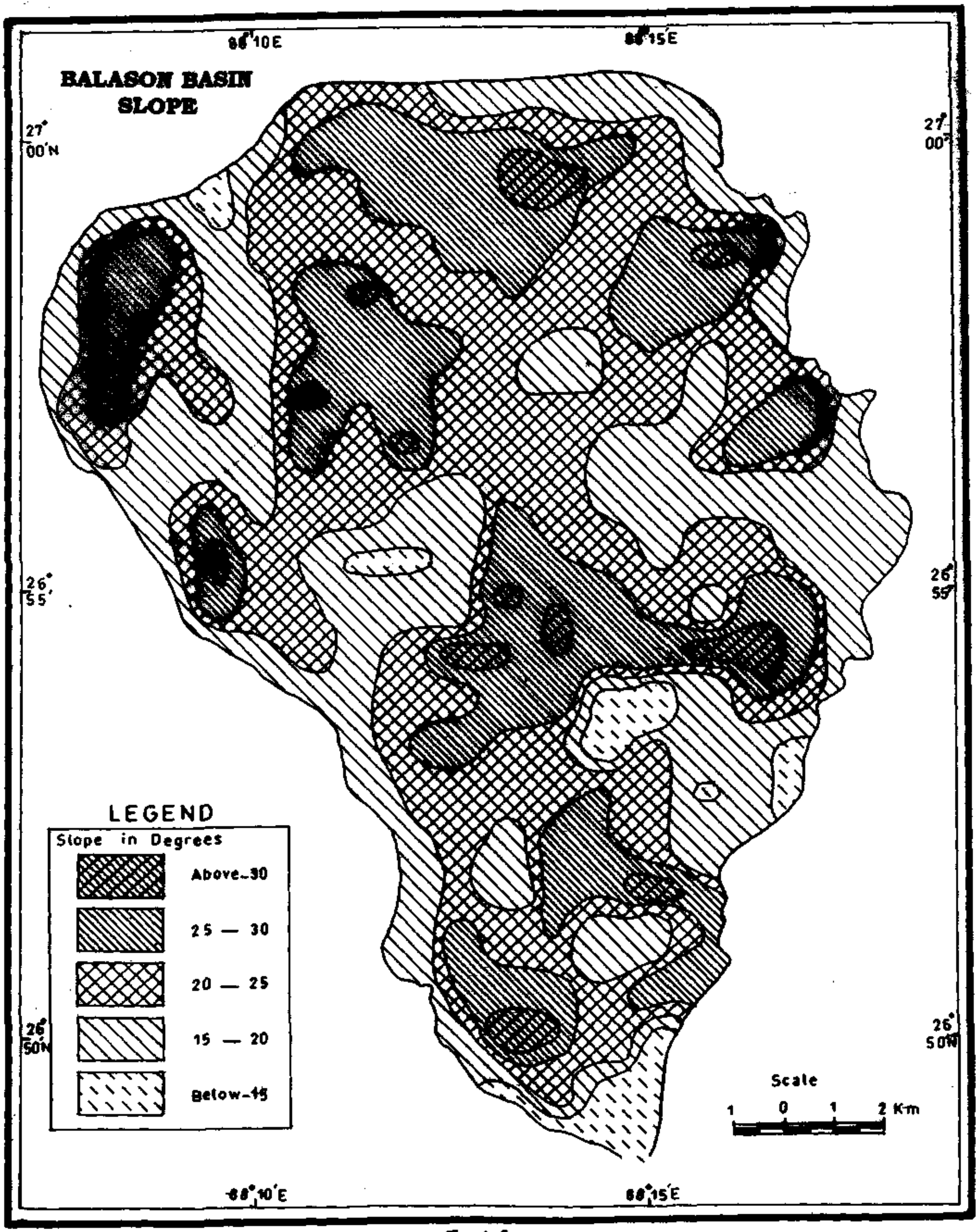

BALASON BASIN
SLOPE
88°10'E
88°15'E
27°
00'N
26°
55'
26°
50'N
LEGEND
Slope in Degrees
Above-30
25 — 30
20 — 25
15 — 20
Below-15
Scale
1 0 1 2 Km

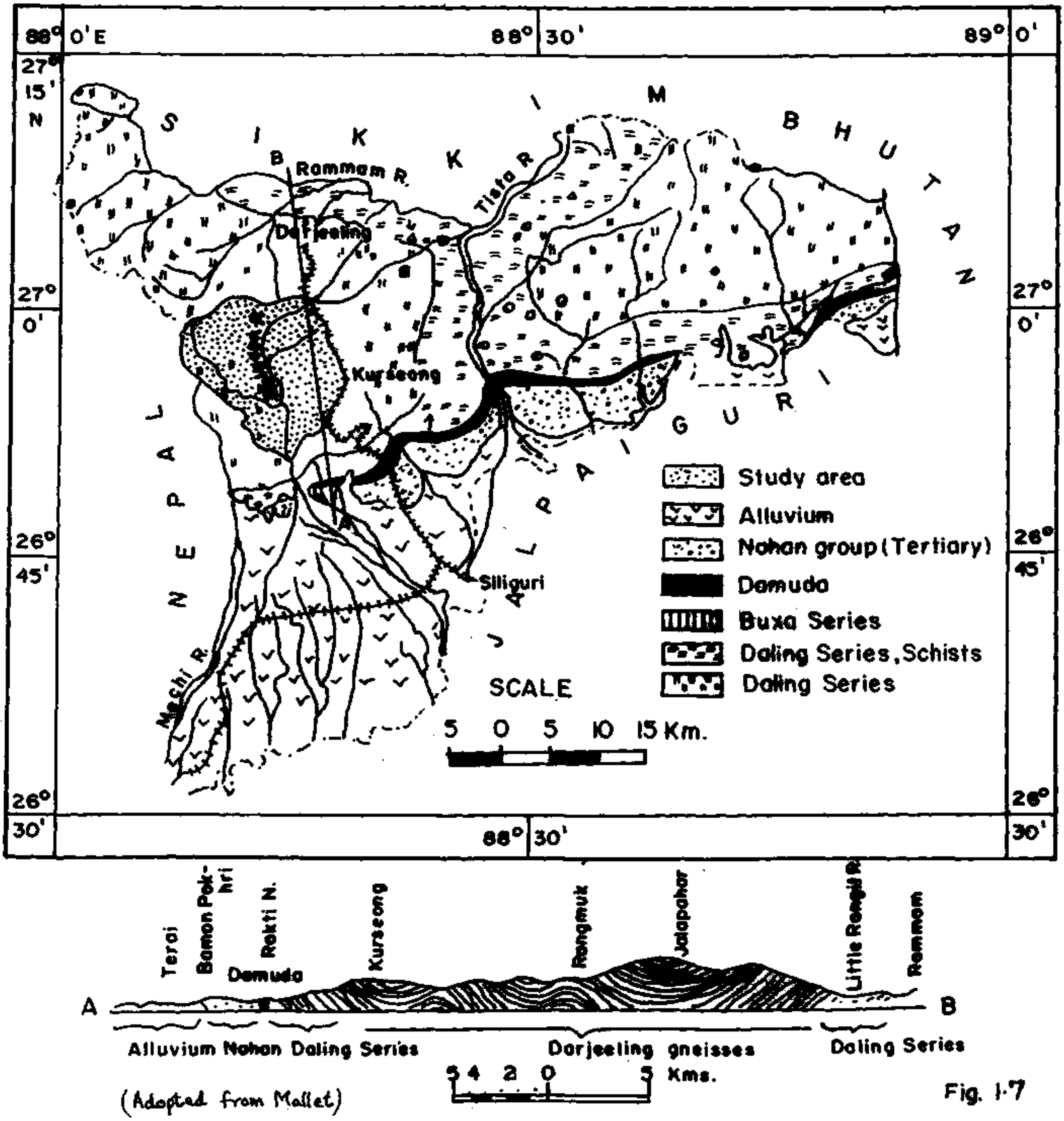
Fig.1.6

In the northern part of the Balason basin, high relative relief zone is coinciding with high steepness of slope. Wherever relative relief is above 500m, the slope is above 30°. This indicates that the river is in its youthful stage and the erosive power of the river is very high. Thus vertical corrasion is very high and the river is flowing through gorge like features with steep sides. Relative relief of the tributary rivers of Balason is high at the middle of their course probably due to the joining of the maximum number of rills and gullies in that zone. This as a result increases the volume of water, which increases the erosive power of the tributary rivers of Balason. Moderate relative relief with gentle slope is a usual occurrence from where the tributary rivers of Balason are originating. This might be due to the presence of rills, which has less erosive power and is unable to erode the existing hard rocks. The ridges and spurs have less relative relief and moderate to gentle slope, indicating less erosion. As the rivers are flowing down the valley, the steepness of the slope and relative relief is increasing. This is because as more and more rills and gullies are joining, the erosive power of the rivers is increasing. To the south of the Balason basin, the relative relief is gradually decreasing and the slope is either moderate or gentle along its two banks.

1.2. GEOLOGY

The geological formations of Darjeeling district consists of few rock formations varying in age between recent to possibly Archaean age. As one passes from the plain northward to higher elevations, one meets alluvium rocks of Siwalik series, a narrow band of rocks of Damuda series, rocks of Daling series and Darjeeling gneiss and mica schist, each succeeding rock, with possible exception of the last, being older than the one before it (Government of West Bengal, 1959). The Himalayas is geographically a complicated mountain system. The complexity of structure and metamorphism that the rocks have undergone has posed challenging problems for co-relation of the different rock formation on a regional scale. Geological investigations in

GEOLOGICAL MAP OF DARJEELING DISTRICT (BALASON BASIN)



(Adopted from Mallet)

Fig. 1·7

Darjeeling and the adjoining regions began in the middle of the last century. In 1854, J.D. Hooker reported the geological findings of his extensive travels spread over the two years – 1848 and 1849. He traced on the regional domal picture of the gneiss and observed the over line sedimentary bedding but the systematic geological examination of the Darjeeling are first done by C. Mallet in 1874. He classified the metamorphic works of Darjeeling and western Duars into the Daling Series and the Darjeeling gneiss.

Since then, several officers of the Geological Survey of India as well as many scientists have recorded local observation. Among them, Ray (1945) has differentiated progressive zones of metamorphism of Daling series and Darjeeling gneiss. Ghosh (1950) has carried out a detailed geological mapping of parts of the Darjeeling Himalayas. M.B.Pande and S.S.Saha (1982) have also studied the Darjeeling Himalayas extensively. If a section is drawn from the Terai area to Rammam river through Kurseong and Darjeeling, it will be found that the entire succession of rocks has, prima facie, the appearance of a great syncline. In the southern part of the section, namely, in Bamanpokhari, around Rakti river and in and around Kurseong town, all the strata are inclined towards the north at rather higher angles. In the central part of this section, namely, around Hope Town spur (Sonada), Rangmuk river, Ghoom and Jalapahar peak, the dips are rolling and irregular. Towards north, starting from Birch Hill, to Little Rangit and the Rammam rivers, the dip of strata is southerly (Fig. 1.7). This is suggestive of complete inversion of strata due to the synclinal thrust of the Himalayan uplift. Among these rock groups, the relationship between the Daling and the Darjeeling series is quite characteristic. Towards the top of the Daling series metamorphism increases up to the Darjeeling gneiss with share of garnet and sillimanite and this is taken as evidence by many scholars that Daling series and Darjeeling series are not divided by an area of overthrust, but constitute a single vast nappe of inversed strata (Starkel, 1972). The outcrop of these, form a series of bands running more or less parallel to the general trend of the Himalayas and dipping one beneath the other into the hills (O'Mally, 1907). The great range was elevated during the tertiary period on the site of an ancient sea that had accumulated sediments of different geological ages, the movement resembling the crumpling of the thin sheet of a flexible material held edge on between the jaws of a slow moving vice, one jaw fixed and the other moving up towards it (Raistrick, 1943). The mountains are made of folded rocks, piled one over another by a series of north – south horizontal compression movements and tangential thrust which also folded the strata on the sea floor and caused their upheaval by stages (Govt. of West Bengal, 1970). The present relief of high peaks and deep valleys has been carved by wind, water and snow.

The rock formations in the study area are Darjeeling gneiss most commonly mixed with some pockets of sandstones, siltstones and dark slates commonly referred to as the Darjeeling series. The rocks are micaceous frequently passing into mica schist (Saha et al, 1982). The rock formation of the entire study area can be described as granetiferous mica – schist, quartzite and biotite – kyanite and sillimanite gneiss. Both muscovite and biotite are common. Some common accessory minerals of this area are kyanites, sillimanites, hornblende, garnets, bands of quartzite and aluminous chlorites along with some calcite, the garnet, at places, disseminated through the mica – schist in coarse crystals of considerable size and are prized as a gem (Govt. of West Bengal, 1981). The gneiss is always well foliated and exhibits strongly marked features of disturbances, which is evident from much folding and crumbling. It is highly micaceous and is composed of colourless or grey quartz, white opaque feldspar, muscovite and biotite. It varies in texture from a fine grained to moderately coarse rock, lenticular layers of different degree of coarseness being commonly interbedded (Govt. of West Bengal, 1976). From Kurseong to Ghoom on the eastern side of the study area, the gneiss is continuous. As explained, the dips are uncertain and irregular but are, on the whole, northerly near Kurseong and southerly near

Ghoom and beyond. Gneiss is also met in traverses along Ghoom – Sukhiapokhri road. Typical succession of sillimanite – kyanite – garnet metamorphic zones among this gneiss is well seen in these traverses. At places, numerous veins of quartz pegmatite and aplite traverse gneiss. Thin bands and lenses of carbonaceous matter, usually graphitic in appearance, are also found in the gneiss. Of special interest is lime – silicate inclusions or concretions in Darjeeling gneiss. They seem restricted to gneiss. The inclusions usually form lenticular bodies with curiously bent tail ends. Free lime is rarely present, but a concentric arrangement of a characteristic mineral paragenesis can be observed. From the host rock to the core of the concretion sequence is as follows: quartz, oligoclase – andesine, biotite, garnet, titanite (country rock): quartz, little andesine, little biotite, garnet, titanite (contact): bytownites, green hornblende, garnet, quartz, titanite (contact): bytownite, garnet, diopside, quartz, titanite and bytownite, quartz, fine reticular garnet (titanite) (Govt. of West Bengal, 1981). Introduced quartz usually surrounds garnet and bytownites. Some other concretions have a core of pure red garnet with grains up to 2 cm. The latter show characteristic sieve and drop like inclusion of magnetite and quartz often concentrically arranged. More basic inclusions or concretions have been observed in the form of diopside bearing garnet hornblende. The location of the study area in the gneissose rock formations has a very profound effect on the other parameters having bearing on the soil erosion from the area one of the most important of which is the character of the drainage of the area.

1.3. DRAINAGE

The river Balason is one of the easternmost tributaries of the river Mahananda. The literal moaning of the word 'Balason' is 'the river of golden sand', a Bengali name suggested by the wide bed of yellowish sand as it descends down in the plains. The river Balason rises in the Lepcha Jagat near Ghoom Simana range of Darjeeling Himalayas. The Balason flows south almost parallel to the 88°15'E meridian till it

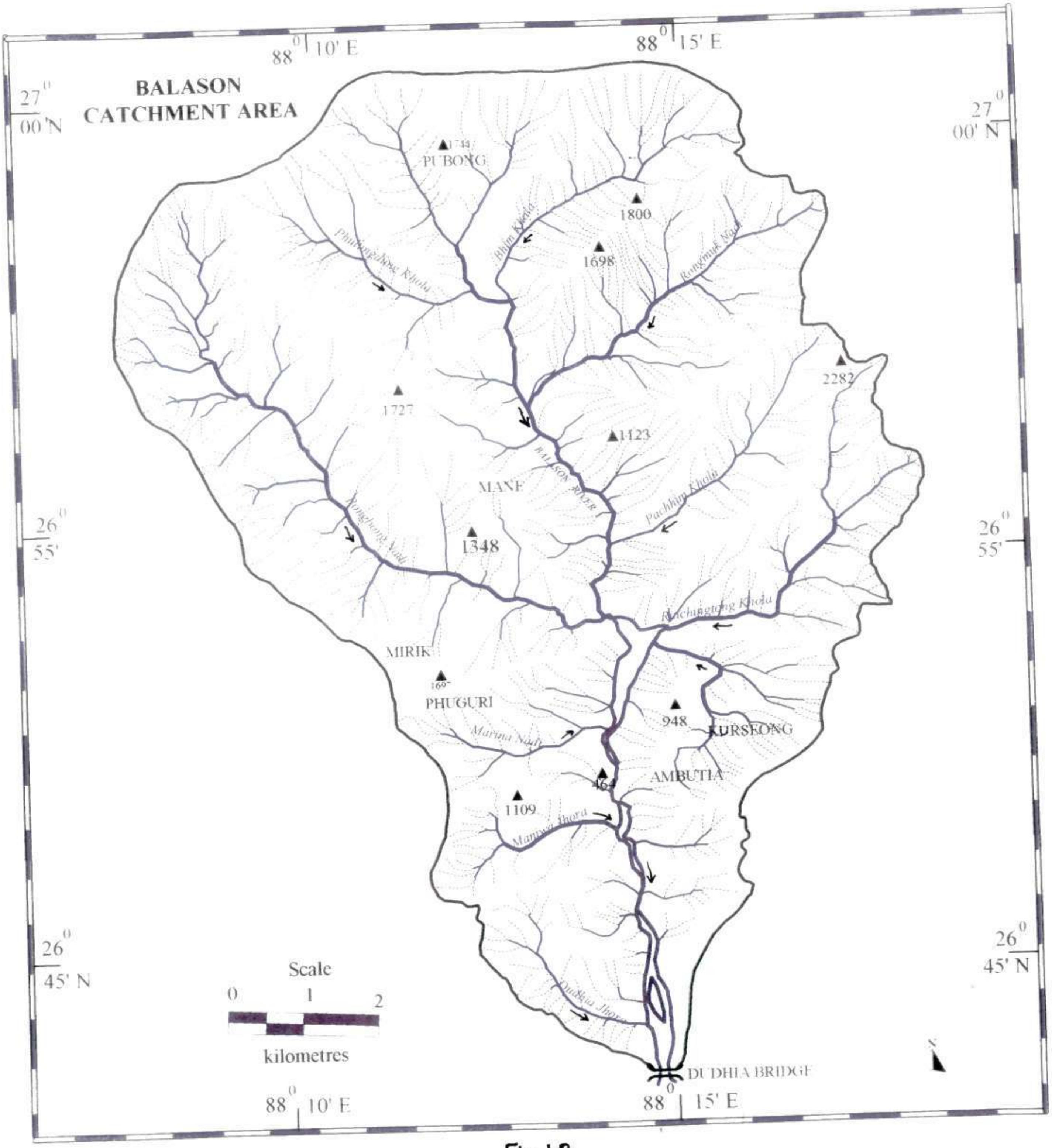

BALASON
CATCHMENT AREA
88° 10' E
88° 15' E
27° 00' N
26° 55'
26° 45' N
PUBONG
1800
1698
1727
1123
2282
MANE
1348
MIRIK
PHUGURI
948
KURSEONG
AMBUTIA
1109
Bhim Khola
Rongmuk Nadi
Phuchingdhow Khola
BALASON RIVER
Pachhim Khola
Ronghong Nadi
Rachungtong Khola
Marina Nadi
Manjwa Jhora
Dudhia Jhora
Scale
0
1
2
kilometres
DUDHIA BRIDGE
N

Fig. 1·8

reaches the plains at an altitude of 304.8m and then turns south-east where its valley is larger than that of the Mahanadi, although its catchment basin does not receive so heavy a rainfall as that of the latter. Of its innumerable right-bank tributaries, the chief are Pulungdung *khola* that rises from the southern face of the Ghoom saddle just below the Sukhiapokri- Simanabasti road, flows southeast the Ghoom Pahar Reserved forest, and debouches into the Balason at an altitude of about 912.24*m* (Fig. 1.8).

The Rangbang *nadi* originating below Simanabasti (2299.38m) on the southern extension of the Singalila range flows south-east through reserved forests and a number of tea gardens and meets to Mirik pass over two bridges, one at 1044.85m (Gopaldhara Tea Garden) and the other at 1356.36*m* (between Siyok and Selimbong Tea Garden). For its picturesque grandeur the Rangbang gorge is a potential tourist attraction. The Marma *nadi* rising from the south-facing escarpment of the Mirik dome flows east and meets the Balason in a deep gorge. The valleys of the Rangbang and Marma *nadi* very closely resemble hanging valleys. The Manjwa *jhora*, only 0.75km to the south of Marma *nadi*, flows almost parallel to the latter through dense forests. The Dudhia *jhora* descends from 1106.72m (Phuguri T.G.), flows southeast in a concave gradient and debouches into the Balason at an altitude of about 304.8m. For the greater parts of their courses, the south-southeast flowing tributaries, the Chenga and Manjha *nadi*, negotiate the Terai forests and the plains. From north to south the chief left-bank tributaries of the Balason are the Bhim *khola*, the Rangmuk *nadi*, the Jore *khola*, the Pachhim *nadi*. And the Rinchingtong *khola* all of which rise from the Senchal spur south of the Ghum saddle and flow from north-east to south-west through deep and precipitous gorges, a few tea gardens and dense forests. Below Kurseong the main tributaries of the Balason are south flowing. The river Teesta drains the northern and eastern sides of the Balason catchment, which is a tributary of the river Brahmaputra. The Mechi river drains the western side of the Balason catchment.

1.4. CLIMATE

The climate of the study area varies from tropical on lower reaches to temperate on higher reaches closer to the rim of the Balason basin. Darjeeling hills, in general, have a unique climate of their own. The temperature and rainfall data has been collected from Singel T.G., which is located in the vicinity of Kurseong town and is presented in Table 1.2.

Table1.2. Average meteorological data of Singel Tea Garden (2000–05)

Months	Rainfall in mm	No. of rainy days	Temperature in °Centigrade		
			Maximum	Minimum	Average
Jan	18.5	2.7	15.6	7.8	11.7
Feb	21.0	4.7	16.0	8.8	12.4
Mar	30.7	5.0	20.8	10.8	15.8
Apr	122.2	10.7	21.9	14.3	18.1
May	254.7	14.5	24.5	15.2	19.8
Jun	722.7	21.8	24.9	16.4	20.7
Jul	1098.8	23.0	25.0	17.4	21.2
Aug	834.8	22.0	24.5	18.0	21.2
Sep	434.0	18.2	23.7	16.8	20.2
Oct	181.0	5.5	23.8	14.1	19.0
Nov	9.7	1.2	21.1	10.4	15.7
Dec	5.0	0.7	18.1	8.1	13.1

(Source: Singel T.G., Kurseong.)

Temperature in the study area varies depending on altitude. The average temperature for six years has been taken into account. The

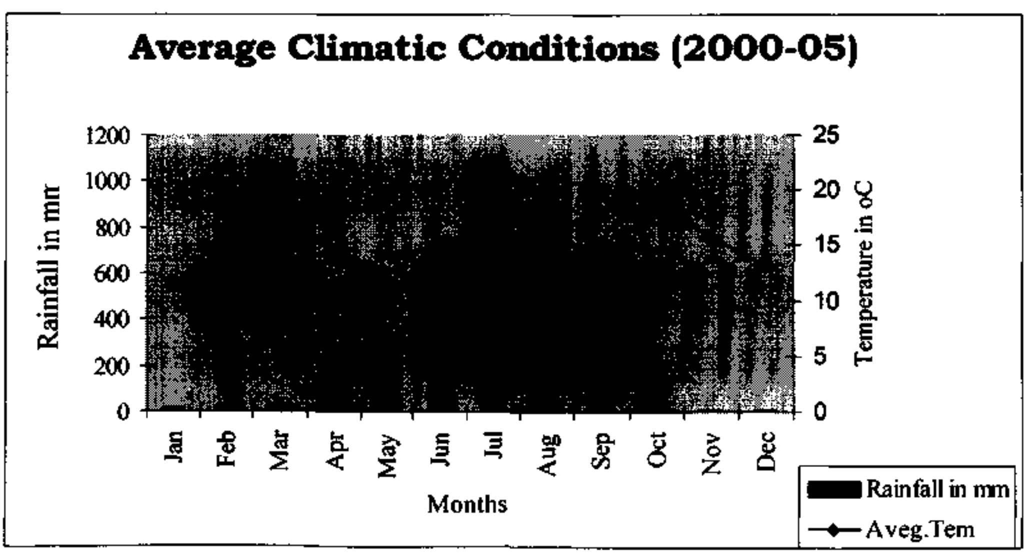


Fig.1.9

extremes of temperatures are felt in areas of high hills (1500m to 2500m) lying along the ridge tops delineating the main basin (Govt. of West Bengal, 1986). As seen from the table1.2, January is the coldest month having average temperature11.7°C and July – August records the average temperature i.e. 21.2°C being the hottest months. The lower altitudes have higher temperatures and higher altitudes have lower temperatures due to altitudinal variations (Mani, 1981). The average annual rainfall in the study area is 3733mm.Most of it is received during the monsoon months between June and September. About 83% of the total rainfall occurs during these four months. The rest of the year is almost dry (Fig.1.1). On account of such heavy concentration of rainfall in a few months, monsoon becomes atrocious during this period (Raghuraman, 1975). Highest average rainfall of 1098.83mm is observed in the month of July, which also has the highest average number of rainy days (23 days). During this monsoon, large sized boulders are reported to flow down through the rivers of the study area. This is one of the reasons for excessive soil erosion and failure of engineering structures, constructed in the river for moderating their flow. The month of December has the lowest average rainfall (5mm) being the driest month with least number of rainy days. In the last few years, 2002 recorded the highest number of rainy days annually (138). Rainfall is higher in the forested areas. During monsoon the weather is generally foggy but from October till April weather is usually dry, clear and fog free. This is the time when people suffer from acute crisis of water. The atmosphere is highly humid throughout the year and relative humidity is highest in summer than in winter.

During the period November-May upper winds over the Himalayan region are predominantly westerly. With the setting in of the monsoon, however, there comes a conspicuous reduction in wind speed persisting until the arrival of winter. Surface winds in Darjeeling district have usually an easterly component. From November and throughout the winter prevailing wind direction is east- northeast. In the spring and upto June there is a tendency for a west or southwest component to enter and in the monsoon (June to September) prevailing direction is east- southeast.

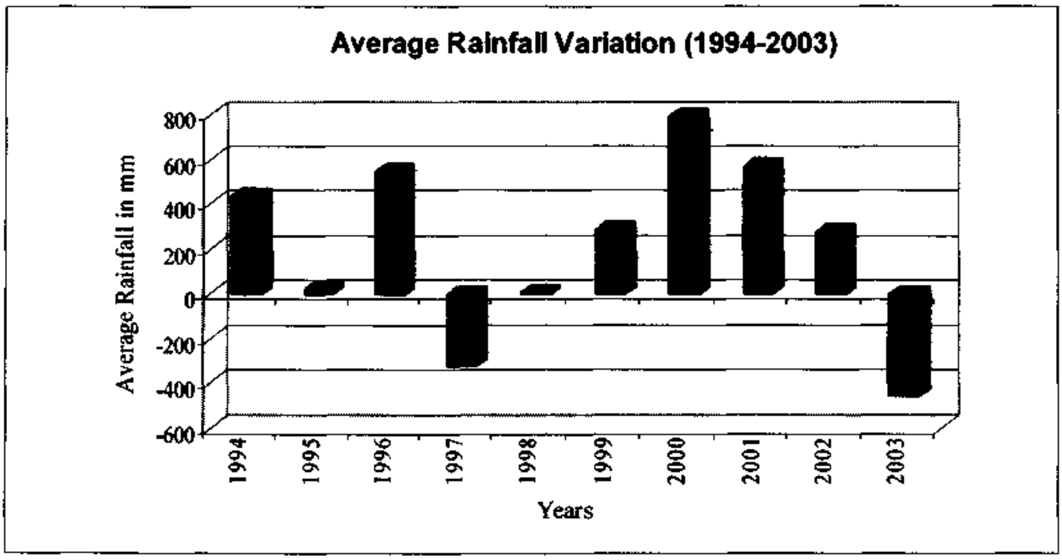


Fig.1.10

1.5. SOIL

Soils are a dynamic part of the earth's geomorphic cycle of surficial weathering, erosion, deposition, sinking, digenesis, metamorphism, upliftment and mountain building (Jackson, 1976). The process of soil formation is quite complex in nature and varies from place to place. The factors, which affect the soil forming processes, are nature of parent material, topography, climate and biosphere. The parent material is fractured, splintered, pried apart and dissolved through the process of solution, freezing, thawing and oxidation – all called together as processes of chemical and physical weathering (Bennett, 1955). Climatic factors have multidimensional effects. These help to develop a wide variety of soils in the study area. The climatic conditions determine the rate of this primary weathering process to a large extent. Apart from physical weathering, the nature, direction and the rate of chemical reactions are affected by the nature of reactants and products, their concentration and amounts, the manner of their supply and subsequent removal of the products from the site as well as temperature, pressure and volume (Barshad, 1976). Soil is a natural body having depth and surface area, existing as a continuous cover on the land surface, except on very steep slopes and is a product of natural destructive and synthetic forces (Ghildyal, 1981). The physical and chemical weathering of rocks and minerals result in the formation of unconsolidated debris, the regolith, the upper biochemically weathered part of which is the soil.

In the study area, very shallow skeletal to deep soils are found. Red yellow soils, usually gritty, have developed in Darjeeling gneiss and schist occurring in the study area. Darjeeling gneiss commonly decomposes into a stiff reddish loam but may also produce, occasionally, pure sand or stiff red clay. The colour of red soil, derived as it is by meteoric weathering from gneiss and schist, is due more to wide diffusion than to high proportion of iron content (Govt. of West Bengal, 1981). This type of soil occurring in the study area is mainly siliceous and aluminous with free quartz as sand. It is usually poor in lime, magnesia, iron oxide, phosphorus and nitrogen but fairly rich in potassium derived from muscovite and feldspar of gneiss. The podzolic soil i.e. the bleached sandy soils poor in humus are good for tea cultivation. The brick red coloured clay loam soils, considered best for tea growing, occur in piedmont slopes. The soils have great variability in their productivity and in combination with climate; the study area produces a wide range of vegetation.

1.6. VEGETATION

Differences in elevations and variable productivity of soil in combination with height variable temperatures in the study area have produced different types of vegetation. The original vegetation of the land hardly exists. Through ages the virgin forests are almost removed and degraded. Experiments through the years have given a new definition to the vegetation types that are found at present. The present vegetation types are as follows:

1.6. a. Humid Temperate Forest Zone: This type of vegetation occurs along the brim of the basin in an approximately 3 to 4 km wide strip except in the southern part. The lower limit of this zone is bounded by

2000m contour line. The species met are Katus (*Castanopsis indica*), Lekh Dabdabe (Meliosma *wallichii*), Tite Champ (*Michaelia cathcartii*), Phalado (*Erythrina indica*), Lapche Kawla (*Machilus edulis*) Musre Katus (*Castanopsis tribuloides*), Lekh Chilauni (*Nyssa sessiliflora*), Walnut (*Juglans regia*), Malata (*Macaranga sp.*) and Arupate (*Prunus nepaulensis*). In several patches plantations of Dhupi (*Cryptomaria japonica*) have been raised.

1.6. b. Moist Scrub Vegetation Zone: To the south of the humid temperate forest lies this zone. This area is more moist and cooler and has characteristic vegetations. The species encountered are Panisaj (*Terminalia myriocarpa*), Lahsune (*Amoora rohituka*) and Lali (*Amoora wallichii*). The species found in the undergrowth are mainly Bepari (*Ostodes paniculatus*), Choya (*Dendrocalamus hamiltonii*), Hatisar (*Alpinia nutans*) and other herbaceous annuals and shrubs.

1.6. c. Dense Scrub With Human Settlements: This region lies between 1500m and 1000m elevation. Settlements and agricultural lands are located in this region. On the steeper slopes and terrace risers perennial grasses like Amlisho (*Thyssanolena maxima*) and Narkat (*Arundodonax sp.*) are planted. Besides being good fodder and only fodder grasses available during winters, these perennial grasses have very good soil binding capability and are a good deterrent against surficial landslide. Among the trees planted by farmers on their fields, fodder trees are of prime importance. The main fodder tree species planted are Gogun (*Saureria nepaulensis*), Nebharo (*Ficus hookerii*), Dudhilo (*Ficus nemoralis*), Utis (*Alnus nepaulensis*) and Weeping Willow (*Calix indica*). Some temperate fruit trees such as plume, peach and oranges are also planted in this zone.

1.6. d. Wasteland with Dry Scrub: This zone lies below 1000m height and consists of wasteland with rock outcrops with occasional skeletal soil. Growth of vegetation is poor on account of poor soil depth and even tree species have stunted growth. Species found are Siris (*Albizzia sp.*), Phaledo (*Ertthrina sp.*), Parari (*Stereospermum chelonoides*) and Malata (*Macaranga sp.*) with undergrowth of Amlisho (*Thysanolena* *maxima*), Assamlota (*Eupatorium odoratum*), Tarika (*Pandamus furcatus*) and Choya Bans (*Dendrocalamus hamiltonii*)

1.6. e. Tea Gardens: Tea gardens occupy the largest area in the Balason basin. Shady trees are planted in the tea gardens. Rolling piedmont slopes are occupied by tea bushes whereas *jhora* banks and other steeper areas are kept under permanent vegetation for the purpose of protection. The species met in such patches kept under permanent vegetation are: Chilaune (Schima wallichii), Mauwa (Engelhardtia spicata), Angare (Phoebae attenuata), Strobilanthus sp., Sisnu (Girardinia sp.), Boehmeria sp. and ferns.Bamboo clumps are also seen in some places.

CONCLUSION

Thus it is seen that the study area lies in a geographically complicated mountain system. The basin is balloon shaped which is broad in the north and tapers to the south. The rivers mainly flow from west, north and east of the basin towards the south. The Darjeeling gneiss and Daling series are the main geological formations in the area. The terrain of the areas above 1900m height is quite rugged and mainly forested. The spurs are emerging from the heights ranging from 1100m to 1900m. Below 1100m height, the terrain is rolling and below 800m it is the foothill area with accumulation of numerous colluvial deposits. High relative relief is found in the northern part of the basin, where the slopes are very steep. The average slope of the study area varies from 15° to 30°. Where high relative zone coincides with high steepness of slope, it indicates that the river is in its youthful stage and the erosive power is very high. The climate of the area varies from tropical in the lower reaches to temperate in the higher reaches. Climate of the area is quite interesting with the minimum temperature 7.8°C and maximum temperature is 23.0°C. There is sharp change in between summer and winter temperatures. Places like Jorebunglow and Sonada experiences snowfall during the winter months of December, January and February since the last few years. This might be due to the effect of global warming and environmental degradation. Rainfall is very high in the basin and continues for four months from June to September. Highest average rainfall of 1098.8mm is recorded in the month of July and lowest average rainfall of 5.0mm is recorded in the month of December. The relative humidity is as high as 94% and never goes below 66% in the study area. High and fog are also quite common. These two are much unpredicted and can happen at any time of the year. Very shallow skeletal to moderately deep soils are found in the study area. Occasionally rock outcrops are also seen. Podzolisation and leaching of soil is very common. Yellowish colour of soil shows washing down of iron and aluminium to a great extent. The soil formation in the study area is not uniform. Soil forming process is slow and soils are relatively young in the steep slopes. In milder slopes soil forming processes are most active forming matured soils. Study area has a wide variety of vegetation. Humid temperate forest vegetation is found along the ridges of the basin. The species grown are Katus (*Castanopsis indica*), Tite Champ (*Michaelia cathcarti*), Musre Katus (*Castanopsis tribuloides*) and its associates. Moist scrub vegetation consists of Panisaj (*Terminalia myriocarpa),* Lahsune *(Amoora rohituka*) and their associates are found in the northern part of the study area. Dense scrub vegetation with human settlement is seen on warmer south western aspect lying all along the eastern side of the study area. Western side has Dhupi (*Cryptomeria japonica*). Tea gardens are mostly concentrated in the middle reaches on all sides of the basin. Wasteland with dry scrub consisting of Siris (*Albizzia sp.*), Parari (*Stereospermum chelonoides*) and associates are encountered in the lowest reaches of the study area.

In view of this discussion it is eminent to study the drainage systems and their network for determining the level of erosion and their impact on agriculture and forestry in the study area. Moreover rivers and springs not only help the agriculture but also generate the hydel power to supply the immediate vicinity.

CHAPTER II

DRAINAGE CHARACTERISTICS IN THE BASIN

INTRODUCTION

The Balason basin is drained by river Balason and its ten major tributaries and numerous minor tributaries. The basin is funnel shaped with rivers draining from north, northeast, northwest, east and west towards the south. The right bank tributaries are Pulungdung *khola*, Rangbang *nadi*, Marma *nadi*, Manjwa *jhora* and Dudhia *jhora*.The left bank tributaries are Bhim *khola*, Rangmuk *nadi*, Pachhim *nadi*, Rinchingtong *khola* and Ghatta–Hussain *nadi*. All these rivers erode the land and set a typical pattern over the land.

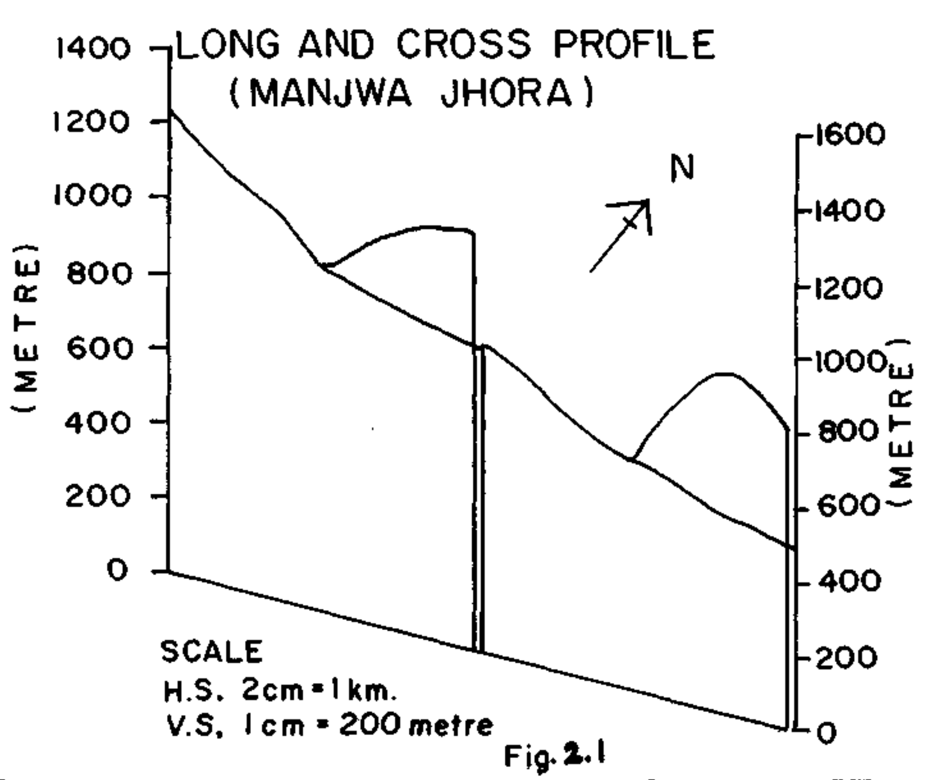
2.1 DRAINAGE CHARACTERISTICS

Entire Balason basin shows a dendritic pattern of drainage. All the streams join each other at acute angles. But along the steep slopes in few areas parallel drainage pattern can also be identified. Parallel drainage pattern shows the structures control over drainage.

2.1.1 Long and Cross Profile

Dudhia jhora has a length of 4.75km. It rises along the Nepal border in the south western part of the study area.

Manjwa jhora, which has a length of 4.1km, originates at an elevation of above 1200m and flows eastwards to meet river Balason at an elevation of 450m.The tributaries at the upper course of the river are almost parallely aligned indicating the presence of steep slope. In the lower course the river has fewer tributaries. Along the long profile there are two sudden changes, one at 1000m and again at 800m.The cross profile at 900m is 'V' shaped. The cross profile at 600m elevation shows steep slope on the left bank whereas right bank has gentle slope. The convex slope of the left bank may be due to the presence of more resistant rocks and less tributaries. In the upper part, the slope of the land is 20° but in the lower part the slope is steep, above 25° (Fig. 2.1).



LONG AND CROSS PROFILE
(MANJWA JHORA)
1400
1200
1000
800
600
400
200
0
(METRE)
1600
1400
1200
1000
800
600
400
200
0
(METRE)
N
SCALE
H.S. 2cm = 1 km.
V.S. 1 cm = 200 metre

Fig. 2.1

Marina nadi stretching over a length of 4.25km is slightly longer than Manjwa *jhora*. The course of the river has a typical concave slope. The river rises at an elevation of 1600m, flows eastwards to join river Balason at an elevation of 540m. Under normal circumstances of lithology and structures, weathering and erosion will encourage the formation of concave slope out of a given uniform slope. Gilbert related concavity to water discharge and sediment load. The greater the discharge, the quicker and greater is the transport of load. This would promote concavity. If discharge increased more rapidly down slope than accompanying sediment load, then the whole matter (sediment and load) can be effectively transported even if the slope declined. This would also cause concavity. De la Noe and E. de Margerie(1888) had noted that if weakness of rocks increased upward this would cause the concavity of slopes. Long profile of Marina *nadi* shows the various stages of erosion. At first, the rocks are hard which helps the river to make a convex slope and further down, the river flows through a uniform slope. After flowing 1.5km from the origin, the river flows along a rectilinear slope with declined slope angle. The cross profile at 1000km is peculiar with left bank steeper than the right bank and the right bank is gentle with a sudden break of slope. The cross section at an elevation of 600m shows that the right bank is under continuous erosional process leading to flattish slope. Left bank has harder rock, which is getting eroded at a slower rate than the right bank showing more concavity (Fig. 2.2).

Rangbang nadi extends for a length of 17km. The source lies at a height of 2250m and ends at a height of 525m approximately. Along the long profile of the river, two knick points are visible, one at the height of 1700m and the other further down at an elevation of 900m. The river valley in the upper course that is between the source and 1700m is extremely steep. The angle of steepness or the gradient here is 25°. Between 1700m and 1100m the river has moderate steepness, being 20°- 25°. Between 1100m and 900m the river flows strikingly over a gentle slope making an angle of 20°. At 800m there is a break of slope.

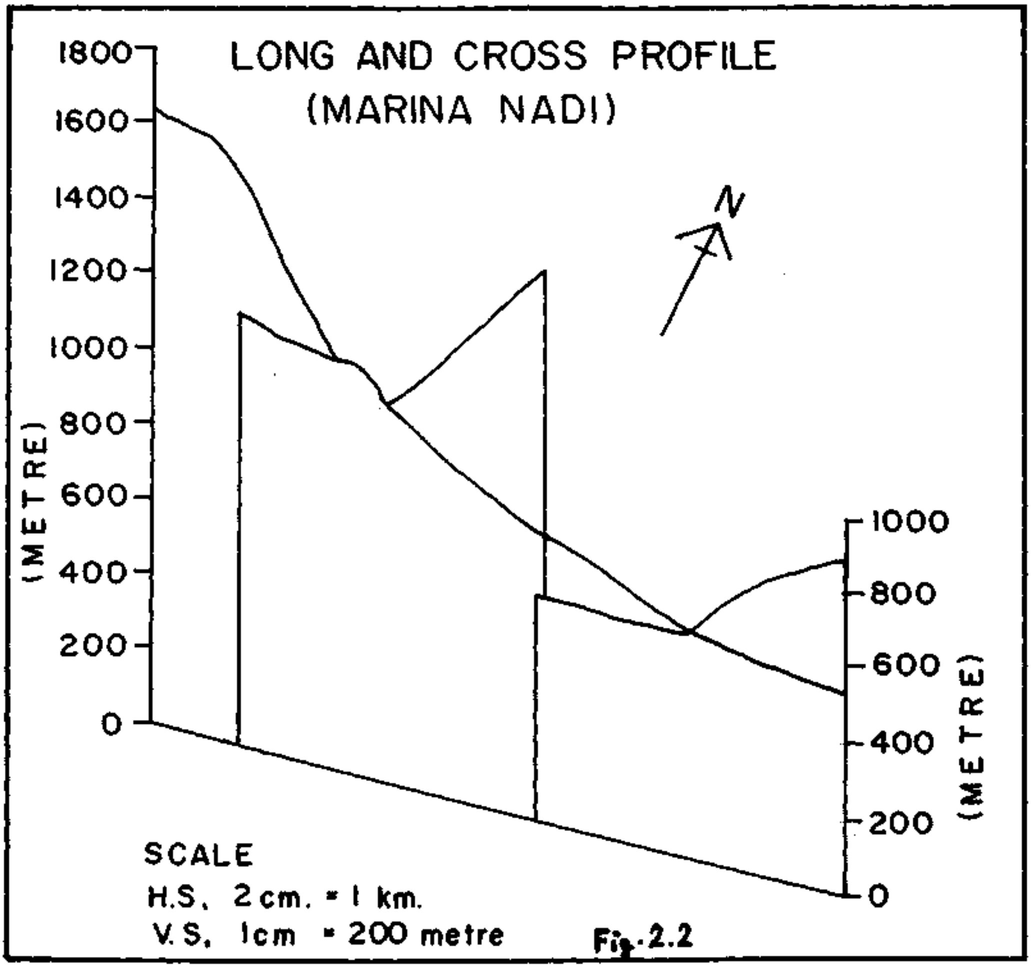

LONG AND CROSS PROFILE
(MARINA NADI)
1800
1600
1400
1200
1000
800
600
400
200
0
(METRE)
1000
800
600
400
200
0
(METRE)
N
SCALE
H.S. 2 cm. = 1 km.
V.S. 1cm = 200 metre

Fig. 2.2

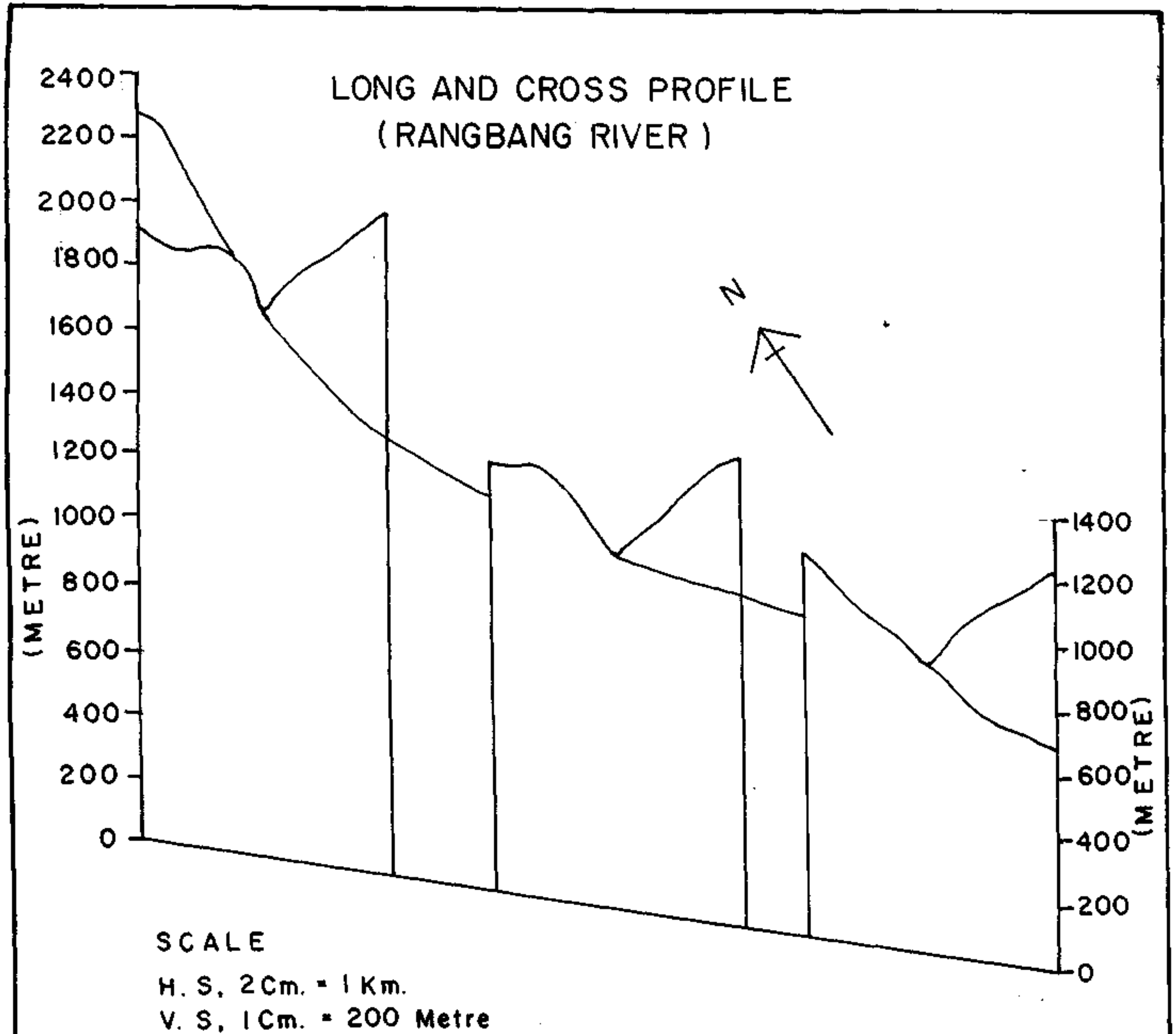
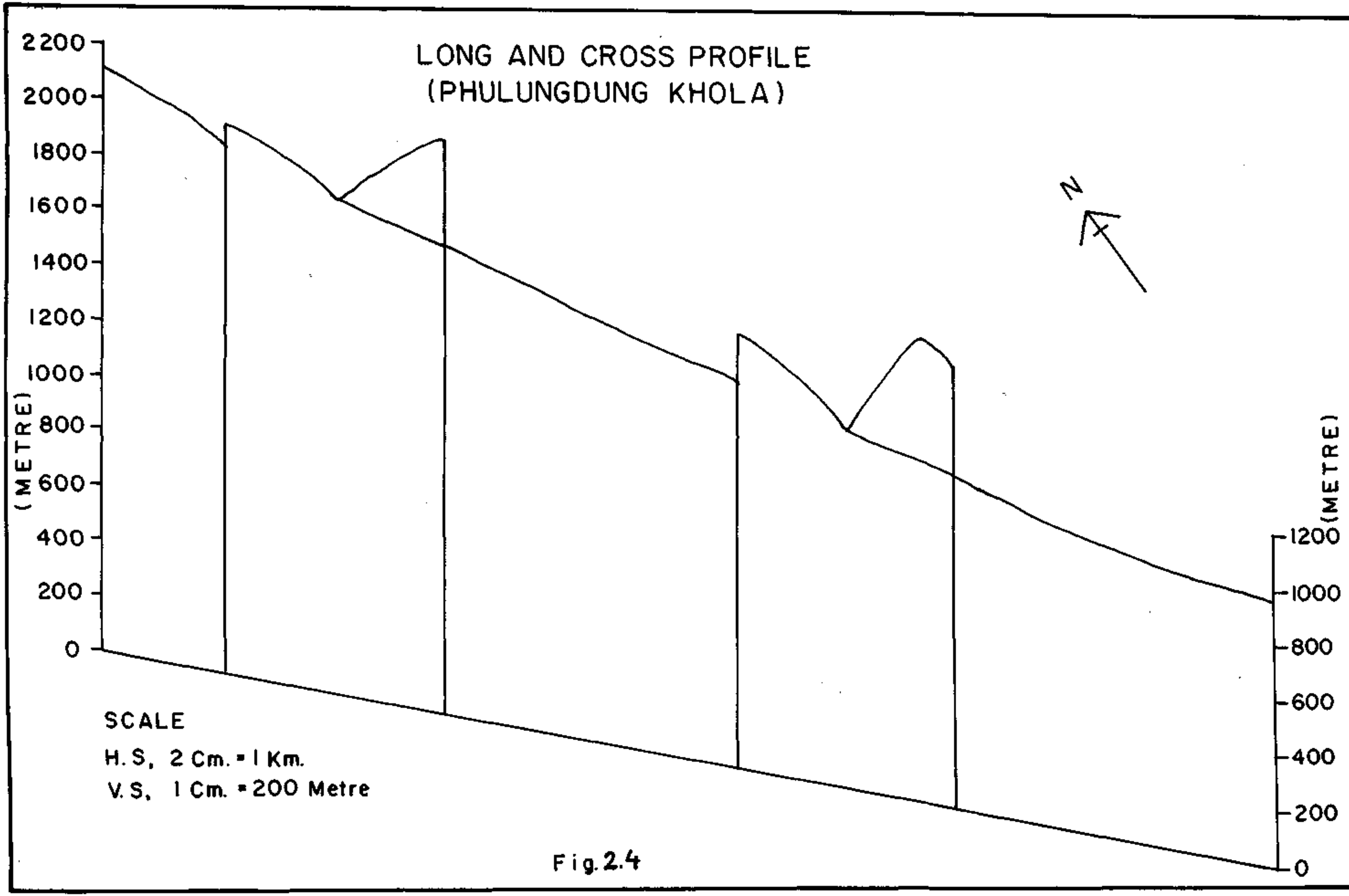

LONG AND CROSS PROFILE
(RANGBANG RIVER)
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
(METRE)
N
1400
1200
1000
800
600
400
200
0
(METRE)
SCALE
H. S, 2Cm. = 1 Km.
V. S, 1Cm. = 200 Metre

Fig.2.3

Between 800m and the end point of the river where it meets the mighty Balason approximately at a height of 525m, the Rangbang *nadi* forms a moderately steep slope, similar to the slope between1700m and 1100m. Where the slope is steep, the reason might be the presence of resistant rocks whereas the gentle slopes might result due to the presence of comparatively softer rocks. In the steep slopes there might be probability of flash floods during heavy rain. Gentle and moderate slopes are usually prone to soil erosion and landslides. The cross profiles give a clear idea about the change in the shape of the valley. In the higher altitudes the valley is deep forming narrow 'V' shaped valley. Where the river is flowing at an elevation of 1100m, the 'V' shaped valley is comparatively wider. Around 900m elevation the sides of the river are eroded to a great extent due to lateral corrasion and mass wasting. Thus the valley became much wider. In the last cross section at an elevation of 600m again the 'V' shaped valley became narrow might be due to the local variation of rocks. Below the knick point at an elevation of 900m the river again reached its youth and vertical corrasion has increased forming such a valley (Fig. 2.3).

Phulungdung khola extends for a length of 5.55km. Its source lies at a height of 2150m and joins Balason river at a height of 975m. The long profile of the *khola* shows almost gentle slope except between 1900m and 2000m. Here the slope is slightly steep and the angle of steepness is 15° to 20°. Gentle slope all along the course indicates homogeneous rock structure in the area. The cross profile, where the *khola* is at a height of 1800m is a wider 'V' shaped valley than at a height of 1300m where the valley is comparatively narrow. This might be due to the presence of more resistant rock at the lower elevation (Fig. 2.4).

Bhim khola is one of the longest tributaries of river Balason with a length of 7km. Bhim *khola* originates at a height of about 2100m. Along the long profile a knick point can be observed at a height of 2000m. The slope between 1900m and 2000m is comparatively steep. Further down stream the river slope is gentle. In the upper course, the contours are



LONG AND CROSS PROFILE (PHULUNGDUNG KHOLA)

Fig. 2.4

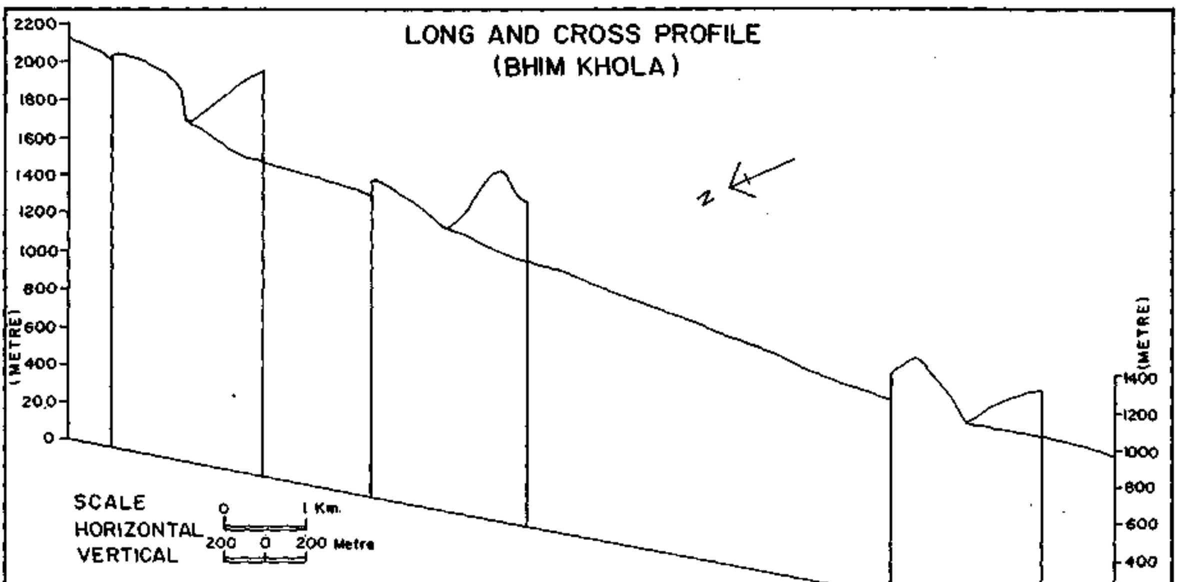
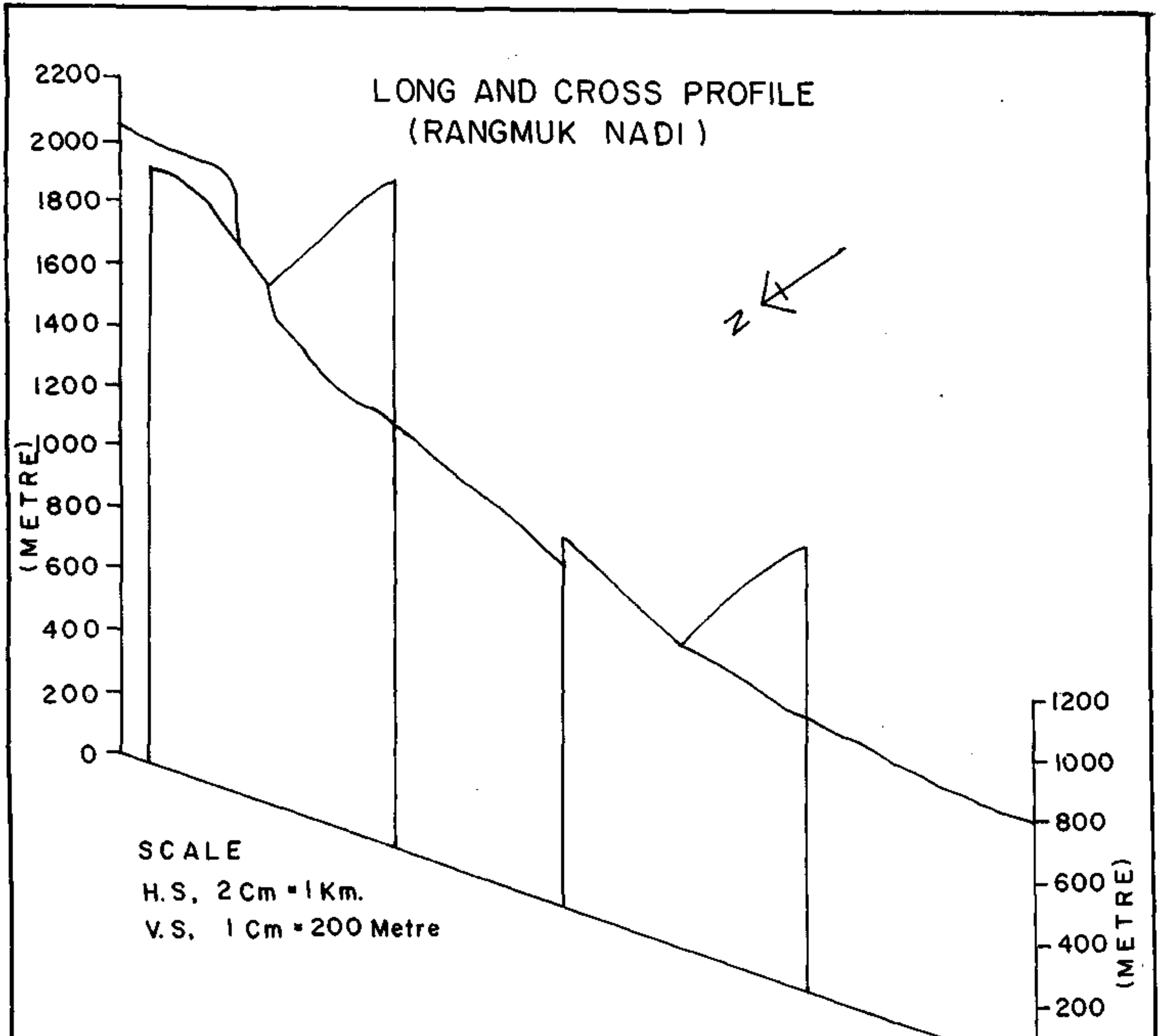

LONG AND CROSS PROFILE
(BHIM KHOLA)
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
(METRE)
1400
1200
1000
800
600
400
200
0
(METRE)
N
SCALE
HORIZONTAL
VERTICAL
0
1 Km.
200
0
200 Metre

Fig. 2.5

closely spaced, middle course contours are moderately spaced and in the lower course contours are sparsely spaced. The slope in the upper, middle and lower part of the river course is 20°, 30° and 25°respectively. The cross profiles give a clear idea about the change in the slope of the valley. Where the river is flowing at a height of 1800m the 'V' shaped valley is extremely steep on the right bank and comparatively gentle on the other side. Further down stream where the river is flowing at a height of 1500m the right bank is extremely eroded may be due to the presence of softer rocks or landslide. The left bank forms a small summit at a height of above 1800m. At about 1000m, the right bank is again steep due to the presence of hard rock and left bank is extremely gentle due to excessive erosion (Fig. 2.5).

Rangmuk nadi rises at a height of 2050m and flows southwards for a distance of 8km, to meet river Balason at an elevation of 800m. Along its course there is sudden break in slope at an elevation of 2000m. From 2000m downwards, the slope is almost vertical. Below the height of 1500m, the slope is quite uniform or rectilinear. Severe down cutting in the upper course of Rangmuk *nadi* leads to the formation of steep slope. The angle of slope is 25°. As we go downstream the angle of steepness decreases. The cross profile at three different heights like 1700m, 1300m and 1000m are 'V' shaped and shows uniformity in the structure of the underlying rocks. Right bank is steeper than the left bank (Fig. 2.6).

Pachhim khola originates at a height of about 1950m and after flowing over a distance of 6.9km meets river Balason at a height of 675m. There are two sudden drops in height, one at an elevation of 1900m and another at 1500m. These two heights might be referred to as knick points. The angle of steepness at 1900m and 1500m are 25° and 20° respectively. Where the river is flowing at a height of 1400m, the valley is narrow 'V' shaped because the *khola* is fast flowing with acute vertical corrasion. At an elevation of 1100m the 'V' shape of the valley has become wider due to lateral erosion. At an elevation of 900m the right bank of the river is completely eroded and lies at a lower



LONG AND CROSS PROFILE
(RANGMUK NADI)
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
(METRE)
N
1200
1000
800
600
400
200
0
(METRE)
SCALE
H.S, 2 Cm = 1 Km.
V.S, 1 Cm = 200 Metre

Fig. 2.6

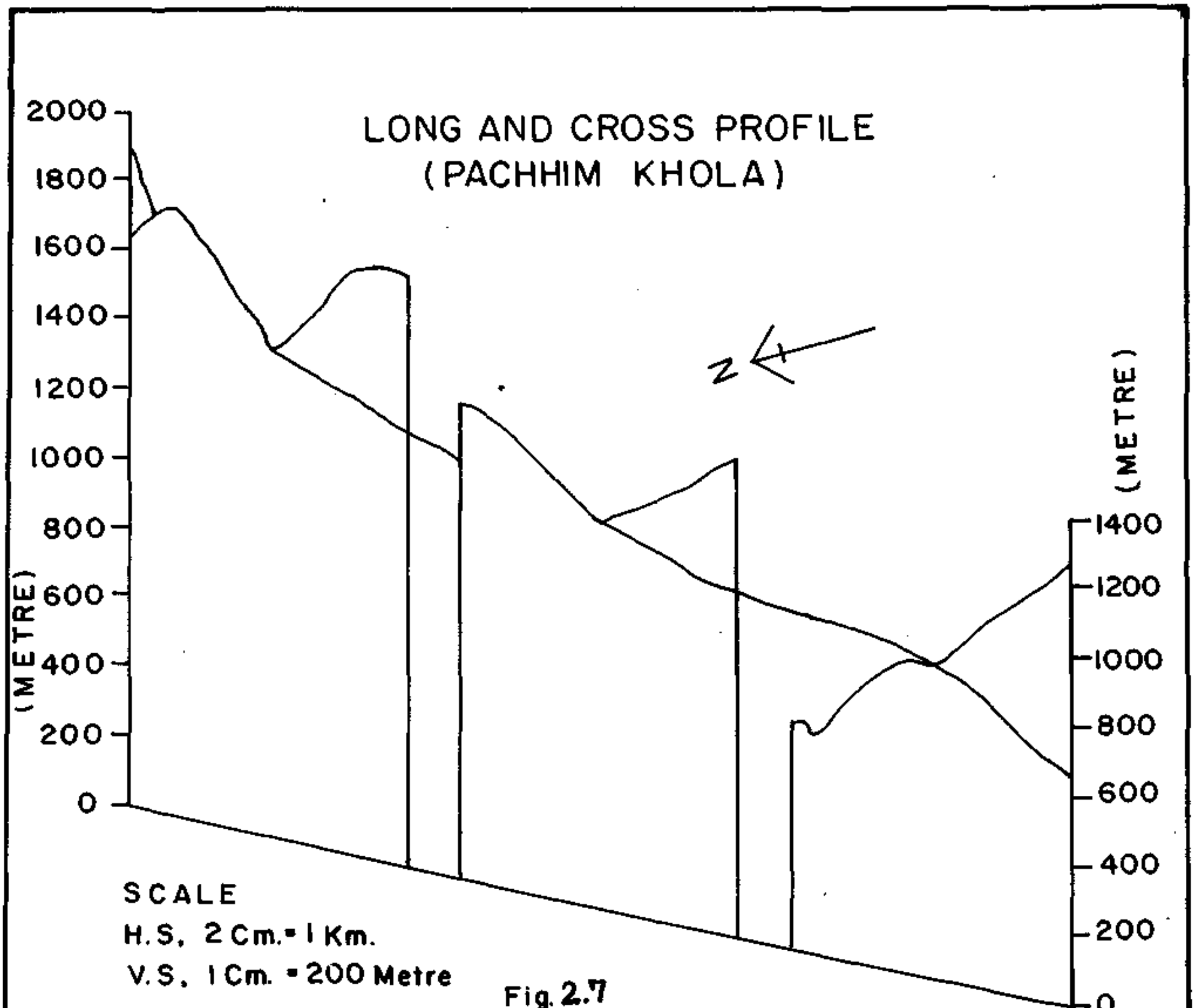

LONG AND CROSS PROFILE
(PACHHIM KHOLA)
2000
1800
1600
1400
1200
1000
800
600
400
200
0
(METRE)
N
(METRE)
1400
1200
1000
800
600
400
200
0
SCALE
H.S, 2 Cm.= 1 Km.
V.S, 1 Cm. = 200 Metre

Fig. 2.7

elevation than the river. On the bank there is an interfluve between the heights of 650m and 900m (Fig. 2.7).

Rinchingtong khola has a length of 7.13km from the source to the point where it meets the Balason river. It rises at an elevation of 1700m and flows southwestwards almost parallel to Rangmuk and Pachhim *khola* in its upper course. Till 1200m elevation, the long profile shows steep slope. Here the slope is also concave and the knick point lies at an elevation of 1200m.Below this, the slope is gentle and at the end it is convex in shape. In the three cross profiles at heights 1500m, 1200m and 700m, the left banks are steeper than the right banks in the upper course (Fig. 2.8).

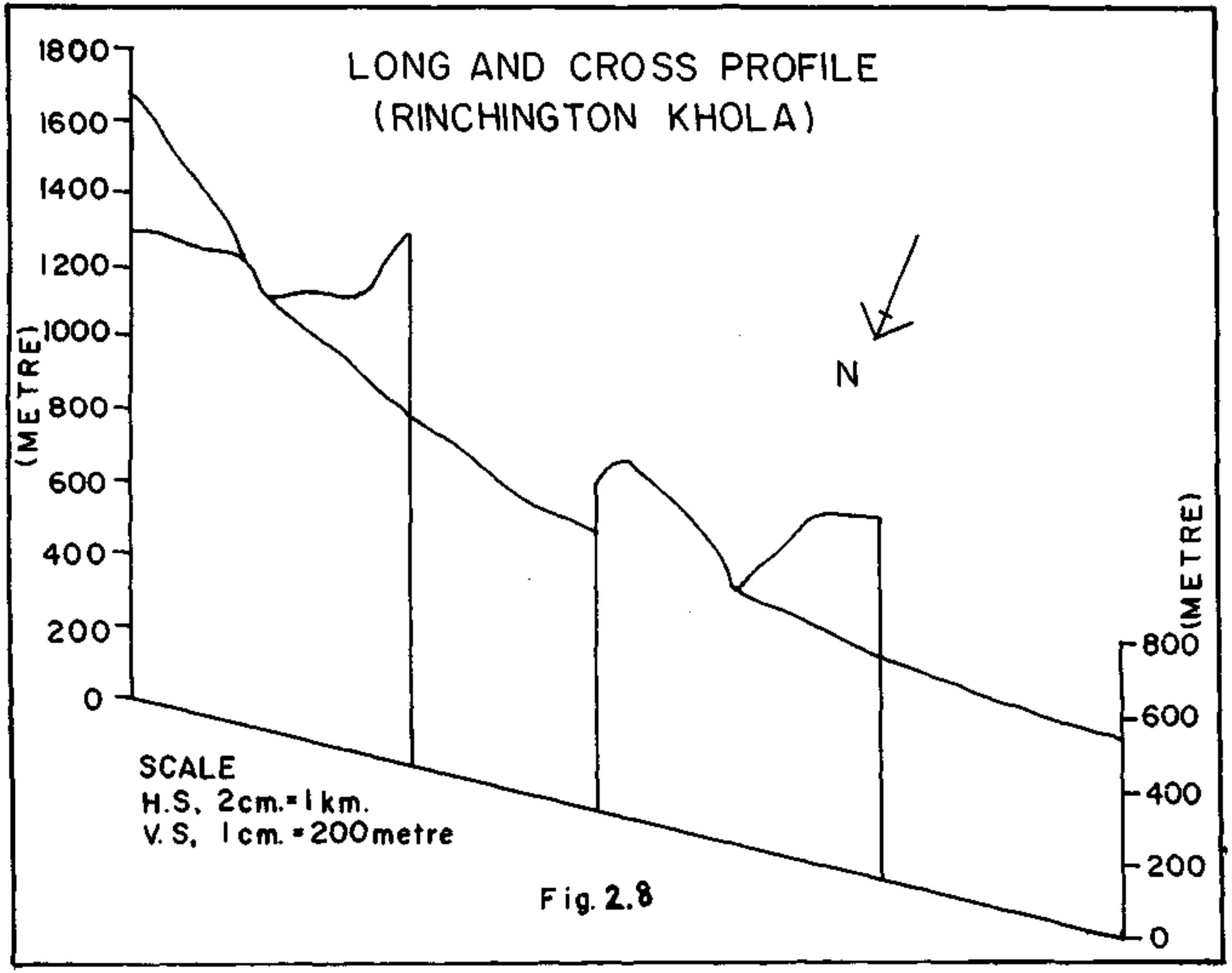
2.1.2. Stream Ordering

Rivers like Dudhia *jhora,* Marina *nadi,* Phulungdung *khola,* Bhim *khola* and Pachhim *khola* has only till third order streams.Other rivers like Manjwa *jhora,* Rangbang *nadi,* Rangmuk *nadi,* Rinchington *khola* and Ghatta – Hussain *nadi* has till fourth order streams. The three rivers namely Dudhia *jhora,* Manjwa *jhora* and Marina *nadi* which drains almost same area of land, Dudhia has the largest number of first order streams which indicated more erosion. The next four rivers, which drain almost the same area of land, are Phulungdung *khola,* Pachhim *khola,* Rinchington *khola* and Ghatta- Hussain *nadi.* Rinchington has the largest number of first order streams (Fig. 2.9).

Among all the tributaries of Balason river, Rangbang *nadi* has the highest number of first order streams with maximum dissected valleys. Rangbang flows through a valley with slope ranging between 20^0 and 25^0. In the upper reaches the drainage density is high indicating massive erosion of the rock along the hill slopes. So, Rangbang basin is likely to have more flood peaks. In the entire Balason basin, first order streams are almost five times more than the second order streams. This indicates that the entire basin is prone to severe soil erosion.

2.1.3. Drainage Frequency

Balason basin has been divided into five drainage frequency regions. Very low drainage frequency is found in the northern part of


LONG AND CROSS PROFILE
(RINCHINGTON KHOLA)
1800
1600
1400
1200
1000
800
600
400
200
0
(METRE)
N
SCALE
H.S, 2cm.=1km.
V.S, 1cm.=200metre
800
600
400
200
0
(METRE)
Fig. 2.8

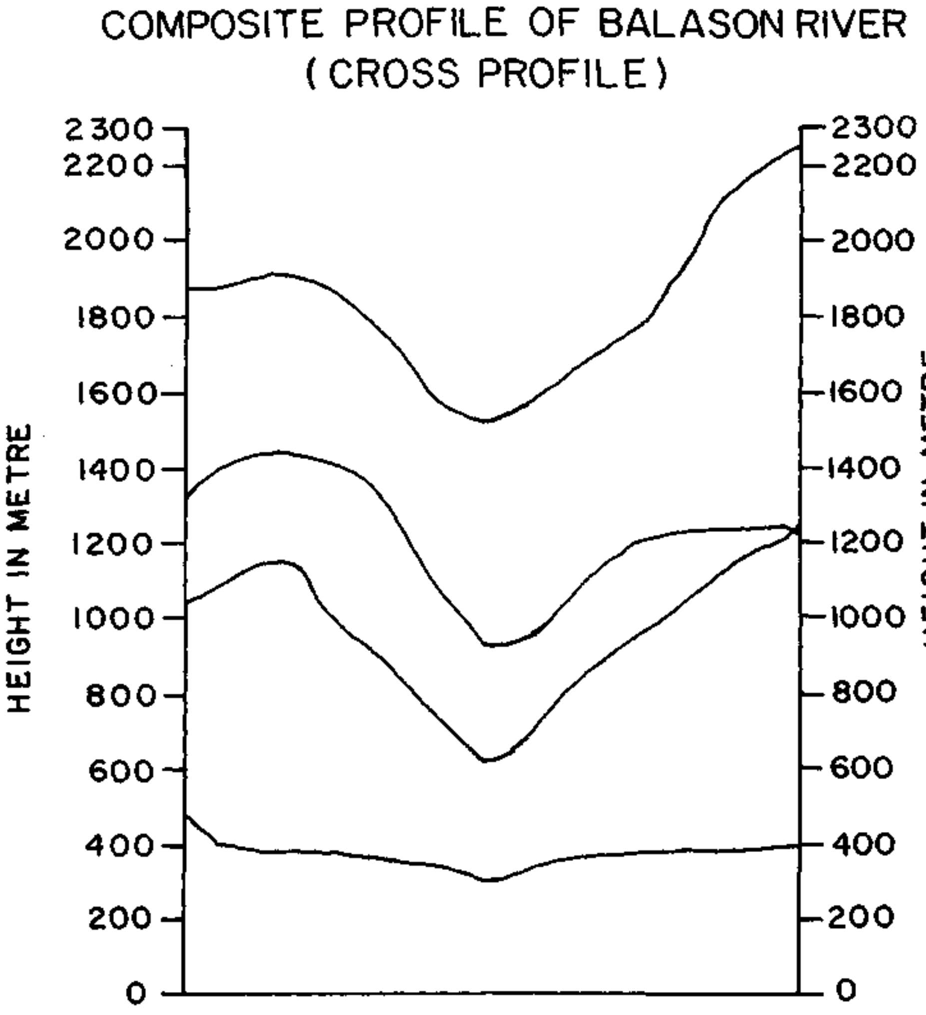

COMPOSITE PROFILE OF BALASON RIVER
(CROSS PROFILE)
HEIGHT IN METRE
HEIGHT IN METRE
2300
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
2300
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0

Fig. 2.8a

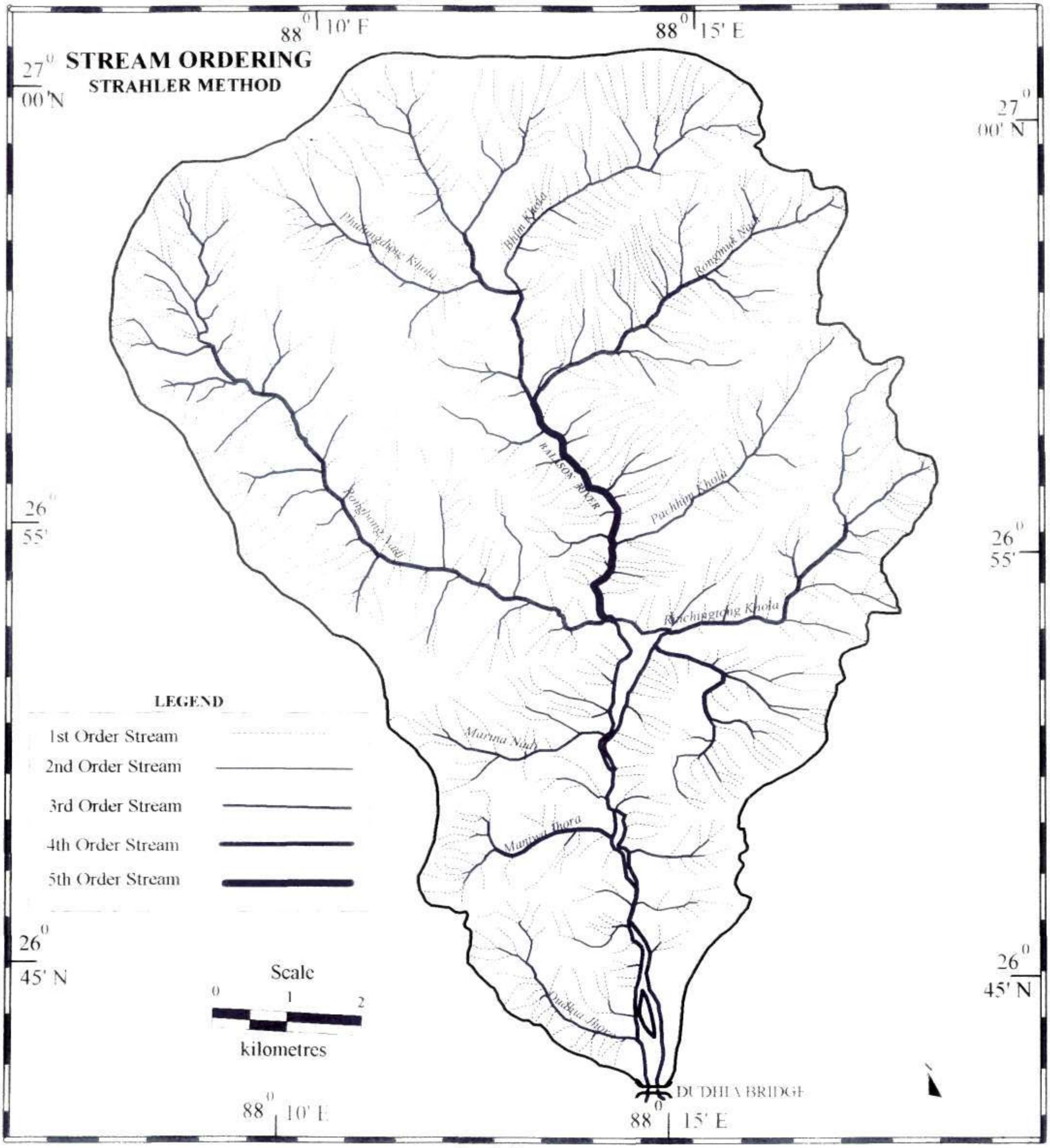

STREAM ORDERING
STRAHLER METHOD
88° 10' E
88° 15' E
27° 00' N
26° 55'
26° 45' N
Phulungdhong Khola
Bhim Khola
Rongmuk Nadi
BALASON RIVER
Pachhim Khola
Rongbong Nadi
Rachingtong Khola
Marma Nadi
Manjwa Jhora
Dudhia Jhora
DUDHIA BRIDGE
LEGEND
1st Order Stream
2nd Order Stream
3rd Order Stream
4th Order Stream
5th Order Stream
Scale
0
1
2
kilometres

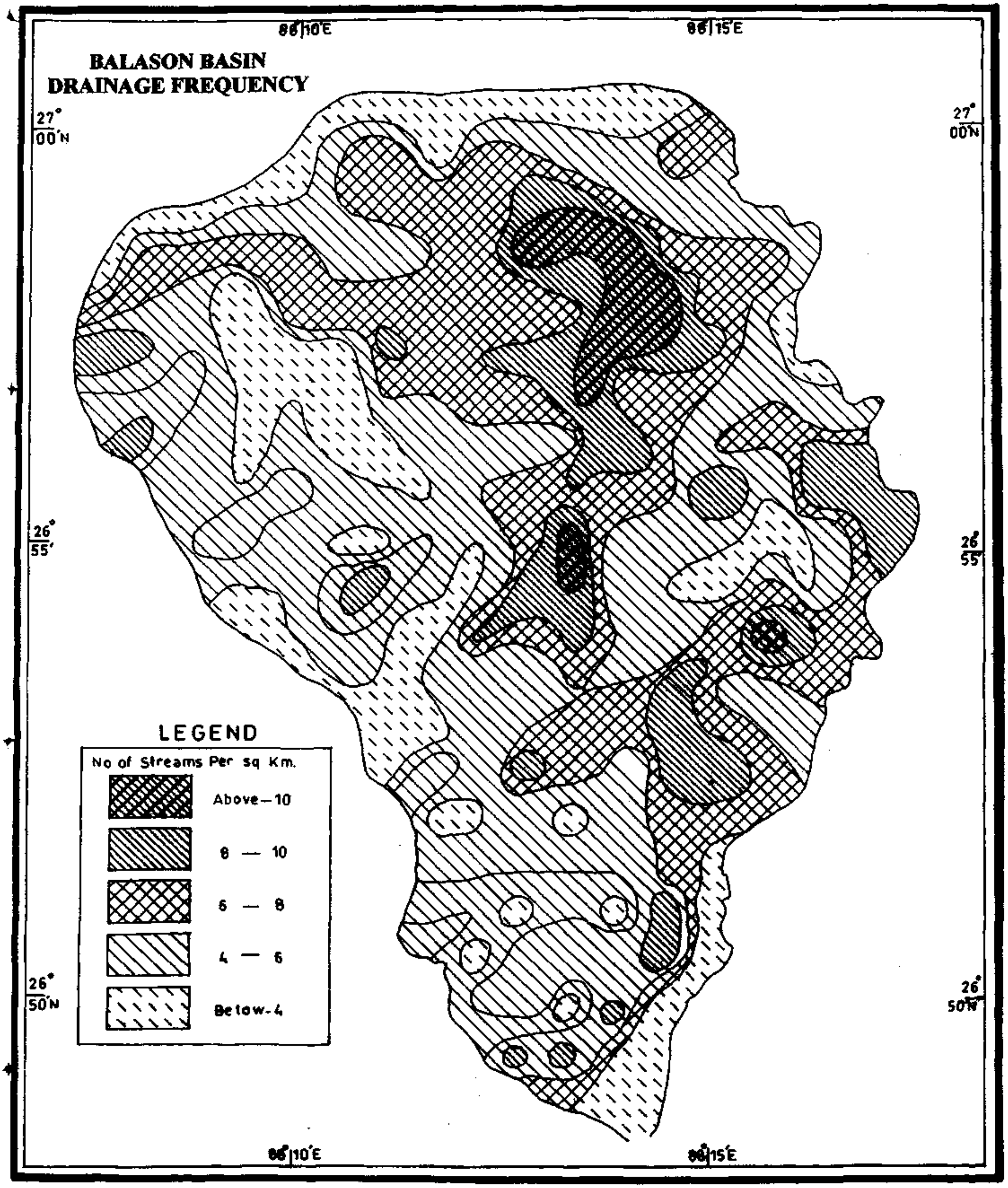
Fig. 2.9

the basin along the Jorebunglow – Sukhiapokhri ridge. Other areas are found as small isolated pockets. Medium drainage frequency i.e. 6 to 8 streams per km^2 dominates maximum area of the Balason basin. High drainage frequency areas are coinciding with high relative relief areas. Very high drainage frequency areas are restricted to certain areas only in the northeastern corner of the map (Fig. 2.10).

2.1.4. Drainage Density

The drainage density of any particular area is a function of geologic structure and climatic factors, specially, rainfall. A drainage network of specific pattern and density develops on account of the fact that streams always seek out and take advantage of weakness in the rock strata over which they flow. They provide useful clues about land stability and in turn, important clues about feasibility of certain land management practices (Hornbeck, 1984). The drainage density could be assessed for the entire basin or can also be assessed for a specified stream order where it will represent length of all channels above the specified stream order, per unit of drainage area (Langbein, 1975). High drainage density affects run off pattern. A high drainage density moves surface water rapidly decreasing the lag time and increasing the peak of hydrograph (Singh et la, 1991). In other words, higher the drainage density, more efficient is the drainage and more flashy is the stream flow and vice versa (Varshney, 1971). The drainage density has an important bearing on transport of eroded material. Higher the drainage density, higher is the sediment delivery ratio (Oyebande, 1981). The values of sediment delivery ratios vary as widely as 5% - 100% (Chow, 1964). The drainage density exhibits a wide range of values in nature and varies from 3 – 4 to as high as 1300 (Chorley, 1971). In areas having comparable rainfall pattern it is a function of permeability of the soil mantle. The sandy soils shall show the least values and the impermeable clays the highest (Fig. 2.11).

The drainage density in the study area varies from 4.0 to 10.0km per km^2. The drainage density is high along the ridge areas where the relative relief is moderate. This may be due to the presence of hard



BALASON BASIN
DRAINAGE FREQUENCY
88°10'E
88°15'E
27°
00'N
26°
55'
26°
50'N
LEGEND
No of Streams Per sq Km.
Above—10
8 — 10
6 — 8
4 — 6
Below-4

Fig. 2.10

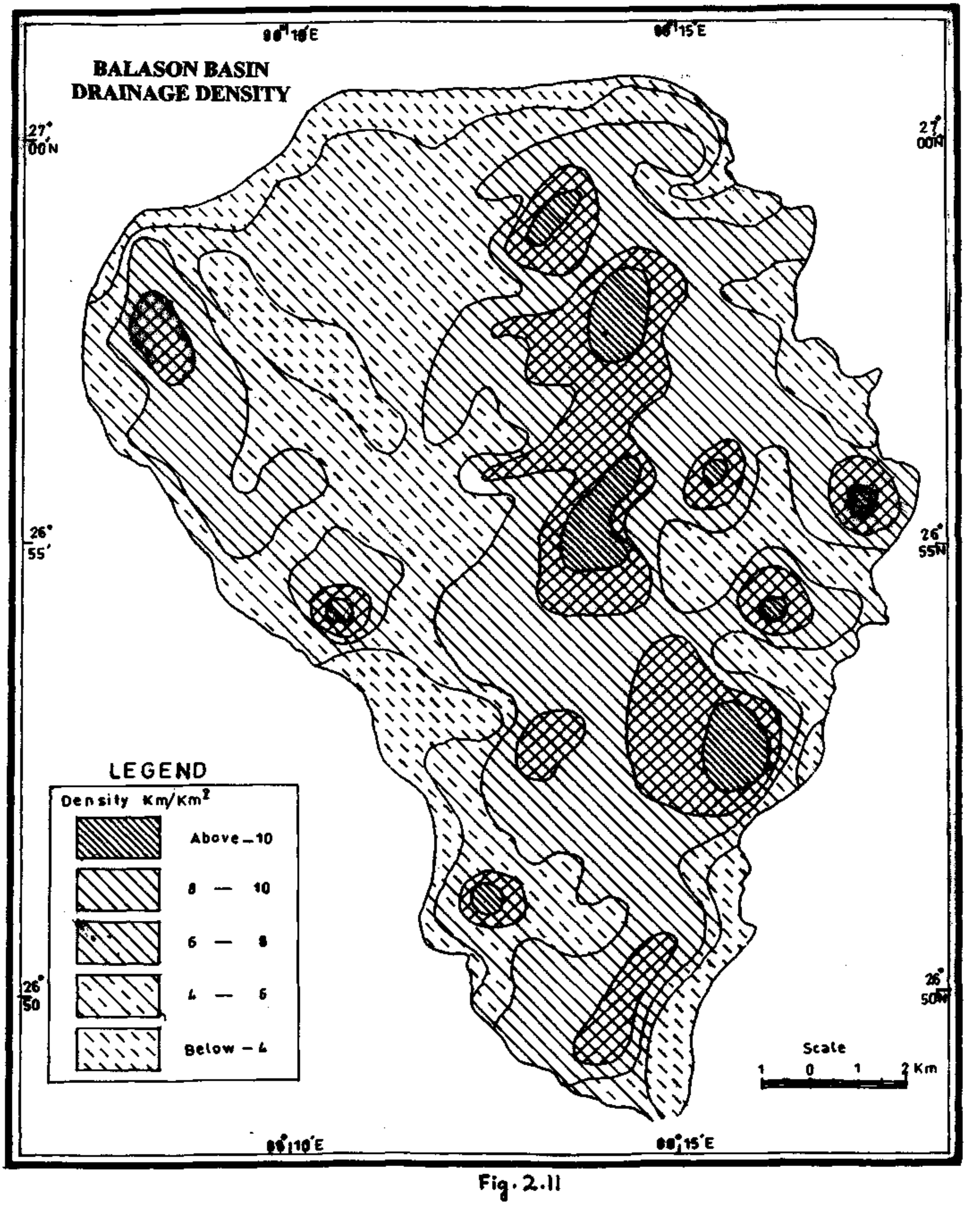

BALASON BASIN
DRAINAGE DENSITY
27° 00'N
26° 55'
26° 50'
LEGEND
Density Km/Km²
Above – 10
8 — 10
6 — 8
4 — 6
Below – 4
Scale
1 0 1 2 Km

Fig. 2.11

rock. The small streams are unable to cut the hard rock. Only rills can be formed. Drainage density is high in the middle and lower part of the rivers and these are the places of moderate to low relative relief. The areas of high drainage density are located in Thurbo T.G. in the west, Tongsong and Rangmuk T.G. in the north, Dilaram, Ringtong and Ambootia T.G. in the east, Mondakoti, Dhajea and Phulbari T.G. in the center and Phuguri T.G. in the south. All these areas have drainage density above 10.0km per km^2 and are found in small isolated pockets. Maximum area of the basin falls under 6.0 to 8.0 km per km^2 drainage density region, which shows moderate density. Along the western part of the basin, tea gardens, which lie in this area, are Chamu, Seyok and Marma. Along the eastern part lie Talkat and Okas T.G. In the water divide between Rangbang and Phlungdung *nadi,* the relative relief is moderate but drainage density is very low. This indicates less down cutting power of the small first order streams. Lowest drainage density is below 4km per km^2, which is also found in the southern most part of the basin.

2.1.5. Bifurcation Ratio

The bifurcation ratio of the ten sub – basins of river Balason, ranges from 2.9 to 7.3. The higher the bifurcation ratio, the younger is the drainage. So Bhim *khola* (rb = 7.3) is younger compared to Manjwa *jhora* (rb = 2.9). Bifurcation ratio above 3 usually indicates that the river is prone to floods. The hydrograph of Manjwa basin is therefore, the most acute and that for Bhim is flattest of all. The bifurcation ratio of the entire Balason basin is 5.2, which shows that the area is prone to floods. The determination of bifurcation ratio of basins has been done following standard techniques (Chorley, 1971).

2.1.6. Circularity Ratio

In circularity ratio, value ranges from 0 to 1. Values above 0.5 indicate maturity of the river basin in its evolutionary cycle. Circularity ratio of Rangbang *nadi* and Phulungdung *khola* is high ranging from 0.5 to 0.6 whereas that of Manjwa jhora, Bhim khola, Rangmuk nadi and Ghatta – Hussain *nadi* ranges from 0.6 to 0.7. Basins of

Rinchington *khola*, Dudhia *jhora*, Marina *nadi* and Pachhim *khola* have circularity ratio below 0.5 which indicates that the rivers are in their youthful stage, eroding more by vertical corrasion.

Table: 2.1 Morphometric characteristics of the major rivers in the basin.

Name of sub-watershade	Bifurcation Ratio	Circularity Ratio+	Elongation Ratio#	Form Factor*	Compactness Co-efficient
Dudhia *Jhora*	4.9	0.48	0.61	0.75	1.44
Manjwa *Jhora*	2.9	0.68	0.70	0.73	1.22
Marina *Nadi*	4.3	0.48	0.63	0.81	1.44
Rangbang *Nadi*	5.4	0.57	0.61	0.30	1.32
Phulungdung *Khola*	5.8	0.55	0.71	0.46	1.34
Bhim *Khola*	7.3	0.66	0.73	0.47	1.23
Ramgmuk *Nadi*	4.4	0.66	0.65	0.40	1.23
Pachhim *Khola*	5.7	0.49	0.54	0.70	1.43
Rinchingtong *Khola*	4.3	0.37	0.54	0.65	1.64

*(*Horton1932, +Miller1953, #Schumm1956)*

2.1.7. Elongation Ratio

Lower the value of elongation ratio, the basin is more elongated which means that the basin is structurally controlled and relatively in a youthful stage and hence more prone to erosion (Mithra & Rao, 1993). In the Balason basin in case of both Pachhim and Rinchingtong *khola*, elongation ratio is 0.54, which is less compared to 9.2 of Ghatta – Hussain *nadi*. So soil erosion caused by Ghatta – Hussain *nadi* is less since it's in its mature stage. Both Pachhim and Rinchingtong are in their youth and so these rivers more effectively do soil removal.

2.1.8. Form Factor

This is the shape index of the basin. Form factor is highest (0.81) in Marina *nadi* and lowest (0.30) in Rangbang *nadi*. So the shape of the Rangbang basin is more elongated than the Marina basin.

2.1.9. Compactness Co-efficient

Compactness co-efficient is highest (1.64) in Rinchingtong Khola and lowest (1.22) in Manjwa jhora. If this value is greater than one, it indicates that the basin in compact in nature. All the tributaries of river

Balason flows through compact basins.

CONCLUSION

River Balason flows from north (Lepcha Jagat) to south. Among the ten major tributaries, which spread over the basin, Marina, Rangbang and Rangmuk are perennial. Rivers like Rangbang, Phulungdung and Rangmuk rises at an elevation of above 2000m. All the rivers flow through deep and precipitous gorges in their upper course. Long profile of the rivers show concave and rectilinear pattern of slopes. The cross profiles are different in case of different rivers. In Marina *nadi* and Rinchingtong *khola*, the left banks are steeper whereas in Bhim and Rangmuk *nadi*, the right banks are steeper. The rivers through gentle slope indicating homogenous rock structure in the area. The study area has mainly dendritic drainage pattern accompanied by parallel drainage pattern wherever the land is very steep and this indicates structural control over drainage. In the entire basin, as usual, the number of first order streams is more than the other ordered streams. Rangbang *nadi* has the largest number of first order streams with maximum dissected valleys. The study area is dominated by medium frequency (6 to 8 streams per km^2). High drainage frequency areas have high relative relief. The drainage density in the study area varies from 4 to10km per km^2. The drainage density is high along the ridge areas where the relative relief is moderate. Maximum part of the basin has medium drainage density (6 to 8 km per km^2). Lowest drainage density, below 4km per km^2 is found in the southern part of the study area. Bifurcation ratio of the entire basin is 5.2, which indicates high flood peak. Circularity ratio of six tributary rivers is above 0.5, whereas rest tributary rivers have circularity ratio below 0.5. Elongation ratio and form factor both confirm the elongated shape of majority of the tributary basins. All the tributary drainage systems are compact in the study area. The settlements depend on the availability of water so generally population lives on the bank of river or valley of the river. Availability of water has greatly influenced the spread and growth of population. The study area is mountainous with fast flowing rivers. So distribution of settlements and growth of population with their demographic characteristics can be discussed in the next chapter.