STUDY OF SOIL EROSION PROBLEMS IN EASTERN BALASON CATCHMENT

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TO WHOM IT MAY CONCERN

I am pleased to certify that Mr. S. Patel, DFO. Kurseong Division worked under me on 'Soil Erosion Problems in ~~the~~ Eastern Balason Catchment' for his Ph.D. Thesis of this University. He prepared this Thesis based on field work in the Study Area. He also collected data from the secondary sources from different Government Offices and Private Organisation for his Thesis. He collected data by monitoring some jhoras in the study area. He is sincere and methodical in his work. So far my knowledge goes no one worked in this topic in the past.

I am sure that the work will be a model one for future Researchers, Planners and others those are interested to work in this line.

I wish him success in future carreer and life.

mmjana

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PREFACE

A large scale alteration in land use took place in eastern Himalayas in early part of this century with establishment of tea gardens. Most of the lands where tea gardens came up were natural forests and grasslands. In Darjeeling hills, too, land use pattern changed. Kurseong sub-division was the worst affected. In this sub-division, a large tract of natural forests and grass lands between 700 mt and 2000 mt contour line was cleared and tea garden established. The basin of the Balason river was very badly affected. Large number of labour was imported from outside to meet the requirement of tea industry. Traders, middlemen, and artisans closely followed the labour. The density of human and cattle population sought up dramatically in the Balason basin. Most of the human and the cattle population was concentrated on the sunnier eastern part of the Balason catchment. Mildly sloping piedmont slopes of these parts has the greatest concentration of the tea gardens, too. No study of Balason catchment for assessment of soil conservation status has been done so far. The traditional soil and water conservation techniques used till now has failed to check the pace of soil degradation in the area.

PURPOSE OF STUDY:

The eastern Balason catchment selected for the study has the following salient features that attract a closer survey:-

i. This part has high concentration of human and cattle population. The demand of fuel by this population had put limited forest resources under severe strain. Forests owned by Govt. and tea gardens are degrading fast. Preventive measures are needed immediately.

ii. Most of the Govt. forests, tea garden forests, waste scrub forests, and abandoned agricultural fields are being grazed far beyond their carrying capacity. Scrub and sterile cattle are aplenty. They are trampling the soils compact. The problem needs immediate attention and investigation.

iii. Torrential jhoras are found in the upper reaches. High concentration of rainfall in monsoon months makes them disastrous. They often erode their banks. Landslides result, if they are not trained instantly.

iv. Weak geological formation in the study area, necessitates a sound combination of engineering and biological measures for soil and water conservation. Traditional soil and water conservation practices are inadequate.

v. Rivers are sinuous and meandering in lower reaches. The direction of flow alternates between clockwise and anticlockwise in sinuous sections. Extensive bank failure are seen in such sections.

vi. Agriculture is poorly developed. Field terraces often slope outward. They are badly maintained. Proper channels for safe disposal of excess water is rarely provided. Erosion permitting crops are extensively cultivated. Strip cropping is not practised.

vii. Landslides are a menace in the study area. They devastate human habitations, productive fields and communication routes, etc. A few litres of water seeping into the soil per hour is often enough to trigger mass movement in these weak geological formations.

viii. Terraces in many tea gardens are very poorly maintained. Several tea gardens maintain sickly tea bushes on slopes fit only for afforestation. Such lands are subjected to extensive sheet washing and rill erosion.

ix. The catchments for supply of water to Darjeeling and Kurseong town are located in the study area. The yield of streams has gone down severely due to deforestation. Ground water recharging is inadequate because of absence of tree vegetation in the catchment. Overgrazing, forest fires and compaction of ground also impede the infiltration of water into the soil. Yield of streams is going down year after year during summer. Kurseong and Darjeeling have chronic shortage of water during dry weather. Investigation is necessary in the matter.

OBJECTIVES OF STUDY:

The main objectives are :-

i To study the physical aspects like geology, relief, drainage, climate, soil and vegetation of the study area and their interrelation for assessing major problems of soil conservation.

ii. To study soils and their characteristics such as soil types, their formation, texture, structure, profile development, fertility, infiltration capacity, and water holding capacity.

iii. To study parameters of drainage such as density, frequency, order, cross and long profile and relief.

iv. To study various forms of surface and fluvial erosion including landslips.

v. To study rivers in the basin area for total discharge and sediment load.

vi. To study faulty agricultural practices, unauthorised quarrying, over settlement, development and extension of roads, deforestation, overgrazing and forest fires.

vii. To study shortage of fuel and fodder, scarcity of water supply during dry season, floods, damage to irrigation channel by siltation and damage to communication routes by sliding.

viii. To study soil and water conservation techniques currently being used by Govt. Departments, private organizations and individuals.

ix. To study different schemes of soil and water conservation executed in the area.

x. and, finally to suggest a relevant strategy for soil and water conservation.

METHODOLOGY:

i. Four rivers in the study area were monitored for two years to assess the soil loss. The cross section area - velocity method was used for the purpose. Rivers were monitored below the bridge over them. Water samples were collected and the quantity of sediment determined.

ii. Satellite imageries were collected and interpretted.

iii. The data and information were collected from Govt. and private organisations, clubs, municipalities and private individuals.

iv. Information and literature have also been collected from different libraries, journals and personal experiences.

v. Available data were analysed by computer for obtaining explanations and conclusions.

vi. Maps and diagrams have been drawn using different cartographic techniques to illustrate the data and information.

vii. On the basis of investigations reports have been prepared and various literatures cited to compare the study with those relating to similar problems in the country and abroad.

LIMITATIONS:

No investigation of soil erosion problems has been done in the area. Therefore, secondary data available was not much. Data was collected by field work. Hilly terrain and poor communication posed a great problem. Monitoring of rivers could be done only through cross section area - velocity method. More refined measuring devices were beyond the reach. Still more intensive soil sampling was not possible due do difficult communication. Infiltration was determined by an improvised single cylinder infiltrometer.

DESIGN OF THESIS:

The whole work commences with identification of the location of Eastern Balason Catchment in West Bengal State of Indian Union and giving the purpose, objective, and methodology adopted for the study.

Then the work commences with the first chapter which discusses the physical background of the area. The second chapter deals with the detailed investigation of soils. The third chapter deals with the analysis of various morphometric factors of relief and drainage and their relationships with soil erosion. The fourth chapter deals with the mechanism of various erosion forms met within the area. The fifth chapter deals with faulty land usages and effects of soil and water erosion. The sixth chapter details various methodologies used for investigation of problems. The seventh chapter deals with the review of earlier strategies and various Govt. schemes for soil and water conservation. And, finally, the eighth chapter comprises of suggestions regarding soil and water conservation.

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GLOSSARY

Serial	Term	Description
1	Ambake	A tree species bearing edible fruits
2	Amla	A tree species bearing edible fruits
3	Amlisho	A perennial multipurpose grass- Thysanolena maxima
4	Angare	A medium size tree
5	Arkawla	A medium size tree
6	Arupate	A medium size tree
7	Assomlota	An annual herbaceous weed
8	Balli	A piece of round timber of any length above 2.5 mt and not more than 30 cm in diameter at butt end
9	Basti	A rural settlement
10	Bathan	A cattle station in side a forest
11	Bohmeris	An annual herb of ground cover
12	Buk	A large size tree
13	Chilauni	A big size tree
14	Chiple Kawla	A large size tree
15	Dalne Katus	A large size tree
16	Dhupi	An exotic conifer- Cryptomaria japonica
17	Dhura	Quarters
18	Dudhilo	A fodder tree
19	FRH	Forest Rest House
20	Gamar	A large size tree. Timber much valued for making furniture.
21	Gogun	A fodder tree
22	Jamun	A medium size tree bearing edible fruits
23	Jhingani	A tree species of understorey

Serial	Term	Description
24	Jhora	A small seasonal stream
25	Kamle	A shrub of under storey
26	Kapasi	A medium size tree
27	Katus	A big sized tree
28	Kharane	A tree species of understorey
29	Khasmahal	Land owned by Govt.
30	Khola	A stream or water course
31	Kumale	Relating to potters
32	Lahsune	A medium size tree of understorey
33	Lali	A medium size tree of understorey
34	Lapche Kawla	A tree species
35	Lapche Kawla	A large size tree
36	Lekh chilauni	A tree species
37	Lekh Dabdabe	A tree species
38	Lepchajagat	The lepcha toll bar
39	Malata	A medium size tree of understorey
40	Maling	A bushy bamboo of lower storey, a serious weed in high hills
41	Mauwa	A big size tree
42	Mithe Champ	A large size tree. Timber much valued for making furniture.
43	Musre Katus	A big size tree
44	Nalla	A ravine
45	Narkat	A perennial grass-Arundo donax
46	Nebharo	A fodder tree
47	Panisaj	A big size tree
48	Parari	A big size tree
49	Phalado	A medium size tree of understorey
50	PHE	Public Health Engineering
51	Phuljharu	Flowers of a perennial grass, Amlisho, used for sweeping floors

Serial	Term	Description
52	Pipli	A timber and fodder tree
53	Senchal	The damp misty hill
54	Sepoydhura	The sepoy's lines
55	Simana basti	The boundary village
56	Simana	Refers to a ridge
57	Siris	A big size tree
58	Sisnu	An annual herb of ground cover
59	Strobillan-thus	A bush of ground cover
60	Sungure Kat	A large size tree
61	Tagar	A bush of ground cover
62	Tarika	A bush of ground cover
63	Thatch	A perennial grass
64	Tindharia	The three ridges
65	Tite champ	A big size tree
66	Tung	The place of Tun tree
67	Utis	A big size tree, fixes atmospheric nitrogen
68	Walnut	A big size tree

INTRODUCTION

The river Balason is one of the eastern most tributaries of the river Ganges . The Northern and the Eastern side of the Balason catchments are drained by the River Tista which is a tributary of the Brahmputra . This river drains a part of the Eastern Himalayas forming the central western part of the District Darjeeling which falls in the State of West Bengal . The District of Darjeeling has a chequered history of its own as the climatic and physiographic variations .

The District has been so named after its chief town Darjeeling , a picturesque hill resort of which there are few equals in the whole world . The name Darjeeling is thought to be derivation of ` Dorjeling ´ , meaning the place of the `Dorje´, the majestic thunderbolt of the Lamaist religion . (Census of India , 1981). The District was the part of the dominions of the Raja of Sikkim up to the beginning of 18th century . The present Kalimpong sub - Division of the district was taken from the Raja of Sikkim by the Bhutanese in 1706 . The Gorkhas seized power in Nepal and invaded Sikkim in 1780 and overran Sikkim for next thirty years . The present district of Darjeeling is a creation of the nineteenth century and is a result of almost accidental involvement of the British Indian Government in the affairs of neighbouring Himalayan States . In 1817 , The East India Company

LOCATION MAP

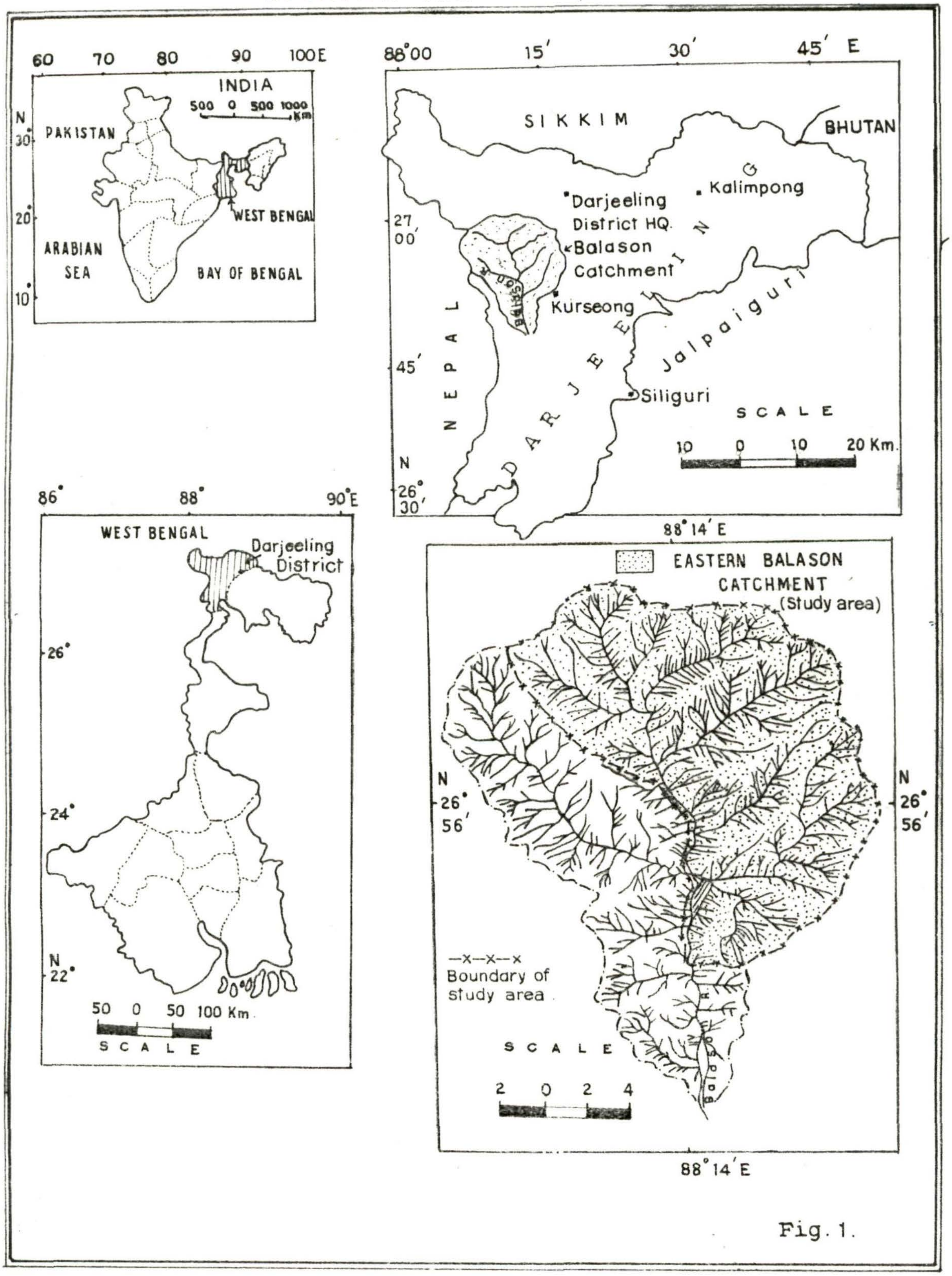


Fig. 1.

struggled with a Himalayan State on behalf of the Raja of Sikkim and restored to him his lost territories through the Treaty of Titaliya of 1817 which provided for British arbitration for any boundary disputes . It was during one of those arbitration proceedings that the Britishers were attracted by the climate of Darjeeling and they took over the territory from the Raja of Sikkim through execution of a deed grant on 18th February , 1835 (Govt. of West Bengal , 1981). Since then the district has been with Britishers and now forms a part of the Indian Union .

LOCATION :

The district of Darjeeling lies between 26° 31′ and 27° 13 ′ north latitude and between 87° 59 ′ to 88° 53 ′ east longitude (Fig. 1) . On its north and north – eastern side lie , respectively , the state of Sikkim and the territories of Bhutanese Kingdom . On its western side lies the territories of Nepal . The natural features of the district consist of a portion of the outlying hills of lower Himalayas and a stretch of territory lying along the base of the hills known as the Terai . The terai is only 91 metres high above sea level but there are parts of the district in the hills which are nearly 3657.6 metres high . As one ascends from the terai or Jungle in the lower valleys to the tree line and the snow line in the Darjeeling Himalayas , one passes over the whole range of the world′s climate from tropical jungles to frozen slopes (Mani , 1981.). All the rivers draining the district ultimately flow to south and the Balason is one of such six major rivers . The literal meaning of the 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 funnel shaped Balason catchment having an area of 250 sq. km. is located between 88°07′ to 88°19′ E longitude and 26°49′ to 27°51′ N latitude (Fig. 1). The river Balason rises from a peak known as the Lepchajagat and flows south almost parallel to 88°15′ meridian till it emerges in the plains after crossing a gorge at a point about 26 kms south in its traverse from its origin. The Balason catchment contains twenty tea gardens, the majority of which are located in the eastern part of it (Yadav et al, 1982). As is seen from the Fig 1, the number of streams directly draining into the river Balason is also highest on the eastern side of the catchment which also has high concentration of roads . Highly drained slopes , higher concentration of tea gardens and of roads makes the eastern Balason catchment quite interesting from the view point of soil erosion .

The eastern Balason catchment is situated between 26°51′ to 27°01′ N latitude and 88°09′ to 88°19′ E longitude . It has an area of 153.25 sq. km. (Govt. of India, 1981). Of the total area more than 55 percent (87.55 sq.Km.) is under tea gardens the rest are either forests or are waste lands. The study area is drained by five major rivers , namely , from north to south (Fig. 2) :-

Divisions of Balason River Basins

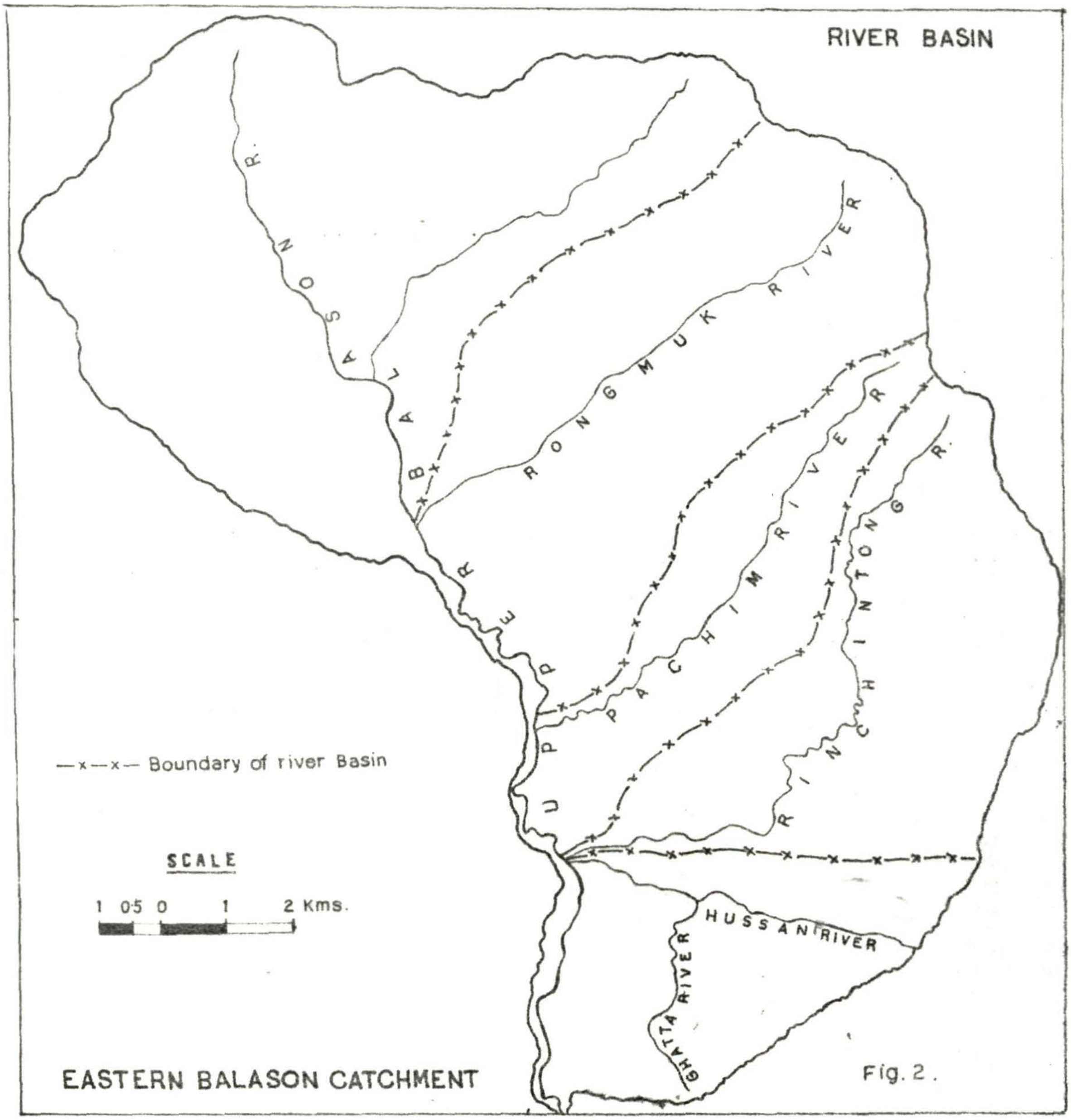


Fig. 2.

DIVISION OF RIVER BASINS

(Basis of contours)

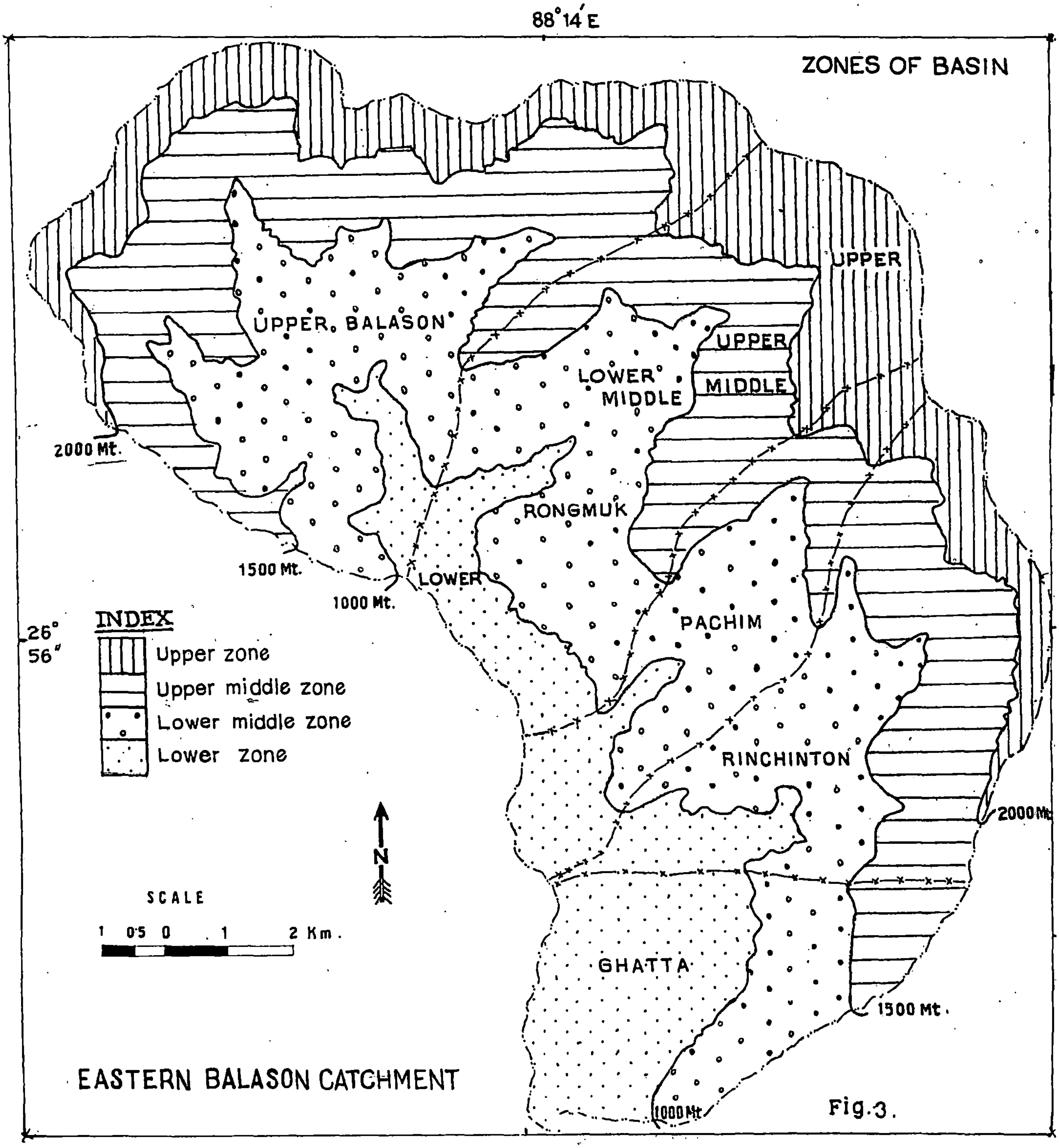


Fig.3.

1.	Upper Balason	55.00 sq. Km.
2.	Rongmuk	36.75 sq. Km.
3.	Pachim	16.00 sq. km.
4.	Rinchintong	28.25 sq. Km.
5.	Ghatta-Hussain	17.25 sq. Km.

The five river basins in the area have been taken as units for the study of various parameters having bearing on the soil erosion status of the region . For making the study areas still smaller for more detailed observations and analysis , each basin has further been divided in following zones (Fig. 3).

1.	Lower zone	below 1000 mt
2.	Lower middle	1000 mt - 1500 mt
3.	Upper middle	1500 mt - 2000 mt
4.	Upper zone	above 2000 mt

CONCLUSION :

Thus it is seen that the study area, the Eastern Balason Catchment, is located in the District of Darjeeling which is a part of the West Bengal State of the Indian Union. The district has got a historical background. The district has got a variety of climate, vegetation and altitudinal zonation. For the purpose of study each river has been taken as unit which is further divided into zones for ease of study.

CHAPTER I

GENERAL BACKGROUND OF THE AREA

INTRODUCTION :

This chapter deals with general background of the study area and illustrates various characteristics which have great bearing on the erosivity of the soils in the area . Two such major characteristics are geology and relief which , on one hand , decide the drainage pattern of the area and , on the other , through a complex interaction with climate , give rise to soil and vegetation characteristic to that particular area . All these independent and dependent variables have enormous bearing on the status of the soil erosion and have been studied in detail .

1.1 RELIEF :

The highest point in the study area is Tiger Hill peak , (2560 mt), and the lowest (500 mt) in the bed of the Balason close to the southern tip of the Ambootia tea garden . It is at the lowest point that the river Balason passes through a moderate gorge before finally emerging into the plains of North Bengal . The Balason catchment is delineated on its northern side by a ridge emanating from the massive Singhlila range and going almost straight to east forming the Maneybhanjeng - Ghoom ridge . This ridge throws smaller spurs having general direction south to south-west . From Ghoom a complex system of ridges and spurs emanate , the longest of which is Tiger Hill - Dow Hill and makes the entire eastern boundary of the study area . This ridge ascends to the height of 2560 mt at the Tiger Hill and descends down gradually running almost straight to south to Dow Hill making roughly right angle with the Maneybhanjang - Ghoom ridge . The Tiger Hill - Dow Hill ridge descends about 560 mt in altitude in Dow Hill (about 15 kms south of the Tiger Hill), thus , making a slope of less than 4 percent . From Dow Hill , this ridge dips down sharply taking a turn towards south west and looses its altitude from 2000 mt at Dow Hill to 1400 mt at Kurseong town in its traverse of 4 km . After this , the slope of the descending ridge becomes milder for another stretch of 2 km at which point a spur emanates from this ridge descending sharply straight west at right angle with a slope of 35 percent . The meeting point of this spur with the Balason river marks the mouth of the Balason catchment which is of the shape of a huge amphitheatre (Fig. 1.1). On the western side , a huge Nagri spur emanates from the main northern ridge , descends down sharply in the south- east direction from an altitude of 2350 mt at Simana on the Indo - Nepal border to 900 mt in the bed of the river Balason . This distance is of about 8 km . On the southern most tip of the area lies a huge colluvial deposit forming a flat terrain almost 5 Km^2 in extent . The entire southern-most width of this flattish part of the territory has

DIVISION OF RELIEF

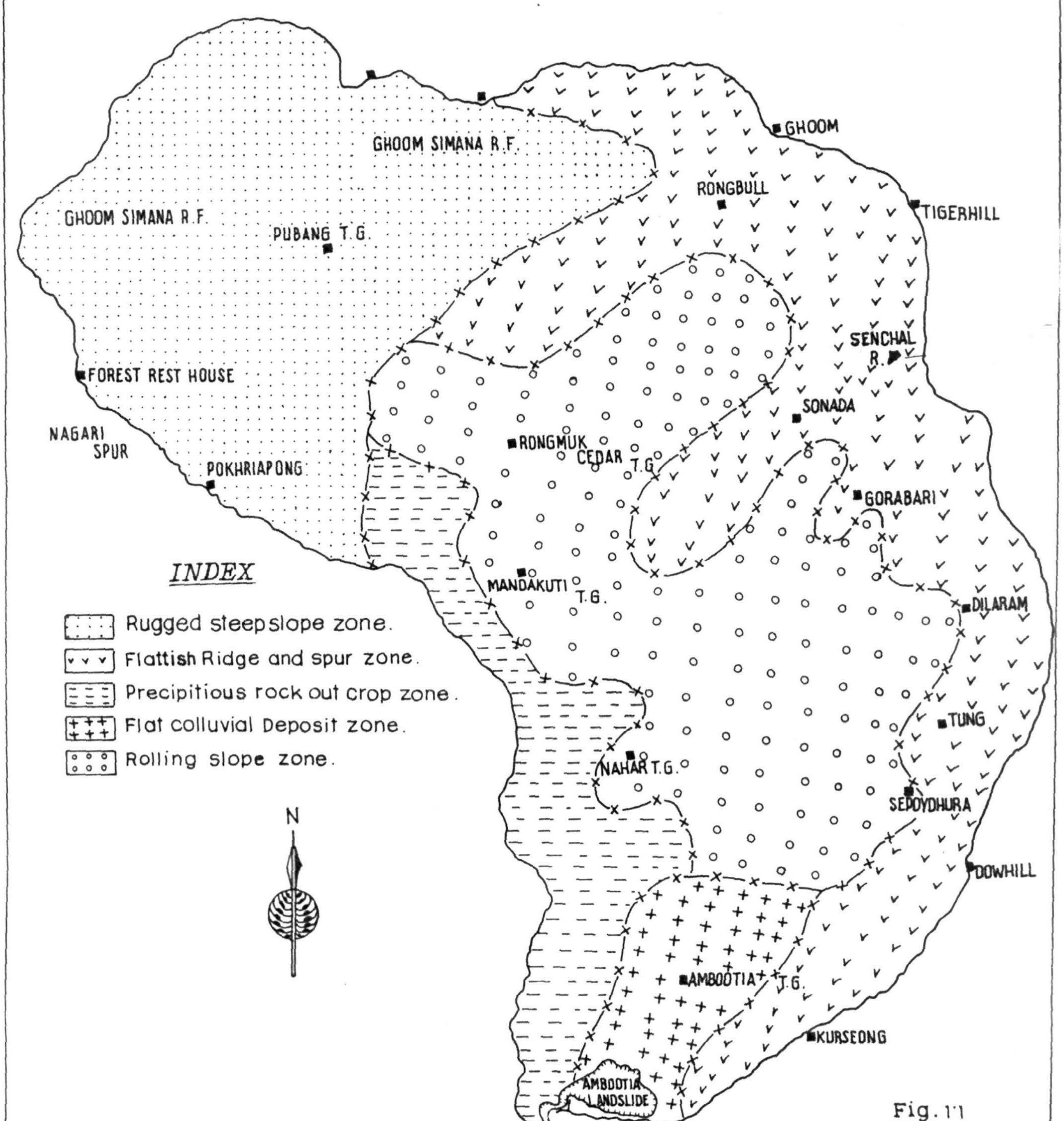


Fig. 11

been affected by the notorious Ambootia landslide . This landslide is considered to be the largest in the eastern Himalayas and has already eroded down huge quantity of earth . In the study area , the valley slopes are more flat and open towards the top but attain a steeper gorge like character near the beds of the streams . The villages are almost always located on the ramifying lateral spurs which give off lesser ones which , again , give others of a third degree . This cuts up terrain into as many spurs , ridges and ranges as there rills streams and rivers .

On the basis of above observations the study area can be divided in to five distinct relief zones (Fig. 1.1) .

1.1.1 RUGGED AND STEEP SLOPE ZONE :

The western part of the study area falls in this category (Fig 1.1) . This zone is characterised by the steep slopes having a concentric direction towards the centre of the zone . On account of this , the slopes in the northern parts of the zone are towards south , south - west and south - east directions whereas in the western part, the direction is east to south - east . 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 Nagari spur on the western and south - western sides . A few tea gardens are located in this zone . A considerable part of it constitutes the Ghoom Simana reserve forest which is located all along the ridge on the north , north - west and south - west. Waste lands with scrub and useless vegetation having wild growth of bushes are in plenty in the middle part on account of steep slopes and dissected terrain. So, the development of the roads in this part is conspicuously meagre, except those running along the ridges. On the other hand , the eastern parts of the study area has high concentration of road networks . The zone is prone to rock falls . The north and north eastern slopes make the aspect of this zone most moist in the study area leading to the growth of luxuriant forests close to ridges. Steep and rugged slope in the middle and lower parts has imposed limitation on the extent of the utilisation of the land resources .

1.1.2 PRECIPITOUS ROCK OUTCROP ZONE :

This zone lies along the lowest segment of the study area falling along the main channel of the river Balason . It encompasses the lower segments of the Rongmuk Cedar , Mandakoti , Nahar and Ambootia tea gardens . This zone 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 (Plate 1) . Major parts of this zone are barren and inaccessible . Open scrubs and mixed jungles are the characteristic vegetation of this zone .

1.1.3 FLATTISH RIDGE AND SPUR ZONE :

This zone falls on the eastern and north eastern side of the study area and covers the entire

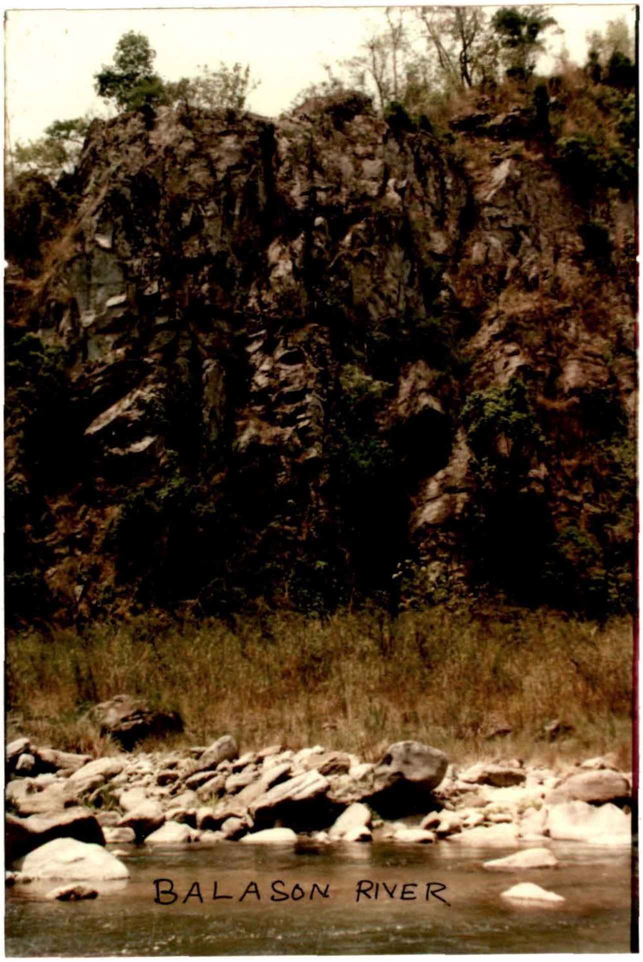


PLATE 1: DARJEELING GNIESS
OUTCROP SHOWING
FOLDING AND CRUMBLING

ridge on that side and a substantial lengths of the spurs emerging from the ridges and running , generally , in south west direction . This zone is quite fertile and densly populated . The Hill cart road runs through this zone all along its traverse from Kurseong town to Ghoom . The density of population has been increasing all along the Hill Cart road by leaps and bounds in recent years . Several hamlets , whose size increases on spurs , are located all along the road . Besides Kurseong town with a population of 27,419 (Govt.of India, 1991), some other prominent settlements along the Hill Cart road are Rogbull , Sonada , Gorabari , Dilaram , Tung , and Sepoydhura . As one passes from Kurseong to Ghoom on one´s way to Darjeeling , the scenario of surprisingly large number of houses all along the Hill Cart road rarely fails to strike . On the ridge top , the Govt. reserve forest is located and , except a few exceptions here and there , most of it is under tremendous biotic pressure and is very severely degraded .

1.1.4 ROLLING SLOPE ZONE :

This zone constitutes the middle reaches of the eastern slope of the study area and has a uniform sloping and rolling terrain. As it is the most fertile so majority of tea gardens in the study area are located in this zone . Because of the milder slopes , this part has well developed road networks and the beds of all the five rivers in the study area 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 jungles on their banks . On account of lack of proper 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 banks is very much in evidence .

1.1.5 FLAT COLLUVIAL DEPOSIT ZONE :

This zone lies on the southern tip of the study area and gives an appearance of a perched flat table top land . The entire zone is occupied by the Ambootia , Singel and Springside tea gardens . The Ghatta river flowing through this zone has a very mild gradient. Contrary to general south - west direction of flow of rivers in the rest of area ,it flows in north to north - western direction . The central part of this zone has a slight depression and the slope is undulating . The southern tip of this zone has culminated into the Ambootia landslide occupying an area of 65 ha , total length of 2.5 km , height difference from crown to toe 600 mt - all this on account of dislodgement of rock volume of the order of .4 million cubic metre as in 1978 . (Bandopadhyay , 1978) . Before it got affected by the landslide, this area was a scrub jungle with bamboo forest . This scrub jungle was also having a wet area about 2 ha in extent at its upper margin which had been marked as "thatch" in the older maps (Starkel, 1991).

1.2 GEOLOGY :

The geological formations of Darjeeling district consist of few rock formations varying in age between recent to possibly archean era . As one passes from plains northward to higher elevations , one meets alluvium , rocks of Sivalik series , a narrow band of rocks of Damuda series (Fig 1.2) , rocks of Daling series , and Darjeeling gneiss and mica schists , each succeeding rock , with possible exception of the last , being older than the one before it . (Govt. of West Bengal , 1959) . If a section is drawn from the Terai area to Ramam 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) , Rongmuk river , Ghoom and Jalapahar peak , the dips are rolling and irregular . Towards north , starting from Birch Hill (Darjeeling Zoo area) , to Little Rangit and the Ramam rivers , the dips of strata are southerly . (Fig 1.2 inset) . Another geological section across Darjeeling hills drawn through Tindharia , Kurseong , Tiger Hill and Darjeeling shows that the central part of the section , having rolling dips , has Darjeeling gneiss exclusively as its rock formation . (Fig 1.3 inset). This section also brings out very

EASTERN BALASON CATCHMENT SHOWN IN THE

GEOLOGICAL MAP OF THE DARJEELING HILL TERRITORY

(Adapted From Mallet)

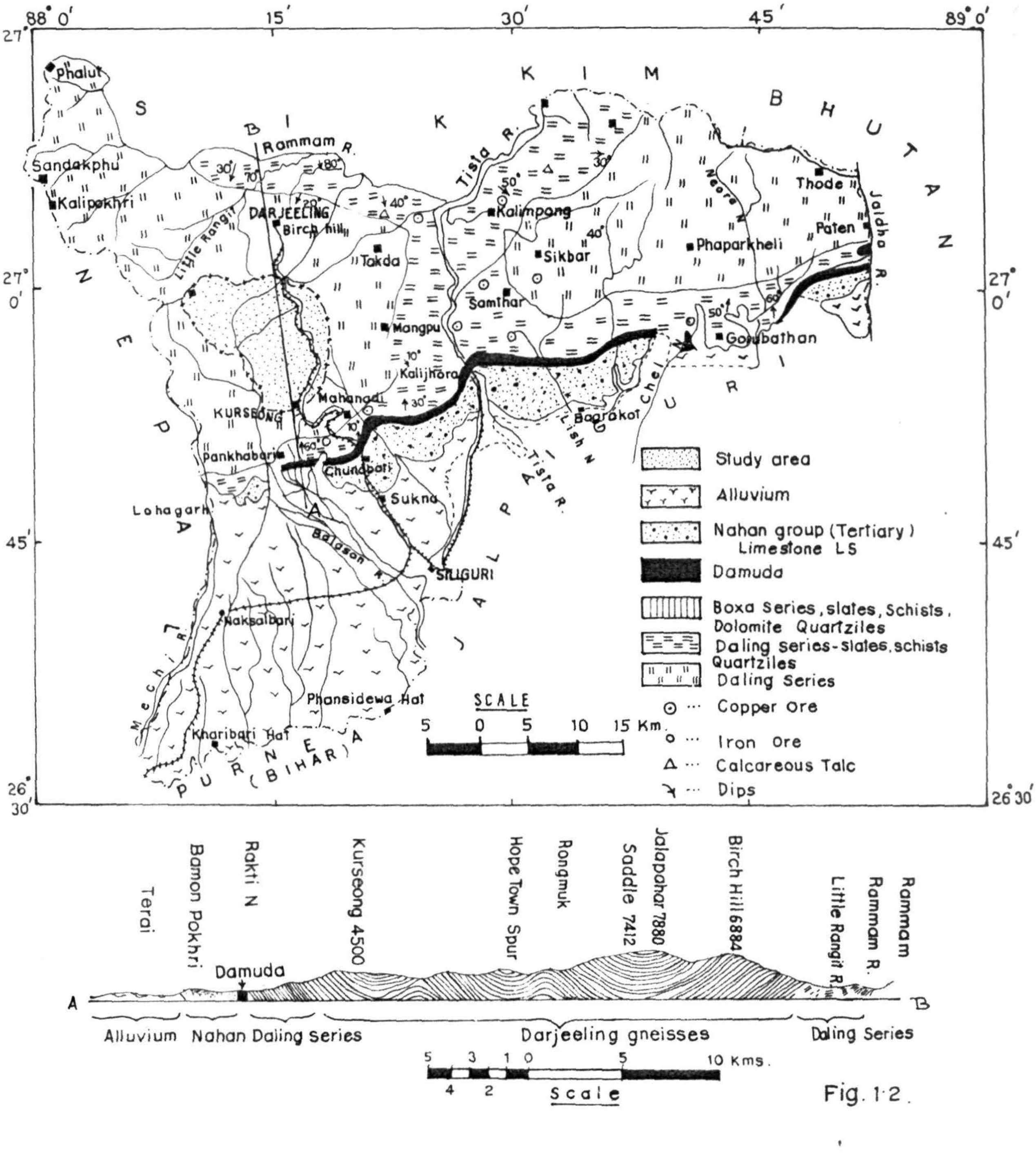
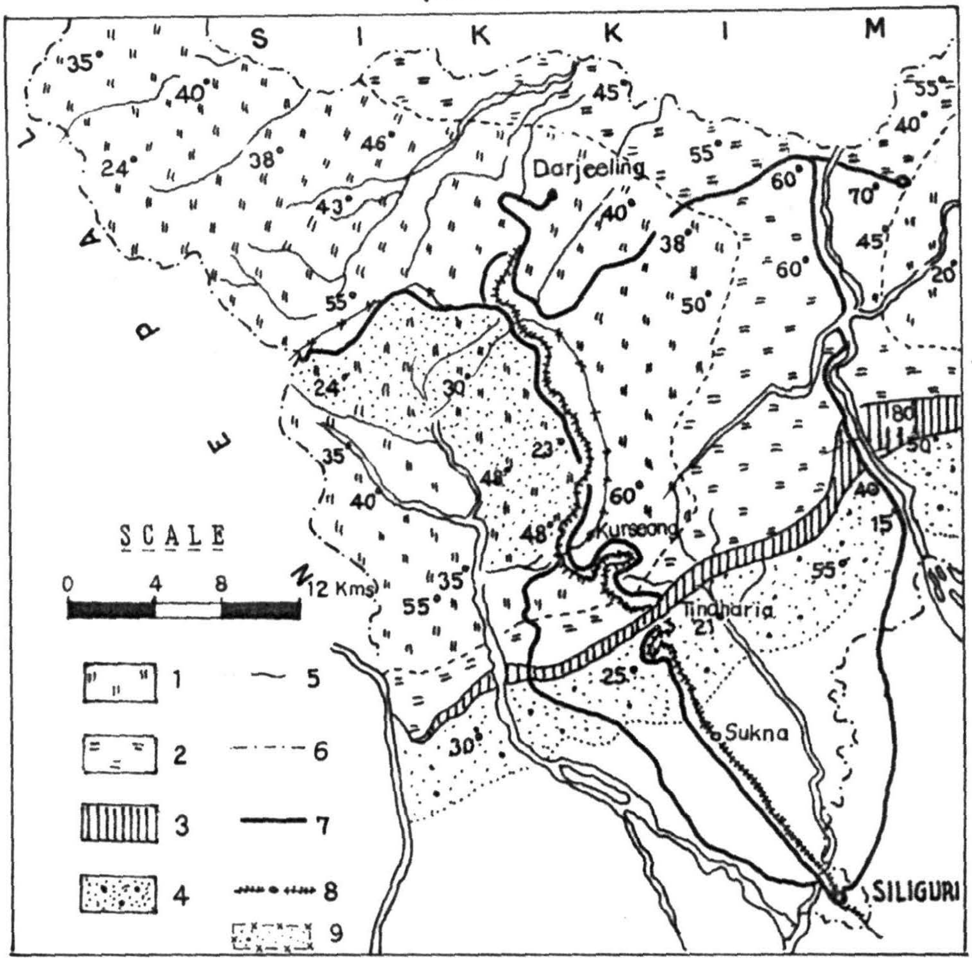


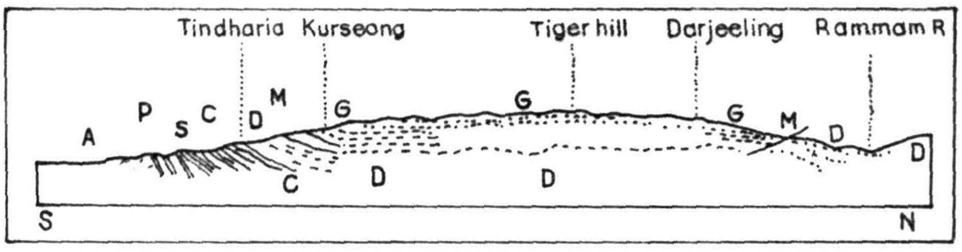
Fig. 1·2.

Eastern Balason Catchment

Geological map of Darjeeling Hills
(After Ganser & others)



1. Darjeeling gneisses 2. Daling series 3. Damuda series 4. Siwaliks 5. Dep of beds. 6. State boundary 7. Roads. 8. Railway line. 9. Study area.



GEOLOGICAL SECTION ACROSS DARJEELING HILLS (AFTER HEIM, 1939)

A- Alluvium P- Pleistocene boulders S- Siwaliks C- Damuda series D- Daling phyllites and slates M- Mica schist G- Darjeeling gneisses.

Fig. 1·3.

clearly the phenomena of inverse metamorphism in the Darjeeling hills at the southern part .

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 an evidence by many a scholars evidence 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 thrusts 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 study area is located in thick overthrust series of metamorphic palaeozoic and precambrian rocks bent in the form of a wide syncline having rolling dips and lying over the rocks of Permo - Carboniferous age dipping northward and southward at an angle of up to 80 degrees . (Fig 1.3 inset). The boundary line of the Daling series of rocks lies about 2 km south of the southernmost tip of the study area. . In the southern part of the study area , rock strata dip in the north to north west direction. The dip is 48° near Ambootia Tea Garden and near Phazi Hydroelectric project close to the Balason bed . (Fig 1.3). Near the Goethal's Memorial School the dip of the strata is 23° north west whereas that at the lowest tip of the Rongmuk tea garden is 30° , the direction being more westerly than those in the southern parts of the study area . On the Nagri spur the strata has a dip of 24° north-east.

The rock formations in the study area are Darjeeling gneiss most commonly mixed with some pockets of sand stones , silt stones 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 garnetiferous mica - schist , quartzite and biotite - kyanite and sillimanite gneiss . Both muscovites and biotite are common . Some common accessory minerals of this area are kyanites, sillimanite , hornblende , garnets , bands of quartzite , and aluminous chlorites along with some calcite , the garnet , at places , disseminated through the mica - schists in course crystals of considerable size and is prized as a gem (Govt. of West Bengal , 1981) . The gneiss is always well foliated and exhibit strongly marked features of disturbances which is evident from much folding and crumbling . (Plate 1) . 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 degrees 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 . Gneisses are also met in traverses along Ghoom - Sukiapokhari road . Typical succession of sillimanite - kyanite - garnet metamorphic zones among these gneiss is well seen in these traverses . At places gneiss are traversed by numerous veins of quartz pegmatite and aplite . 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 generally surrounds garnets 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 inclusion 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 study area .

1.3 DRAINAGE :

The study area is drained by several rivers and rivulets . All of them are leading to Balason which runs straight in south direction almost parallel to the 88 ° 15 ′ meridian (Fig. 1.4) . The catchment of Balason being fan shaped , the drainage in the study area shows flow to the centre of the basin . On account of highly resistant gneissose rock formations in the study area , coupled with faults and fractures , drainage lines show sudden turns and twists . The beds of the streams of higher orders have huge gneissose boulders spread all over (Photograph 1). Several instances of river capture , some subtle and others highly pronounced , are also seen in the area . There are some localised areas having parallel drainage patterns and , dendritic patterns are also not lacking .

DRAINAGE

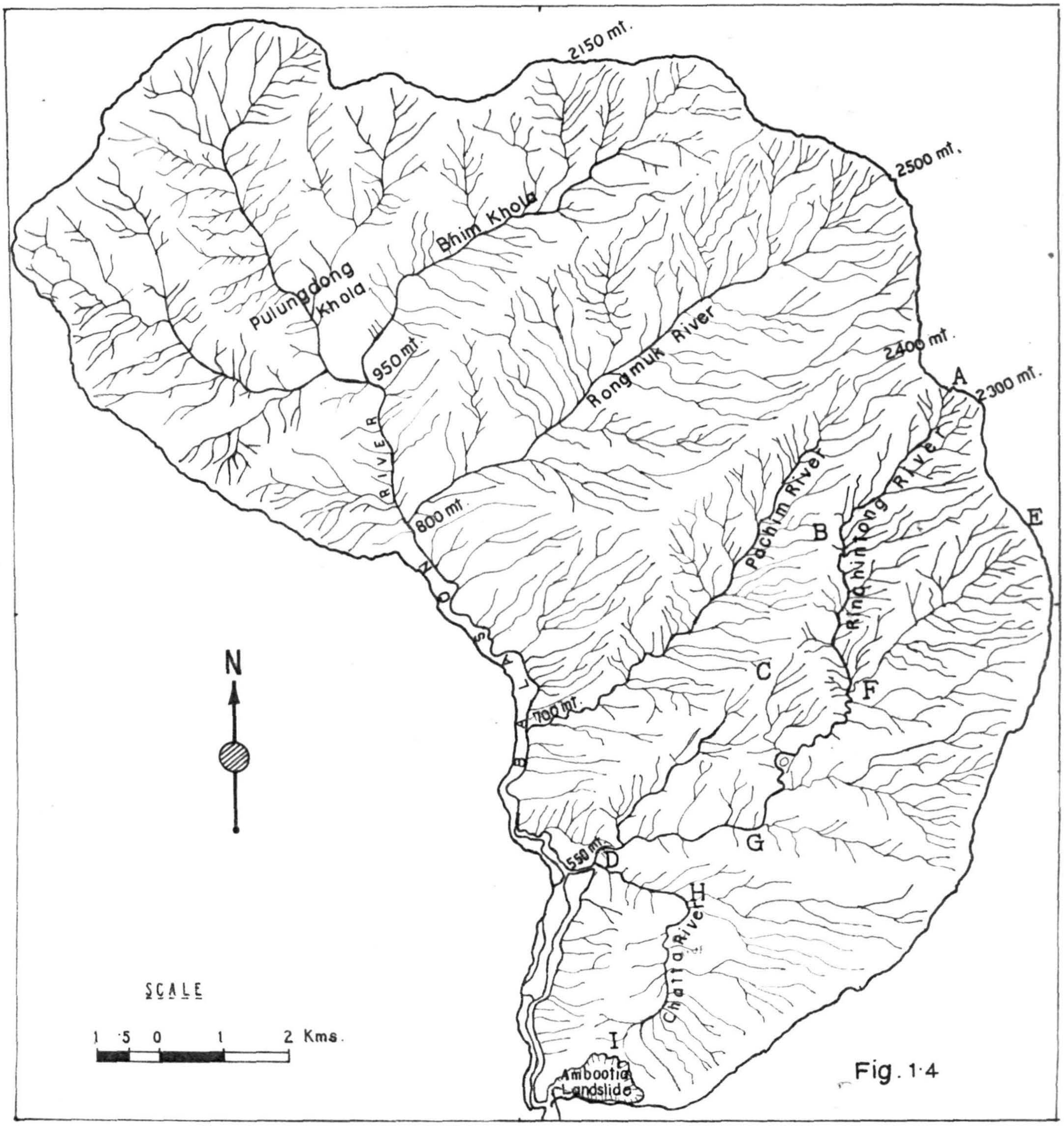


Fig. 1·4

1.3.1 DRAINAGE ZONES :

From the view point of predominant direction of flow , following zones are discernible in the study area (Fig. 1.5)

1.3.1 a. Western Zone : This zone occupies western part of the study area. Its boundary is descending down almost straight to the confluence point of Upper Balason and the Rongmuk rivers in the south . This zone has low drainage density and the predominant direction of the flow of the stream is east and south-east . The main stream is Pulungdong river which drains the entire tract bounded by Sukiapokhari - Simana - Debrepani - Pukhriapong ridge . The drainage pattern is radial on the northernmost tip of this zone. Whereas that near Pugriapong and the tract lying north of it , it is parallel. The aspect of this area is eastern and hence the locality is moist . Discharge of the streams originating from this zone is far better than those from the drier western and southwestern slopes on the eastern side of the study area . The drainage density of this zone is , however , one of the lowest indicating that rock formations , though gneissose , have higher permeability. The easternmost streams of this zone have a tendency to flow straight south and south - west and make a transitory tract with the adjoining zone .

1.3.1 b. North Central Zone : This zone forms the central part of the study area and is the largest one . It has high drainage

DRAINAGE ZONES OF THE STUDY AREA

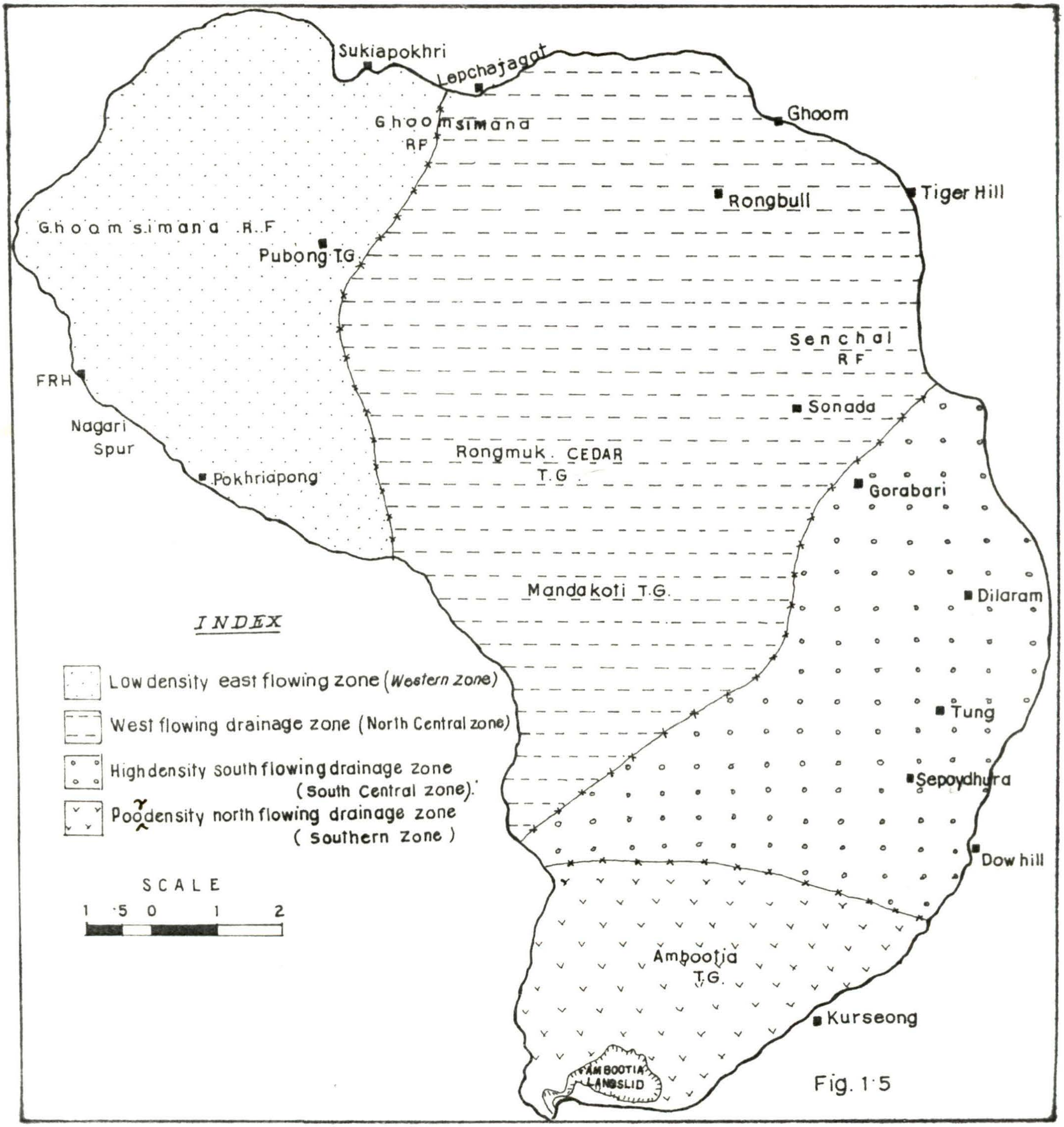


Fig. 1·5

density and all the rivers in this zone have predominant direction of flow towards south - west . Bhim Khola (a tributary of Upper Balason) has originated at the saddle point at Ghoom (2150 mt) . It flows down in south - westerly direction keeping Dooteria reserve forest and Dooteria tea garden on its left bank whereas Tamsong , Pussimbing and Pubong tea gardens lie on its right bank. It meets with Pulungdong khola at an altitude of 950 mt above m.s.l. after traversing for over 6 km . The river next to its south is Rongmuk. It has originated at Tiger Hill in Senchal reserve forest (2500 mt) and flows almost in a straight line down in south - west direction for about 9 km to an altitude of 800 mt where it meets Upper Balason to form the Balason river . In and around Milling tea estate on its right bank , parallel drainage pattern indicates strong faulting and fracturing in the underlying rocks . This is a sinking zone and it has not been possible as yet to develop a good road net work in this area . The Pachim river , lying still south has originated at a point midway between Sonada and Gorabari spur (2400 mt) and flows down almost parallel to Rongmuk to an altitude of 700 mt where it meets with Balason . This river shows dendritic drainage pattern and its stretch of higher order shows considerable sinuosity .

1.3.1 c. South Central Zone : This zone is constituted , exclusively , by the Rinchintong river. The river originates at 2300 mt above m.s.l. and flows down in a peculiar ` S ´ fashion to meet Balason at an altitude of 550 mt after traversing a distance of 12 kms . For a major part, Rinchintong flows almost straight towards south , roughly parallel to Balason river . Many of its tributaries , in its lower reaches, specially those on its right bank , follow the same direction. A very sharp turn , on a perfect right angle to its right at a point 3 kms upstream from its confluence with Balason is quite spectacular . This river makes a complicated pattern of drainage and one can find streams flowing in all possible directions . Drainage density is quite high and stretch of streams having higher order are quit sinuous.

1.3.1 d. Southern Zone : This zone is occupied , exclusively , by the Ghatta river and has low drainage density. The Ghatta river is flowing towards north - a direction exactly opposite to that of Balason . The tributaries from the upper parts of the slope join the main stream at almost right angles . Major part of this zone has a parallel drainage with very strong tendency among the streams to run parallel to one another . The small strip (3 km wide) in northern part running east west has a very low drainage density indicating highly permeable rock material .

1.3.2 SPECIAL DRAINAGE CHARACTERISTICS :

The south central and south zones are very interesting in regard to the activities of the rivers in the geological time frame . The lineament of rivers in this zone is quite revealing . Lineament sections AB and CD coincide perfectly as if they are sections of the same river snapped in between and are now separated by an intervening distance of about 3 km (Fig. 1.4) . Similarly , section EG and HI make a perfect coinciding lineament . This is also noteworthy that the lines formed by these two sets of lineaments are parallel to the drainage lines (namely , Bhim Khola , Rongmuk and Pachim) occurring in the adjoining north central zone . It appears that in ancient days, two rivers, constructed by these lineaments, used to flow parallel to one another when one represented by ABCD was snapped on account of capture of section AB by the adjoining river and this section was forced to meet it at point F . Such river capture became possible when one of the two adjoining rivers started cutting deeper than the other and its tributaries , on account of greater fall and greater velocity of their discharge , got an increased cutting power . Many such instances of river captures are reported (Raistrick , 1943). This appears to have been the case with the river EFGHI . As the valley head has been cut back by erosion , it might have soon intersected the upper part of the ridge common to both and would have cut into the upper parts of the tributaries of the slower ABCD stream . In time , it might have cut so far as to intersect stream ABCD at point B , and then has diverted the upper water of section AB through its new cut gap into its own drainage . The increased flow in the river EFGHI must have unstablised the river bed as river would have tried to increase its hydraulic radius by eroding banks on the side and by deepening river bed down below . The effect would have been acute at Ambootia tea garden where the river was sure to have been passing through a deep and narrow gorge . The failing banks must have led to damming of the river in the section where it passed through deep and narrow gorge . The swelling water

, in turn , must have saturated soil cap lying still higher on the slope of the banks leading to its sloughing and further damming up of the already dammed river channel . This process is likely to have continued on and on till some weak point in the ridge separating rivers CD (the lower trucated part of river ABCD after river capture) and EFGHI would have given way . The fact that currently river CD (a tributary of Rinchintong) , ABFGD (Rinchintong) and IHD (Ghatta) meet with Balason at the same point, gives credence to this hypothesis. The direction of the flow of the section IH has completely reversed. It also gives credence to the presumption that had the river not been passing through a deep and narrow gorge , that could not have happened .

This is also noteworthy that , both , Richintong and Ghatta rivers have a right angle turn in their courses at about 2.5 km and 1.5 km upstream from their mouths respectively . Both of these turns fall on the reconstructed lineament of old Rinchintong river . The drainage map gives an impression as if one triangular wedge , 1.5 km to 2.5 km long has broken through , and has withdrawn back , across the valley of the original river bisecting it (Fig. 1.4). The development of colluvial fan was such that the general direction of slope of original valley was reversed by almost 180 degrees leaving that of upper reaches little affected .

The length of the slope where from the debris material might have come for development of this colluvial fan , shows that it is about one kilometre long close to the southern tip of the basin (near Ambootia landslide) and as long as 3 kilometres at the point where Ghatta takes a right angle turn . The slope of upper part being comparable in these locations , the gravitational forces acting on the debris material shall have been more or less uniform , and hence , the material must have moved uniformly . That being so reversal of the slope of the valley could not have taken place unless the original river was passing through a deep and narrow gorge in its lower reaches as moved debris could have been only one third around the confluence point (near Ambootia landslide) than on the upstream side (near Ambootia factory) . Judging by distance between successive slopes draining to south near the northernmost edge of the Ambootia landslide (about 1.5 km North to the possible confluence point) the deep gorge at the confluence point and in the region immediately upstream could not have been more than 500 mt in its width .

The initial process of development of colluvial fan by filling up of entire river basin in its lower segment must have resulted in damming of river , leading to breakage of the ridge separating it from the Balason . The fact that , both , Ghatta and Rinchintong meet river Balason at the same point is also quite unusual . In all probability , the great built up of water was released to Balason at a single point (the release must have been catastrophic) . Later on as the water level reduced , original river was forced to take a right angle turn to the right to meet the Balason through that opening. Whereas, a new river developed in the colluvial fan flowing in exactly the opposite direction. As the river approached the farther end of the colluvial fan , it took a turn at right angle to its left to meet the Balason through the same opening . Both of them cut deep gorges which can be seen at present too . This is also very significant that Rinchintong and Ghatta rivers have , respectively , 7 percent and 9 percent slopes on down-ward side just after their right angle turns . This shows that they have cut their courses through materials similar in nature . The development of a huge landslide in a zone having predominantly gneissose rocks also proves that huge quantity of colluvial deposition has taken place at the possible confluence of the imaginary river EFGHI . This colluvial deposit later gave way , and formed the slide , on the occurrence of an storm of unprecedented dimension .

The drainage systems of the study area have a profound effect on soil erosion status. But the climate of the region controls drainage . So it is very important to study the climate.

1.4 CLIMATE :

The climate in 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 . Some of the parameters of the special weather phenomena of the study area, as recorded in Darjeeling observatory (which is 7 km away from the study area) are shown in Table 1.1 .

TABLE 1.1
METERIOLOGICAL DATA OF DARJEELING OBSERVATORY

Month	T°C	t°C	RH %	Cld	MWS	DWH no.	DWF no.
Jan	8.6	1.9	76	4.1	4.5	0.3	5.2
Feb	9.0	2.6	76	4.3	6.8	0.4	5.9
Mar	13.2	6.2	70	3.6	8.4	1.0	4.8
Apr	16.2	9.3	74	4.9	9.3	1.1	1.9
May	17.3	11.4	86	6.8	8.1	1.4	10.9
Jun	18.4	13.7	93	8.6	6.8	0.1	19.1
Jul	18.8	14.4	94	9.0	6.1	0.0	21.1
Aug	18.8	14.3	92	9.0	5.9	0.0	21.9
Sep	18.2	13.4	90	8.1	5.5	0.0	15.8
Oct	16.7	10.2	81	5.3	4.5	0.0	3.0
Nov	13.3	6.2	70	3.3	3.5	0.0	2.8
Dec	10.4	2.7	66	3.1	3.4	0.0	2.4

T = mean maximum temperature , t = mean minimum temperature , RH = relative humidity , MWS = mean wind speed (km/hr) , DWH = days with hail , DWF = days with fog , Cld = whole day cloudy equivalent to 10

(Source : Govt. of West Bengal , 1981)

The table 1.1 shows that during the period April - October the sky remains overcast for more than 50 percent level. The months of July and August are the most cloudy with values of cloudiness being 9 . Whereas relative humidity never goes below 70 percent, and in rain drenched months of (May - October) it is more than 80 percent. These months are also the foggiest in the year. Pre-monsoon months (February - May) are the windiest .

Hail storm of quite severe intensity occurred frequently in the study area (Ram & Patel , 1993). The weigth of stones are no where near the maximum recorded (Berry and Bally , 1973) but damage is wide spread .

The rainfall data has been collected from the Singel Tea Estate located in vicinity of Kurseong town and is presented in Table 1.2 .

TABLE 1.2
RAINFALL, NUMBER OF RAINY DAYS AND TEMPERATURE AVERAGE FOR 1990 - 1995

Month	Rainfall mm	No. of rainy days	Mean Maximum °C	Mean Minimum °C	Average °C
Jan	29.7	2.0	15.2	9.2	12.2
Feb	42.3	3.3	16.6	10.4	13.5
Mar	43.8	3.8	20.4	14.1	17.3
Apr	84.0	6.3	24.2	18.6	21.4
May	326.0	16.2	25.0	19.8	22.4
Jun	1076.2	23.3	26.2	20.8	23.5
Jul	1338.8	26.8	25.9	21.3	23.6
Aug	910.7	23.8	25.3	21.4	23.4
Sep	471.0	19.4	25.8	20.6	23.2
Oct	121.0	5.0	25.1	17.7	21.4
Nov	2.8	0.4	21.0	14.5	17.8
Dec	13.0	0.8	17.7	11.1	14.4
Tot	4459.3	131.1	-	-	-

(Source : Single Tea Estate , Kurseong.)

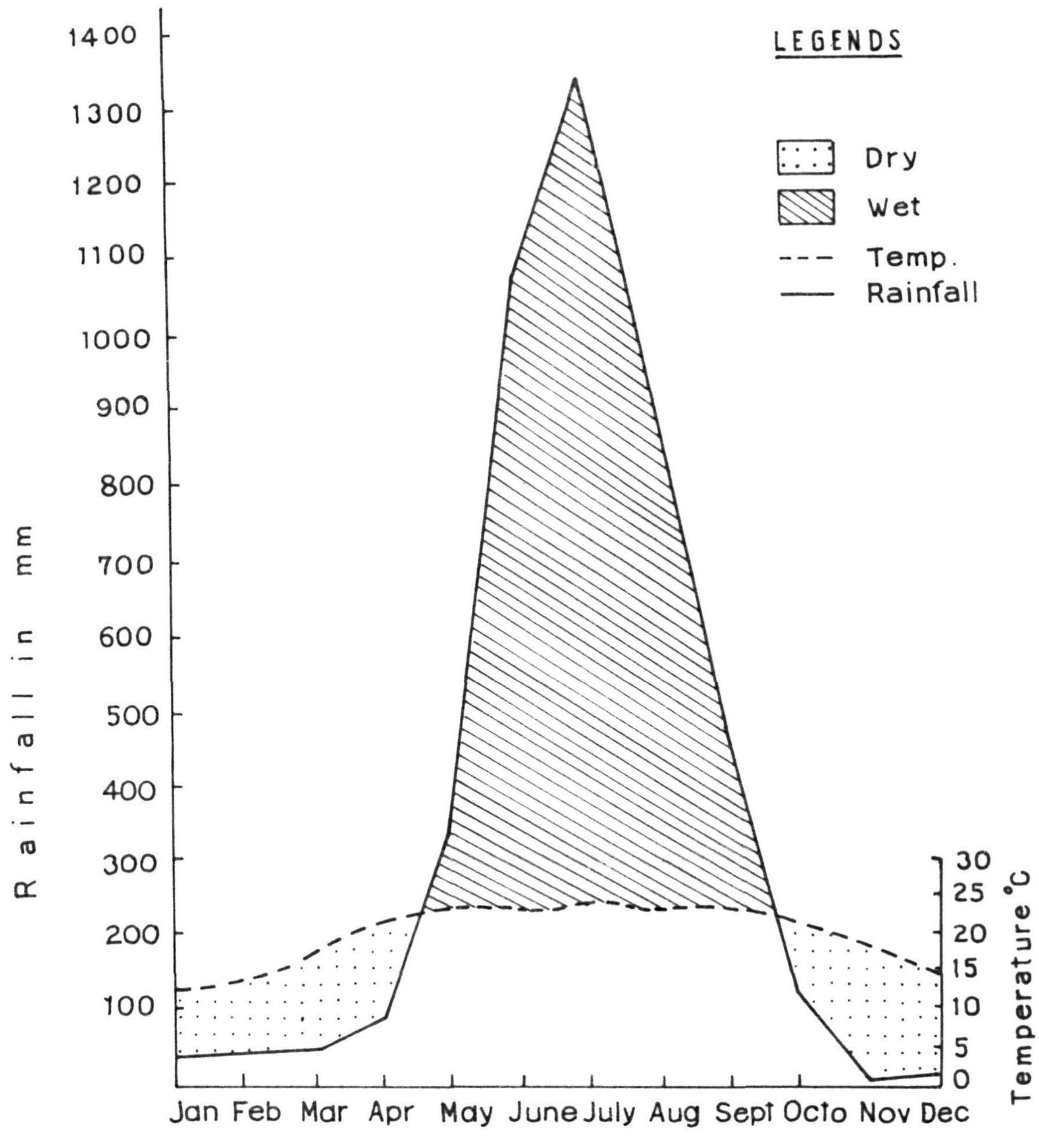
1.4.1 TEMPERATURE :

Temperature in the study area varies from place to place and hour to hour . The eastern part of the study area , having slopes facing south and south - west is warmer . The extremes of temperatures are felt in areas of high hills (1500 mt to 2500 mt) lying along the ridge tops delineating the main basin . (Govt. of West Bengal , 1986) . As is seen from the table 1.2, January is the coldest month and June - July are the warmest . The lower altitudes have higher temperatures and tropical climates whereas higher areas have lower temperature due to altitudinal variation (Mani, 1981).

1.4.2 RAINFALL :

The average annual rainfall for the study area as revealed from the Table 1.2 is 4459.3 mm . Most of it received during Monsoon months i.e. May to August. The rest of the year is almost dry (Fig 1.6). On account of such heavy concentration of rainfall in a few months , monsoon becomes atrocious during this period . (Raghuraman , 1975). During heavy rains the intensity of individual storms may occasionally be as high as 30 cms to 40 cms per hour . (Ray , 1964) . Large sized boulders are reported to flow down through the rivers of the study area. This is one of the reasons for soil erosion and for failure of engineering structures constructed in the rivers for moderation of their flow . The month of November is the driest with lowest rainfall and the least number of rainy days . As is revealed from the table 1.2 and the Fig. 1.6 , the distribution of rainfall is quite skewed. The monsoon months have rains pouring down whereas some other months have barely enough rains for crops to survive . The picture becomes clearer if one takes a look at the number of rainy days . This makes the study area to suffer on two counts - one, erosion due to excessive runoff during monsoons and , two , drought during summer months .

OMBROTHERMIC DIAGRAM



Source : SINGEL TEA ESTATE
Kurseong 1995

Fig .1·6.

1.4.3 HUMIDITY :

As seen from the table 1.1, the months of June to September are most humid. The relative humidity is more than 90 percent . This is the period when the monsoon is the most active . December is the driest with relative humidity 66 percent . January to April humidity hovers around 70 to 80 percent . The climate of the study area is basically humid and its upper reaches remain mist shrouded for half of the year (Sahani , 1981) . As is seen from the Table 1.1 , fog is most common in May to September. The tract around Sukiapokhri - Lepchajagat - Ghoom - Rognbull - Sonada is almost always enveloped in a thick fog . Hails are also a regular feature during March to May often being most severe on Ghoom saddle and Rongbull spur reaching down up to 2000 mt contour line . Snowfall is occasional . All these factors combined together make distinct climatic zones in the study area.

1.4.4 CLIMATIC ZONES :

Following micro - climatic zones are discernible in the area .

1.4.4a : Wet Temperate Climatic Zone : This zone is confined to the higher parts (above 2000 mt) of the study area (Fig 1.7). This zone is enveloped in the mist almost through out the year and is quite damp . The winter is very severe. Sunnier aspects lying on the eastern part are , however , pleasant during summer . The north western part of this zone is moist and much cooler .

CLIMATIC ZONES

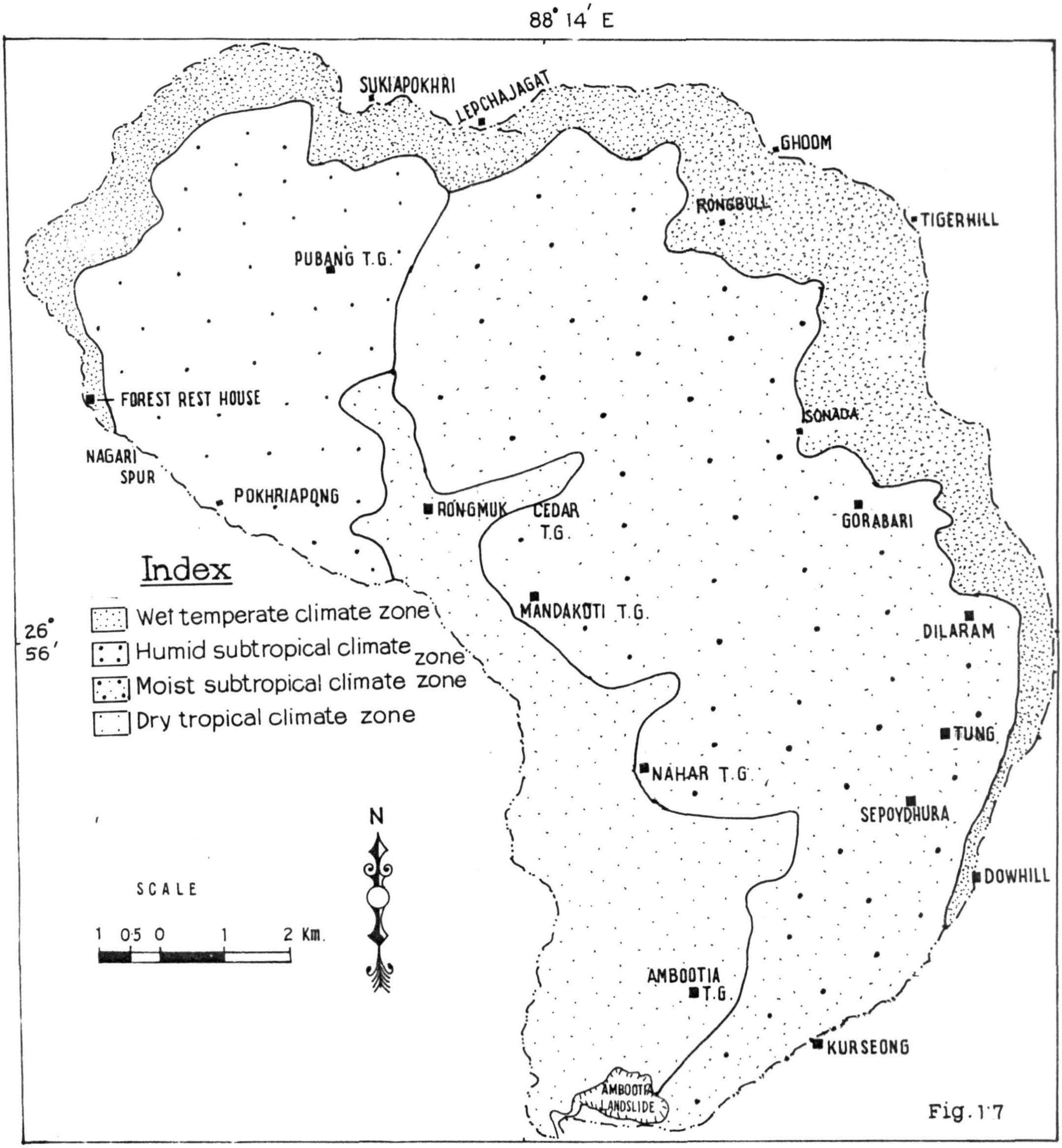


Fig. 1·7

1.4.4b : Humid Subtropical Climate Zone : This zone is located in the north western side of the study area (1000 - 2000 mt) . The aspect is eastern to south eastern . This zone is much less exposed to sunrays and is humid and cool. It has luxuriant growth of forest on account of better moisture regime . The forests of this zone are less damaged on account of low population density which probably is a consequence of excessive dampness in the area .

1.4.4c : Moist Subtropical Climate Zone : The entire stretch of the slope on the eastern part (between 1000 mt and 2000 mt) falls in this zone . The aspect is south-western and is exposed to sunrays for almost whole day . This zone has most of the tea gardens and human establishments with high concentration of population . Winter is not very severe and the summer is pleasantly warm .

1.4.4d : Dry Tropical Climate Zone : This zone includes areas below 1000 mt and includes steep jhora banks and sandy bouldery river beds. The summer is hot but winter is not very cold . Exposed rock outcrops are not infrequent . Here, waste land are mostly covered with dry scrub vegetation .

1.5 SOILS :

Climatic factors have multidimensional effects. These help to develop a wide variety of soils in the study area. 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 results 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 on Darjeeling gneiss and schists occurring in the study area. Darjeeling gneiss commonly decomposes into a stiff reddish loam but may also produce , occasionally , pure sand or a stiff red clay . The colour of red soil , derived as it is by meteoric weathering from gneiss and schists , 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 silicious 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 on 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 :

Variable productivity of soil in combination with highly variable temperature in the study area has produced different types of vegetation which are divisible in following zones .

1.6.1 HUMID TEMPERATE FOREST VEGETATION ZONE :

Forest vegetation occurs all along the brim of the basin in an approximately 3 to 4 km wide strip except in the southern part (Fig 1.8) . The lower limit of this zone is bounded by 2000 mt 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*) , Mauwa (*Engelhardtia spicata*) , Pipli (*Bucklandia populnea*) , Lekh Chilauni (*Nyssa sessiliflora*) , Walnut (*Juglans regia*) with an understorey of Jhingani (*Eurya japonica*) , Kharane (*Symplocus theifolia*) , Malata (*Macaranga sp.*) , and Arupate (*Prunus nepaulensis*) . In several patches plantations of Dhupi (*Cryptomaria japonica*) have been raised .

VEGETATION ZONE

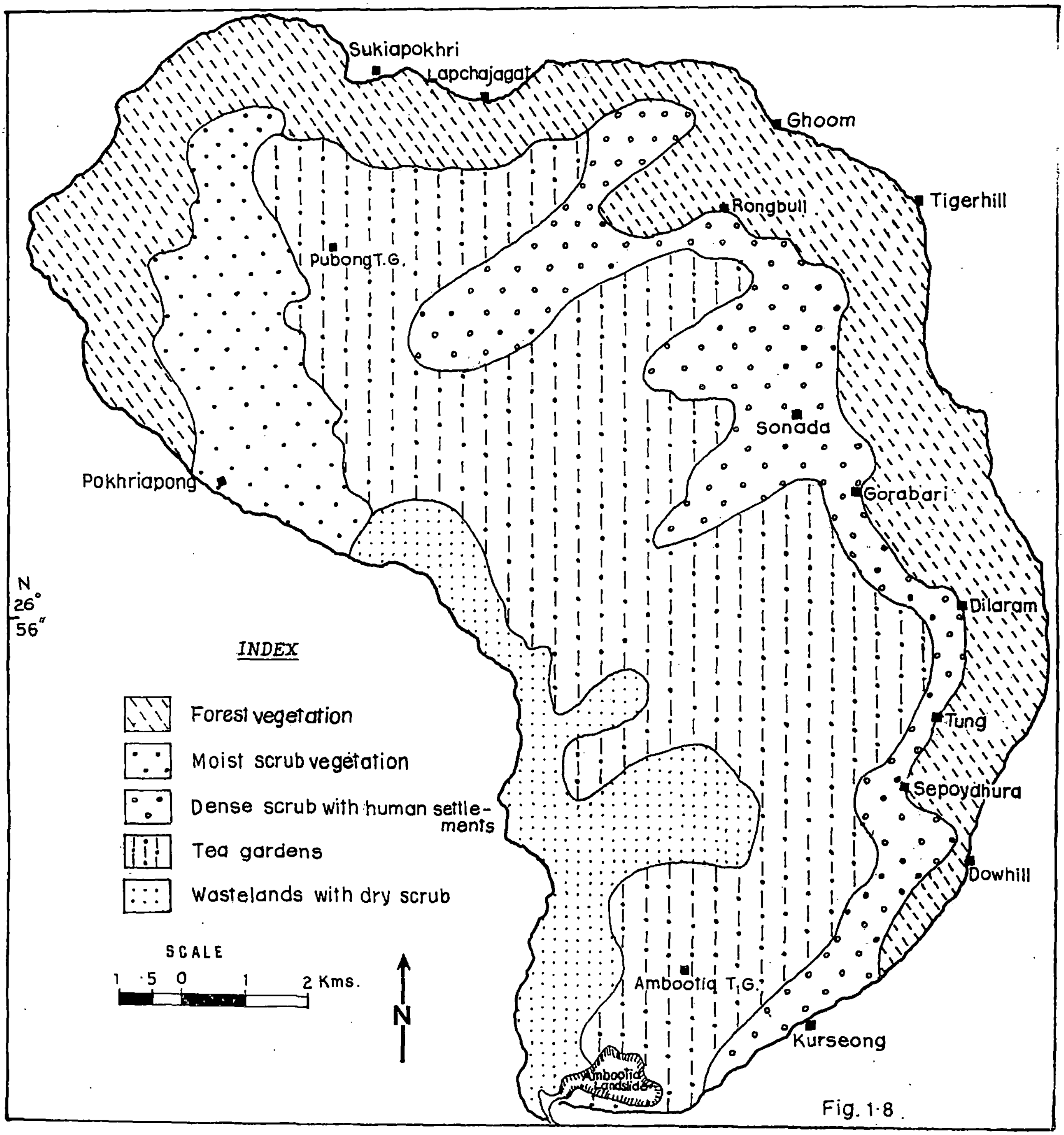


Fig. 1·8

1.6.2 MOIST SCRUB VEGETATION ZONE :

This type of vegetation is met in a small strip running north to south on the western side of the study area . This area is moister and cooler on account of eastern aspect and has characteristic vegetation . The natural grown species encountered are : Panisaj (*Terminalia myriocarpa*) , Lahsune (*Amoora rohituka*) , 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 .

1.6.3 DENSE SCRUB WITH HUMAN SETTLEMENTS :

This zone is encountered on the warmer south western aspect lying all along on the eastern side of the study area . This occupies the spurs and a strip all along the Hill Card road . Most of the agricultural lands are located on this tract . 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 land slides . 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*) , Pipli (*Bucklandia populnea*) and Weeping Willow

(*Calix indica*) . Some temperate fruit trees such as plume , and peach and oranges are also planted in this zone .

1.6.4 TEA GARDENS :

Tea gardens occupy the largest area . Like any other tea garden of the hilly terrain , no shade trees are planted in the tea gardens in Balason catchment too. 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 .

1.6.5 WASTELAND WITH DRY SCRUB :

This zone lies below 1000 mt contour line and consists of wastelands with rock outcrops with occasional skeletal soil (Plate 2) . Growth of vegetation is poor on account of poor soil depth and even tree species have stunted growth . Species encountered are Siris (*Albizzia sp.*) , Phaledo (*Erythrina sp.*) , Parari (*Stereospermum chelonoides*) and Malata (*Macaranga sp.*) with undergrowth of Amlisho (*Thysanolena maxima*) , Assamlota (*Eupatorium odoratum*) , Tarika (*Pandamus furcatus*) , Kamle (*Boehemia sp.*) , Tagar (*Tabernomontana coronaria*) and Choya Bans (*Dendrocalamus hamiltonii*) .

PLATE 2 : WASTELANDS WITH DRY SCRUB

CONCLUSION :

Thus it is seen that the study area has distinct slope zones with western part of it having rugged steep slopes , the lowest reaches with precipitous rock outcrops , east and north - east side with flattish ridge and spur zone , middle eastern reaches with rolling slopes and a flat colluvial deposit zone at the southern side . Geological formations of the study area consist of gneissose rock materials showing inverse metamorphosis . The study area is , thus , located in thick overthrust series of metamorphic , paleozoic and precambrian rocks . In respect of drainage , western part shows a concentric flow pattern with low drainage density . The north - central part has high concentration of streams and flows predominantly to south - west . The south - central part is constituted by Rinchintong river showing highly confusing drainage pattern . The southern part has rivers flowing north and having far flatter gradients . Interesting cases of river capture and complete reversal of direction of flow are also encountered . The climate of the area is quite interesting . Minimum temperature is 1.9° C whereas the maximum is 18.8° C . Relative humidity is as high as 94 percent and never goes below 66 percent . The cloudiness is as high as 9.0 during July - August and is never less than 3.4 even during the driest of months . Hail and fog are also quite common . Average rainfall for last 95 years is 4459 mm . The area has four distinct climatic zones . The wet temperate climate is met above 2000 mt contour line all along the ridges . Humid sub - tropical climate is found within 1000 mt to 2000 mt contour line on north - western side . The aspect here is eastern and south - eastern making the area humid . Moist sub-tropical climate is found between 1000 mt to 2000 mt contour line on eastern part of the study area . Here aspect is sunnier and the area most productive . Dry tropical climate is found below 1000 mt contour line and includes steep jhora banks and sandy bouldey river beds . Soils in the study area vary from very shallow skeletal to very deep. Red yellow soils have developed from Darjeeling gneiss. Brick red colured clay loam soils occuring on piedmont slopes are good for tea cultivation. Study area has a wide variety of vegetation. Humid temperate forest vegetation is seen along the ridges of the basin. The species growing are Katus (Castanopsis indica), Tite Champ (Michaelia cathcartii), Musre Katus (Castanopsis tribuloides), Mauwa (Englehardtia spicata) and its associates. Moist scrub vegetation consisting of Panisaj (Terminalia myriocarpa), Lahsune (Amoora rohituka) and their associates are found on 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. Tea gardens are mostly concentrated in the middle reaches on the eastern side. Wastelands with dry scrub consisting of Siris (Albizzia sp.), Parari (Stereospermum chelonoides), Malata (Macaranga sp.) and associates are encountered in the lowest reaches of the study area.

Thus it is seen that the factors relating to the relief , geology , climate , and vegetation have a close interaction . This process which is , both , destructive and synthetic , leads to formation of soils . The soils and their characteristics developed on account of these processes are of fundamental importance for any study of soil related problems which can be discussed in the next chapter.

CHAPTER II

SOILS AND THEIR CHARACTERISTICS

INTRODUCTION :

This chapter deals with various properties of soil found in the study area . These properties are of paramount importance as they affect erosivity and productivity of the soils in the study area . A large number of soil characteristics are associated with erosivity and productivity of soils .

2.1 SOIL TYPES AND THEIR DISTRIBUTION :

Soils are a dynamic part of the earth's geomorphic cycle of surficial weathering , erosion , deposition , sinking , diagenesis , metamorphosis , upliftment and mountain building (Jackson ; 1976) . Accordingly soil types as distributed in an area are a function of several factors like climatic , biotic , and geomorphic only to mention a few . So far, no attempt has been made to identify soil types and their distribution in the study area . Following five soil types and zones are identifiable .

2.1.1 MODERATELY DEEP DARK GREY SANDY LOAM SOIL ZONE :

This zone of soil is located on the higher reaches and is generally bounded by the 2000 mt contour line (Fig. 2.1) . Most of these areas contain forest vegetation . Humus is plentiful . Some localities , specially those on the north western side of the study area contain thick mat of undecomposed organic matter . Slopes are steeper . Occasionally rock outcrops are also seen . The soil is skeletal to moderately deep . Large stretch of skeletal soils are encountered between Sonada and Gorabari and again in between Sepoydhura and St. Mary´s Hill . Huge rock outcrops could be seen jutting out of quite steep terrain . Soils on the north and north-eastern side of this zone are moderately deep , sandy loam in texture and dark grey in colour .

2.1.2 SHALLOW DARK BROWN CLAYEY LOAM SOIL ZONE :

This zone of clayey loam soils occur on western part and extreme southern part of the study area (Fig. 2.1) . This zone has cooler and moister eastern and northern aspects . On account of less exposure to the radiation , the process of soil formation and rate of decomposition of organic matter is rather slow . The clay content of soils is slightly higher than that of those located higher up . Dark brown colour of soil is on account of leaching down of soluble salts leaving behind iron oxides in the upper layers of soils . The soils are

SOIL ZONES

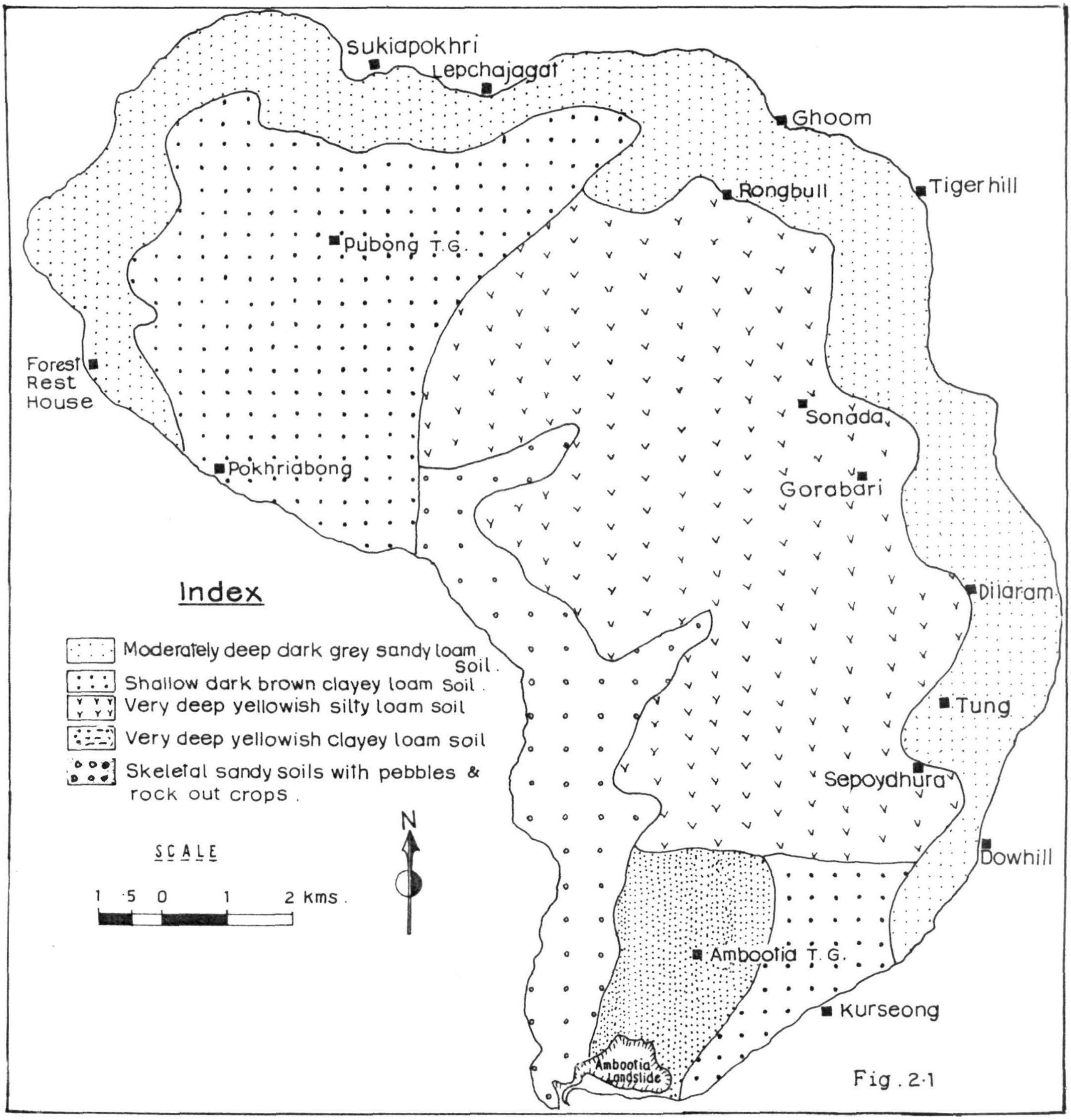


Fig. 2·1

clayey loam on the lower reaches of this zone . Rock out crops and skeletal soils are not frequent . On account of poor depth of soils, this zone has least agricultural farming and very few tea gardens .

2.1.3 VERY DEEP YELLOWISH SILTY LOAM SOIL ZONE :

This zone constitutes the largest area and is also the most productive and contains high concentration of population . This zone is confined to piedmont slopes lying between 1000 mt to 2000 mt contour line . The slopes are milder and rolling in nature . Soils are very deep silty loam , and yellow in colour . These are moderately rich in organic matter , and very well drained . The yellowish colour of the soil indicates that most of the iron and aluminium has been washed down in the process of podzolisation . Most of this zone is covered with tea gardens .

2.1.4 VERY DEEP YELLOWISH CLAYEY LOAM SOIL ZONE :

This zone is quite small in extent and is located in the southern most tip of the study area . It has very deep clayey loam soils having good drainage . The soil is occasionally gritty and shows moderate richness in organic content . This zone is located on colluvial deposits and has great productivity . Almost entire zone is occupied by Ambootia tea garden with Springside and Singel tea gardens touching its fringes . The slope is an almost perfect table top . Yellowish colour of soil shows washing down of iron and aluminium to a great extent .

2.1.5 SKELETAL SANDY SOILS ZONE :

This zone is confined to the steep river banks and river beds , the upper limit being 1000 mt contour line (Fig 2.1) . Huge rock outcrops are seen on the river banks . Such areas are mostly devoid of any tree vegetation . Dry scrub predominates . This zone consists of most difficult terrain and entire area in it is wasteland . Scrub vegetation is seen wherever little skeletal soil is developed . On some slopes specially between Ghatta and Rinchintong rivers , the soils contain lots of pebbles. They are sandy , poor in organic matter and have low water holding capacity . Permeability is higher .

Thus , it is seen that the study area has a variety of soils distributed in different zones . This is a result of various destructive and synthetic soil forming processes depending on geomorphic , climatic and biotic factors .

2.2 SOIL FORMATION :

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) . 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) . The topography through its altitude , slope and aspect affects the amount of heat reaching to a given area through radiation and movement . Among the elements of biosphere , the phytosphere is of greater importance , the contribution of zoosphere being primarily mechanical in nature through digging and burrowing activities of worms , ants , termites , rodents , etc. (Jacob , 1965) . The growing plants and organisms feeding on such plants and its litter affect , both , the nature of weathering of rocks and the fate of the product of weathering (Nortcliff , 1989). From soils, plants take up soluble mineral salts which are later returned to the surface in form of fallen leaves , twigs , stems and branches or to the subsoil in form of decayed roots . This dead vegetation and living and dead plant roots are source of food for a variety of soil organisms which affect soil by their physical and biological activities.

The soil formation in the study area is not uniform . The north-western and the extreme south-eastern parts contain shallow to skeletal soils and are endo-dynamomorphic in nature. Here, parent material has resisted the climatic and biospherical factors on account of lower temperature caused by colder south-eastern and northern aspects . The soils are relatively young in these zones . In the upper zones of Pachim and Rinchintong river basins , too , skeletal soils , are endo-dynamomorphic in nature . These soils are found on steep slopes where little percolation of water has slowed down the soil forming processes . So is the case in the lower zones of all the five river basins where steep banks have slowed down the soil forming processes resulting in young soils . The lower middle and the upper middle zones of the river basins have well developed mature soils of ecto-dynamomorphic in nature . Soil forming processes are most active in these zones because of milder slopes , higher temperatures , and greater percolation of rain water . In patches, red coloured soil occur indicating that iron has accumulated after removal of large quantities of other mineral constituents . In the upper zones of the river basins , where forest vegetation predominates , the effect of vegetation is quite pronounced in soil forming processes . The permanent vegetation is known to have a most efficient , almost closed nutrient cycle with products of litter fall and the washing of canopy taken up directly in dense root mat close to the surface and mineral salts in biological cycle can be considerably higher than the amount leaching out of the soil profile into the stream . The intensive decomposition of organic matter liberates large quantities of acids which causes partial break down of clay minerals admitting into circulation iron , aluminium , manganese and leaving behind SiO_2 . As a result, red hydrated iron oxide mixes with dark organic matter giving a brown to grey brown Colour to top soil (Jacob , 1965) . This is precisely what is happening in the forest areas located in the upper reaches .

The organic matter is an important constituents of soils and no less important are a variety of soil organism which act on them and generate huge number of related organic and inorganic substances which play very vital role in the entire process of development of soil body .

2.3 SOIL ORGANISMS :

The soil organisms also referred to as soil fauna need a fairly well aerated soils for their active growth and reach their greatest population in the soil surface layers of forests and old pastures in the top 20 to 50 mm layer (Newman , 1989) . Without the intermeshing vital process of bacteria , actinomycetes , fungi and algae (the microflora) , the protozoa , and nematode worms (the microfauna) and mites , earthworms , root devouring beetle larvae and other associated mesofauna , the soil would become a repository of dead plant remains with no facility for recycling of vital nutrients such as carbon , nitrogen and phosphorus for plant growth . A naturally fertile soil is one in which soil organisms are releasing inorganic nutrients from the organic reserves at a rate sufficient to sustain rapid plant growth (Harris , 1989) . Various groups of soil organisms do not live independently of each other , and may have developed a series of symbiotic relationships with others in vicinity . Besides , total microbial activity increases with application of fertilizer (N) and application of phosphate stimulates microbial activity even during the period of incubation (Tripathi et. al., 1993) . The larger saprophytic soil animals , the most important of these being earthworms , by virtue of remaining mobile , distribute , both , decaying organic matter and some of the microbial population through out the soil layer in which they are active as they will be ingesting food at one place , mixing this with bacteria in their gut , excreting it at another location . The earthworms play a vital role in breaking down and in distribution of dead organic matter in the soil besides bringing a wide variety of microorganisms in intimate contact of their substrate and presenting large surface area for their action .

The earthworms do their works primarily at night dragging down grass and leaves from the surface soil into their burrows , thereby mixing the materials of horizons . They are active in soils rich in organic matter and they prefer neutral to alkaline medium , but are also encountered in forests which are moderately or even strongly acidic . Materials passing through the body of the earth worms undergo physical and chemical changes . The soil after passage through the gut of the earthworms contains higher soluble phosphorus and lime (Jacob , 1965) . The earthy excrement of earthworms have , respectively , water holding capacity , contents of organic substances , and number of bacteria , on an average , 78.3 % ,91.9 % , and 25 - 234 % higher than those contained in the surrounding soils (Kollmannsperger , 1980) . The earthworm excrement crumbs are considerably more stable than the soil crumbs on account of higher content of organic substances cemented together by secretions of bacteria and , probably , also on account of chemical stabilisation as the humus compounds which dissolve in the intestines of earthworms afterwards precipitate and cement excrement crumbs . Thus the activities of the earthworm changes normal soil into one which is light , crumby , with finer granulations , higher contents of colloids with all the desirable chemophysical and biological activities .

Contrary to claim that earthworm fauna in the Himalayas is practically unknown (Kollmannsperger , 1980) , it is met within the study area though its distribution is highly erratic . Table 2.1 shows the result of sampling done to assess the presence of earthworms in a pit of the size 15 cm x 15 cm x 10 cm in the surface soil .

Table 2.1

OCCURRENCE OF EARTHWORMS

Location	Date	Land use	No.	Size &	Remarks
Dhobijhora	16/09/95	1	9	70mmx2mm	
Mahldram	10/09/95	2	-	-	*
Dowhill	17/09/95	3	20	100mmx3mm	**
St. Mary´s	15/09/95	4	-	-	***
Sonada	14/09/95	5	75	15mmx.5mm	****
Ambootia	10/09/95	6	-	-	
Rongbull	10/09/95	7	5	70mmx2mm	

Land Use :

1. Misc. broad leaved forest with cover of Cynodon dactylon.
2. Cryptomaria japonica (Dhupi) 1931 plantation.
3. Cynodon dactylon turf.
4. Open Cryptomaria japonica plantation.
5. Degraded old Cryptomaria japonica plantation with Cynodon dactylon mat growing on organic matter.
6. Tea bushes.
7. Agricultural land .

& Length and mid diameter of earthworms .

Remarks :

* Earthworms found only on the fringes of the plantation . Out of four sites only one of that contained one earthworm .

** Some specimens are as long as 150 mm with diameter of 4 mm or even higher . They are very active and give frightening look of a young snake .

*** Most of the specimens are like hair and very numerous . Surprisingly no adults have been seen .

(Source : Author,s own work)

As is seen from the table 2.1 Cryptomaria japonica plantations despite having a thick cover of decomposing organic matter on the soil surface is completely devoid of earthworms . Occasional earthworms are encountered only in the fringes of these plantations . Even degraded ` Dhupi ´ plantations which have almost reduced to pastures , too , are completely devoid of earthworms .Tea gardens , too , because of their cultural practices of keeping the soil surface under the bushes completely clean of any weed growth and also because of use insecticides and weedicides are completely devoid of earthworms . It is seen during the course of investigation that covers of Dub grass (Cynodon dactylon) are always associated with the presence of earthworms . In degraded Dhupi forests some sites have excessive number of hair like earthworms where Dub grass grows and undecomposed organic matter is present . One wonders if earthworms are attempting to colonise such areas . The presence of earthworms is highly significant in well protected grass turfs where their number and size are spectacular .

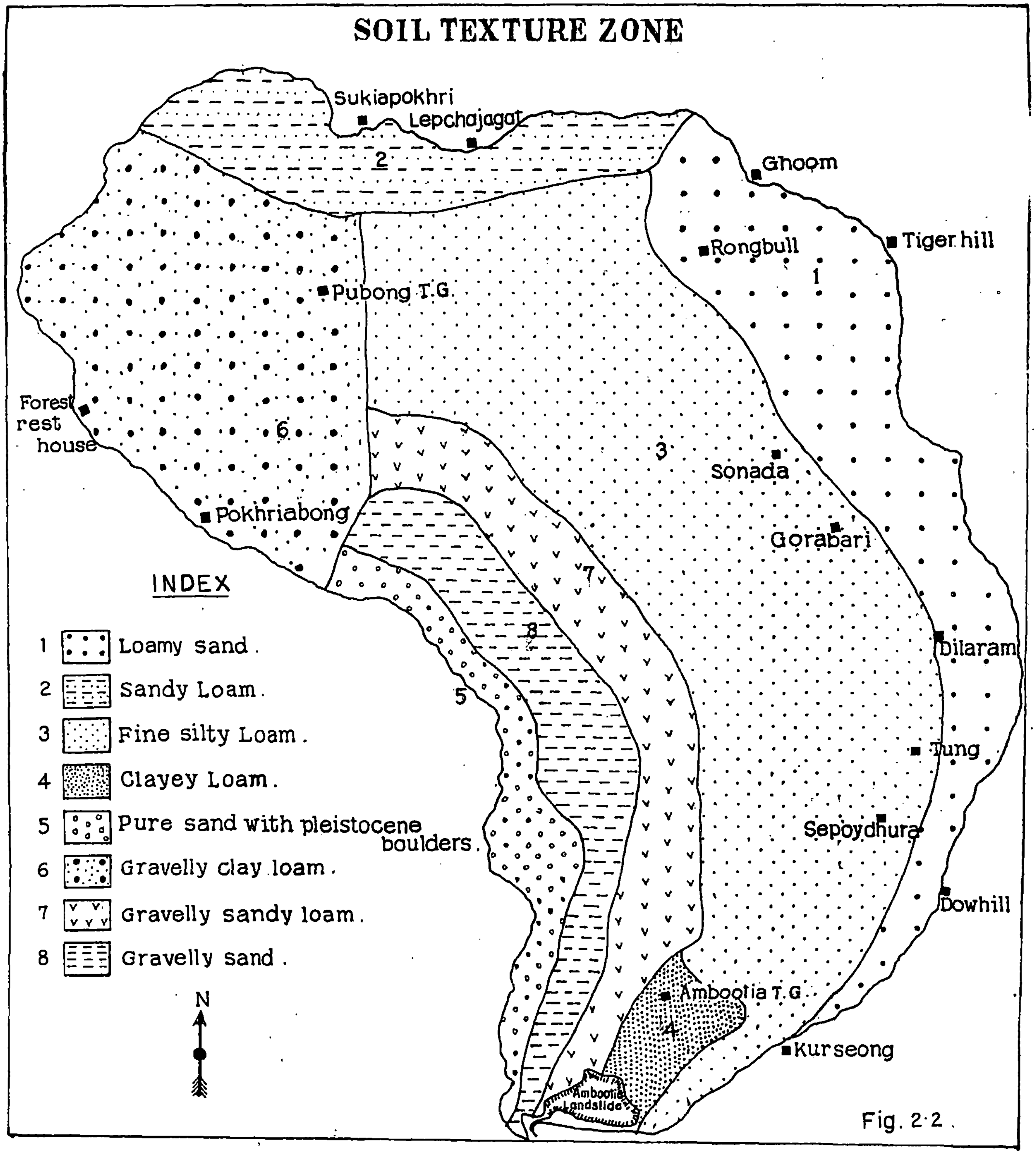
One astonishing fact about the occurrence of earthworms in the study area is their highly erratic distribution . Within a small radius of one metre one spot may hardly be having any earthworms while the other could be bubbling with them . This may be on account of the fact that the species met within the area are great colonizers or may also be on account of greatly exacting requirements of earthworms and being highly mobile during the night they might be accumulating in most favourable locations .

Besides soil organisms , the soil texture is another important characteristics which has great effect on their erosivity and productivity .

2.4 SOIL TEXTURE :

The texture of any soil is the proportionate distribution of different sizes of the solid mineral particles in it , that is the percentages of sand , silt and clay . Although the sizes of the mineral particles and the relative proportions of size groups vary greatly among soils , they are not , unlike most chemical and biological properties of soils , a subject of easy alteration by soil management practices (Klock , 1984) . Soil texture largely controls shapes and sizes of pore space , and hence , ultimately , governs the infiltration capacity of soil and extent of run off from it (Datta , 1986) . . The texture of the soil has important influence on soil´s ability to take up moisture , to dry out , the ease of tillage , and the character of seed bed meant for growth of young plants (Foster , 1965). This nomenclature of textural classes as light , medium or heavy depends on the ease or difficulty with which the soil may be ploughed , disked , dug or cultivated (Jacob , 1965) . Certain textural names are in vogue and we have loam , sandy loam , fine sandy loam , clay loam , silt loam , loamy sand , sandy clay , gravelly loam , gravelly sandy loam, etc. .

The study area contains a wide variety of textural classes (Fig. 2.2) . The upper zone of all the five basins have loamy sand to sandy loam soils . Loamy sand soils are met in the forest on the eastern side of the study area , viz , in Dhobijhora , Mahaldram and Senchal forest blocks . The clay portion increases slightly in the soils of upper zone and the sandy loam soils are encountered in Ghoom - Sukiapokhari stretch . Fine silty loam soils are encountered on spurs of Sonada , Rongbul , Gorabari in the upper middle and lower middle reaches . On the north western side of the study area gravelly clay loam is found. As one descends down from the ridge and reaches the lower zones , one gets gravelly sandy loam to gravelly sand . The river



SOIL TEXTURE ZONE
Sukiapokhri
Lepchajagat
Ghoom
Tiger hill
Rongbull
Pubong T.G.
Forest rest house
Sonada
Gorabari
Pokhriabong
Dilaram
Tung
Sepoydhura
Dowhill
Ambootia T.G.
Kurseong
Ambootia Landslide
INDEX
1 Loamy sand.
2 Sandy Loam.
3 Fine silty Loam.
4 Clayey Loam.
5 Pure sand with pleistocene boulders.
6 Gravelly clay loam.
7 Gravelly sandy loam.
8 Gravelly sand.
N

Fig. 2·2.

beds in some stretches contain pure sand . Some pockets of clayey loam soils are also discernible at the southern tip of the study area .

2.5 SOIL STRUCTURE :

Besides texture yet another important characteristic of the soil , its structure , influences its erosivity and productivity to a large extent .

The aggregation of textural units of the soil mass into variously shaped and sized soil particles forms the units constituting soil structure . A favourable soil structure provides pore space which facilitates movement of water through the soil body . These soil aggregates take up water by capillary action while rain water is passing by them through gravitational flow and , thus , create ideal conditions of moisture and air supply for crop production . Besides , soils with good structure resist compaction and erosion . The soil structure is of interest mainly because of its effect on the geometry of soil pores which , to a large extent , control the availability and rate of movement of water , aeration of soil , and to a lesser extent , the permeability of soils to roots (Payne , 1988) . A certain minimum of clay , not less than 8 to 10 percent , must be present in soil to give aggregates and none may form without it (Jacob , 1965). Addition of bulky organic manure to the soil increases aggregation by 20 to 44 percent (Rajan & Rao , 1978)

. Higher the molecular weight , greater is the effectiveness of organic matter (Payne , 1988) . Application of ammonium phosphate is reported to improve the physical properties of soils including structure (Kanwar & Parihar , 1962) whereas application of ammonium sulphate has deleterious effect on soil structure (Pathak , 1954 ; Biswas et al , 1969 ; Pharande , 1964) . The fires , especially extensive as in forests and grass lands , bring about substantial reduction in organic matter and , hence , deteriorates soil structure (Singh et al , 1980) . Compaction of soil also bring about destruction of soil structure (Sharma et al , 1993 ; Ghildyal et al , 1965) . Cultivation of a non-leguminous crop following a leguminous one tends to deteriorate soil structure promoted by the latter and improvement could be maintained by judicious application of bulky organic manures (Rajan & Rao , 1978) . Two natural materials , calcareous marl and weathering product of dolomite rocks , are used for treating acid soils , the former of which improves the soil structure and nutrient retention capacity of the soils (Riedl,1984) . There are four primary type of structures , namely , laminar , prism like , blocky and spheroidal depending on natural cracking in the soil body (Payne , 1988) .

The soil structures have great effect on non - erosivity of soils and also on the patterns of soil erosion . Structureless soils are eroded uniformly , soils with laminar structure tend to form horizontal tunnels , and prism like structure tends to produce deep gullies quite easily . Of all , the platy or laminar structure impedes percolation and enhances run off the most (Datta , 1986) .

In the study area spheroidal structures are seen in forests with mixed tree cover . Usually such soils have a thick layer of undecomposed and partly decomposed leaf litter at the surface , and are under the process of podzolisation . This structure is seen in Dhobijhora forest and some parts of Senchal and Ghoom - Simana forests covered with miscellaneous tree species .Permeability of such soils is quite high . Structure is granular in areas where forest have thinned out (Mahaldram forest) and is crumby in undisturbed forests (Senchal and Ghoom - Simana forest) . Blocky structures are seen in Dilaram and Milling tea gardens . Most of them are sub - angular blocky . Laminar soil structure is seen in areas having acute biotic interference , with very little organic matter and very low soil permeability . Some stretches of Senchal forests , degraded forest located close to Sepoydhura , Tung , Gairigaon are having laminar structure . It is seen that non - cultivated barren lands tend to develop laminar soil structure over a period of time . Prism like structure is seen in some well protected patches having high content of organic matter . The lower zones of the study area are sandy having no identifiable soil structure .

2.6 SOIL PROFILE :

After the soil has supported vegetation for a longer period of time , the litter becomes partly decomposed and the humified material is gradually infiltrated by percolating water or is incorporated into the upper portion of mineral soil thus forming a dark partly mineral and partly organic layer . This darkening or melanisation of the soil surface constitutes the initial phase in the development of soil profile . Percolating rain water reinforced with carbon dioxide and organic acids , gradually leaches a portion of humus and mineral salts from the upper layers of soils which are precipitated or flocculated deeper down due to the presence of bases or due to other factors . Besides usual A , B and C horzons , partly decomposed leaf litter with botanical structure still visible is also referred to as F and H-F layer and the humified layer of dark finely divided material with colloidal properties as H - layer (Maslekar , 1981) . The plants growing in the soil affect profile differentiation on account of extent of leaf litter available on the surface , composition of leaf litter particularly with respect to CaO , Fe_2O_3 and SiO_2 (Barshad , 1976) .

TABLE 2.2

MORPHOLOGICAL FEATURES OF SOILS

Site	Hrzn	Depth	colour	Stru	Text
PULUNGDONG 1670 MT	A1	0-12	10YR 6/2	MSAB	scl
	B1	12-43	10YR 5/3	MSAB	cl
	B21	43-60	10YR 6/6	MSAB	cl
	B22	60-100	10YR 7/6	WSAB	cl
SONADA 1500 MT	A1	0-20	10YR 5/3	WSAB	scl
	B1	20-30	10YR 6/6	MSAB	cl
	B21	30-60	10YR 5/6	MSAB	cl
	B22	60-80	10YR 7/6	MSAB	cl
	B23	80-120	10YR 6/4	SSAB	cl
MAHALDRAM 1700 MT	A11	0-6	10YR 4/6	WSAB	sl
	A12	6-21	10YR 6/6	MSAB	sl
	B11	21-41	10YR 6/6	L	l
	B12	41-100	10YR 7/6	WSAB	l
DHOBIJHORA 1500 MT	A	0-26	10YR 6/3	MSAB	scl
	B1	26-52	10YR 6/6	MSAB	cl
	B21	52-72	10YR 6/6	WSAB	cl
	B22	72-103	10YR 7/4	WSAB	cl

Structure : MSAB = medium subangular blocky ; WSAB = weak sub angular blocky ; SSAB = strong subangular blocky ; L = loose .
Texture :scl = sandy clay loam ; cl = clay loam ; sl = sandy loam ; l = loam ;ls = loamy sand .
Others : Hrzn = horizon ; stru = structure ;Text = texture
(Source : Author´s own work)

There is , thus , a condition of dispersion in surface horizon and of flocculation in sub soil horizon . Deep well drained soils are formed in these areas from underlying gneissic parent material. Four numbers of soil profiles were exposed in Pulongdong , Sonada , Mahaldram and Dhobijhora (

Fig 2.3) and morphological features were recorded (Table 2.2). These were analyses for pH (1: 2.5) , organic carbon , exchangeable (ammonium acetate extractable) cations and soil separates (international pipette method) as per the procedure prescribed by Piper (1950) . For the estimate of total acidity 1 N KCl solution was employed as extractant and for total sesquioxides perchloric acid digestion was followed (Black , 1965) . Mobile form of iron and aluminium oxides were determined according to Dhir (1967) . As is seen from the table 2.2, the structure in the soil varies from weak to strong subangular blocky on all the four sites where the soil profiles were exposed . The texture of the soils varies from sandy loam to clay loam . The horizons are very well defined and soils are mature . In Mahaldram loose loam soils are encountered in the subsoil below 21 cm to 41 cm . The reason is not quite understood and is , most probably , due to the activities of some meso soil fauna . In Pulungdong few iron concretions were encountered at a depth of 35 cms below the soil surface . So was the case in Dhobijhora , too , where ferruginous concretions were seen at a depth of 42 cm below the soil surface . Some chemical characteristics of the soils of these sites give the clear picture about the soil properties (Table 2.3).

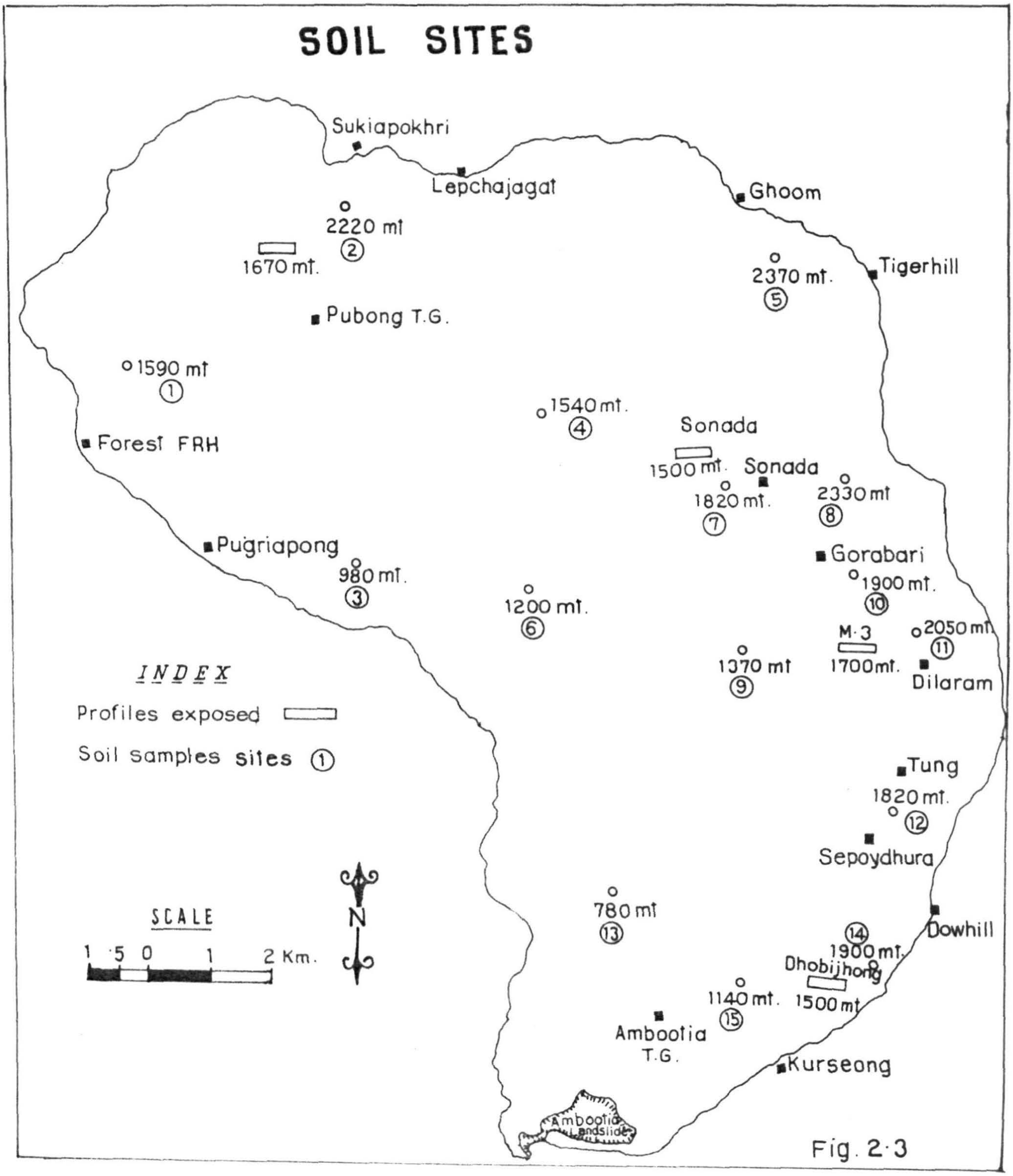

SOIL SITES
Sukiapokhri
Lepchajagat
Ghoom
2220 mt
2
1670 mt.
2370 mt.
5
Tigerhill
Pubong T.G.
1590 mt
1
1540 mt.
4
Sonada
Forest FRH
1500 mt.
Sonada
1820 mt.
7
2330 mt
8
Pugriapong
980 mt.
3
Gorabari
1900 mt.
10
1200 mt.
6
M·3
2050 mt
11
1370 mt
9
1700 mt.
Dilaram
INDEX
Profiles exposed
Soil samples sites 1
Tung
1820 mt.
12
Sepoydhura
780 mt
13
SCALE
1 ·5 0 1 2 Km.
N
14
1900 mt.
Dowhill
Dhobijhora
1140 mt.
15
1500 mt
Ambootia T.G.
Kurseong
Ambootia Landslide

Fig. 2·3

TABLE 2.3

SOME CHEMICAL CHARACTERISTICS OF SOILS

Site	Hrzn	pH	Org C	CEC	Clay %
PULUNG DONG	A1	4.3	5.1	14.9	25
	B1	4.3	3.3	21.8	35
	B21	4.4	1.7	23.6	42
	B23	4.5	1.3	22.8	39
SONADA	A1	4.5	4.9	10.8	29
	B1	4.4	3.2	12.2	36
	B21	4.6	2.1	14.1	40
	B22	4.7	1.6	18.2	40
	B23	4.8	1.1	16.2	39
MAHALD RAM	A11	3.5	5.4	15.1	8
	A12	4.0	3.1	9.6	8
	B11	4.6	2.1	8.6	14
	B12	4.3	0.4	8.3	17
	BC	4.3	0.2	5.8	10
DHOBIJ HORA	A	4.7	4.8	23.8	27
	B1	4.6	2.9	24.4	31
	B21	4.9	1.3	20.4	31
	B22	4.9	0.9	24.4	31

* Cation exchange capacity in m.e. per 100 gm of organic carbon .
**Exchangeable cations in m.e. per 100 gm of organic carbon.

(Source : Author´s work)

As is seen from the table 2.3 , pH values generally increase in lower horizons . The organic carbon shows a decline at all the sites with increasing soil depth . At all the sites higher the pH more is the total exchangeable bases , namely , Ca_{++} , Mg^{++} , Na^{+} and K^{+} . This is also seen that the percentage of clay has increased with increasing depth on all the four sites .

2.7 SOIL FERTILITY :

Besides the factors of precipitation , solar radiation , topography , and soil parent material the soil has three modifiable intrinsic attributes , called together as soil fertility , namely , soil moisture , plant nutrient availability , and soil aeration which affect the growth of vegetation . In the study area , soil aeration and soil moisture are not a problem , the availability of plant nutrients being of paramount importance . The deficiency of plant nutrients produces symptoms and roots are able to respond more rapidly to changes in nutrient supply than shoots (Harrison , 1992) . Phosphorus and potassium are frequently deficient in humid regions (Rhodes et al , 1969) . In top soil 90 to 95 percent of total nitrogen occurs in form of organic compounds and the rest as nitrates and ammonium ions (Wild , 1988) . Nitrogen is an essential constituent of protein and protein like compounds which are at the seat of all life processes . Though there is some output of nitrogen in form of farm produce , there is net intake and , in case of forests , the output of nitrogen is only about one fifth of the total input (Kumar , 1981) . Phosphorus is a constituent of nucleus , plays an important part in cell division , acts as a catalyst in respiration though its deficiency is not as easily discernible from plant growth as that of nitrogen , and hence , is often overlooked . Potassium speeds up assimilation of carbon dioxide , facilitates the intake of water , and increases the utilisation of nitrogen and is important in formation and utilisation of sugars and starches in plants , synthesis of proteins and cell division . Its deficiency causes stunted root system and soft and sappy leaves .

The nutrient status of any soil in respect of major nutrients is judged by the following rating chart (Govt. of West Bengal , 1995) .

TABLE 2.4
RATING CHART OF MAJOR PLANT NUTRIENTS IN SOIL

Parameters	Low	Medium	High
Organic carbon (%)	< 0.5	0.5 - 0.75	> 0.75
Avail. nitrogen (%)	< 0.012	0.012 - 0.022	> 0.022
Avail. phosphorus (Kg/ha)	< 10	10 - 25	> 25
Avail potassium (Kg/ ha)	< 120	120 - 280	> 280

(Source : Govt. of West Bengal , 1995)

From the study area fifteen number of soil samples , well distributed over the entire area , were collected (Fig 2.3) . The results obtained from the nutrient analysis are presented in Table 2.5 .

TABLE 2.5
SOIL NUTRIENT STATUS IN THE STUDY AREA

Sample	Basin	Zone	Alti. mt	Land use	Av.N (%)	Av. P Kg/ha	Av.K Kg/ha
1	UB	UMZ	1590	Orchard	.069	10.65	78.26
2	UB	UZ	2220	Forest	.062	18.01	88.49
3	RM	LZ	980	Fallow agri.land	.043	5.32	92.26
4	RM	UMZ	1540	Tea garden	.039	10.05	241.54
5	RM	UZ	2370	Forest	.070	11.65	110.54
6	RM	LMZ	1200	Tea garden	.041	15.56	88.31
7	RM	UZ	1820	Tea garden	.042	18.36	97.60
8	PM	UZ	2330	Forest	.060	6.89	114.55
9	PM	LMZ	1370	Tea garden	.036	6.95	83.96
10	RN	UMZ	1900	Forest	.078	20.05	74.36
11	RN	UZ	2050	Forest - open	.041	14.05	65.07
12	RN	UMZ	1820	Forest - degraded	.039	12.36	74.36
13	RN	LZ	780	Tea garden	.049	9.28	153.28
14	GK	UMZ	1900	Tea garden	.078	21.36	83.66
15	GK	LMZ	1140	Tea garden	.079	10.29	110.54
Av.					.051	12.26	96.15

Basin : UB = Upper Balason ; RM = Rongmuk ; PM = Pachim ; RN = Rinchintong ; GK = Ghatta - Kumale .
Zone : UZ = Upper zone ; UMZ = Upper middle Zone ; LMZ = Lower middle zone ; LZ = Lower zone .

(Source : Author's own work)

As is revealed from the Table 2.5 , the soils of the study area are quite rich in available N , (0.051 percent). They are , thus , overflowing with N . All the samples collected from the forests , namely , sample no. 2 , 5 , 8 , 10 and 12 show high percentage of available N except sample no. 12 which has a value of 0.039 percent .This sample site was badly damaged because of political disturbances in hills during 1986 - 88 and is now devoid of any tree vegetation . The low value of available N could be on account of this degradation . Samples from tea gardens show lower values of nitrogen except sample no 14 and 15 which have available nitrogen to the level of that of forests . Sample no. 1 from orchard also shows a high value . All these three sample sites , namely , 1 , 14 and 15 are located on moister aspects (site 14 and 15 on north western and site 1 on north eastern) and this might be the reason for higher values on account of better moister conditions , especially on lower reaches , where temperatures are higher . Four samples , namely , no. 3 , 8 , 9 and 13 are deficient in available phosphorus . Poor phosphorus status of sample no. 8 is quite surprising as its nitrogen and potash status is one of the highest . The reason is the skeletal nature of soil or the parent material . The fallow lands (sample no. 3) are starving of phosphorus whereas , in general , forest areas are good in this regard. Nevertheless , the entire study area has a poor phosphate status (12.26 kg per ha). The deficiency in respect of potassium is really quite revealing . Except two samples (no. 4 and 13) collected from tea gardens , which barely qualify as having medium and low availability , respectively , all the other samples show a very strong deficiency of potassium . The average availability of potassium at 96.15 kg / ha reaches nowhere near 120 kg / ha of potassium which is the minimum for any soil to qualify as the one with low potassium as per the scale given in Table 2.4 . It is reported that higher the run off , higher is the loss of potassium from the soil (Kang et al , 1990) . High rain fall in the area coupled with high level of biotic interference and the nature of the parent material might be the cause of this . What is surprising is that no forest soil in the area is ever reaching anywhere near even the low status class of soils in respect of potassium availability .

Only the presence of adequate quantity of soil nutrients is not enough . Their availability is very important and is affected by several factors , one of the most important of which is soil pH .

2.8 SOIL pH AND CATION EXCHANGE CAPACITY :

The pH is closely connected with the availability of nutrients in the soil . The soils with low pH generally tend to have low availability of essential elements like , nitrogen , phosphorus , potassium , sulphur , magnesium , boron and molybdenum (Rajan & Rao , 1978) . Both , organic and inorganic acids , contribute to the acidity of the soil . For many purposes it is convenient to think of soil pH as the pH of a solution in the pores of a moist soil since this solution is in contact of the surface of roots and many chemical reactions in the soil are governed by this solution (Rowell , 1989) .The pH is the most important single property identifying the chemical character of the soil . Lower pH promotes hard pan in sub-soil , hinders absorption of basin ions , reduces efficiency of fertilizers , disperses clay and humus content of soil and reduces activity of micro-organisms . Soil pH along with moisture and total nitrogen in top soil accounts for 99.9 % variance in site index (Dury , et al , 1992) . Soil pH fundamentally influences phosphate reaction systems in soil (Kardos , 1976) . Generally speaking a soil with a pH below 5.5 may be regarded a potential carrier of soluble iron and aluminium unless the soil has high organic matter content which acts as buffer . Any sudden pH drop is to be looked on as danger signal indicating possible break down of buffer effect and hence a threat to the normal functioning of plants .

In the study area soils are acidic . Table 2.6 gives some of the chemical characteristics of the soils in the study area .

TABLE 2.6

CHEMICAL CHARACTERISTICS OF SOIL

Samp	Land use	pH	CEC *	OM (%)	OC (%)	C/N
1	Orchard	5.20	18.00	7.06	4.080	11.89
2	Forest	4.65	14.90	5.45	3.150	12.50
3	Fallow agri. land	4.70	10.00	2.29	1.320	11.57
4	Tea garden	4.25	10.20	3.01	1.740	11.22
5	Forest	5.00	15.20	5.87	3.390	11.37
6	Tea garden	4.65	10.10	2.18	1.260	12.85
7	Tea garden	4.90	11.40	2.70	1.560	12.18
8	Forest	4.80	12.40	4.26	2.460	11.03
9	Tea garden	4.55	7.40	2.85	1.650	10.44
10	Forest	4.80	17.20	8.31	4.800	11.85
11	Forest - open	4.90	10.60	3.22	1.860	11.77
12	Forest - degraded	4.95	13.00	4.73	2.730	11.09
13	Tea garden	5.05	11.70	3.89	2.250	11.36
14	Tea garden	4.70	17.70	9.09	5.250	12.09
15	Tea garden	4.70	11.00	3.43	1.980	11.31
AV		4.79	12.72	4.56	2.632	10.90

CEC * = Cation Exchange Capacity in m.e. per 100 gms of soil.
OM = Organic matter content of soil in percentage.
OC = Organic carbon content of soil in percentage .

As is seen from the Table 2.6 , the soils are having pH varying from 4.25 to 5.20 , the average being 4.79 . In a solution having pH below 5.5 iron and aluminium shall exist in soluble form and which is quite toxic to plants . If the soils in the study area are not toxic , are having productivity despite the pH being so low , it is because of the buffering action of soils on account of clay and most important , high organic content of the soils . It is seen that the pH of soil does not show any altitudinal variation in the study area and varies from place to place as per local conditions . It appears that parent material is having predominant influence on the pH value of the soils . The other important physicochemical property of the soils is its cation exchange capacity .

Although the mineral soils contain only a few percent of humus carbon , the humic substances have a very large influence on the cation exchange capacity of soils , often contributing half or more (Jenkinson , 1988) . The CEC is concerned with the capacity of the soil to exchange cations and describes a rather abstract idea - the negative charge density of soil - which is of interest in terms of nutrient holding power of soil (Mott , 1988) . It is seen from the Table 2.5 that CEC has higher value where organic content of the soil and pH values are higher . Humus becomes increasingly important as the seat of cation exchange as the pH of soil rises . For each unit increase in pH , the change in cation exchange capacity of organic matter is several times greater than that of clay . It follows from this that full benefit of liming of acid soils for improvement of pH could be harnessed only if the soils have higher organic carbon content .

2.9 SOIL INFILTRATION CAPACITY :

Infiltration is a complex process and refers to the penetration of water from the soil surface to lower layers and is governed by a multitude of factors , mainly associated with precipitation and the properties of soil including those arising out of land use (Gerrard , 1991 ; Michael et al 1981 ; Brechtel , 1979) . Properties of the soil affecting infiltration are initial soil moisture content , the amount of air carried by infiltrating water into the soil , the stability of soil aggregates and the proportion of psuedo - aggregates , volume of pore space of soil and ratio of non - capillary soil . Infiltrating water mostly moves through the non - capillary pore spaces but gradually an increasing amount of semi-capillary water held in the soil before the arrival of infiltration water , participates in overall movement of water. In a soil of low moisture content and high proportion of air in pore spaces , the infiltration water at first advances rapidly , causing the air to be displaced to lower levels . Gradually the air pressure builds up below the infiltration front , and if the air can not escape , the rate of infiltration decreases as the hydrostatic component of the water potential gradient decreases (Slack et al , 1990) . The infiltration front is not a plane but advances in tongue like projections according to the local heterogeneity of the soil (Kresl , 1984) . Cracks and channels left by dead roots and earthworms play an important part in infiltration process . In forest soils upper humus layer has the important effect of absorbing the energy of falling raindrops , and of preventing the formation of a continuous surface layer of water , thereby allowing the air in the soil to escape more easily and , thus , brings about more rapid infiltration in these soils than those under other vegetation . The situation is not quite the same , even if it be forest land , where litter and humus has been destroyed by logging operations , grazing , or burning and thereby mineral soil has been exposed (Lull et al , 1975) . Excessive biotic interference such as grazing , movement of heavy trucks and dumping effect of heavy logs , too , bring about soil compaction reducing initial infiltration rate by as much as 22 to 36 percent in comparison to that in the undisturbed forest areas (Ram & Patel ., 1993a ; Ram & Patel , 1992) . The amount , size and arrangement of pore space are also a function of soil texture , soil colloids and organic matter in it . Coarser the texture , higher is the infiltration rate (Shaw , 1983) . Higher the percentage of colloids after wetting , larger is the reduction of non - capillary pore space and lower the infiltration capacity (Hornbech et al , 1984 ; Payne , 1988 a) . The ground litter has more effect on infiltration rate than the main vegetation cover itself (Penman , 1963) .

The soil infiltration capacity was determined at all the fifteen sites where from soil samples were collected . Few other physical characteristics , too , have been assessed . The data is tabulated in Table 2.7 .

TABLE 2.7

CHEMICAL CHARACTERISTICS OF SOIL

Samp	Land use	IR *	SG **	PS (%)	WHC (%)	VE (%)
1	Orchard	2.4	1.91	58.86	59.04	16.64
2	Forest	8.2	2.01	59.49	60.85	24.63
3	Fallow agri.land	11.0	2.10	55.65	55.82	15.93
	Tea garden	1.6	2.16	57.12	58.99	18.09
5	Forest	8.4	1.96	60.66	64.97	15.90
6	Tea garden	2.4	2.01	54.55	58.39	17.47
7	Tea garden	8.0	1.97	56.22	60.41	18.58
8	Forest	6.4	2.02	55.17	62.04	16.40
9	Tea garden	4.0	1.89	51.23	53.46	14.68
10	Forest	7.8	1.92	58.86	48.46	18.07
11	Forest - open	3.6	2.14	59.19	61.66	15.39
12	Forest - degraded	1.8	2.00	59.01	59.40	26.69
13	Tea garden	2.1	1.91	51.45	55.45	26.55
14	Tea garden	8.8	1.98	59.38	61.51	18.38
15	Tea garden	2.2	2.13	58.63	62.87	24.22
AV		5.2	2.00	57.03	58.89	19.17

IR = Infiltration rate in cm per hour ; SG = Specific gravity of soil in gm per c.c.; PS = Pore space in percent ; WHC = Water holding capacity in percent ; VE = Volume expansion in percent .

(Source : Author's own work)

As is seen from Table 2.7 , the infiltration capacity of soils varies from 1.6 cm per hour to 11.0 cms per hour . The methodology used was to push a 15 cms dia and 45 cm long iron cylinder about 20 cm underground and filling the above ground part with water till brim . Water was allowed to percolate for 30 minutes and then the level of water in the cylinder was measured and the rate of infiltration per hour was calculated . The methodology varies from the standard techniques adopted where infiltrometer having double concentric cylinders of 30 cms and 60 cms dia , for inner and outer cylinders respectively

, and 60 cms height have been used (Yadav , 1976 ; Mathur et al , 1982 ; Soni et al , 1985 ; Vashisth , 1989) . The results , nevertheless , present a comparative account even if it does not represent the infiltration rates as would be obtained from the standard techniques .

The highest rate of 11 cm per hour has been seen 500 mt above the confluence point of Rongmuk and Upper Balason rivers . Generally speaking , sites in forest areas represented by no. 2 , 5 , 8 , 10 , 11 , and 12 have higher infiltration rates except on sites 11 and 12 (Dilaram and Sepoydhura) where forests are degraded and soils are greatly compacted . Some tea gardens , too , have very low infiltration rates . The other parameters shown are specific gravity , pore space (both capillary and non - capillary) , water holding capacity and volume expansion on wetting . Generally speaking , higher the volume expansion on wetting , lower is the infiltration rate except in sample no. 2 where infiltration rate appears to have been affected by tunnels made by macro soil organisms .

2.10 SOIL WATER HOLDING CAPACITY :

Infiltration capacity of soil alone is not enough to define the productivity of any soil . Its water holding capacity is also equally important . The waterholding capacity of soil is field capacity less the wilting point (Schwab et al , 1971) . The field capacity is the moisture content of the soil after it has been thoroughly wetted and sufficient time allowed for gravitational water to have flown down (Haise , 1969) . As is seen from Table 2.7 waterholding capacity of soil varies from 48.46 percent in Rinchintong upper middle zone to 64.97 percent in Rongmuk upper zone. It is seen that the degraded forest areas falling in the Rinchintong upper zone have the lowest water holding capacity whereas the highest waterholding capacity is met in the forests of Sechal (64.97 %) . It is thus seen that the forest , once degraded , present the worst soils in resect of moisture holding capacity . The sites falling in the tea gardens , too , have good moisture holding capacity - the best among the tea gardens being Ambootia (62.87 %) . Soil texture appears to playing dominant role in this regard .

2.11 SOIL ORGANIC MATTER :

The soil water holding capacity and a hoard of other physical and chemical properties of soil are affected by soil organic matter which is very important for productivity as well as non - erosivity of the soils . The soil organic matter is , no doubt , one of the most complex material existing in the nature (Mortensen , 1976) . In addition to the organic constituents present in the undecomposed plant and animal tissues , soil organic matter contains living and dead microbial cells , microbially synthesised compounds , and an endless array of derivatives of these materials produced as the result of microbial activity . Soil organic matter probably contains most , if not all , of the naturally occurring organic compounds . Some components of soil organic matter are distinctive to the soil environment particularly those involving inorganic - organic complexes . The organic matter also includes ephemeral products arising out of decomposition of plant and animal tissues , on one hand , and fairly stable ` humus ´ on the other .

Humus is a resistant brown or black organic complex resulting from degradation of raw organic deposits and includes microbial cells and other resistant products of metabolism (Stevenson , 1976) . The decomposition of organic deposits is positively correlated with rainfall and in monoculture plantation the rates are lower despite heavy rainfall (Swamy , 1992) . The rate of decomposition of litter and release of nutrients also depends on its chemical composition (Gupta et al , 1991) . During decomposition , the pH of the soil is lowered and the rate can be enhanced by applying lime (Das et al , 1989) .

The humus fraction , in effect , acts as a reservoir for elements essential for organic life and acts as exchange and catalytic agent . Organic matter increases the water holding capacity and makes it easier for water to soak into the heavier soils like loams , silt loams and clays (Boswell et al , 1969) . Organic matter shows a strong increase with increase in altitude in eastern Himalayas (Dutta et al , 1989).

Table 2.6 shows the organic matter present in the soil of the study area . True to the generalisation available in the literature C \ N ratio falls within 10.40 and 12.85 , the average being 10.90 . The highest C \ N ratio is encountered in Rongmuk tea garden . The organic matter varies from 2.18 percent in Rongmuk to 9.09 percent in Springside tea garden lying on north western slope . The average organic matter content is 4.56 percent . Despite such variability of organic matter content , the C \ N ratio is fairly constant . The C \ N ratio of the study area is indicative that the process of humification is fairly advanced . The distribution of organic matter in the study area does not follow any zonation on the basis of altitude probably on account of severe biotic interference in the forest areas and other fallow or waste lands and also due to intensive management of soils in tea gardens with specific requirement of tea production .

CONCLUSION :

Thus it is seen that five soil types are identifiable in the study area . Moderately deep dark grey sandy loam soils are located on the upper reaches all along the brim of the Balason basin . The lower-most reaches consist of skeletal sandy soils with pebbles and rock outcrops . These are mostly waste lands . Moister northern and southern parts , contain shallow dark brownish clayey loam soils whereas very deep yellowish clayey loam soils are met on the colluvial deposits on the southern part . The extensive tract of very deep yellowish silty loam soils is located on piedmont slopes between 1000 mt and 2000 mt contour lines . Soil formation in the study area varies greately . Soils are endodynamomorphic on south-western and extreme south-eastern parts . Lower middle and upper middle zones of basins have well formed ectodynamomorphic soils . High rainfall has produced podzolic soils . Survey done shows that distribution of earthworms follows a highly erratic pattern . Contrary to clains in literature , earthworms are aplenty in Darjeeling Himalayas . Investigation reveals several textural classes . Those identified are loamy sand and fine silty loam on eastern side , sandy loam and gravelly clay loam on north and north-western side , clayey loam on southern-most side and gravelly sandy loam , gravelly sand and pure sand with pleistocene boulders in the central part . Crumby spheroidal soil structure is seen under forest vegetation which turns granular in degraded areas . Sub-angular blocky structure is seen in some tea gardens . Laminar soil structures are met in areas subjected to acute biotic intergference . Four number of soil profiles were exposed . The horizons in all the sites are well differentiated indicating mature soils . Some ferrugenous concretions were seen . Soil fertility tests carried out show abundance of nitrogen , moderate availability of phosphorus , and very severe scarcity of potassium . Soils are highly acidic , their productivity being maintained , due to buffer action of organic matter . Cation exchange capacity is higher wherever organic carbon and pH are higher .Infiltration capacity of forest soils is higher . Some tea gardens are seen having very low infiltration values . Water holding capacity of soils show wide variation . Forests have high value , but once degraded , they are worst in respect of water holding capacity . Soils are rich in organic matter . Average C / N ratio shows fairly advanced humification of soils . Distribution of organic matter does not follow any altitudinal zonation .

Through close interaction with factors of climate and geology , soil have profound impact on various morphometric features. The study area is located in the hills of Darjeeling Himalayas and has various types of landforms and drainage systems. All these are most important for studying the problems of soil erosion and these can be studied in detail in the next chapter.

CHAPTER III

MORPHOMETRIC ANALYSIS OF RELIEF AND DRAINAGE AND THEIR RELATIONSHIPS WITH SOIL EROSION

INTRODUCTION :

This chapter deals with analysis of various , morphological features and those discussed in detail are profile , drainage patterns, drainage density , drainage order , drainage frequency , number and lengths of streams , bifurcation ratio , stream length ratio , sinuosity among the drainage characteristics and cross and composite profiles . Ruggedness , slope zones , relative relief , hypsometric analysis related to the slope and relief characteristics are also discussed here .

3.1 DRAINAGE LONG PROFILE :

The long profiles of all the five rivers in the study area have been calculated and tabulated in he table 3.1 . The cross profile data has also been plotted in Fig 3.1. The general slope of the rivers , with exception of Rinchintong , goes on reducing . Overall gradient of Ghatta - Hussain , Pachim ,

LONG PROFILE

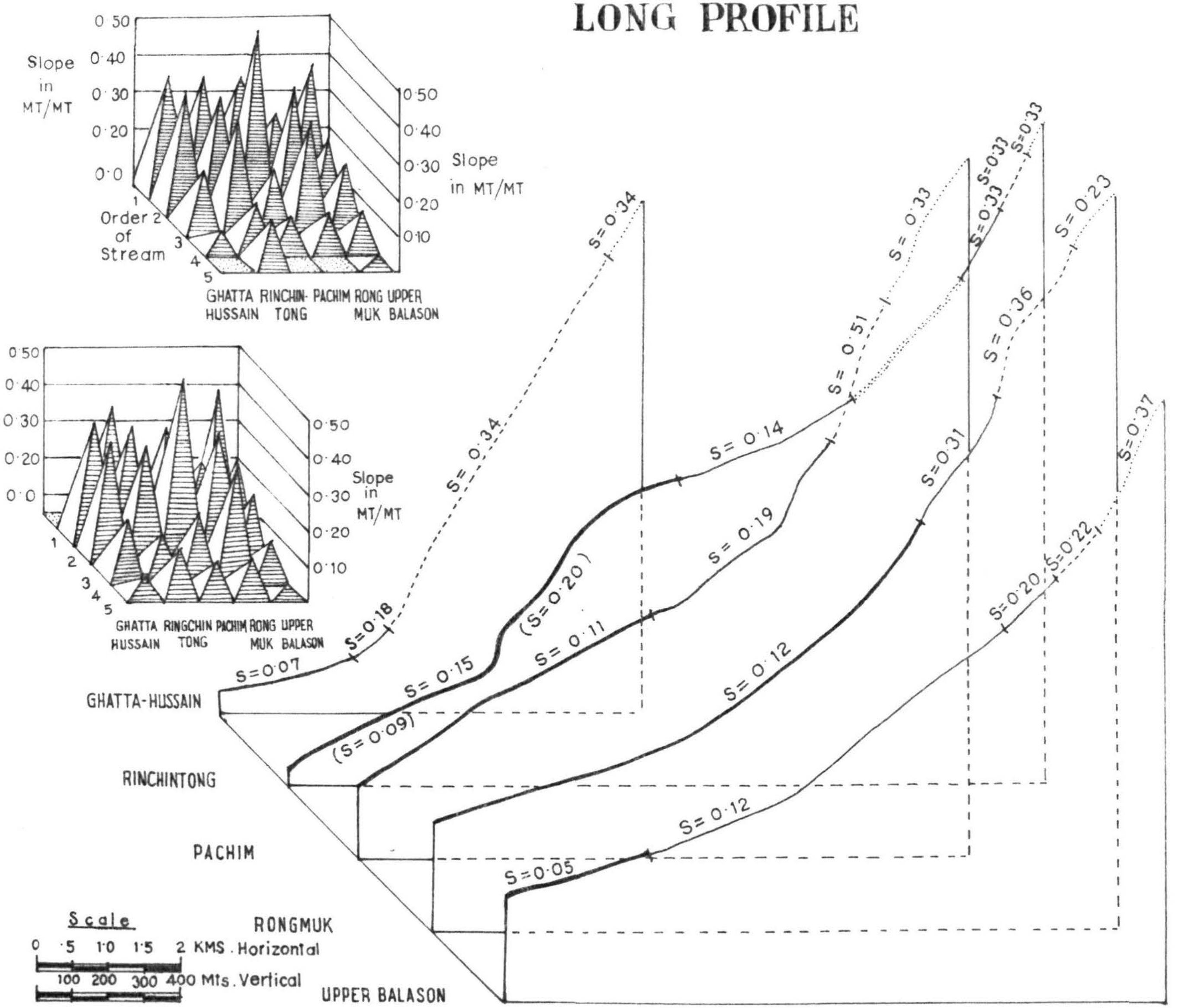


Fig. 3·1

Rongmuk and the Upper Balason rivers are , respectively , 0.22 ,0.20 , 0.18 and 0.15 mt per mt (Fig 3.1) .

The only exception is the Rinchintong river which has an over all gradient of 0.17 mt per mt whereas the ghatta - Hussain located down below adjacent to it has an overall gradient of 0.22 mt per mt and the Pachim , located higher up next to it , has 0.20 mt per mt .

TABLE 3.1

LONG PROFILE OF STREAMS

STAT	GT-HSN		RNCHNTONG		PACHIM		RONGMUK		U.BLSON	
	DIST MT	ALT MT	DIST MT	ALT MT	DIST MT	ALT MT	DIST MT	ALT MT	DIST MT	ALT MT
1	0	550	0	550	0	700	0	800	0	800
2	1200	600	950	600	750	800	1900	900	1900	900
3	2350	700	1400	700	1500	900	3200	1000	3300	1000
4	2650	800	2800	800	2500	1000	4200	1100	4300	1100
5	2850	900	2900	900	3350	1100	4850	1200	4800	1200
6	3100	1000	3400	1000	4500	1200	5500	1300	5500	1300
7	3400	1100	3750	1100	4950	1300	6000	1400	6150	1400
8	3750	1200	4050	1200	5800	1400	6450	1500	6900	1500
9	4000	1300	4950	1300	6100	1500	6750	1600	7450	1600
10	4350	1400	6500	1400	6400	1600	7150	1700	8000	1700
11	4600	1500	7500	1500	6650	1700	7600	1800	8350	1800
12	4900	1600	8100	1600	6850	1800	7800	1900	8650	1900
13	5250	1700	8600	1700	7050	1900	8000	2000	8850	2000
14	5600	1800	9150	1800	7250	2000	8150	2100	9100	2100
15	5900	1875	9500	1900	7550	2100	8600	2200	9250	2150
16			9850	2000	7800	2200	8900	2300		
17			10150	2100	8100	2300	9200	2400		
18			10400	2200	8500	2400	9600	2500		
19			10600	2300						
GRADIENT	.22%		.17%		.20%		.18%		.15%	

GT-HSN = Ghatta - Hussain basin ; RNCHNTONG = Rinchintong basin ; DIST = Distance from mouth of the river ; ALT = Altitude above msl .

(Source : Author´s own calculation)

A closer look at the long profile of the Rinchintong river shows that approximately top 50 percent of the river is much more flatter than the corresponding sections of the other rivers in the study area . There is sudden rise in the level of the river after it has traversed about 25 percent of its course from its mouth . At this point the river takes a turn almost at right angle and starts rising suddenly and covers its next 25 percent of the course in this steeply rising fashion . The course of the river tapers down at about 50 percent point of its traverse which is located a little below the factory of the Dilaram tea estate . It is precisely this point where from the water of the Rinchintong river has been tapped by the Department of Electricity , Govt. of West Bengal for the Phasi Hydroelectric project . Beyond this point the flatter section of the Rinchintong river begins. Here the tea factory and the various establishments of Dilaram tea estate are located . In flatter section, the average velocity of the flow is much lower . Hydraulic radius of the river is much higher and size of the boulders in the bed much smaller .

The Table 3.2 gives the length of all the five rivers in different orders in the study area. Profiles of lognest drainage have been drawn to compare their lengths (Fig. 3.1). There are some striking features which need mention.

TABLE 3.2

LENGTH OF STREAMS

OR	LENGTH OF STREAMS IN KMS				
	GT	RN	PM	RM	UB
1	0.5	0.2	1.1	0.6	0.9
2	3.0	0.5	0.9	1.1	0.6
3	0.5	0.6	2.5	1.1	0.7
4	1.9	4.0	4.1	6.8	5.0
5	0	5.4	0	0	2.1
TO	5.9	10.6	8.5	9.6	9.3

OR = Order of streams ; GT = Ghatta - Hussain ; RN = Rinchintong ; PM = Pachim ; RM = Rongmuk ; UB = Upper Balason ; TO = Total

(Source : Author´s own calculation)

One striking feature to be mentioned is the extremely long section of the river Ghatta - Hussain falling in the second order . The entire length of the river is 5.9 km . Out of this, 3 km is represented by the second order stream . This indicates a very strong tendency to flow parallel and thus making relatively longer sections of lower order streams . The other striking feature in this regard is very long section of the river Rongmuk representing the highest order of the stream in the basin . It is seen that out of a total length of 9.6 km of the main drainage line , 6.8 km (71 percent of the entire length of the main drainage line) is of 4th order. This indicates strong tendency among the tributaries to run parallel to one another and meet the main channel directly and , probably , relatively longish shape of the drainage basin . This will definitely be reflected in the bifurcation ratio of the stream . This will also have effect on the shape of the hydrograph and peak will be less pronounced , comparatively speaking .

Table 3.3 represents the gradients of the various sections of all the five streams arranged in accordance with their orders . The data has been scribbled at the body of the individuals profiles too (Fig 3.1).

TABLE 3.3

SLOPES OF DIFFERENT ORDERS OF STREAMS

ORDER	SLOPE IN MT PER MT				
	GT	RN	PM	RM	UB
1	0.34	0.33	0.33	0.23	0.37
2	0.34	0.33	0.51	0.36	0.22
3	0.18	0.33	0.19	0.31	0.20
4	0.07	0.14	0.11	0.12	0.12
5	NE	0.15	NE	NE	0.05

(Source : Author's own calculation)

section Ghatta - Hussain has the highest overall gradient (0.22 mt per mt) . This implies that the action of the eroding agents will be most intense in this section of the river resulting in bank cutting , slides , rockfall and bebris flow . In fact , the Hussain Khola which passes almost touching the northern periphery of the Kurseong town is one of the most turbulent streams in the area . Major parts of its reaches , specially the lower reaches around the Ambootia Tea Garden , has lots of rock slides and huge scale of bank cutting.

The second interesting feature of the highest order streams is the steepest slope of the Rinchintong river (0.15 mt per mt) . It is seen that the upper half of the Rinchintong river is the flattest amongst the corresponding sections of other rivers . The Fig. 3.1 and the inset diagram , too , show the abrupt fall of the river gradient as the river descends from 4th to 5th order . The nature of the gradients of various sections of the Rinchintong river shows occurrence of harder and stiffer rocks along its course between 2500 mt and 4000 mt from its mouth . These rocks are much more resistant towards various eroding agencies than their counterparts either in the upper or in the lower reaches of the stream . The steep gradient coupled with the 5th order of the stream makes this zone most active so far as the river activities in the study area are concerned . If one takes a closer look in the corresponding parts of the other streams of the study area , one wonders why such stiff and resistant rocks are not present in the other rivers . One also wonders if these stiff rocks are only localised . If that be so , the possibility of the Rinchintong river changing its course in times to come can not be ruled out . The sharp right angle turn of the river at distance about 3000 mt from its mouth indicates that the river has changed its course in the past . If Rinchintong river finds more erodible rocks in its process of development , it may change its course violently affecting the flatter terrain on the upstream side and , simultaneously , bringing about very severe erosion in the area .

The third interesting feature is the uniformity with which the gradient of the river Upper Balason river decreases from the 1st to the 5th order. As is seen from Fig. 3.1 the inset diagram ,the gradient of this river is 0.31 , 0.22 , 0.12 and 0.05 mt per mt for 1st to 5th order streams in the same sequence . This shows the relative maturity of the river Upper Balason . The uniform degradation also indicates that its basin is constituted by rocks having more or less similar resistance to erosion .

The fourth interesting point about the gradients of the rivers is the highest ever gradient in the study area (0.51 mt per mt) occurring in the river Pachim in its section constituting the second order stream . This is also very well brought out by the inset diagram of Fig.3.1 . This gradient towers above all , This region is about 6500 mt from the mouth of the river and stretches for about 1000 mt . It stretches from Gorabari to Sonada bazaar. The terrain in this part , is charcterised by the steepness of the huge rock outcrops having very little or no vegetation along with huge engineering structures constructed to support the rocks on the uphill side of the road . This part would have been the toughest to negotiate while constructing the road . This area is very prone to rock slides . In fact wherever some flattish ground is available along the Hill Cart road , one hardly ever fails to come across the human settlements . But this is not so in this stretch . The absence of human habitation in this stretch is a proof of the long standing notoriety of this region as rock fall or rock slide zone .

The fifth interesting feature is encountered in the Rongmuk river where second order stream has a gradient of 0.36 mt per mt as against 0.23 and 0.31 mt per mt for 1st and 3rd order streams respectively . This region is encountered about 1000 mt from the top of the river Rongmuk. Near Banglakhola PHE station on Hill Cart road, the stiff rock outcrops along with huge sized boulders are also discernible in the course of the stream .

An attempt has also been made to calculate the percentage long profiles of the rivers . The result has been tabulated in Tables 3.4 and 3.5 . The result has also been plotted in the Fig. 3.2 and the inset diagram in that figure .

Upper Balason and the Rongmuk show more or less same stage of degradation of their courses . The Pachim river shows that its upper reaches are as developed as those of Upper Balason and Rongmuk whereas in the lower reaches , comparatively speaking , still some degradation has to take place to reach the same stage of the development as that of Upper Balason and Rongmuk . The Rinchintong and the Ghatta - Hussain rivers are still young . It is also clear that Ghatta - Hussain river passes through

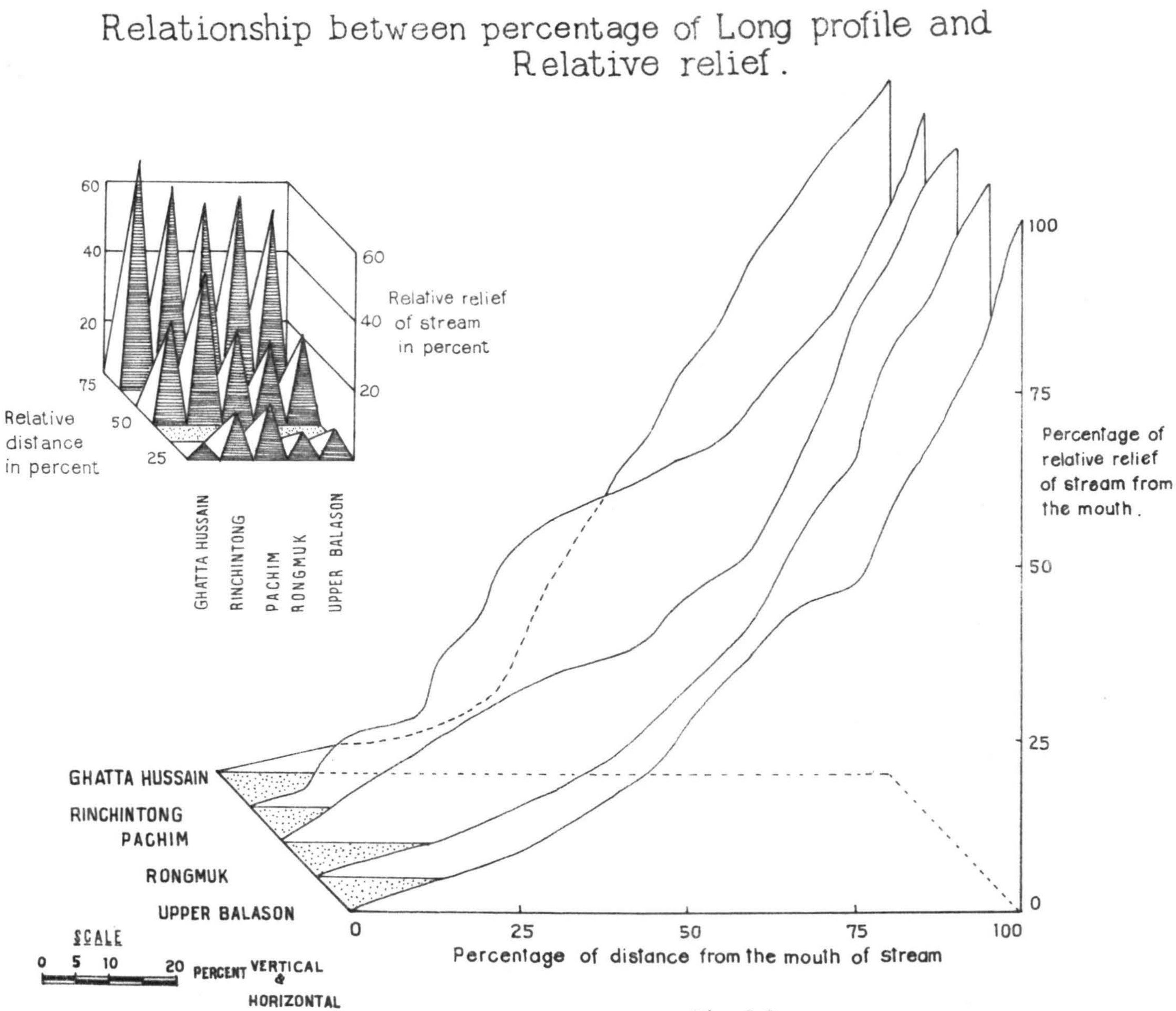

Relationship between percentage of Long profile and Relative relief.
60
40
20
75
50
25
Relative distance in percent
60
Relative relief
40 of stream
in percent
20
GHATTA HUSSAIN
RINCHINTONG
PACHIM
RONGMUK
UPPER BALASON
100
75
50
25
0
Percentage of relative relief of stream from the mouth.
GHATTA HUSSAIN
RINCHINTONG
PACHIM
RONGMUK
UPPER BALASON
0
25
50
75
100
Percentage of distance from the mouth of stream
SCALE
0 5 10 20 PERCENT VERTICAL & HORIZONTAL

Fig. 3·2 .

rocks having uniform resistance through out its upper reaches . In case of Rinchintong river upper and lower reaches are passing through softer rocks whereas the middle reaches consist of stiffer rocks . This is also very clearly brought out by the figure (Fig. 3.2).

TABLE 3.4

RELATIVE LONG PROFILE OF STREAMS

STAT	GT-HSN		RNCHNTONG		PACHIM		RONGMUK		U.BLSON	
	DIST %	ALT %	DIST %	ALT %	DIST %	ALT %	DIST %	ALT %	DIST %	ALT %
1	0	0	0	0	0	0	0	0	0	0
2	20	4	9	3	9	6	20	6	21	7
3	40	11	13	9	18	12	33	12	36	15
4	45	19	26	14	29	18	44	18	46	22
5	48	26	27	20	39	24	51	24	52	30
6	53	34	32	26	53	29	57	59	59	37
7	58	42	35	31	58	35	63	35	66	44
8	64	49	38	37	68	41	67	41	75	52
9	68	57	47	43	72	47	70	47	81	59
10	74	64	61	49	75	53	74	53	86	67
11	78	72	71	54	78	59	79	59	90	74
12	83	79	76	60	81	65	81	65	94	81
13	89	87	81	66	83	71	83	71	96	89
14	95	94	86	71	85	76	85	76	98	96
15	100	100	90	77	89	82	90	82	100	100
16	-	-	93	83	92	88	93	88	-	-
17	-	-	96	89	95	94	96	94	-	-
18	-	-	98	94	100	100	100	100	-	-
19	-	-	100	100	-	-	-	-		

GT-HSN = Ghatta - Hussain basin ; RNCHNTONG = Rinchintong basin ; DIST = Distance from mouth of the river in percentage of total traverse ; ALT = Altitude in percentage of total fall of the river from its topmost point to mouth .

(Source : Author´s own calculation)

At point of 50 percent distance from the mouth , its towering over others is noteworthy .

TABLE 3.5

COMPARATIVE RELATIVE LONG PROFILES

Distance * %	RELATIVE ALTITUDE GT %	RN %	PM %	RM %	UB %
25	5	14	16	8	9
50	30	44	28	24	26
75	66	58	53	56	52

GT = Ghatta Hussain ; RN = Rinchintong ; PM = Pachim ; RM = Rongmuk ; UB = Upper Balason ; * = distance from mouth .

(Source: Author´s own calculation)

Besides the drainage long profiles , drainage density is another important characteristics discussed next .

3.2 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 weaknesses 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 al , 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 varry as widely as 5 - 100 percent (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.

The drainage density in the study area varies from 2.0 to 6.5 km\ sq km (Fig 3.3) . The areas of highest drainage density are located between Dilaram and Gorabari (approx 3 sq km) , about one km north of Tung (approx. 1 sq km) , around Tiger Hill (approx. half sq km) , around Rogbull (approx. half sq km) and in Phulbari tea garden about 3 km south west of Gorabari . These areas shall be having flashy nature of flows and any soil eroded shall , in likelihood , find its way down stream to the active stream . The areas which have drainage density less than 2 are located in southern most tip of the study area along the ridges . Almost entire Ambootia tea garden , a major chunk of Single tea estate and Tomsong , Dooteria , Pussimbing and Simrik tea estates are located on areas having drainage densities 2.0 to 3.5 . This shows that in these localities the soil mantle

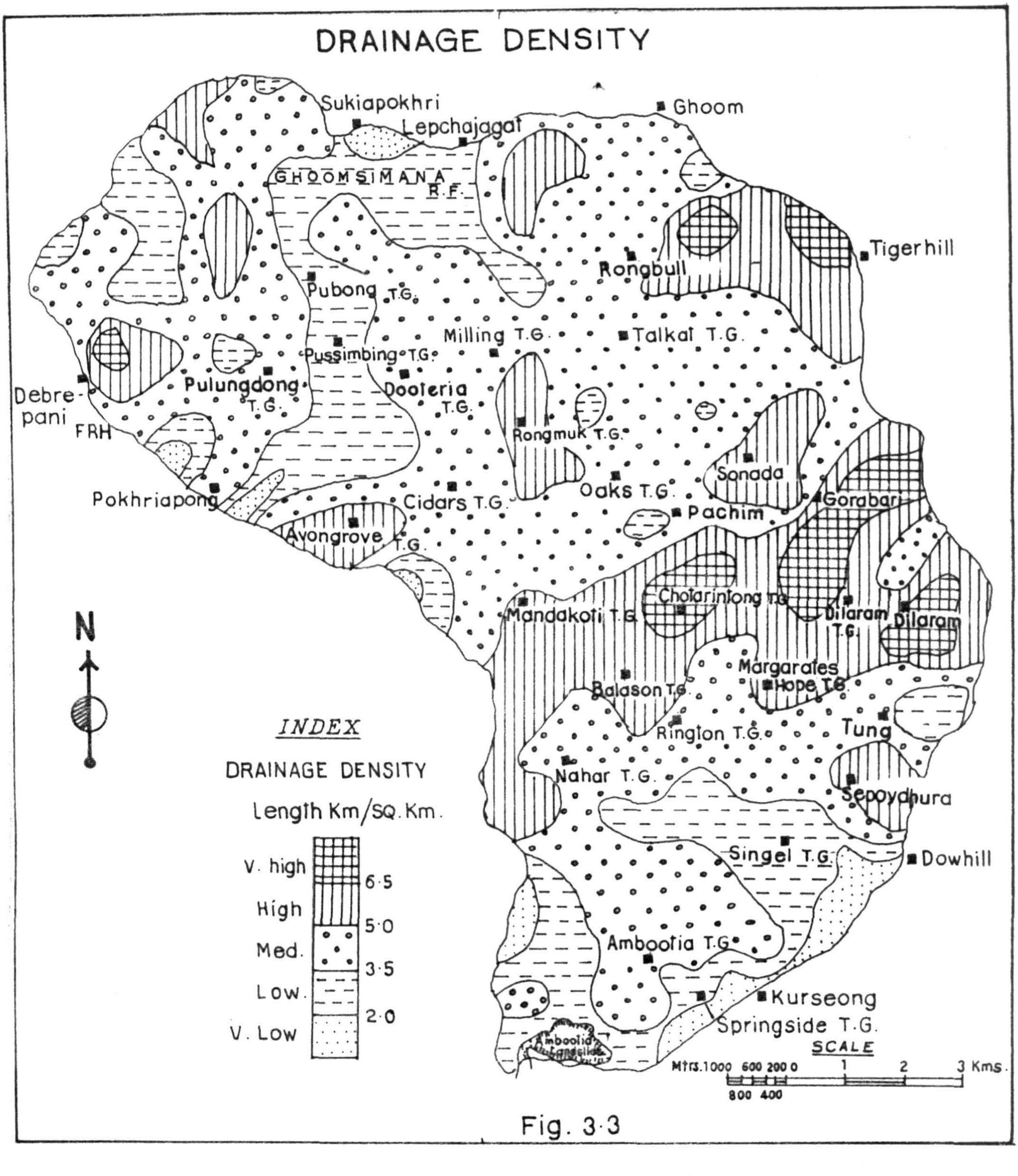

DRAINAGE DENSITY
Sukiapokhri
Lepchajagat
Ghoom
GHOOMSIMANA R.F.
Tigerhill
Rongbull
Pubong T.G.
Milling T.G.
Talkai T.G.
Pussimbing T.G.
Pulungdong T.G.
Dooteria T.G.
Debrepani FRH
Rongmuk T.G.
Sonada
Oaks T.G.
Pokhriapong
Cidars T.G.
Pachim
Gorabari
Avongrove T.G.
Chotarintong T.G.
Mandakoti T.G.
Dilaram T.G.
Dilaram
N
Margarates Hope T.G.
Balason T.G.
Rington T.G.
Tung
INDEX
DRAINAGE DENSITY
Length Km/SQ.Km.
V. high
6.5
High
5.0
Med.
3.5
Low.
2.0
V. Low
Nahar T.G.
Sepoydhura
Singel T.G.
Dowhill
Ambootia T.G.
Kurseong
Springside T.G.
Ambootia Landslide
SCALE
Mtrs.1000 600 200 0 1 2 3 Kms.
800 400

Fig. 3·3

is quite permeable and , hence , probability of occurrence of landslides and rockslides shall be higher . It is seen that very high drainage density (above 5.5) is found in Upper Rinchintong , lower middle Pachim , and upper Rongmuk (Fig 3.4). Classification of zones based on weighted average shows very low drainage density (less than 3.5) in upper middle and lower middle zones of Ghatta-Hussain. Lower zones of Ghatta - Hussain and Rinchintong as well as entire Upper Balason basin have low drainage density (between 3.5 to 4.5) . The low drainage density of Upper Balason basin is quite revealing and shows that the soil mantle in this zone is quite permeable , which , combined with steep slopes in the area , makes it quite prone to landslides and rockfalls . This is probably one of the reasons of the least developed road net work here .

3.3 DRAINAGE ORDER :

Besides drainage density, the other characteristics which is of great value for understanding the drainage is the drainage order .The recognition of a hierarchy of stream segments is important because of different morphometric and hydrological features associated with each one of them . Stream ordering compares streams in within the basin (Hornbeck , 1984) . The most widely used ordering scheme (Strahler's scheme) was adopted despite some shortcomings .

Classification of zones basis on weighted drainage density

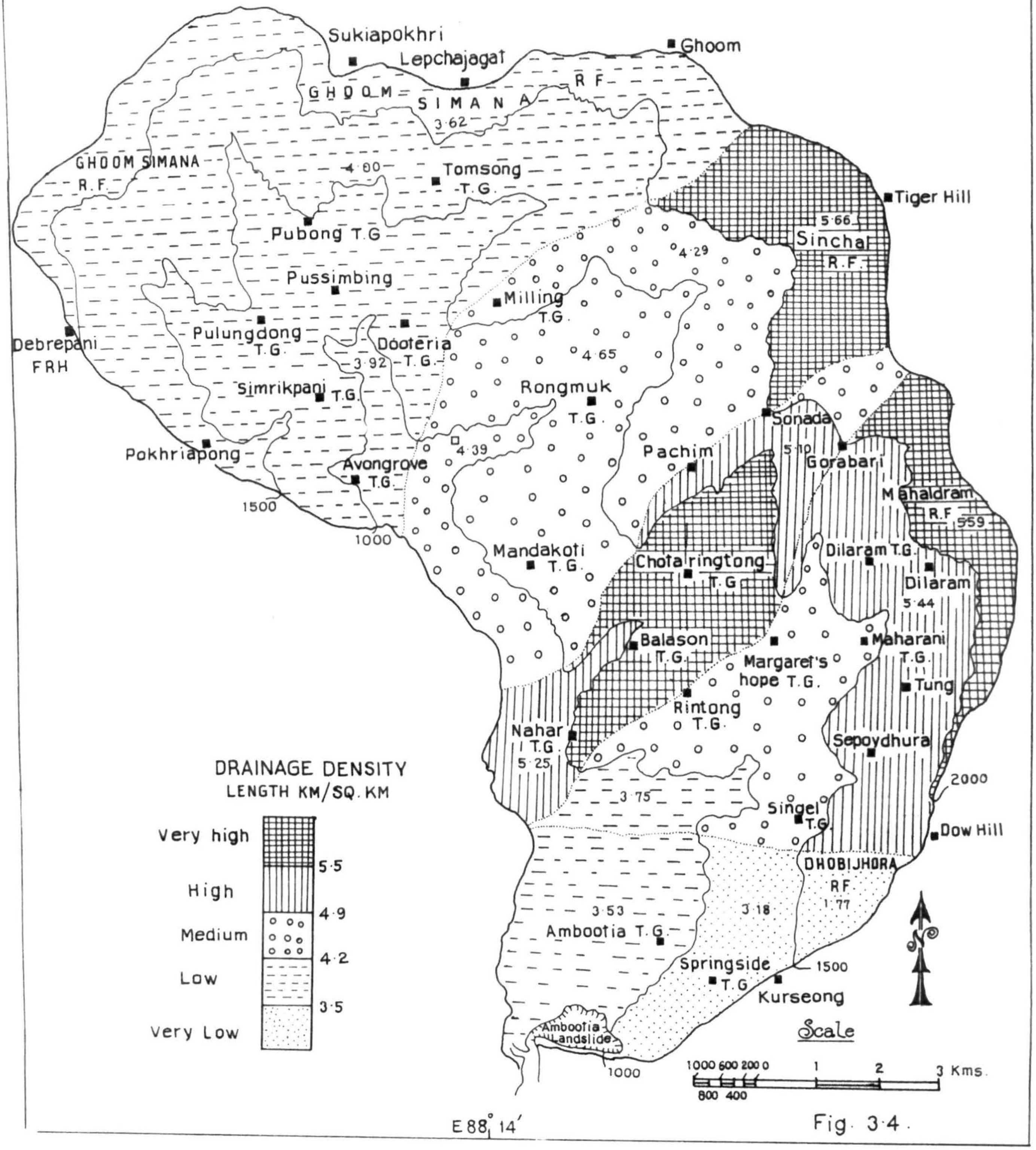


Fig. 3·4.

The streams in the study area have been delineated from satellite imagery dated 26th January , 1996 . It is seen that the highest order met within the area is 6 - this section lying south of the confluence point of Rincintong with Balason river (Fig 3.5) . In Upper Balason and Rinchintong and Upper Balason the highest order is 5 whereas that in Rongmuk , Pachim and Ghatta - Hussain is 4 . In case of Rinchintong the 5th order stream section stretches from near the Dilaram tea estate factory down to its mouth . The length of 5th order section of this stream is spectacular . The Rongmuk basin , despite having an area of 3675 ha (compared to 2825 ha of Rinchintong) could not produce a stream of order 5 basically on account of parallel drainage pattern on both of its banks . Both , dry and rainy season discharge of Rongmuk , prima facie , appears much higher than that of Rinchintong despite the order being lower . This is one anomaly that the Strahler system of ordering of streams brings about . It makes comparison of discharge of streams quite difficult , especially in quantitative terms , even among streams located within the same drainage unit . This is particularly so if the patterns of drainage of various streams are at variance . A parameter , combining the drainage ordering as done by the Strahler system and the drainage pattern , could probably reflect the hierarchy of streams more truly . A similar situation is seen in Ghatta - Kumale basin area where drainage lines of first and second orders show a strong tendency to run parallel to each other . Here , too , the stream order does not reflect the exact hierarchy among all the rivers in the basin .

DRAINAGE
(Based on satellite imagery, 26th January, 1996.

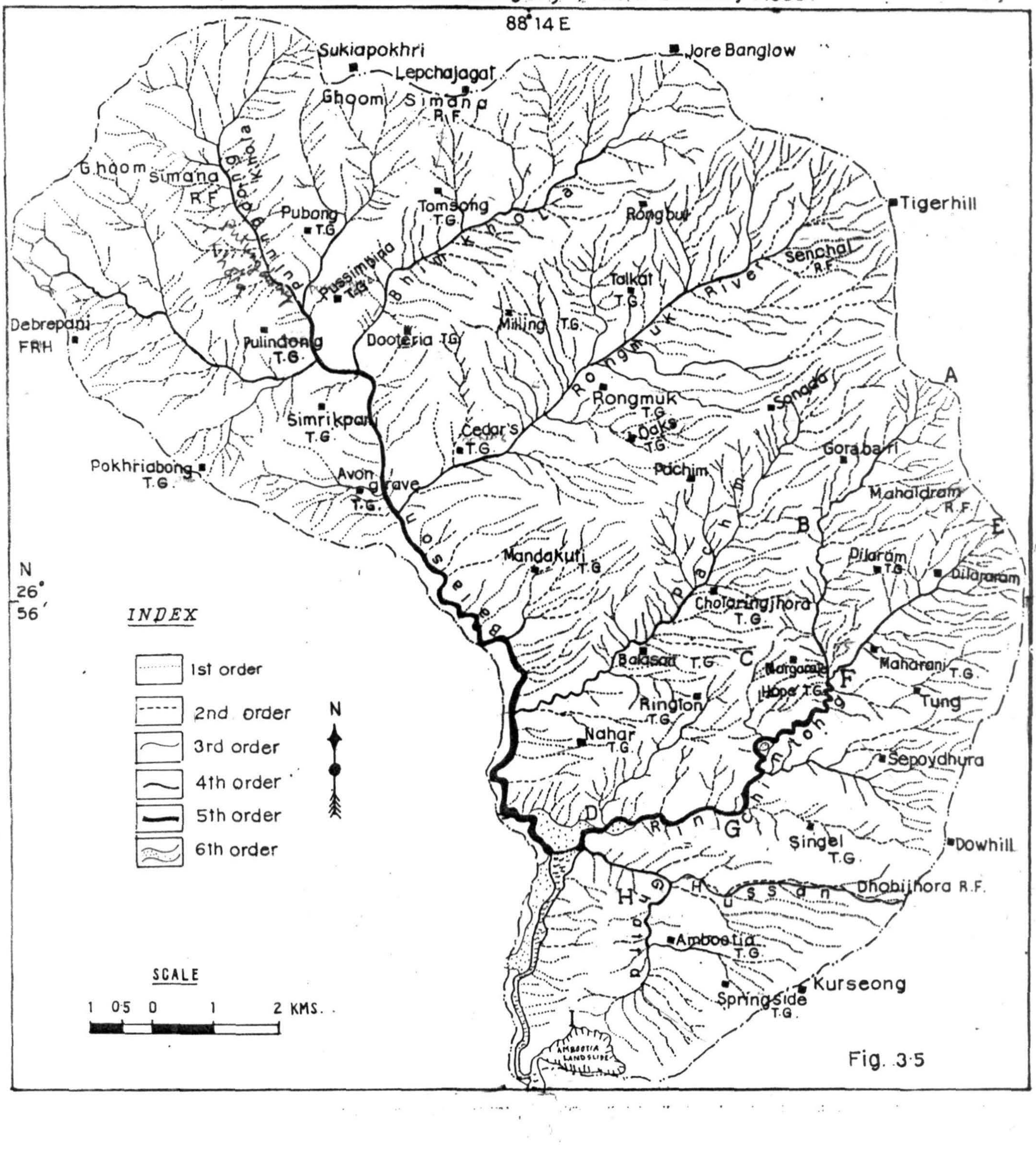


Fig. 3·5

Drainage order , by and large , gives a qualitative description of the drainage sections . The important drainage characteristics which is quantifiable to a large extent for describing a basin is the drainage frequency which is most important for determining the terrain characters .

3.4 DRAINAGE FREQUENCY :

The drainage frequency of any particular area is defined as the number of streams per unit area . The drainage frequency has been studied in the sequence of order of streams . Besides the number of streams , their lengths , too , have been subjected to analysis .

3.4.1 TOTAL NUMBER OF STREAMS :

The five river basins in the study area present some interesting features in respect of the number of streams . The number of streams of different orders in the five different basins is dependent on shape and size of the basins . Nevertheless , they provide some insight into the drainage pattern , nature of rocks , etc. of basins . The table 3.6 gives the number of streams of different order in the five river basins of the study area (Fig.3·6).

Numbers of streams in different Basins.

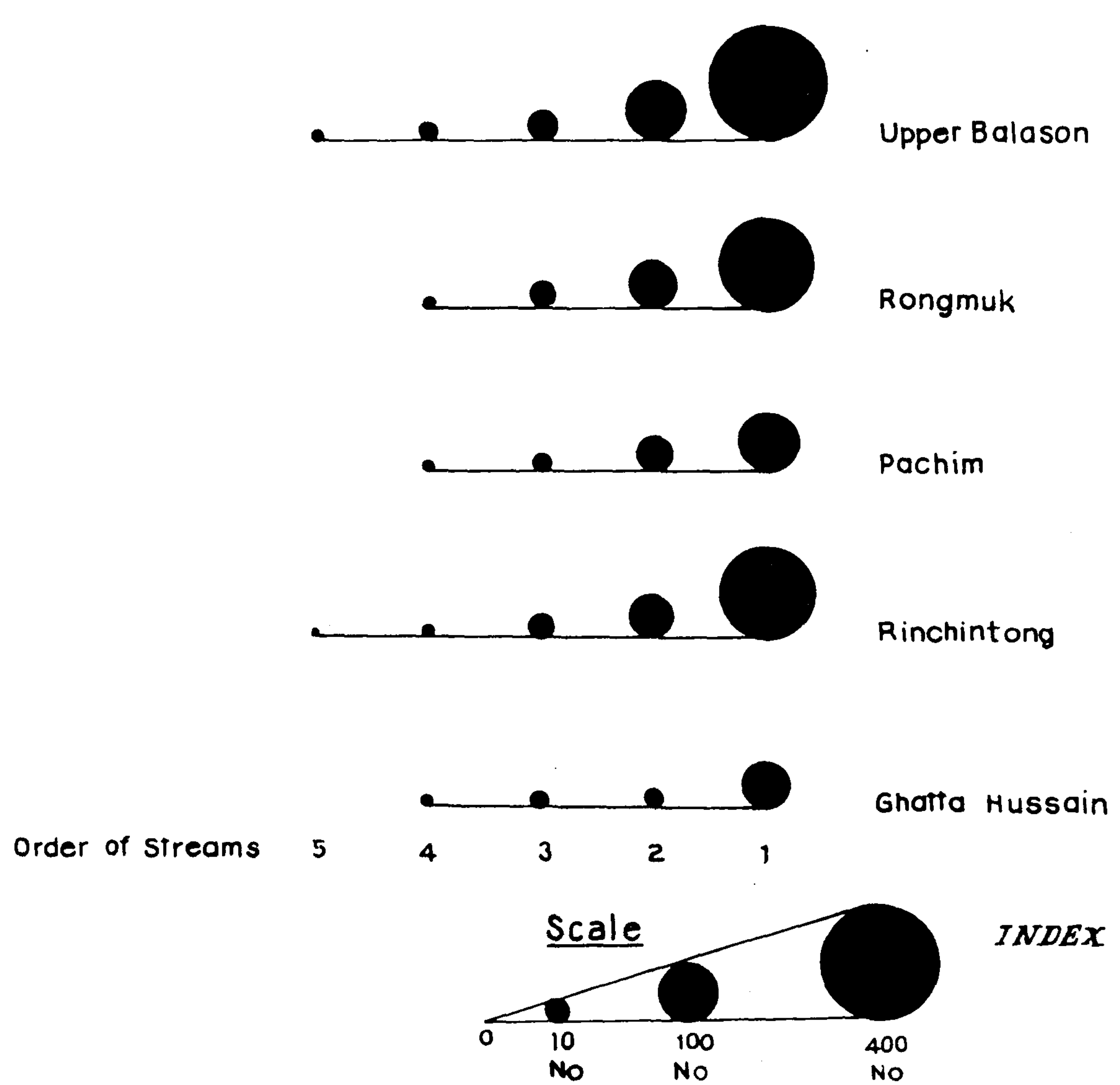


Fig. 3·6.

TABLE 3.6

NUMBER OF STREAMS IN THE BASINS

Order	Ghatta Jhora	Rinchinto-ng Jhora	Pachim Jhora	Rongmuk Jhora	U. Balason Jhora
	Number of streams				
1	59	204	101	186	330
2	10	50	28	45	71
3	3	10	6	11	15
4	1	3	1	1	4
5	0	1	0	0	1
Total	73	268	136	244	421

(Source : Author's own calculation

As is seen , the number of streams of all orders in the Ghatta jhora are spectacularly small . It can be seen that despite having an area a bit more than the Pachim Jhora , the number of streams in the Ghatta Jhora is almost as less as half . This fact very clearly shows that the area drained by the Ghatta Jhora is much more permeable than the Pachim Jhora, though the quantum and the intensity of the rain fall is the same in the two basins because of their proximity. So, sub-surface flows of the precipitation is much higher in Ghatta than that in Pachim . Again Rinchintong has an area of 28.25 sq km and that of the Rongmuk is 36.75 sq km - but the number of the first order streams in the former is about 10 percent more than in the latter . In respect of the total number of streams also , the Rongmuk Jhora is behind the Rinchintong despite having thirty percent more area . This shows that the terrain of the Rinchintong basin are much less permeable than those in the Rongmuk and , therefore , number of streams are much less in the latter .

It will again be quite revealing if one extrapolates the findings in the table 3.6 to a situation where each one of the basins is having total drainage area of 1000 ha . The reduction factor for the number of streams in the study area will be 0.58 , 0.35 , 0.63, 0.27 and 0.18 for Ghatta , Rinchintong , Pachim ,Rongmuk and Upper Balason respectively .

TABLE 3.7

NUMBER OF STREAMS PER 1000 HA IN THE BASINS (N)

Order	Ghatta	Rinchint-ong	Pachim	Rongmuk	U.Balas-on
			Number of streams		
1	34.22	71.40	63.63	50.22	59.04
2	5.80	17.50	17.64	12.15	12.78
3	1.74	3.50	3.78	2.97	2.70
4	0.58	1.05	0.63	0.27	0.72
5	0.00	0.35	0.00	0.00	0.18
Total	42.34	93.80	85.68	65.91	75.42

(Source : Author´s own calculation)

Very clearly , Rinchintong and Pachim form a distinct class with very high number of streams in the basin and also in respect of the individual numbers of the streams of different orders (Table 3.7) . They are on one extreme while the Ghatta Jhora forms the other extreme . Ghatta basin has only 45 , 49 ,77, and 88 percent of the total number streams in its basin as those contained , respectively , by Rinchintong , Pachim , Rongmuk and Upper Balason basins . The Rongmuk and the Upper Balason form the category in between . This comparison of the deduced number of the streams in the five different basins shows that the rock materials are softest in the Ghatta , while they are hardest in Rinchintong and Pachim with the Rongmuk and Upper Balason forming the intermediate category . It follows from the above discussion that while surface erosion is quite pronounced among the Rinchintong and Pachim basins , land slides , debris flows , rock slides etc. are more pronounced in the Ghatta , Rongmuk and the Upper Balason basins .

3.4.2 TOTAL LENGTH OF STREAMS :

The lengths of the streams in the study area present some very interesting features (Table 3.8) .

TABLE 3.8

LENGTH OF THE STREAMS IN KILOMETRES IN THE STUDY AREA

Order	Ghatta	Rinchintong	Pachim	Rongmuk	U.Balason
			Length in Km		
1	38	90	64	210	241
2	11	33	18	43	45
3	3	9	6	13	17
4	3	9	5	8	16
5	-	7	-	-	4
Total	55	148	93	274	323

(Source: Author´s calculation)

As is seen from the table 3.8, the length of streams is the highest in Upper Balason Jhora and the lowest in the Ghatta Jhora basins . Though the length of the streams , as their numbers , is a function of the area of the basin , some clear patterns are easily discernible . The basin areas of the Ghatta Jhora (1725 ha) and that of the Pachim Jhora (1600 ha) are almost equal but the length of the streams in their respective basins shows that the basin of the later contains almost double the total length of the stream as that contained by the former . Given the fact that both of these basins are located very close to each other , and hence the quantum and the intensity of the rainfall are almost similar. Such a wide diversity in the drainage patterns indicates towards the rock formation of these two basins . Since coarser drainage texture indicates higher permeability of the rock material , the hydraulic conductivity of the soils in the Ghatta basin is higher than that of the Pachim basin . Since surface run-off is comparatively lower , surface forms of the soil erosion such as sheet erosion , rill erosion , gully erosion are less . On the other hand , since the flow of the water is more underground , the area has a risk of having landslides and subsidence . The Pachim , on the other hand , having a higher density of the drainage lines , shows poor hydraulic conductivity of the rock material causing more surface run-off , and hence , making the basin more prone to sheet erosion , rill erosion , gully erosion, etc. Similar conclusion can be drawn about the drainage characteristics of the Rinchintong and the Rongmuk basins , even though their areas are not as comparable .

Table 3.9 has been deduced for exploring the characteristics of the basins by calculating the notional area drained by each kilometre length of the stream .

TABLE 3.9

DRAINAGE AREA OF EACH KILOMETRE OF STREAM IN HA

ORDER	GHATTA JHORA	RINCHIN- JHORA	PACHIM JHORA	RONGMUK JHORA	U.BLSON JHORA
			Area in ha		
1	45.39	31.39	25.00	17.50	22.82
2	156.82	85.61	88.89	85.47	122.22
3	575.00	313.89	266.67	282.69	323.53
4	575.00	313.89	320.00	459.38	343.75
5	0.00	403.57	0.00	0.00	1375.00

(Source : Author´s own calculation)

As seen from the Table 3.9, each kilometre of the first order stream in Rongmuk is draining as low as only 17.50 ha of the basin area whereas in Ghatta Jhora drainage by each kilometre stream of that order is as high as 45 ha .Each kilometre of the first order stream in Upper Balason and Pachim drain , respectively , 22.82 and 25.00 ha of basin area whereas that figure for the Rinchintong Jhora is 31.39 . There are , therefore , four distinct categories among the five basins in the study area in this regard . The Rongmuk Jhora being very highly drained , the Pachim and the Upper Balason forming the next category i.e. highly drained , the Rinchintong being the medium drained and the Ghatta the least drained category . There can not be any simplistic explanation for such disparity in the drainage characteristics among various basins in the study area as the development of the drainage is a complex phenomenon involving multifarious factors including the dynamic geological forces . Some conclusions , however , are unmistakable .

In case of Rongmuk the length of the slope , i.e. the distance that a water drop running on the surface has to traverse to reach the stream , shall be the lowest and that for the Ghatta Jhora shall be the highest . In the former , though the length of the slope shall restrict the soil erosion in comparison to the latter , whatever little soil is eroded on account of sheet or rill erosion shall be very likely carried down to the active stream whereas in the latter the eroded soil particles shall have much greater chance to get deposited somewhere on the way . The overall surficial erosion , shall be more severe in Rongmuk basin than in the Ghatta Jhora basin . The other basins will form the erosion hazard categories in between these two .

Another feature of the basins becomes apparent if one takes a look at the number of hectares that each kilometre of the second order streams is draining . Rinchintong , Pachim and Rongmuk present the figures of 85.61 ha , 88.89 ha and 85.47 ha respectively . Their equality in drainage in respect of second order streams , despite their wide disparity in respect of first order drainage , (31.39 ha , 25.00 ha and 17.50 ha respectively) , is quite striking . Assuming that the rainfall is fairly equal in all these three basins because of their proximity , why is it that nature provided varying kilometrages of drainage lines of first order and almost equal kilometrages of that of second order to drain the same area in these three basins ? The answer probably lies in the extent of fractures and faults in the rock material in these three basins as because the drainage lines of basins develop basically on the basis of faults of the rock materials in the basin and their order is decided by the quantum of surface flow needed to be carried to the stream of higher order . Thus the rock material is most severely faulted and fractured in the Rongmuk basin and the least in the Rinchintong basin . Heavily crushed rocks of the Rongmuk basin can also be assessed from the parallel pattern of drainage in the basin , specially in and around Milling Tea Estate .

If one compares the drainage by each kilometre of second order of streams of Ghatta and Upper Balason basin (156.82 ha and 122.22 ha respectively) , one is simply amazed at the close similarity between these two and the wide disparity of this group from the former (i.e. the Rinchintong , Pachim and Rongmuk) . This shows highly permeable rocks in these two basins and also that the surface flows available in these two basins are , probably , so little that one kilometre length of the second order stream could cater to the run off needs of 156.82 ha in Ghatta and 122.22 ha in Upper Balason as against only 85.61 ha , 88.89 ha and 85.47 ha in Rinchintong , Pachim and Rongmuk respectively .

Table 3.10 has been deduced by assessing the proportion of the length of each order of the stream to the total length of that .

TABLE 3.10

PROPORTION OF LENGTHS OF STREAMS OF VARIOUS ORDERS TO THE TOTAL LENGTH OF THE STREAM IN THE BASIN

ORDER	GHATTA JHORA	RINCHIN- JHORA	PACHIM JHORA	RONGMUK JHORA	U.BLSON JHORA
	Percentage to the total				
1	69.09	60.81	68.82	76.64	74.61
2	20.00	22.30	19.35	15.69	13.93
3	5.45	6.08	6.45	4.74	5.26
4	5.45	6.08	5.38	2.92	4.95
5	0.00	4.73	0.00	0.00	1.24
TOT	100	100	100	100	100

(Source : Author´s own calculation)

As is seen , Ghatta and Pachim basins show similarities in respect of the proportion of length of the various order of the streams to the total length . Rongmuk and the Upper Balason basins show similarities among themselves . The Rinchingtong basin with the least proportion of first order and the highest proportion of second and the higher orders forms a class apart . In Rongmuk and the Upper Balason basins ratio of stream lengths of first order is the highest and that for second order the lowest . This shows severe faults and fractures on account of crushed rocks in these two basins . These two basins are likely to see more subsidence , rock slides and landslides , comparatively speaking . The Rinchintong basin has the lowest proportion of the first order and the highest of the second order , even though , it has the highest incidence of first order streams . This shows that the streams of the first order in Rinchintong basin have the strongest tendency , among all the five basins , to join one another to make the streams of higher orders . On the other hand in the Rongmuk and the Upper Balason basins , they tend to run parallel .

Among the Ghatta and the Pachim basins , despite wide variation in number of streams contained per unit area, (Table 3.7), proportion of lengths of first , second and higher order of the streams to the total length is strikingly similar (69.09 % - 68.82 % , 20 % - 19.35 % and 10.90 % - 11.83 % for first , second and higher orders for Ghatta and Pachim basins respectively) . One wonders why is it so . The density of the streams show highly permeable rocks in Ghatta basin and highly impermeable ones in

Pachim . One explanation may be that despite different nature of rock materials , the pattern of faults and fractures in these two basins are fairly comparable giving same proportion of the lengths of various orders of streams . Surficial forms of erosion , however , are more in Pachim than in Ghatta on account of higher density of streams . Hydrograph of the flow , too , is more acute in Rinchintong giving it higher bed load carrying capacity .

3.4.3 AVERAGE LENGTH OF STREAMS :

Wide variation is seen in the Jhoras in the study area in respect of the average length of streams of various orders . The table 3.11 gives this data .

TABLE 3.11

AVERAGE LENGTH OF STREAMS (Km) IN THE BASIN

(1)

ORDER	GHATTA JHORA	RINCHIN- JHORA	PACHIM JHORA	RONGMUK JHORA	U.BALASN JHORA
1	0.64	0.44	0.63	1.13	0.73
2	1.10	0.66	0.64	0.96	0.63
3	1.00	0.90	1.00	1.18	1.13
4	3.00	3.00	5.00	4.00	4.00
5	0.00	7.00	0.00	0.00	4.00

(Source : Author´s own calculation)

Among the first order of the streams the shortest average length (o.44 km) in Rinchintong basin is noteworthy . The Rongmuk basin with the longest average length of its first order streams (1.13 km) makes another spectacular virtue of the study area . The Ghatta and Pachim basins with average length of their first order streams , respectively , 0.64 km and 0.63 km , show a close similarity . The Upper Balason basin with that value as 0.73 km forms a class closer to them .

Despite enormous difference in the over all drainage density in the Ghatta and the Pachim basins (

3.19 km and 5.86 km per sq km respectively) , both show an extraordinary similarity in respect of the average lengths of the first order streams . Another such similarity has earlier been pointed out among these two basins regarding the proportion of lengths of streams of various orders to the total length . The proportion of the lengths of first , second and higher orders of the streams to the total length is 69.09 % - 68.82 % , 20 % - 19.35 % and 10.90 % - 11.83 % for Ghatta and Pachim respectively. Despite the varying nature of the rock material , the localised geological forces acting on the two basins and , consequently , the pattern of faults and fractures in them are fairly comparable. This is the reason for such similarities.

The smallest average length of the first order streams in Rinchintong makes it a basin having the finest drainage texture . The Rinchintong basin shows a dendritic pattern of drainage . Rocks in this basin are the most impervious of all and the soil developed has the least sub - surface conductivity .

The highest average length (1.13 km) of first order streams in Rongmuk basin are, on an average, as long as 2.5 times of those in Rinchingtong. This can be explained by the following statement. In Rinchintong basin every first order stream meets another after it has traversed only about 440 mts of its course whereas in Rongmuk it has to travel as long as 1130 mts to meet another of same or of higher order . Because of their proximity , the quantum and the intensity of the rainfall are roughly comparable . The rainfall pattern can not , therefore

, be the reason for such wide disparity among the two basin of the same catchment. Very clearly the tendency among the first order streams of the Rongmuk river is to travel parallel to one another , comparatively speaking . In respect of average lengths of second order streams , Rinchintong , Pachim and Upper Balason are fairly equal (0.66 km , 0.64 km and 0.63 km respectively) . The two aberrations are Ghatta and Rongmuk with values 1.10 km and 0.96 km respectively . While assessing the significance of the average lengths of the second order streams it must be born in mind that the second order streams are generally located in the middle parts of the slope of the river basins . While Rongmuk maintains its average length (0.96 km) among the highest , what is revealing is the graduation of the Ghatta basin as the holder of the longest second order streams and the stagnation of the Pachim as a basin having the average lengths (0.64 km) almost the lowest (lowest being 0.63 km in Upper Balason). Pachim shows that in its middle slopes too it has similar patterns of the streams as that on its upper reaches . The same is not true for the Ghatta basin . As one descends down from the brim of the basin , in case of Ghatta , one will encounter streams which shall be running longer before changing their order by merging with other similar streams . This shows the strong tendency of the streams in the middle slopes of Ghatta and Rongmuk to run parallel to one another . In the latter , the tendency did exist in case of first order streams located near the brim and was carried down the slope to the second order streams , but in case of latter the streams on the middle slopes developed exaggerated patterns of parallel drainage . This shows that the faults and fractures in the rock materials in the middle reaches of the slopes are most severe , and roughly comparable among them , in Ghatta and Rongmuk basins . No clear pattern are discernible in average lengths of higher orders .

The most uniform increase in average lengths of streams of various orders is seen in respect of Rinchintong basin . This shows that in this basin the drainage patterns have developed basically on account of the requirements for conduction of the surface run off in the basin .

The fig 3.7 very clearly depicts highest average lengths of the first order of streams in the Rongmuk basin and also as to how the Ghatta basin has almost taken over the Rongmuk in respect of the average lengths of the second order streams in the basin . An almost uniform rate of increase of the average lengths of the streams of the first , second and third order in the Rinchintong basin (0.44 km , 0.66 km and 0.90 km respectively) is also very clearly brought about .

Besides drainage frequency , another important characteristics needing consideration is bifurcation ratio of streams which is discussed next .

3.5 BIFURCATION RATIO :

The bifurcation ratio for all the streams in the study area has been determined and is given in table 3.12.

Average Length of stream

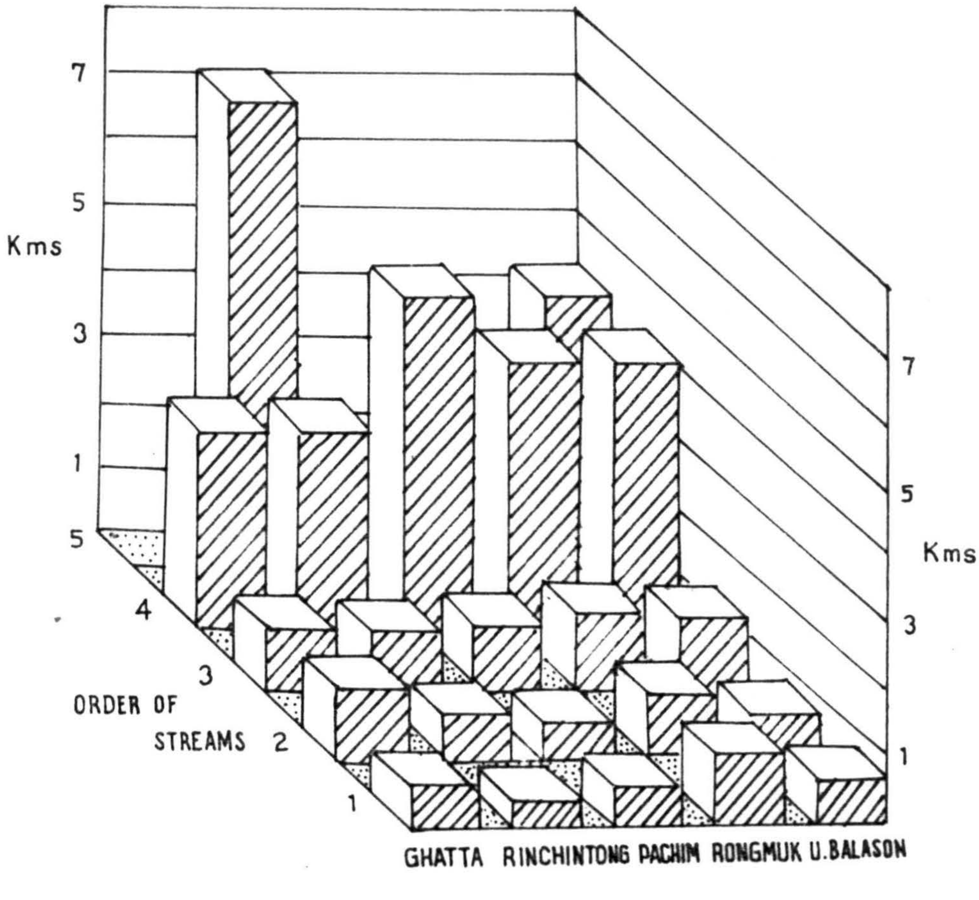


Fig. 3·7

TABLE 3.12
BIFURCATION RATIO OF THE STREAMS
(Rb)

ORDER	GHATTA JHORA	RINCHIN- JHORA	PACHIM JHORA	RONGMUK JHORA	U.BLSON JHORA
1	5.90	4.08	3.61	4.13	4.65
2	3.30	5.00	4.67	4.10	4.73
3	3.00	3.33	6.00	5.50	3.75
4	0.00	3.00	0.00	0.00	4.00
5	0.00	0.00	0.00	0.00	0.00

(Source : Author´s own calculation)

As is seen the bifurcation ratio for the first order streams is the highest for Ghatta Jhora (5.90) and the lowest for Pachim (3.61) .The Rinchintong , Rongmuk and Upper Balason make a comparable group with their values , respectively , as 4.08 , 4.13 and 4.65 . In case of Pachim , number of first order streams is 3.61 times that of second order while in case of Ghatta this figure is 5.90 times . In other words , in case of Ghatta Jhora as many as 5.90 streams , on an average , feed each one of the second order streams whereas in case of Pachim only 3.61 streams do so . Since basins with lower bifurcation ratios are known to have acute shape of hydrographs , drainage of surface run off from first order streams shall be the quickest in Pachim and the slowest in Ghatta . That makes basin area of Pachim more susceptible to sheet and rill erosion . Likewise conclusions can be drawn for streams of other orders too . In case of Pachim and Rongmuk the highest bifurcation ratio of third order basins (6.00 and 5.50 respectively) is noteworthy . This shows that in respect of third order streams they have the strongest tenancy to run parallel to one another. The bifurcation ratio of streams of various orders has also been depicted in Figure 3.8.

Bifurcation Ratio (stream order)

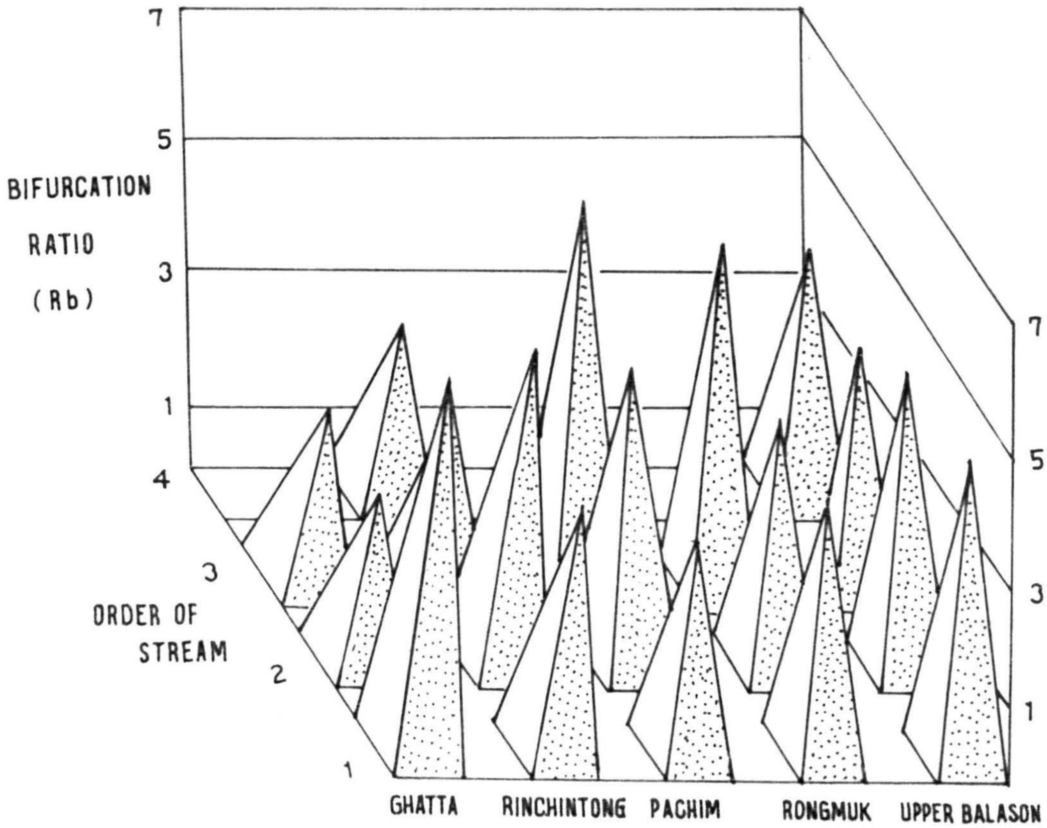


Fig. 3·8

The bifurcation ratio for the basin has also been calculated . The determination of bifurcation ratio of basins has been done following standard techniques (Chorley , 1971) . The bifurcation ratio of Rongmuk (5.4026) is the highest and that of Ghatta the lowest (3.7532) (Fig 3.9) . The hydrograph of Ghatta basin is, therefore , to the most acute and that for Rongmuk the flattest of all . The results are however not exactly comparable , quantitatively , as the drainage density of Ghatta (3.19 km per sq km) is lower than that of Rongmuk (7.40 km per sq km).

3.6 STREAM LENGTH RATIO :

Like bifurcation ratio another important ratio needing attention for exploration of characteristics of basin is the stream length ratio. The stream length ratio in the study area is also quite interesting . This is given in Table 3.13.

TABLE 3.13

STREAM LENGTH RATIO IN DIFFERENT BASINS

(Rl)

ORDER	GHATTA JHORA	RINCHIN- JHORA	PACHIM JHORA	RONGMUK JHORA	U.BALASON JHORA
1	1.00	1.00	1.00	1.00	1.00
2	0.29	0.37	0.28	0.20	0.19
3	0.27	0.27	0.33	0.30	0.38
4	1.00	1.00	0.83	0.62	0.94
5	0.00	0.78	0.00	0.00	0.00

(Source : Author´s calculation)

As is seen from table 3.13 , stream length ratio for second order streams is the highest for

Bifurcation Ratio in the Basins

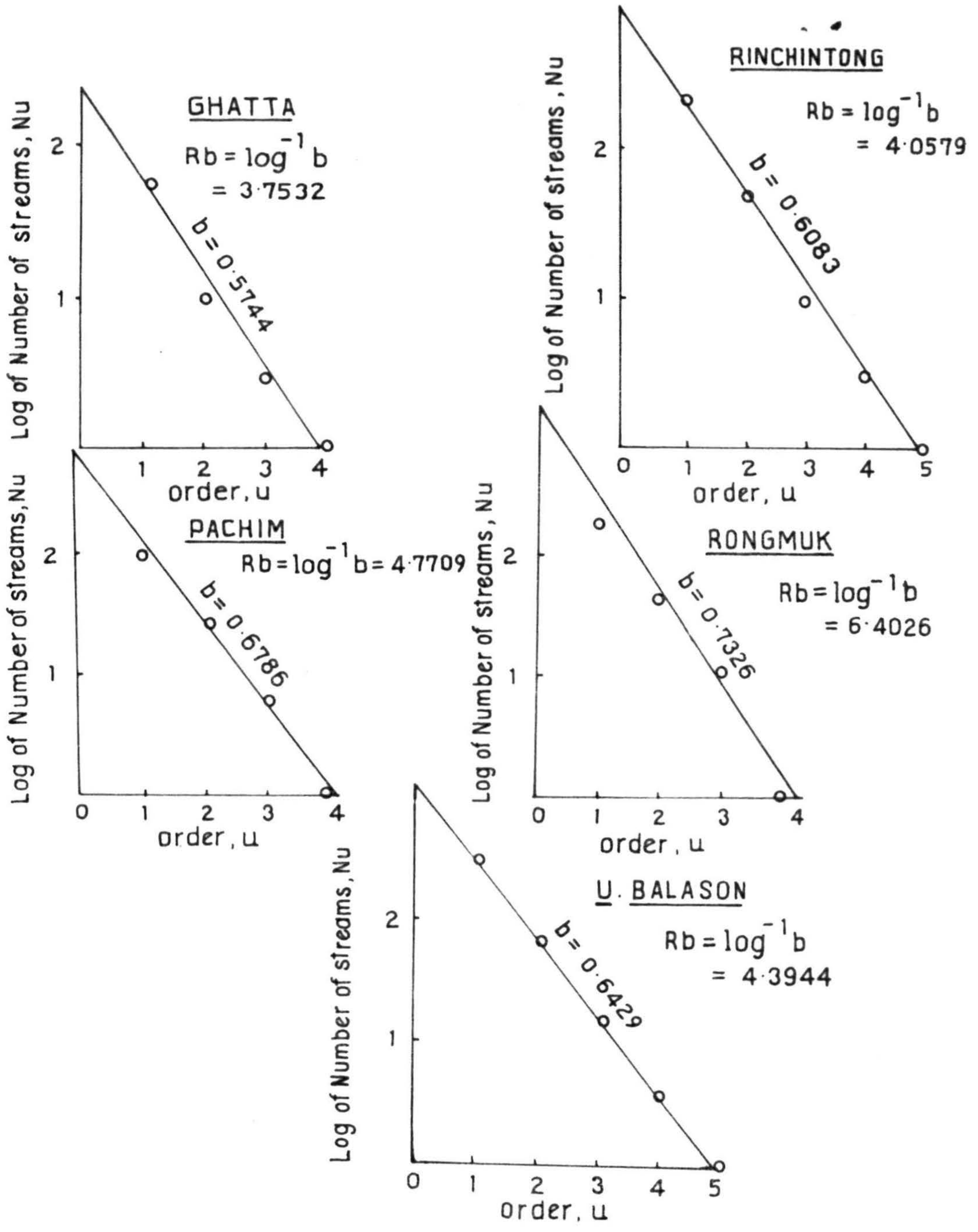


Fig. 3·9

Rinchintong (0.37) and the lowest for Upper Balason (0.19) with Rongmuk very close to it (.20) . The Ghatta and Pachim show a close similarity with their values , respectively , 0.29 and 0.28 . Three distinct categories are visible . The lengths of second order streams are 20 , 30 and 40 percent of that of first order in Rongmuk and Upper Balason , Ghatta , and Pachim respectively . Similarly , these values for third order streams are 30 percent for Ghatta , Rinchintong , Pachim and Rongmuk whereas that for Upper Balason is 40 percent. The values for higher order streams are almost similar . In case of Upper Balason , stream length ratio for second order stream is the lowest and that for third order stream the highest. This is on account of the shape of the basin which is fan like.

From the table 3.13 and Fig. 3.10, three distinct groups in stream length ratio of second order streams have been clearly brought out . The lowest and the highest stream length ratios for second and third order streams of Upper Balason are also discernible. The highest stream length ratio of second order streams in Rinchintong shows the greatest tendency of first order streams to produce those of higher orders in this basin . This is the least in, both, Rongmuk and Upper Balason indicating the strongest tendency of first order streams to run parallel .This shows the severest faults and fractures in these basins . By the same reason, Rinchintong has the least intensity of faulting and fracturing . This makes Rongmuk and Upper Balason most sensitive for slides , sinking , rockfall and similar soil degradation processes and Rinchintong the most sensitive for

Stream length ratio

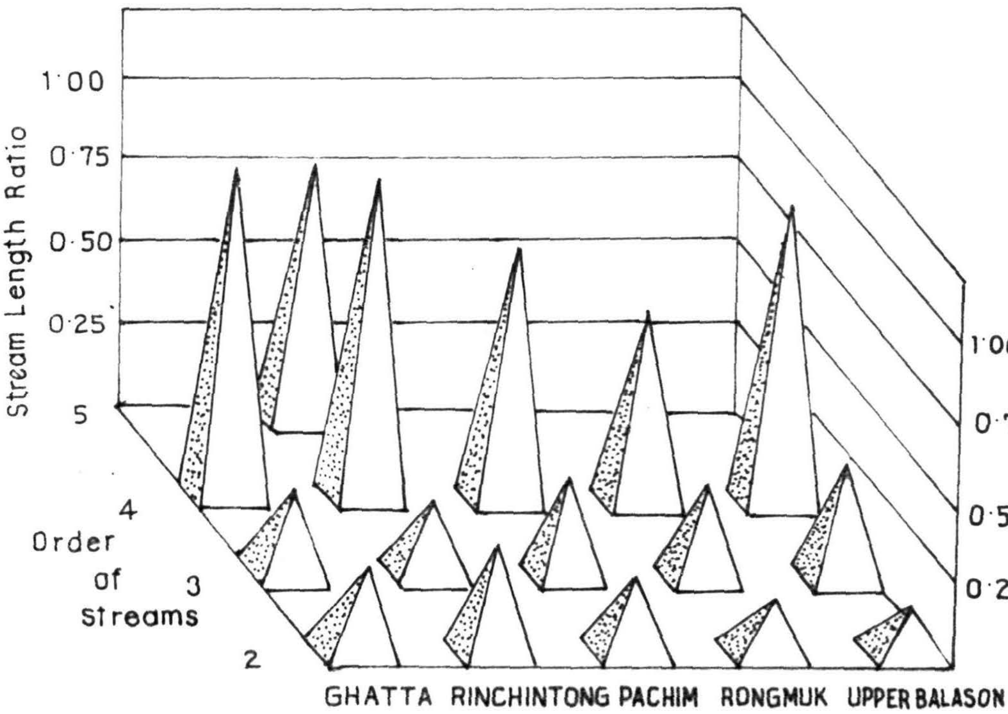


Fig. 3·10.

surficial forms of soil erosion The Ghatta and Pachim basins form the intermediate category . Extremely low drainage density in case of Ghatta (3.19) as against Pachim (5.86) , however , imparts some degree of unreliability in their quantitative comparison . It appears that the pattern of faulting and fracturing is similar in these two basins but more permeable rocks in Ghatta has impeded development of drainage to the extent of that in Pachim. It can be safely concluded that in Pachim , surficial forms of soil degradation , and in Ghatta , sinking and sliding , are the most prominent .

3.7 SINUOSITY :

The sinuosity of the five channels in the study area has been determined by measuring the axial distance and the lengths of the thalwegs (DURY , 1969) as seen from the satellite imagery dated 26th January , 1996 . The results are given in the table 3.14.

TABLE 3.14

SINUOSITY OF THE RIVERS IN THE BASIN

River	channel km	Thalweg km	Sinuosity
Ghatta	3.50	4.10	1.1714
Rnchnto	9.90	13.45	1.3586
Pachim	6.50	6.85	1.0538
Rongmuk	7.90	7.95	1.0063
U.Balas	8.80	9.45	1.0739

(Source : Satellite imagery dated 26-01-96)

As is seen , streams are not much sinuous in comparison to level country where , usually , a sinuosity of 1.5 is taken as the minimum value for accepting the river as a meandering one (Dury , 1969) . But one must keep in mind that rivers under study are located in hilly terrain (gradient from 15 to 22 percent ; Table 3.1) and can not meander as those in the level country . The sinuosity of rivers in the study area , howsoever small , presents some interesting features , nevertheless .

The Rinchintong river is the most sinuous , the least being the Romgmuk . The Ghatta forms the second most sinuous river . The sinuosity of Rinchintong is explainable in view of the highest density of drainage lines (9.38 nos per sq km) and the lowest average lengths of the lower order streams both indicative of the toughest and the least faulted and fractured rock material in its basin . The river could not cut its way straight through . The sinuosity of Ghatta is , however , quite surprising . The Ghatta basin has the lowest number of drainage lines (4.2 nos per sq km) and the lowest drainage density (3.19), the highest average length of the second order streams and the third highest average length of the first order stream . All these indicate parallel drainage pattern .

The sinuosity of the Rongmuk river is seen the lowest at 1.0063 . The Upper Balason and the Pachim make a close group with their values , respectively , 1.0739 and 1.0538 . The sinuosity of rivers is associated with turbulence in the flow of stream . More sinuous the stream , more is the agitation in flow and , consequently , more is the suspended load . Any soil particle dislodged from its position , if once reaches a turbulent sinuous stream of hilly terrain , has very little chance to get deposited in way . Thus, Ghatta and Rinchintong have higher carrying capacity . Besides this , sinuous stream are very actively working on obstruction in their way , are always trying to straighten their courses leading to higher incidence of bank failures . Field verification shows higher instances of bank failures along these two rivers . This is , at least in part , on account of their higher sinuosity , specially , in the lower reaches (Fig. 3.11).

Another spectacular characteristics of streams is revealed if one computes their sinuosity from the topo sheet (survey in 1931) . The result is given in Table 3.15.

TABLE 3.15

SINUOSITY OF THE RIVERS TOPO SHEET

River	channel km	Thalweg km	Sinuosity
Ghatta	3.50	3.95	1.1286
Rnchnt	9.90	10.15	1.0253
Pachim	6.50	6.75	1.0385
Rongmuk	7.90	8.45	1.0696
U.Balson	8.80	9.30	1.0568

(Source : Survey of India topo sheet , 1931)

As is seen , Rinchintong river was the least and Ghatta the most sinuous in 1931 (Fig 3.12 and Table 3.15) . The other three rivers form the intermediate category . A comparison of the lengths of the thalweg as available from the toposheet (1931) and from the satellite imagery (26th January , 1996) reveals another interesting point (Fig. 3.13). Table 3.16 tabulates the comparative figures .

SINUOSITY OF STREAM (3rd order & above)

(based on satellite imagery, 1996 .)

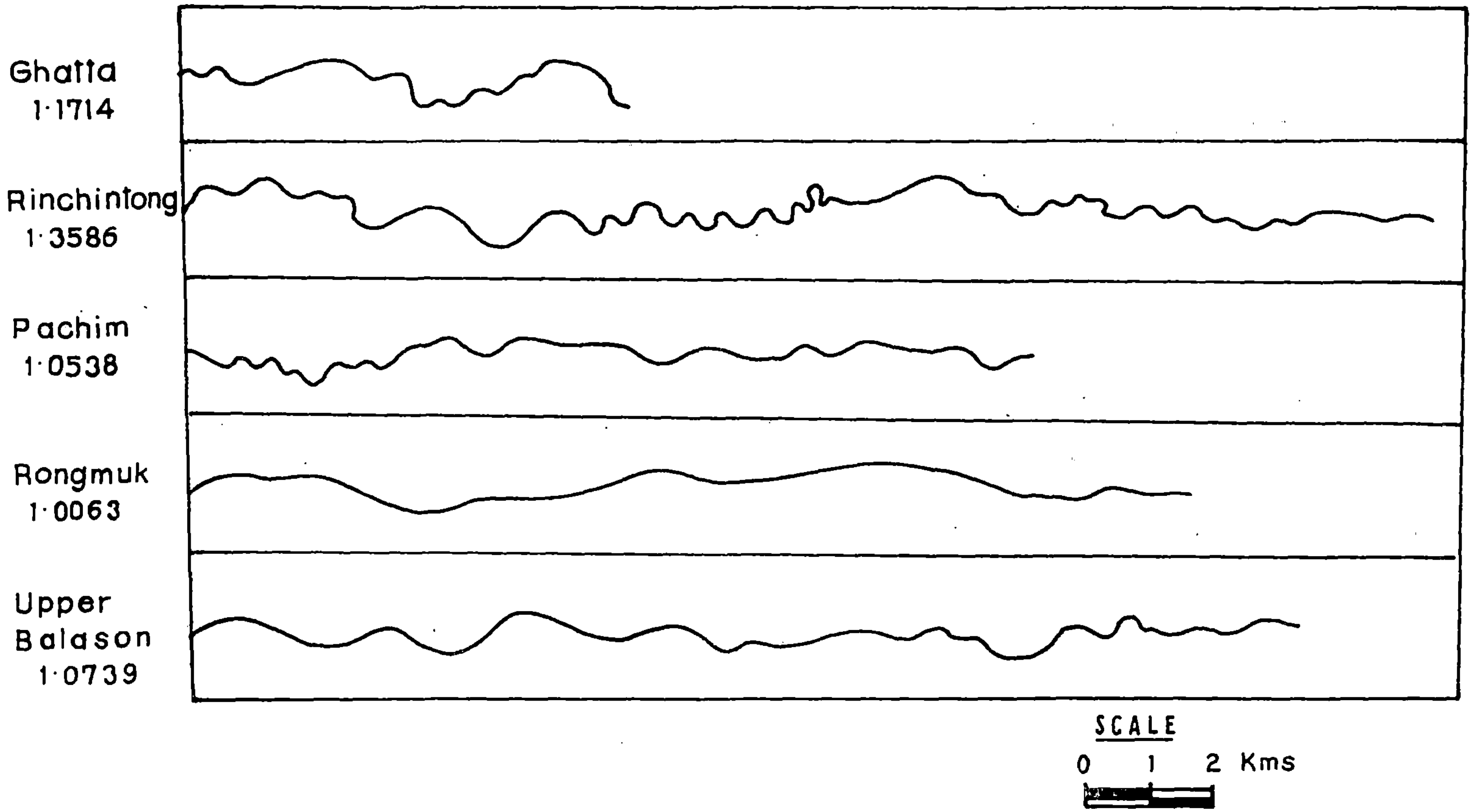


Fig. 3·11

SINUOSITY OF STREAM (1931)

(Based on S.O.I. Toposheet , 1931)

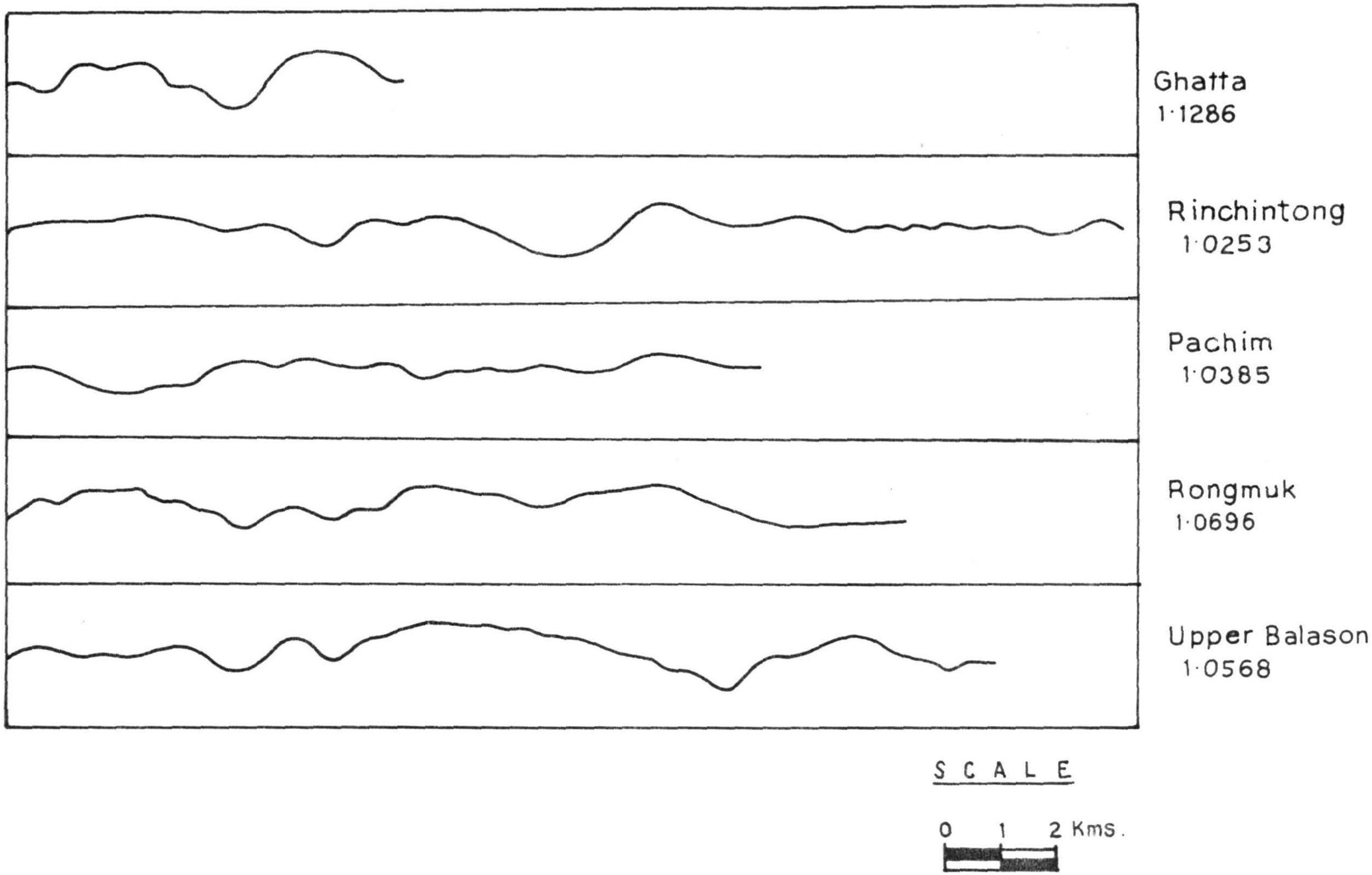


Fig. 3·12 .

Stream Length vs Thalweg

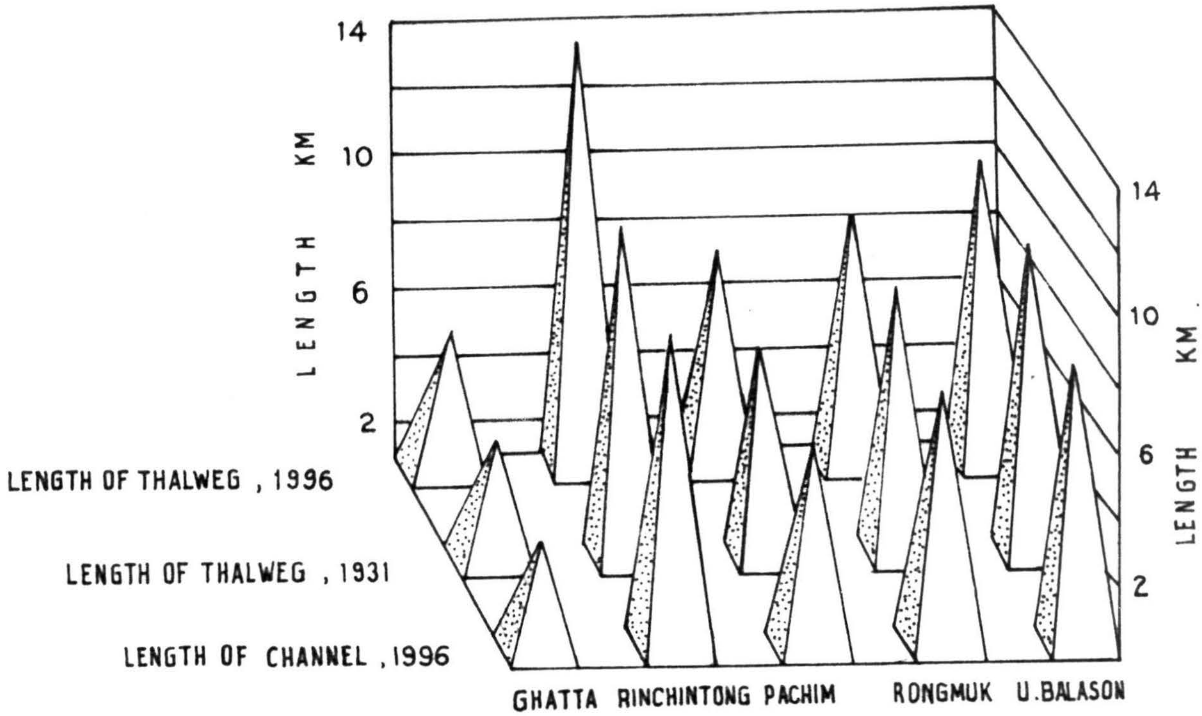


Fig. 3·13

SINUOSITY

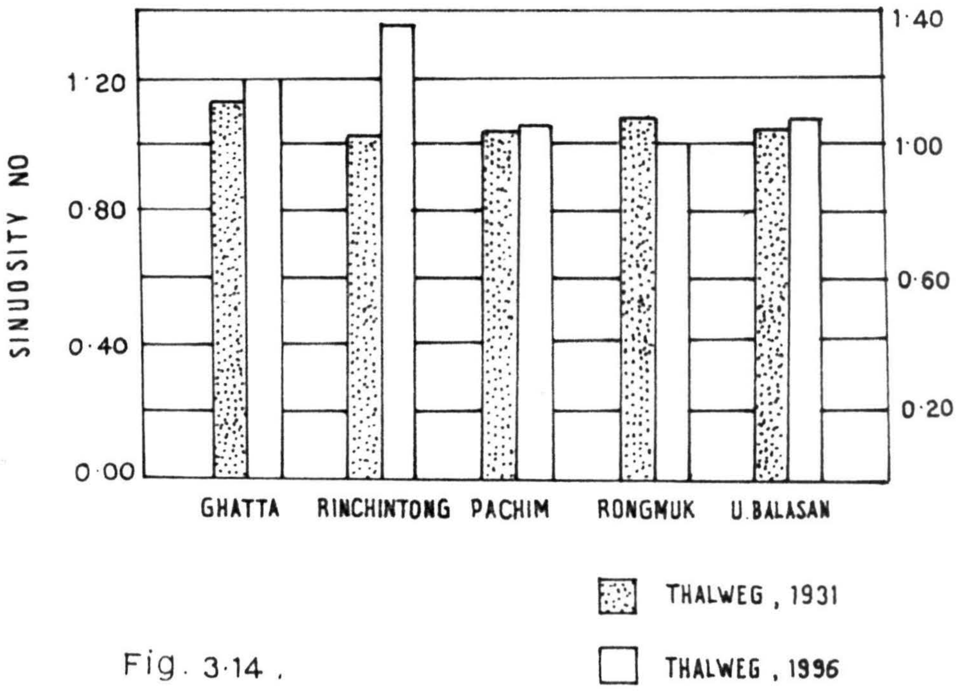


Fig. 3·14 .

TABLE 3.16

SINUOSITY OF THE RIVERS IN THE BASIN

River	Channel km	Thalweg 1931 km	Thalweg 1996 km	Sinuosity 1931	Sinuosity 1996
Ghatta	3.50	3.95	4.10	1.1286	1.1714
Rnchnt	9.90	10.15	13.45	1.0253	1.3586
Pachim	6.50	6.75	6.85	1.0385	1.0538
Rongmuk	7.90	8.45	7.95	1.0696	1.0063
U.Balsn	8.80	9.30	9.45	1.0568	1.0739

(Source : Author's calculation from Survey of India topo sheets and Satellite imagery date 26th January , 1996)

The Fig. 3.14 represents the comparison of the sinuosity of the five rivers in the study area in 1931 and 1996 . The highest increase in the length of thalweg during this period is seen in Rinchintong (10.15 km to 13.45 km) . This is an increase of about 33 percent . Increase in Ghatta has been only 4 percent . Increase in Pachim and Upper Balason is insignificant whereas in Rongmuk , there is a 6 percent decrease (from 8.45 km in 1931 to 7.95 km in 1996).

To understand sinuosity of channels one has to take help of the Manning's formula which defines the flow of water in the open and closed channels . The formula is given below : -

$$V = 1/n\ R^{2/3}\ S^{1/2}$$

where ,

V is velocity of flow in mt per sec.

n is Manning's roughness coefficient for the type of the channel .

R is hydraulic radius or hydraulic depth of the flow and is given by A / P where

A is cross sectional area of the flow in sq. mt.

P is the wetted perimeter of the flow in meters .

S is the slope of the flowing liquid surface (mt per mt of the liquid of the surface) or sine of slope of the water surface .

It can be proved that in an open channel a given peak discharge shall decide the values for V , R and S and , if the peak discharge is altered , these values shall be redefined . The n being a constant , in case of an open channel , an increase in the peak discharge shall also result in an increase in the values of V , R and S , and vice - a - versa . An increase in the value of S shall be a high energy situation , and consequently , more stressful condition . The river ,in such a situation , shall have a strong tendency to grow sinuous to increase effective length of flowing water surface so that energy gradient goes down as much as possible . This shall result in lengthening of thalweg . Thus higher peak discharge shall tend to make rivers more sinuous and vise - a - versa .

The Rinchintong river drains a vast tract of forest (916 ha out of its total 2825 ha being forest) concentrated on its upper reaches . Pachim and the Rongmuk , on the other hand , have only 5 percent and 19 percent of their areas under forest cover, respectively, in upper parts of their basins . The entire forest area , specially that falling in Rinchintong basin , lying close to human habitation such as Sepoydhura , Tung

, Garigaon , Aringale , Dilaram , and Chatakpur Siding has been , and still is , under the most severe biotic pressure among all forest patches in the study area. It appears that this denudation has caused tremendous increase in peak discharge of Rinchintong and has , in turn , caused greater degree of sinuosity .

Increase in sinuosity of Ghatta river is on account of Kurseong town , whose population has increased from 7451 in 1931 (Census of India , 1931) to 27,419 in 1991 (Census of India , 1991) with consequent deforestation, increased runoff , and increased peak discharge from the basin. The decrease in sinuosity of Rongmuk river is , however, quite inexplicable . One reason for reduction of sinuosity is lessened peak discharge due to large scale water harvesting in Senchal forest area . Huge artificial lakes have been constructed and as many as 40 streams originating from forest and feeding Rongmuk have been tapped for supplying water to Darjeeling . Degradation of Senchal forest is also of very high order , and , had the water been not tapped , one would have expected peak discharge of this river , too , to have gone up , and this river too , to have grown more sinuous . This increased sinuosity would have , probably , been catastrophic and areas in and around Milling tea garden would have been sinking much faster than they do now as the garden is located on a site having highly faulted and fractured rocks .

3.8 CROSS AND COMPOSITE PROFILE :

The profile of an area gives a comprehensive over all view of it . The general nature of terrain and the major land use patterns become visible from such profiles if the transect is carefully chosen and passes through representative area .

3.8.1 CROSS PROFILES :

Two cross profiles , one in east - west and other in north - south direction , are depicted , respectively , in Fig. 3.15 and 3.16 . The east - west cross profile shows how degradation of slopes has progressed to far greater extent on eastern side than that on western side of basin . This further shows as to how the entire area is like a tilted saucer , the direction of the tilt being south - western . As is seen , upper reaches of basin are covered with forest below which entire basin is full of tea gardens . Any land which is not usable for cultivation of tea , is generally seen having wild scrub growth coming on its own . This is further heavily grazed and browsed and dominated only by non-palatable thorny bushes . These scrubs are mostly found on steep slopes subjected to extensive sheet erosion . The north - south cross section shows that the slope descends down from north to south . This also shows occurrence of tea gardens on all milder slopes and scrubs on steeper ones .

3.8.2 COMPOSITE PROFILE :

CROSS PROFILE

(East – West)

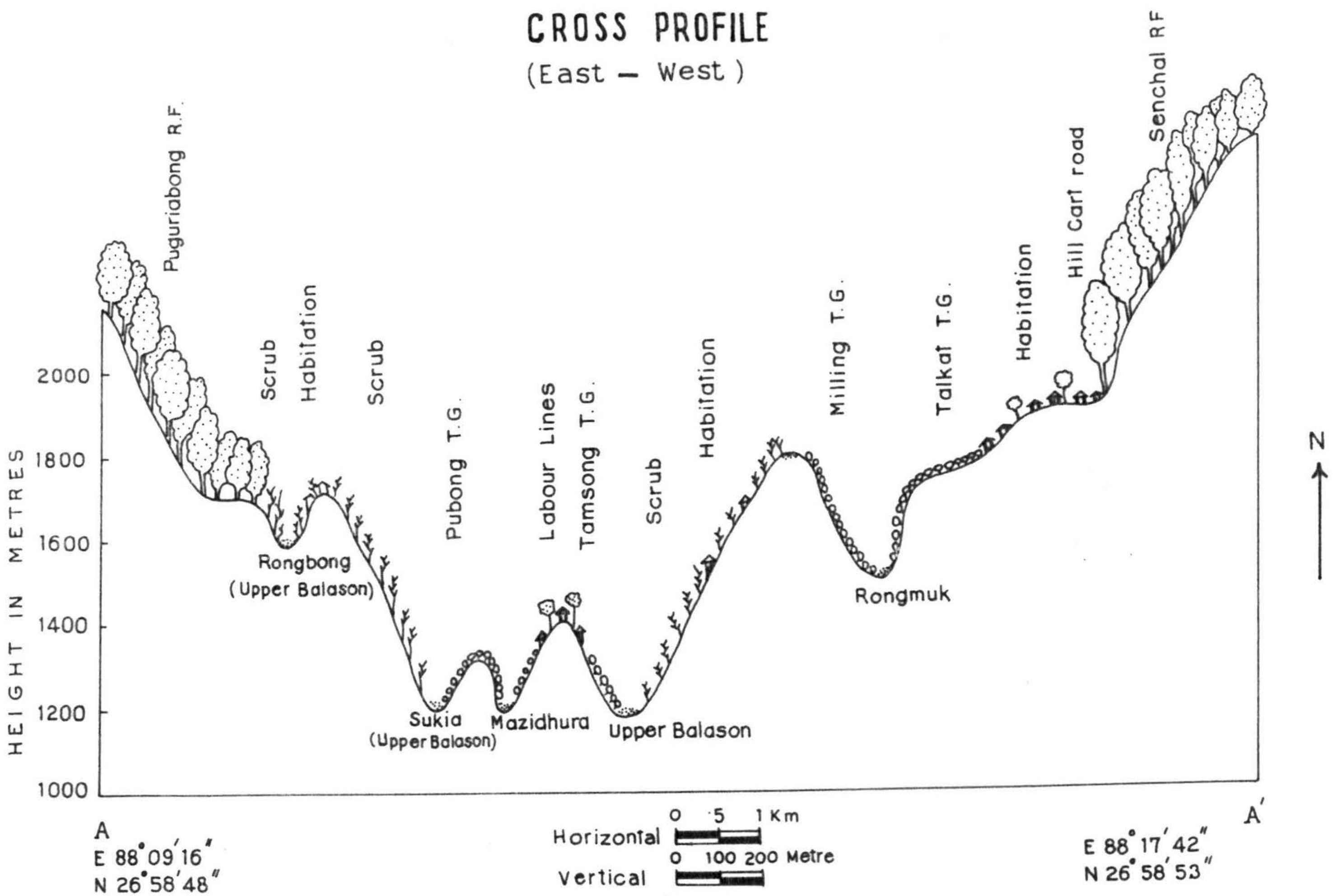


Fig. 3·15

CROSS PROFILE (NORTH- SOUTH)

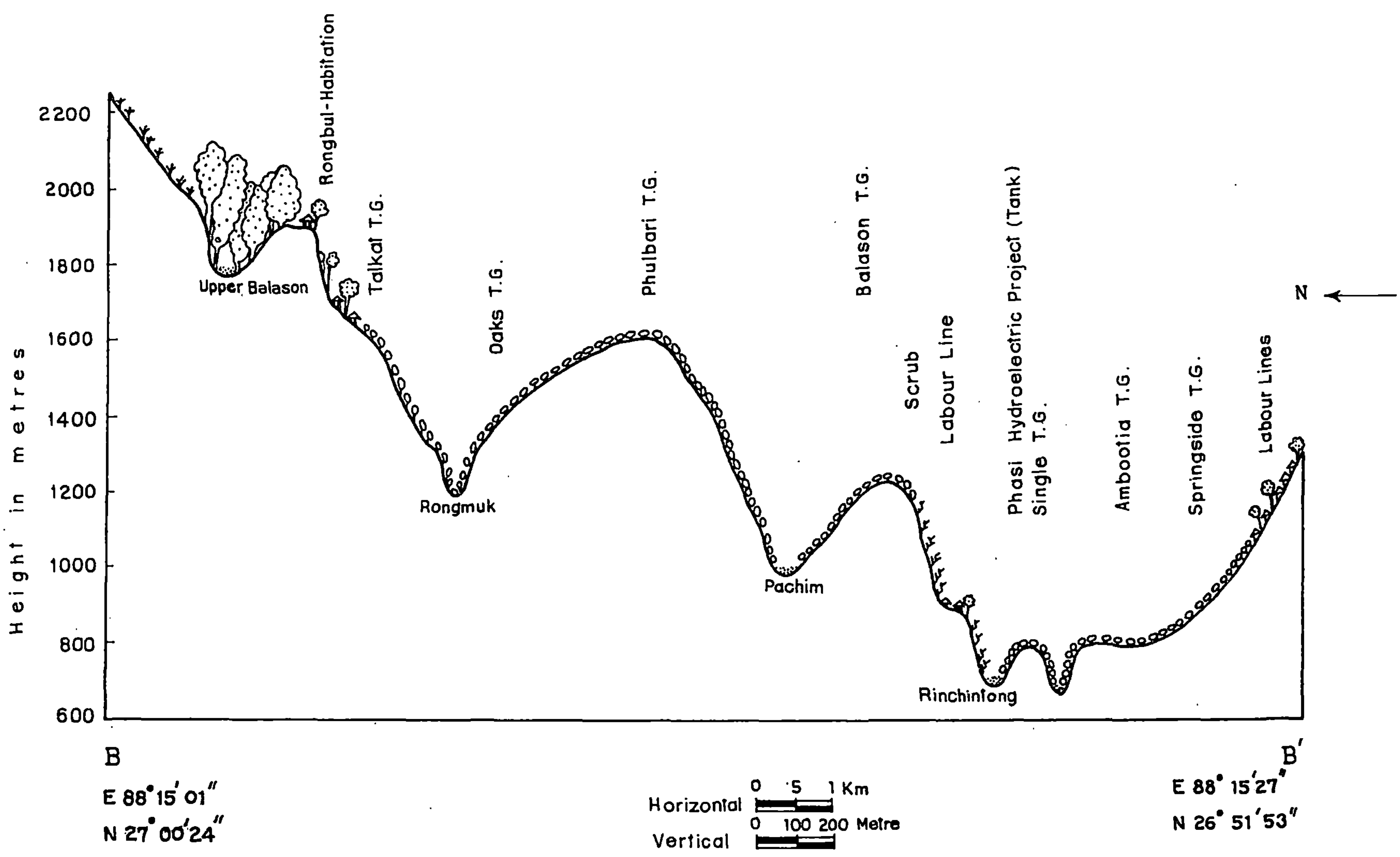


Fig. 3·16.

The composite profile shows that the slopes are steeper in lower parts than those in upper parts of the basin (Fig 3.17) . The length of slopes are shorter in lower parts whereas these are more dissected upwards .

3.9 HYPSOMETRIC CURVE :

The cross and composite profiles of an area give a general and qualitative account of slope development. A more quantitative and definitive account is obtained from Hypsometric curves of the study area.

From the hypsometric curve it is seen that the basins can be grouped into two :- (i) Ghatta : Hussain - Pachim -Rongmuk and , (ii) Rinchintong - Upper Balason . There is marked similarity between curves of Upper Balason and Rinchintong on one hand and those of Ghatta - Hussain , Pachim, and Rongmuk on the other. The contour lines representing 25 , 50 and 75 percent of basin area are shown in Figure 3.18 and are also given in Table 3.17.

TABLE 3.17

PERCENTAGE AREA OF BASINS AND CORRESPONDING CONTOURS

AREA IN PERCENTAGE	CORRESPONDING CONTOUR IN BASIN IN MT				
	GHATTA HUSSAIN	RINCHINGTONG	PACHIM	RONGMUK	UPPER BALASON
0	2060	2450	2500	2500	2400
25	1290	1930	1600	2020	2030
50	980	1580	1230	1490	1730
75	800	1290	1030	1180	1440
100	550	550	700	800	800

(Source : Author's own calculation)

Composit Profile

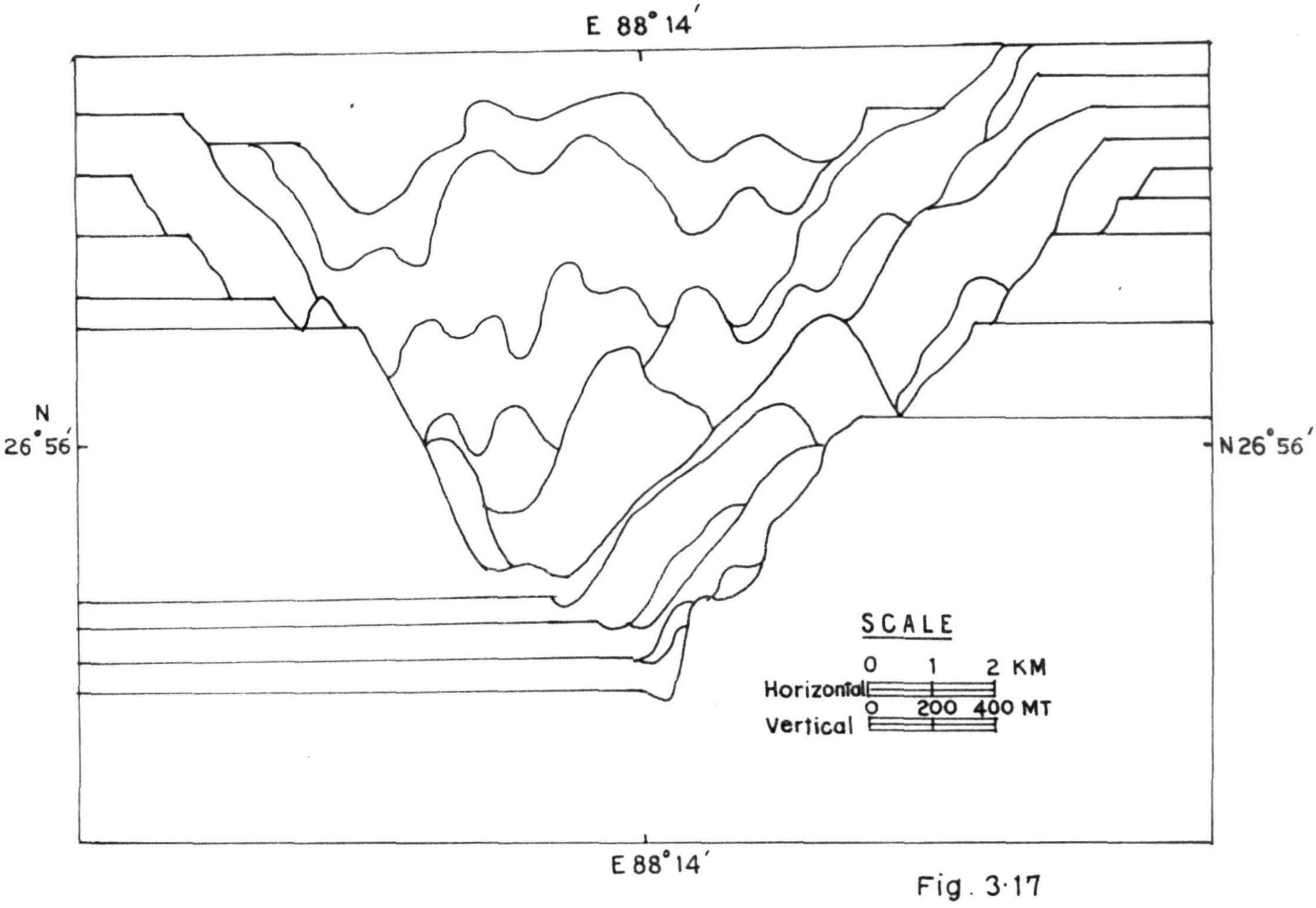


Fig. 3·17

Hypsometric Curve

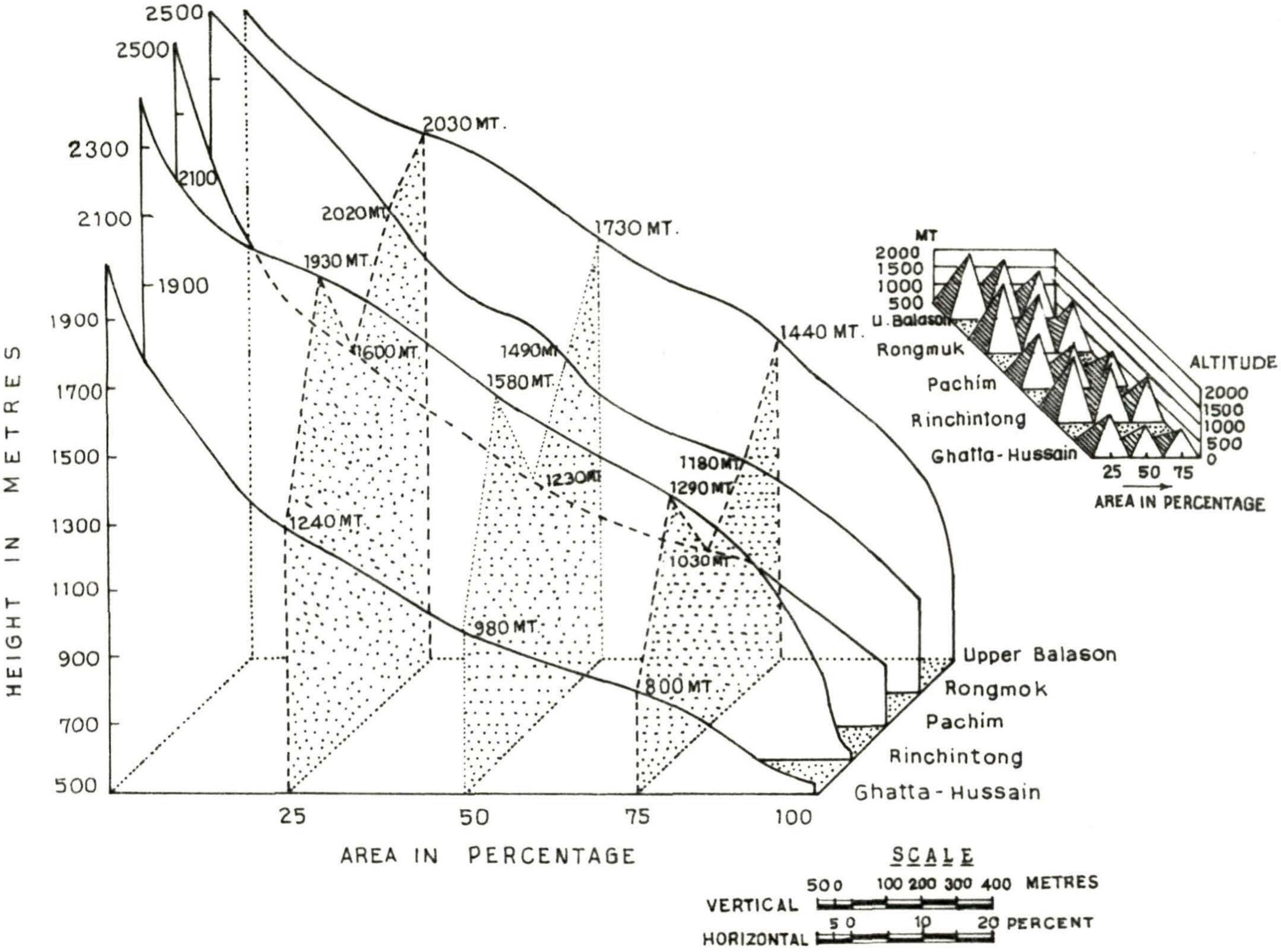


Fig. 3·18

The contour line representing 25 percent top most area of the basin passes at 1290 mt and 1930 mt in case of Ghatta - Hussain and Rinchintong rivers, respectively. This difference for 50 and 75 percent areas is 600 mt and 490 mt respectively . The difference in altitudes of the topmost points of these two basins is 390 mt ; the latter having the higher value . Had distribution of relief been uniform , the difference in contour lines representing 25 , 50 and 75 percent areas from top down would have been , roughly , 300 mt , 200 mt , and 100 mt respectively . The actual difference is higher than the hypothetical difference . A similar comparison of Ghatta - Hussain can be easily done with Upper Balason with like conclusions . This shows relatively younger stage of river development in the Rinchintong - Upper Balason group . A comparison of individual rivers of Ghatta : Hussain - Pachim - Rongmuk group among themselves shows that corresponding differences are not that acute .

As is revealed from the shape of curves (Fig. 3.18) , the basin of the Ghatta - Hussain is past equilibrium stage heading to the maturity . This will also be quite interesting to compare maturity of basins as against that of Ghatta - Hussain . To achieve this , relief of individual basins have been distributed within its lowest and highest points at the same proportion as in Ghatta - Hussain .

TABLE 3.18

MATURITY OF BASINS : GHATTA VIS-A-VIS OTHERS

(Contours and difference in metres)

Rivers	Contour	Area of basin in percentage from top down				
		0	25	50	75	100
Ghatta	Actual	2060	1290	980	800	550
Rinchin gtong	Actual	2450	1930	1580	1290	550
	Calcula ted	2450	1481	1082	873	550
	Differe nce	0	449	498	417	0
Pachim	Actual	2500	1600	1230	1030	700
	Calcual ted	2500	1600	1204	1006	700
	Differe nce	0	0	26	24	0
Rongmuk	Actual	2500	2020	1490	1180	800
	Calcula ted	2500	1633	1276	1089	800
	Differe nce	0	387	214	91	0
Upper Balason	Actual	2400	2030	1730	1440	800
	Calcula te	2400	1584	1248	1072	800
	Differe nce	0	446	482	368	0

(Source : Author´s own calculation)

A look at the Table 3.18 reveals that there are striking similarities between Rinchintong and Upper Balason river basins . The differences in actual and calculated contours corresponding to 25 , 50 and 75 percent of the areas of basin are 449 mt , 498 mt , 417 mt for Rinchintong and 446 mt , 482 mt and 368 mt for Upper Balason basins . On the other hand , these differences for Pachim are 0 mt , 26 mt and 24 mt for 25 , 50 and 75 percentages of areas , respectively . This shows that stage of development of river basins of Ghatta - Hussain and

Pachim are very close to one another and both are past the stage of maturity . As against this , stage of development of Rinchintong and Upper Balason basins are , relatively , young . The Rongmuk river basin falls in between (Fig 3.18) .

Attempt has been made to calculate Percentage Hypsometric Curve for river basins as done following standard techniques used by Strahler (Chorley , 1971) .

TABLE 3.19

PERCENTAGE HYPSOMETRIC CURVE

% rel. relief top down	Area of basin in percentage				
	Ghatta	Rnchntong	Pachim	Rongmuk	U.Balson
25	8.5	17.5	7.5	19.0	29.5
50	25.0	55.5	24.0	39.0	62.0
75	60.0	89.0	56.5	72.0	89.0

(Source : Author's own calculation)

It is seen that Ghatta - Hussain and Pachim basins have passed the Equilibrium (mature) stage and are heading towards Monadnock phase of the basin degradation (Fig 3.19) . The Rinchintong and Upper Balason basins are in Inequilibrium (young) stage of basin degradation . The Rongmuk basin falls in between .

Relative Hypsometric Curve

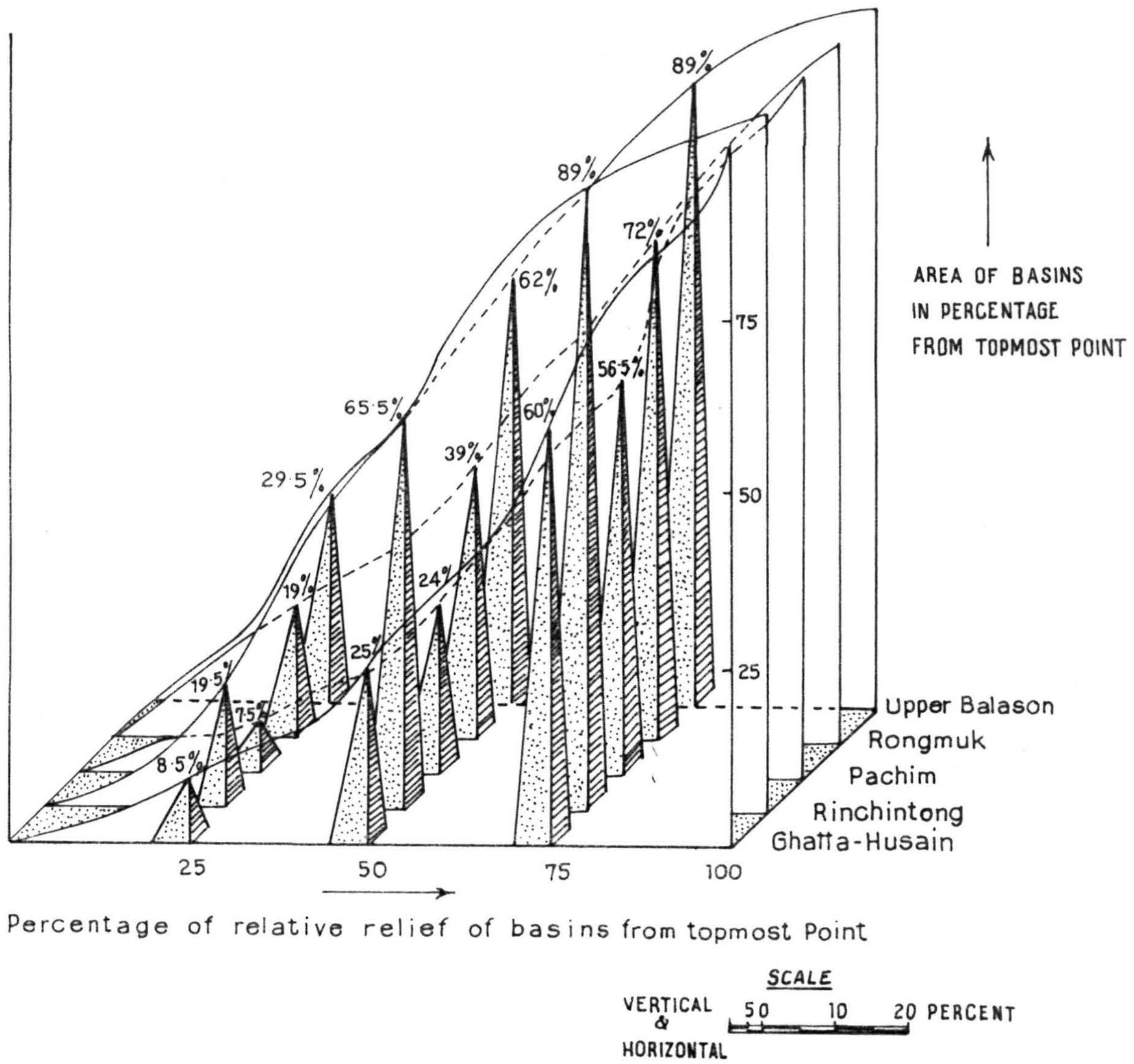


Fig. 3·19

3.10 RELATIVE RELIEF :

As is seen from Fig 3.20 , spots of very high relative relief (more than 500 mt per sq km) are located , on northern side , very close to Lepchajagat encompassing northern parts of Pubong and Tomsong tea gardens ; on eastern side , about half km south of Rongbul close to Talkat tea garden , and in between Sonada and Gorabari etc. The patch of high relative relief between Gorabari and Sonada is located on Hill Cart road. Extensive areas are under high relative relief (400 - 500 mt per sq km) . On north western side , it sprawls over Pubong , Pulungdong , Tamsong , Simrikpani , Dooteria , and Avongrove tea gardens and Ghoom Simana reserve forest . This part has a low drainage density (3.5 to 4.5 ; Figure 3.4) which makes it slide prone . In fact an active huge landslide is located right inside these zones close to Lepchajagat . Due to its effect bench of road connecting Ghoom to Sukiapokhari is subsiding . High relative relief is also encountered in Talkat , Rongmuk , Mandakoti , Oaks , Dilaram , Nahar and Singel tea gardens . In general northern half of study area has higher concentration of higher relative reliefs in comparison to southern half making the former more difficult , more erosive , and less productive than the latter . Most of the best tea gardens are located in southern half whereas north western part has very few of them .

Different zones , too , have been classified with regard to weighted value of relative relief (Fig 3.21) . As is seen from this , lower middle zones of Upper Balason , upper

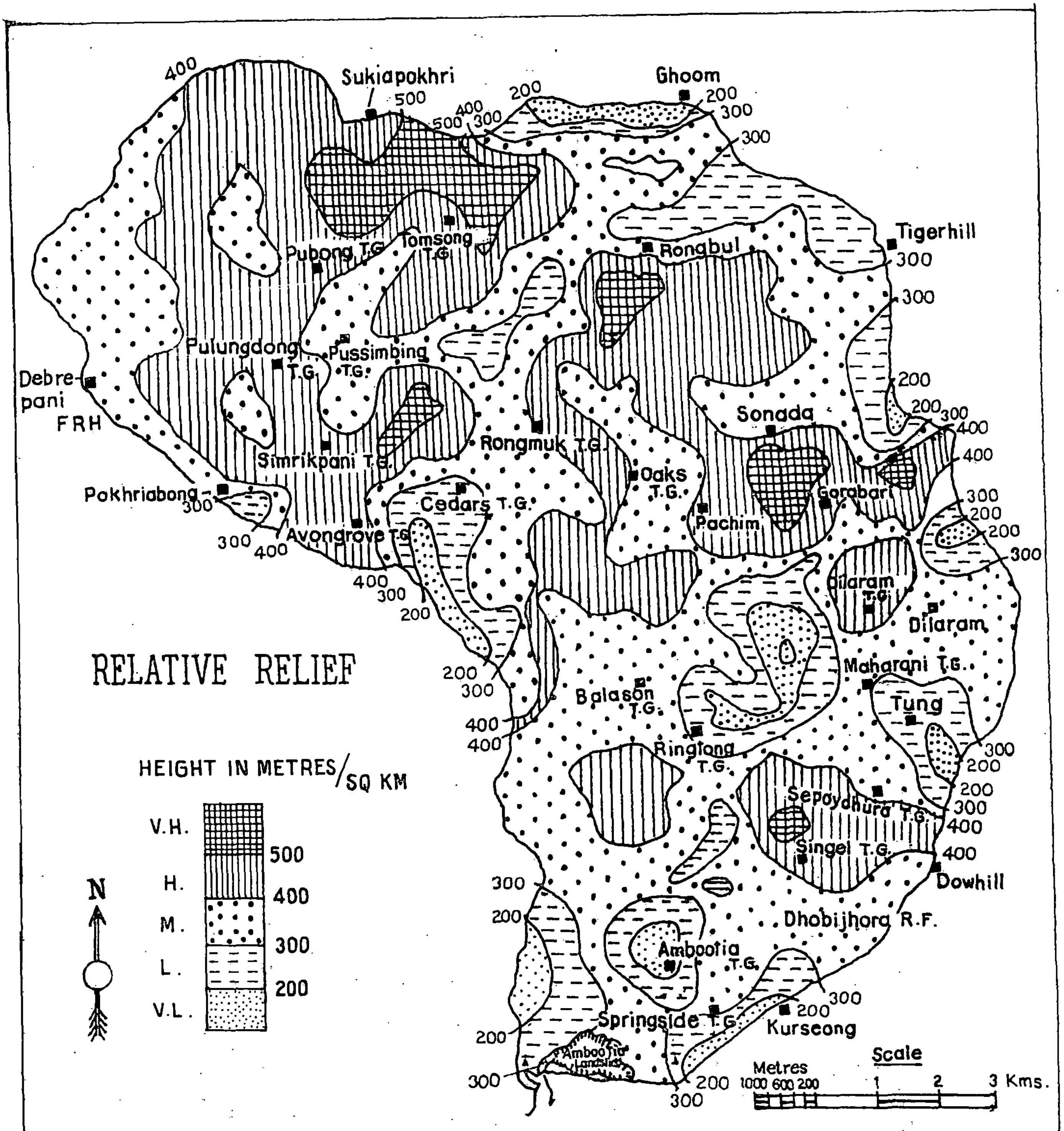

RELATIVE RELIEF
HEIGHT IN METRES/SQ KM
V.H.
500
H.
400
M.
300
L.
200
V.L.
N
Sukiapokhri
Ghoom
Tigerhill
Rongbul
Pubong T.G.
Tomsong T.G.
Pulungdong T.G.
Pussimbing T.G.
Debrepani FRH
Simrikpani T.G.
Rongmuk T.G.
Sonada
Oaks T.G.
Pachim
Gorabari
Pokhriabong
Cedars T.G.
Avongrove T.G.
Dilaram T.G.
Dilaram
Balason T.G.
Maharani T.G.
Tung
Ringtong T.G.
Sepoydhura T.G.
Singel T.G.
Dowhill
Dhobijhora R.F.
Ambootia T.G.
Springside T.G.
Kurseong
Ambootia Landslide
Metres
1000 600 200
Scale
1
2
3 Kms.

Fig. 3·20

Relative Relief

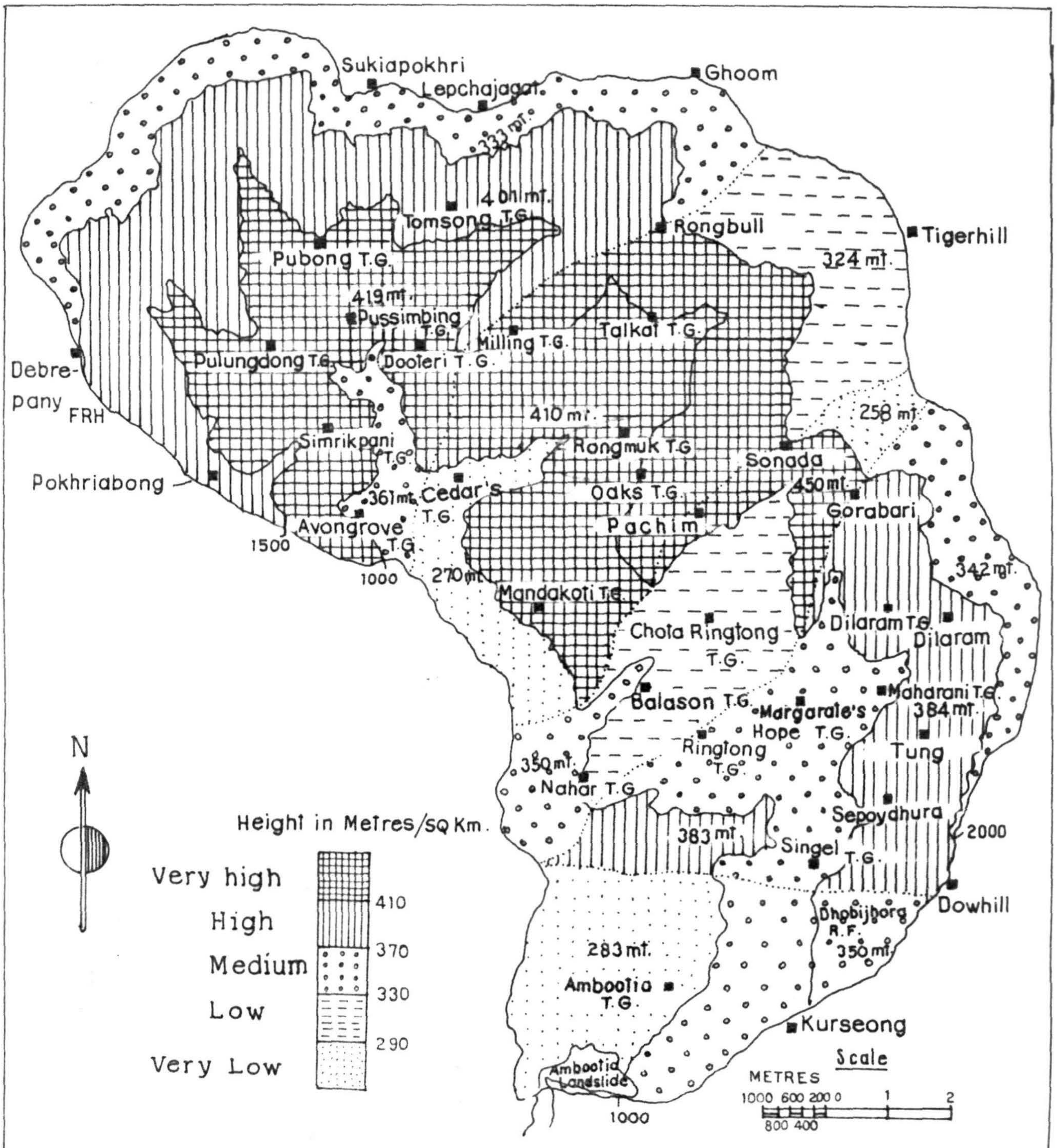


Fig. 3·21

middle and lower middle zones of Rongmuk , and upper middle zone of Pachim fall in very high relative relief category . The high relative relief category sprawls over upper middle zone of Upper Balason and upper middle and lower zones of Rinchintong . Distribution of other classes makes an haphazard pattern . In general, middle reaches of basins in northern half of the area are much steeper and hence more erodible than the southern ones .

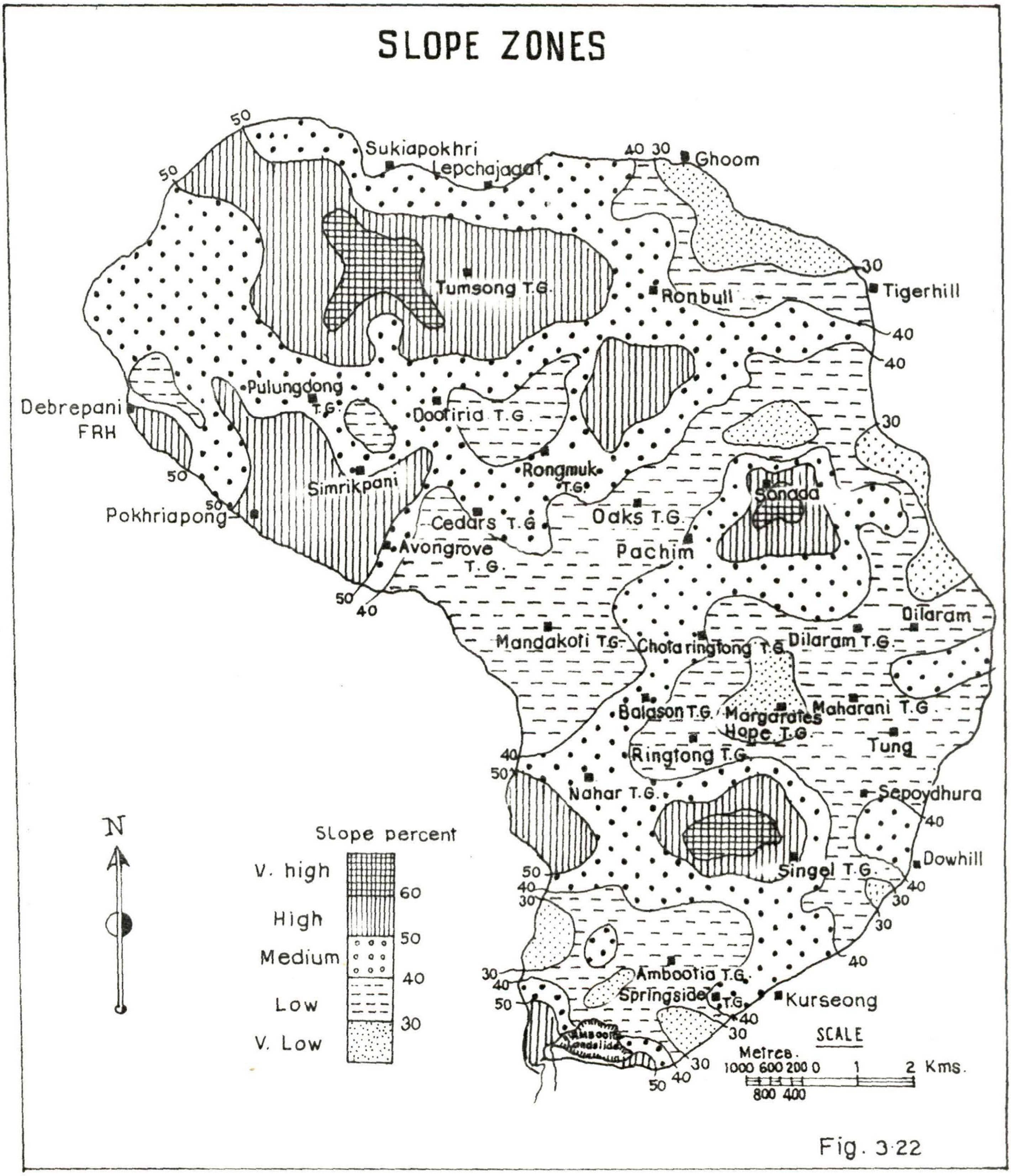
3.11 SLOPE AND ITS DISTRIBUTION :

One of the geomorphological factor influencing the erosion is the sloping of ground surface . The greater the steepness greater is the velocity , carrying capacity , 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 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) . An important parameter is the critical sloping which is the angle of inclination at which malignant erosion begins to occur on unprotected soil . Critical slope varies from 1.7 to 14 percent for surface , for 4 to 29 percent for slope gullies and 1.7 to 11 percent for valley gullies (Zachar , 1984) .

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 phenomena . Weathering of rocks affects their shear strength , bulk density and permeability it penetrates rapidly when rocks are foliated , jointed or crushed (Gerrard , 1991) . From a equally exposed whole free face of rocks , within a unit time , a uniformly thick layer of rocks falls away due to weathering . This accumulates at the base as scree at the angle of repose of material . As the rock slope retreats , the talus slope extends upwards until it completely obliterates the free face . Such talus slopes with exposed rock faces are visible on eastern side of the study area .

As is seen (Fig 3.22) , very high degree of slope zone (more than 60 percent) occurs in and around Pubong , and Singel tea gardens besides a small patch in between Sonada and Gorabari . High degree of slope zone (50 to 60 percent) is most prominent in north western part and is met in Tomsong , Pubong , Pussimbing , Simrikpani and Avongrove tea gardens . Such areas are few in eastern side and are located in Talkat , Singel and Nahar tea gardens and Sonada - Gorabari stretch . Areas of very low degree slope (less than 30 percent) are met in and around Ghoom , Mahaldram and Dhobijhora reserve forest , in Margaret´s Hope , Singel and Ambootia tea gardens . On an overview , medium degree slopes (40 - 50 percent) are most conspicuous in northern half and low degree slopes (30 - 40 percent) in the southern one.

On average slope map (Fig. 3.23) , it is seen that upper and lower middle zones of Upper Balason , upper middle zone of Pachim and lower zone of Rinchintong have more



SLOPE ZONES
Sukiapokhri
Lepchajagat
Ghoom
Tumsong T.G.
Ronbull
Tigerhill
Pulungdong T.G.
Debrepani FRH
Dooteria T.G.
Rongmuk T.G.
Simrikpani
Pokhriapong
Cedars T.G.
Oaks T.G.
Sonada
Pachim
Avongrove T.G.
Dilaram
Mandakoti T.G.
Chota ringtong T.G.
Dilaram T.G.
Balason T.G.
Margarates Hope T.G.
Maharani T.G.
Tung
Ringtong T.G.
Nahar T.G.
Sepoydhura
Dowhill
Singel T.G.
Ambootia T.G.
Springside T.G.
Kurseong
Ambootia Landslide
N
Slope percent
V. high
High
Medium
Low
V. Low
60
50
40
30
SCALE
Metres
1000 600 200 0 1 2 Kms.
800 400

Fig. 3.22

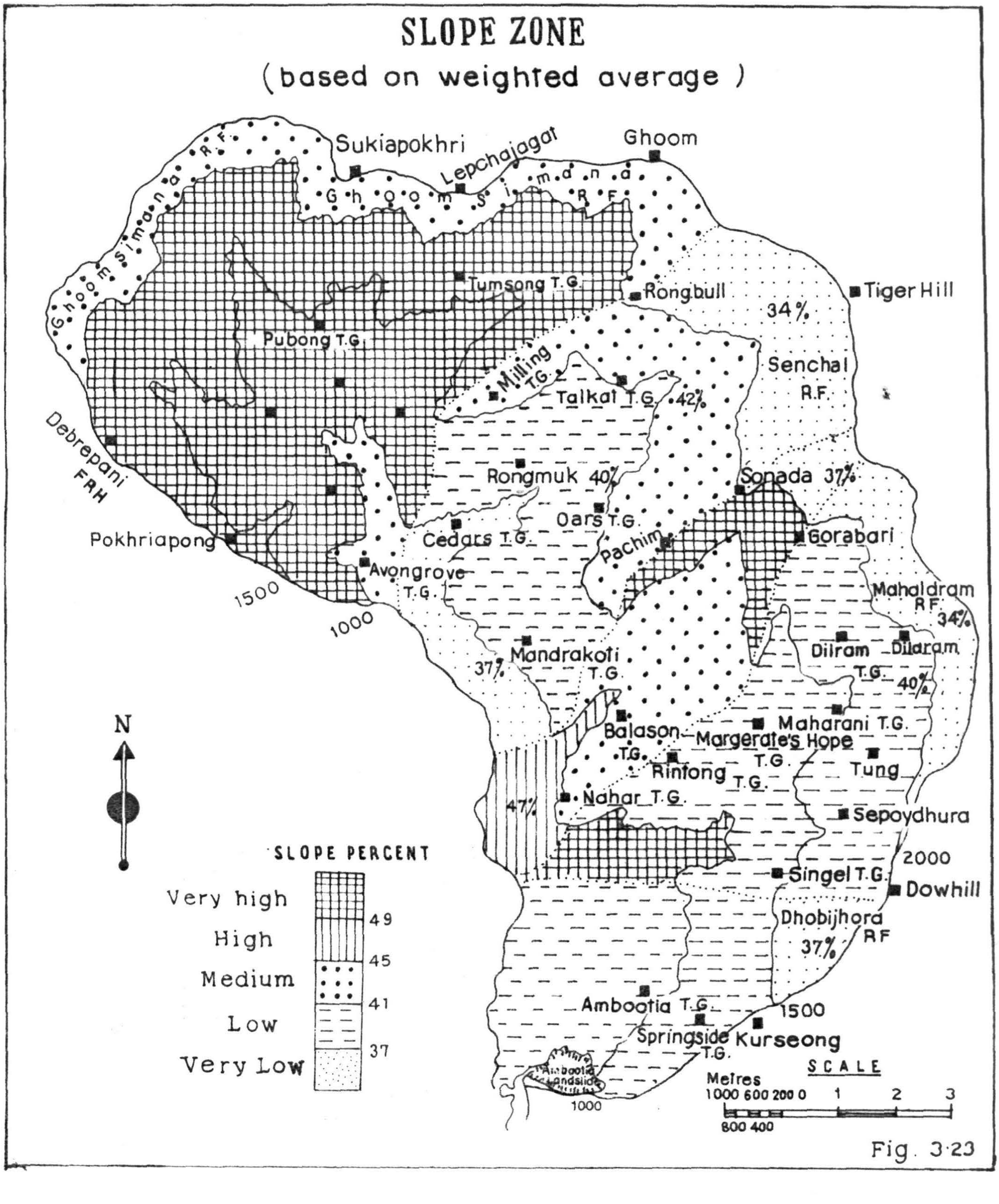

SLOPE ZONE
(based on weighted average)
Sukiapokhri
Lepchajagat
Ghoom
Ghoom Simana R.F.
Tumsong T.G.
Rongbull
Tiger Hill
34%
Pubong T.G.
Milling T.G.
Talkat T.G.
42%
Senchal R.F.
Debrepani FRH
Rongmuk 40%
Sonada 37%
Oars T.G.
Cedars T.G.
Pachim
Gorabari
Pokhriapong
Avongrove T.G.
Mahaldram R.F.
34%
1500
1000
Mandrakoti T.G.
37%
Dilram
Dilaram T.G.
40%
N
Balason T.G.
Margerate's Hope T.G.
Maharani T.G.
Rinfong T.G.
Tung
47%
Nahar T.G.
Sepoydhura
SLOPE PERCENT
Very high
49
High
45
Medium
41
Low
37
Very Low
2000
Singel T.G.
Dowhill
Dhobijhora RF
37%
Ambootia T.G.
1500
Springside T.G.
Kurseong
Ambootia Landslide
1000
SCALE
Metres
1000 600 200 0 1 2 3
800 400

Fig. 3·23

than 49 percent slope . Low and very low degree of slopes occupy major chunk of south and eastern part of the study area and sprawls over entire Ghatta - Hussain , entire Rinchintong except lower zone , upper Pachim , and upper Rongmuk zones . Besides lower middle and lower Rongmuk zones , too , fall in this category. The other classes are randomly distributed .

3.12 RUGGEDNESS :

The slope gives an idea about inclination of grounds but says little about degree of dissection which is best expressed by the ruggedness value . The ruggedness number represents an abstract idea and , roughly speaking , it represents surface area of terrain assuming it to have degraded from a horizontal cuboid with upper edge situated at the highest point of terrain and assuming further that no degradation except by the drainage lines took place and that interfluve points still exist at surface of so called cuboid . This concept is highly theoretical and no such situation can exist in nature . Nevertheless , it gives an indication of dissection of terrain.

As is seen Fig 3.24 , very high and high ruggedness is found close to Sonada , Gorabari , Mahaldram RF , Dilaram , Chota Ringtong , Mandakoti , Rongmuk , Talkat , Tomsong , Pubong and Avongrove tea gardens . Low and very low ruggedness is seen in major part of the area at random . Despite having higher

Ruggedness Zones

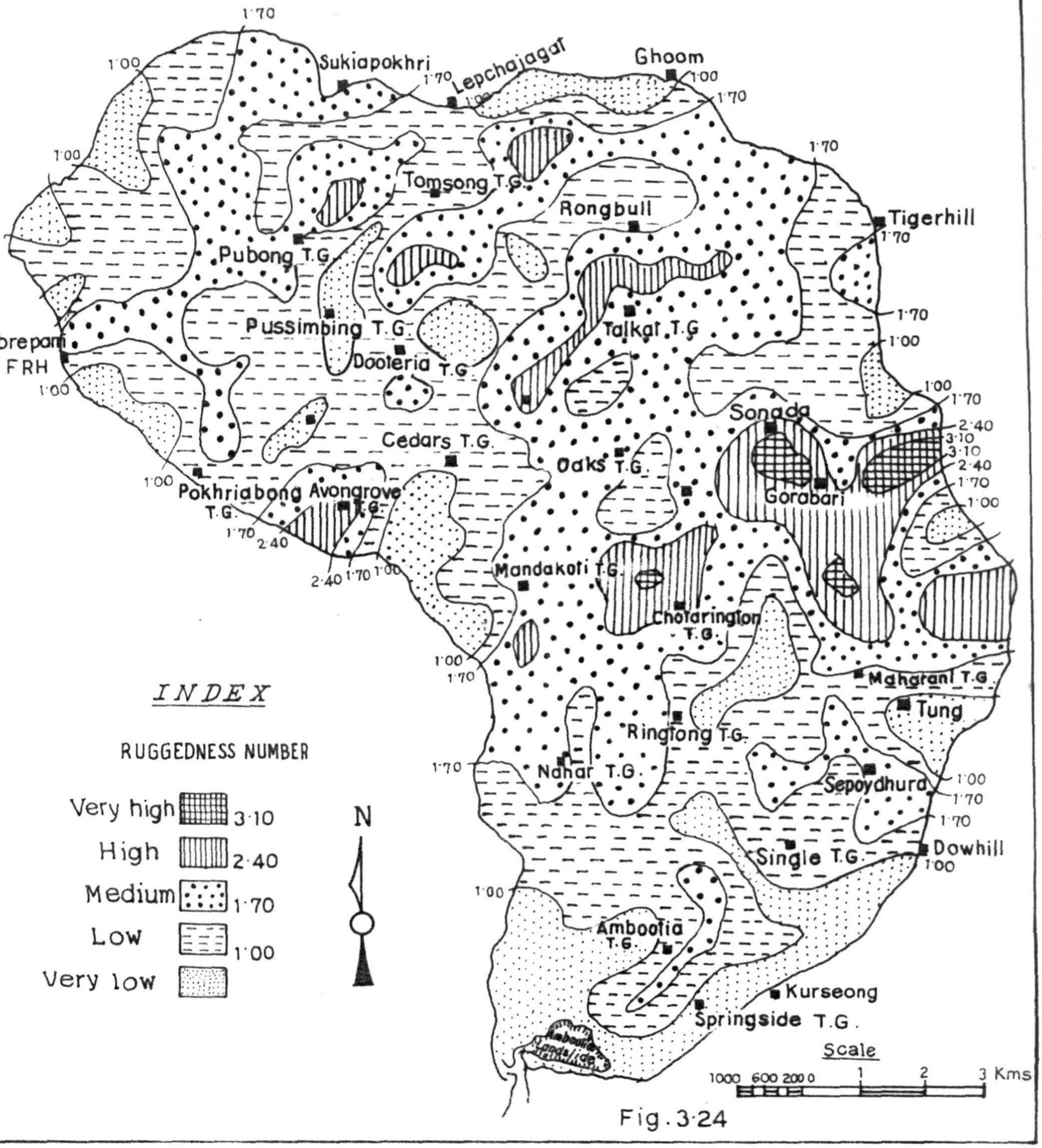


Fig. 3·24

degree of slope (Fig 3.23) and higher relative relief (Fig 3.21) , the north western part of the study area has predominantly very low and low ruggedness . This is again indicative of high permeability leading to coarse drainage texture . The zones of basins , too , have been classified in respect of their ruggedness (Fig 3.25) . As is seen , upper middle and lower middle zones of Pachim have ruggedness number more than 2 , Rongmuk upper , upper middle , lower middle zones , and Rinchintong upper and upper middle zones have ruggedness numbers between 1.66 and 2.00 . Medium ruggedness in north western part is spectacular . In general , central and eastern parts of the basin are most rugged .

3.13 SEDIMENT LOAD , DISCHARGE AND VELOCITY OF JHORA FLOWS :

Ruggedness of terrain indicates the extent of surface area available for eroding agents to operate . The most important and direct evidence of erosion is obtained by sediment load in rivers , the discharge in it and the velocity of flowing water. Four rivers of study area , namely , Ghatta - Hussain , Rinchintong , Pachim and Rongmuk were monitored during July to November in the years 1992 and 1993 for assessing sediment load and discharge . The methodology adopted was not very sophisticated . The level of flowing water of all of them was measured with respect to bench marks fixed on bridges across them . Upper Balason could not be monitored due to absence of any easily approachable bridge

Ruggedness Zones

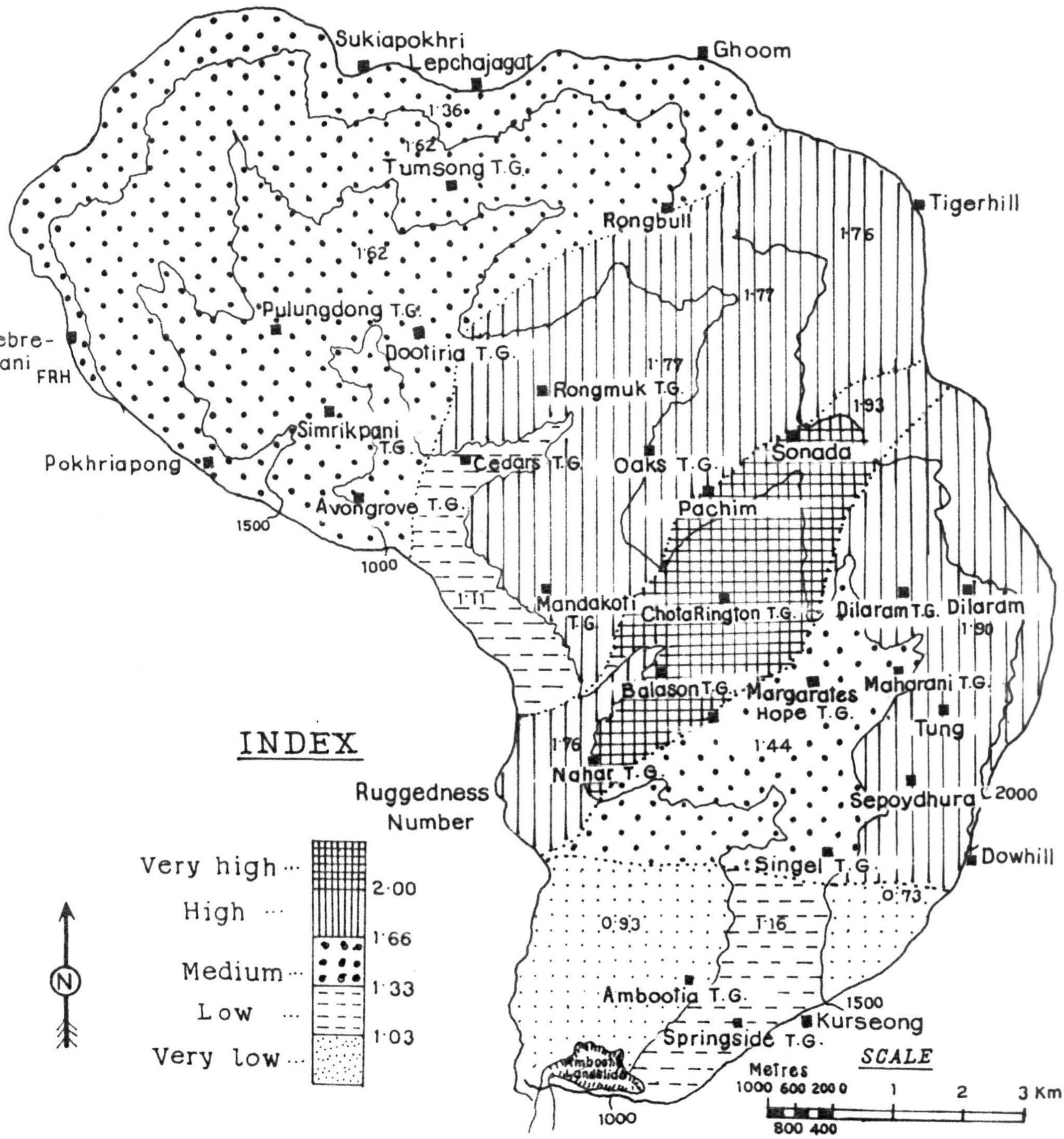


Fig. 3·25.

over it . During currency of rainstorms , attempt was made to measure water levels more frequently . Simultaneously water sample was collected and oven dry weight of sediment in it measured later on . Cross sections of rivers were obtained below the benchmark . Velocity of flowing water was assessed by float method at different levels of flows . The results have been tabulated in Appendices I to VIII .

Measurements of level of flows and collection of sediments could not be done during some parts of some months . In such cases results have been extrapolated for entire months for making realistic assessments . The soil loss per hectare of each basin area as extracted from Appendices I to VIII and is given in Table 3.20. This has also been shown graphically in Figure 3.26 .

As is seen from this , during the period July to November 1992 , Rinchintong and Pachim have produced 0.72 and 0.75 tons of sediment per ha . Soils in Ghatta - Hussain are getting eroded the least (0.57 tons / ha) and those in Rongmuk the most (3.05 tons / ha) . The month of August was most damaging and contributed 0.75 tons / ha out of a total soil loss of 1.27 tons / ha ; close to 60 percent of total during the period . October and November were the least erosive , as expected .

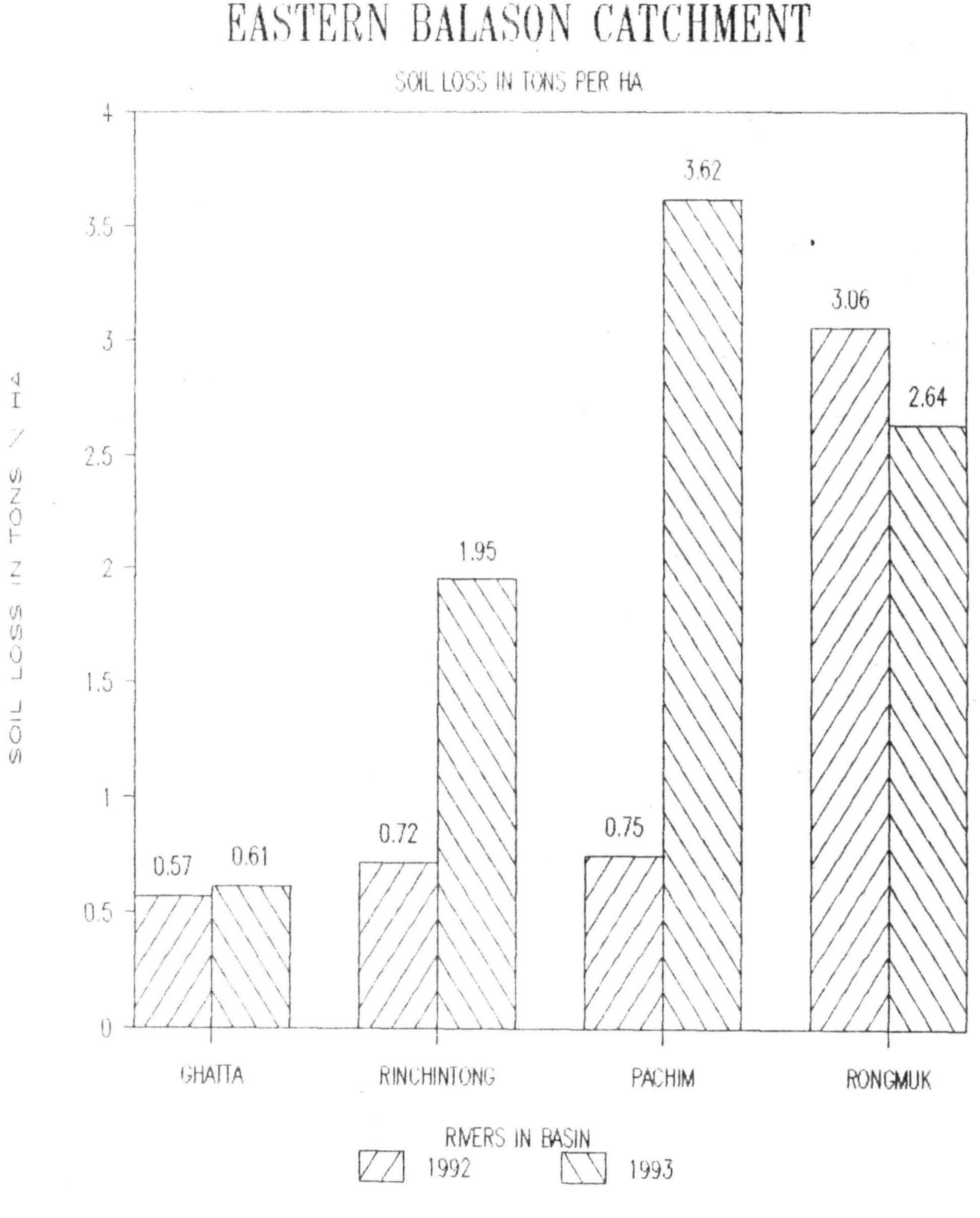

EASTERN BALASON CATCHMENT
SOIL LOSS IN TONS PER HA
SOIL LOSS IN TONS / HA
4
3.5
3
2.5
2
1.5
1
0.5
0
0.57
0.61
0.72
1.95
0.75
3.62
3.06
2.64
GHATTA
RINCHINTONG
PACHIM
RONGMUK
RIVERS IN BASIN
1992
1993

Fig. 3·26

TABLE 3.20

SOIL LOSS IN METRIC TONS PER HA

1992

RIVER	JULY	AUGUST	SEPT.	OCTO.	NOV.	TOTAL
GHATTA	0.18	0.18	0.19	0.02	0.00	0.57
RINCHINTONG	0.14	0.28	0.26	0.02	0.02	0.72
PACHIM	0.17	0.47	0.09	0.01	0.01	0.75
RONGMUK	0.61	2.09	0.29	0.05	0.02	3.06
AVERAGE	0.27	0.75	0.21	0.02	0.01	1.26
			1993			
GHATTA	0.21	0.19	0.19	0.02	0.00	0.61
RINCHINTONG	0.92	0.73	0.26	0.02	0.02	1.95
PACHIM	3.03	0.47	0.10	0.01	0.01	3.62
RONGMUK	1.68	0.60	0.29	0.05	0.02	2.64
AVERAGE	1.46	0.50	0.21	0.02	0.01	2.20

(Source : Author's own calculation)

During corresponding period of 1993 Ghatta - Hussain has produced the least , and Pachim the most , quantity of sediment per ha . Sudden spurt in rate of sediment production of Pachim , only the second lowest during 1992 in this regard , is explainable by collapse of Hill Cart road in between Gorabari and Sonada consequent upon a landslide down below the road bench . Unfortunately , data could not be collected during August and September 1993 (and figures of soil loss had to be assumed from corresponding periods of previous years) , which would have been quite revealing . Nevertheless , this shows that contribution of sediment load on account of other soil degradation processes is pea nuts in comparison to that by landslides , and bank failures . Rongmuk , here too , is seen as one of the highest contributors of sediments (2.64 tons / ha) . Overall soil loss from area was 2.20 tons / ha . Looking at Table 3.20 and Fig. 3.26 , it is not possible to locate any trend in regard to sediment production rate of different basins . The one contributing the least now , can be the highest producer later and vise - versa . It is because of the fact that major chunk of sediments comes from landslides , bank failures , and quarries etc.

The rate of 0.75 tons per ha per year is compensation rate of erosion on the boundary between damaging and unharmful erosion (Zachar , 1984) . Most rivers in the eastern Balason basin are , therefore , either suffering from malignant erosion or are on the verge of it . Given the crude method adopted for assessment , non - inclusion of crucial months of May and June , and non - inclusion of bed load in compilation , the scenario of intensity of malignant erosion is far worse than what the data indicates . Besides the rate , the total soil loss , too ,throws some light on trends of soil erosion .

As is seen from from Fig 3.27 and Table 3.21 , total soil loss was much higher during 1993 than that in 1992 (4410.37 tons as against 3086.53 tons during 1992). Contribution of Rongmuk has always been the highest (2245.18 tons and 1938.31 tons during 1992 and 1993 , respectively) . Rongmuk has contributed over 72 percent of total soil loss in 1992 as against only 44 percent during 1993 .

EASTERN BALASON CATCHMENT

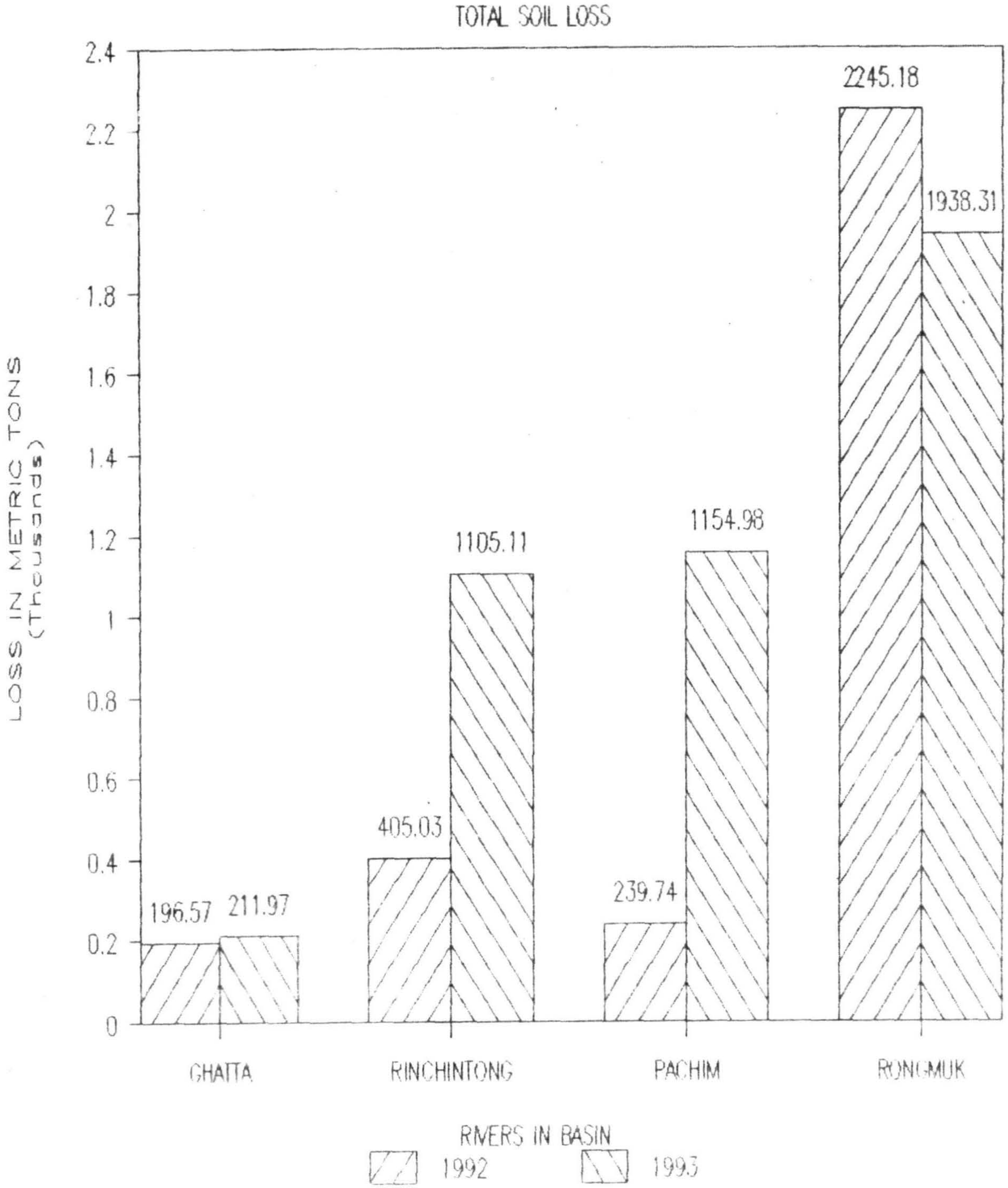


Fig. 3.27

TABLE 3.21

TOTAL SOIL LOSS FROM DIFFERENT BASINS IN METRIC TONS

1992

RIVER	JULY	AUGUST	SEPT	OCTO	NOV	AVERAGE
GHATTA	307.26	307.26	328.95	33.68	5.71	196.57
RINCHINTONG	385.41	789.16	746.01	54.48	50.10	405.03
PACHIM	273.97	746.73	151.13	13.44	13.44	239.74
RONGMUK	2240.29	7682.85	1070.42	170.00	62.32	2245.18
TOTAL	3206.94	9526.01	2296.51	271.61	131.57	3086.53

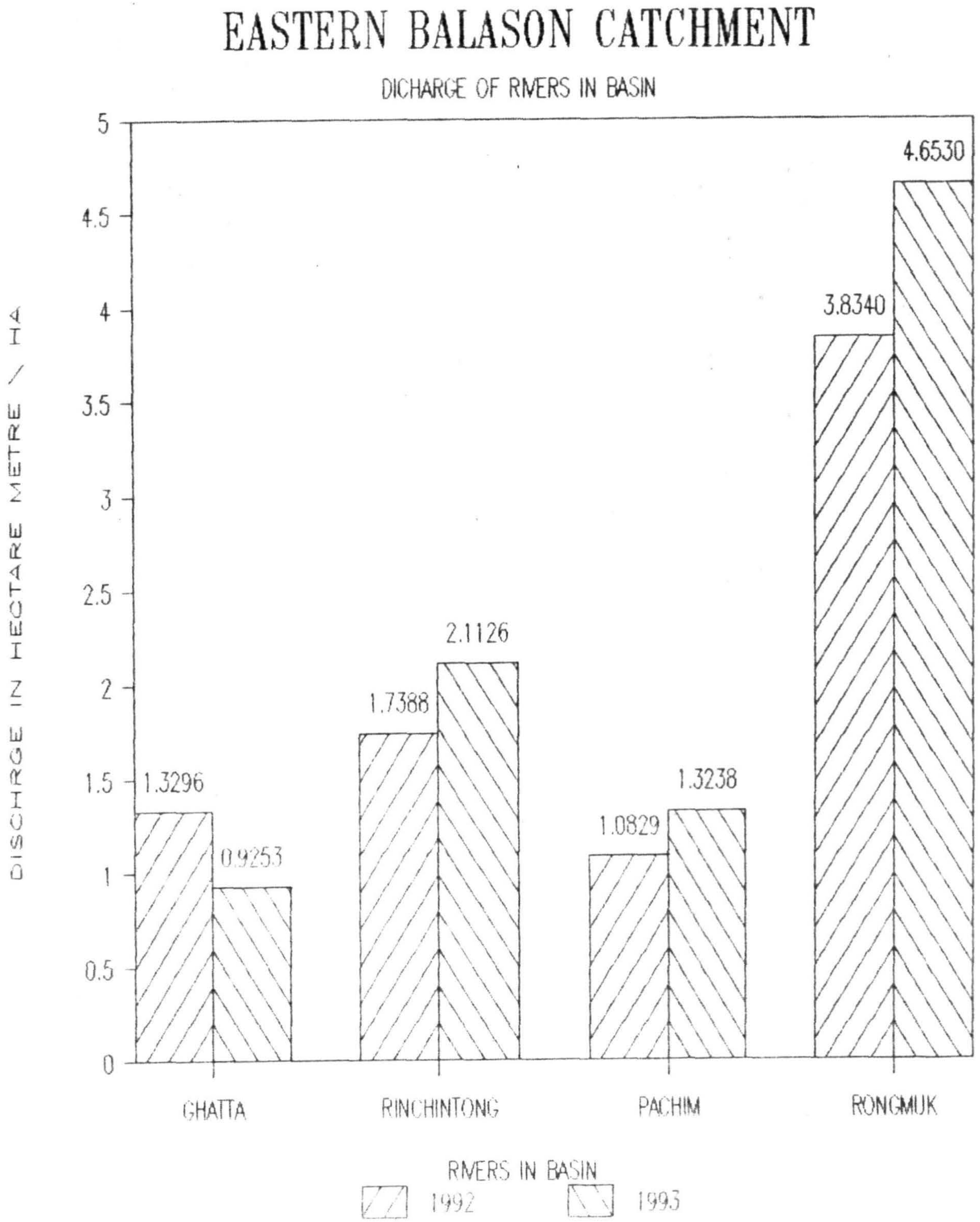
1993

RIVER	JULY	AUGUST	SEPT	OCTO	NOV	AVERAGE
GHATTA	368.46	323.03	328.95	33.68	5.71	211.97
RINCHINTONG	2601.86	2073.09	746.01	54.48	50.10	1105.11
PACHIM	4850.17	746.73	151.13	13.44	13.44	1154.98
RONGMUK	6187.89	2200.92	1070.42	170.00	62.32	1938.31
TOTAL	14008.39	5343.78	2296.51	271.61	131.57	4410.37

(Source : Author´s own calculation)

While sediment discharge from Ghatta - Hussain was almost of similar level in both years that of Rongmuk had gone down during 1993 . The real contributors during 1993 had been Rinchintong and Pachim (273 and 482 percent over and above that of 1992) . Besides total soil loss discharge of rivers , too , throws some light on erosion characteristics of any basin.

Table 3.22 and Fig 3.28 show that in 1993 rate of discharge has registered a increase of 22 , 22 and 21 percent in Rinchintong , Pachim and Rongmuk rivers respectively whereas it has come down by 28 percent in Ghatta - Hussain . Due to lack of appropriate data , it is difficult to explain decline as rate of discharge depends on a number of factors including intensity of rainfall . It , however , does explain the concept of exponential growth of sediment load with slight increase of discharge . A increase of 22 percent in rate of discharge in Rinchintong and Pachim has increased total sediment load by 273 and 482 percent , respectively . The extent of



EASTERN BALASON CATCHMENT
DICHARGE OF RIVERS IN BASIN
DISCHRGE IN HECTARE METRE / HA
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
1.3296
0.9253
1.7388
2.1126
1.0829
1.3238
3.8340
4.6530
GHATTA
RINCHINTONG
PACHIM
RONGMUK
RIVERS IN BASIN
1992
1993

Fig. 3.28

muddiness of water during monsoon is yet another parameter explaining erosion status of any basin .

TABLE 3.22

DISCHARGE OF RIVERS IN HECTARE METRE

RIVER	JULY	AUGUST	SEPT	OCTO	NOV	AV. HA.MT\HA
			1992			
GHATTA	831.09	831.09	359.39	220.83	51.17	1.3296
RINCHINTONG	1838.24	1390.15	944.40	522.02	217.22	1.7388
PACHIM	522.49	511.86	344.49	176.90	176.90	1.0829
RONGMUK	3887.60	2913.38	3312.84	1988.03	1988.03	3.8340
TOTAL	7079.42	5646.49	4961.12	2907.78	2433.31	2.3438
			1993			
GHATTA	402.88	455.26	390.92	220.21	126.92	0.9253
RINCHINTONG	1855.04	1705.82	1302.64	731.45	373.16	2.1126
PACHIM	697.25	511.86	344.49	282.20	282.20	1.3238
RONGMUK	5343.21	4466.61	3179.99	2636.04	1473.88	4.6530
TOTAL	8298.38	7139.55	5218.03	3869.90	2256.15	2.7259

Areas of Ghatta , Rinchintong , Pachim and Rongmuk are , respectively , 1725, 2825 , 1600 and 3675 ha.

(Source : Author´s own calculation)

As is seen from Table 3.23 and Fig 3.29 , turbidity of waters of Ghatta , Rinchintong and Pachim had increased during 1993 by 39 , 79 and 247 percent over that of 1992 . The turbidity of Rongmuk has come down by 43 percent . The great enhancement of Pachim shows highly concentrated delivery of sediments as indicated earlier .

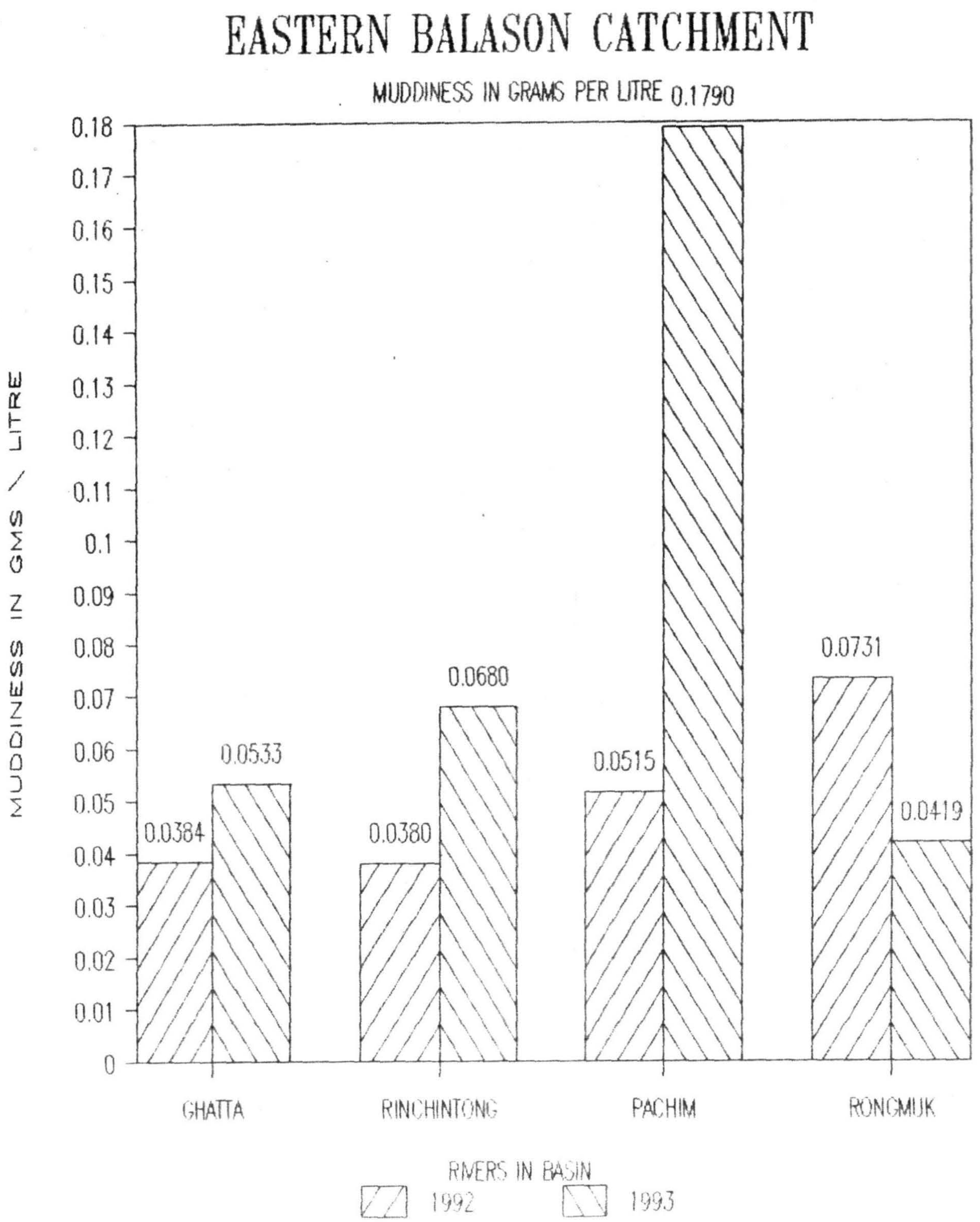

EASTERN BALASON CATCHMENT
MUDDINESS IN GRAMS PER LITRE
0.1790
0.18
0.17
0.16
0.15
0.14
0.13
0.12
0.11
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
MUDDINESS IN GMS \ LITRE
0.0384
0.0533
0.0380
0.0680
0.0515
0.0731
0.0419
GHATTA
RINCHINTONG
PACHIM
RONGMUK
RIVERS IN BASIN
1992
1993

Fig. 3·29

TABLE 3.23

EXTENT OF MUDDINESS IN RIVER WATERS IN gm\litre

RIVER	JULY	AUGUST	SEPT.	OCTO	NOV.	AVERAGE
1992						
GHATTA	0.0370	0.0370	0.0915	0.0153	0.0112	0.0384
RINCHINTONG	0.0210	0.0568	0.0790	0.0104	0.0231	0.0380
PACHIM	0.0524	0.1459	0.0439	0.0076	0.0076	0.0515
RONGMUK	0.0576	0.2637	0.0323	0.0086	0.0031	0.0731
1993						
GHATTA	0.0915	0.0710	0.0841	0.0153	0.0045	0.0533
RINCHINTONG	0.1403	0.1215	0.0573	0.0074	0.0134	0.0680
PACHIM	0.6956	0.1459	0.0439	0.0048	0.0048	0.1790
RONGMUK	0.1158	0.0493	0.0337	0.0064	0.0042	0.0419

(Source : Author s own calculation)

CONCLUSION :

Thus , it is seen that rivers lying on southern side of the study area are steeper in their long profiles than those in northern side . The drainage density shows a mixed trend with high density areas located in central and central east part . The highest order of stream met within area is 6 and is met only in the lowest one fourth stretch of basin . Higher concentration of number of streams is seen in upper parts of southern half of the study area whereas the southern most tip shows the least value . Individual streams are lengthier as one goes from southern to northern side with few exceptions . Average length of streams show a variable trend but , in general , this value is smaller for first order streams in southern half of the study area . In one basin in central part they are exceptionally longer than others showing parallel drainage pattern . Bifurcation ratio of streams shows a mixed distribution and varies from 3.00 to 6.00 . Stream length ratio of rivers does not show any particular pattern but , in general , streams located north ward in the study area have lower values for second and fourth order streams and higher values for others . In last 65 years , sinuosity of rivers have gone up , in general , with one showing a highly significant change . Another river has got its sinuosity reduced quite considerably . The study area is a labyrinth of ridges and valleys having multifarious land uses , the most extensive land use being tea gardens . Hypsometric distribution of area shows that two perched basins in central and northern parts still have to go considerable degradation to achieve maturity . Areas with high relative relief tend to concentrate on lower central part on northern half of study area with lower values for entire southern half . Areas with high degree of slopes are concentrated on north - western part with patches here and there in rest of the area . The ruggedness number shows a definite pattern of distribution with central and central eastern part showing the highest , the southern part the lowest and the north western part medium values . Analysis of sediment load and discharge of four rivers shows that rivers located on northern side are contributing maximum sediment load and discharge to river Balason . Analysis also shows dramatic increase in rate of sediment production per unit area and in turbidity of discharge indicating thereby concentrated delivery of soil into river by bank failures , landslides , quarries etc.

Various morphometric factors as described above , interact with pedological , climatic and biotic factors and have great bearing on ecological soundness of any basin

. For understanding the effect of this interaction on soil erosion status of any area , it is necessary to understand the mechanisms and processes of soil erosion . This is discussed in next chapter.

CHAPTER IV

SOIL EROSION : MECHANISM AND PROCESSES

INTRODUCTION :

This chapter deals with mechanisms and processes of soil erosion . Since the study area is affected by fluvial erosion , mechanisms of various forms of it have been discussed . Those dealt in details are splash , sheet , rill , gully , stream bank , pothole , tunnel and sloughing erosion along with lands slides .

4.1 SPLASH EROSION :

The most important cause of break up of soil clods is the impact of fast falling rain drops in a severe storm , as they possess very considerable kinetic energy and momentum . The greater the intensity of the storm , larger is the drops and faster they fall. Their velocity may even exceed that for free fall because of air turbulence in the storm . The falling rain drops accelerate until the frictional resistance of air is equal to the gravitational force and then continues to fall at that velocity , called the terminal velocity (Datta , 1986) . The frictional resistance of air against the accelerating rain drops is a function of surface area per unit volume of it , which in turn , is affected by intensity of rain , air resistance , atmospheric pressure , temperature and humidity . Hence, larger the rain drops , higher is the terminal velocity . In general , as the height of fall of rain drops increases , velocity increases only up to a height of 10.5 mt after which terminal velocity is achieved (Michael , 1981) . A drop of one mm diameter , typical of fairly light rain , will have a terminal velocity of almost 3.8 mt per second and a drop of 4.5 mm in diameter , typical of a heavy storm , will have one of 9 mt per second , but its kinetic energy will be 500 times , and its momentum 200 times , greater than that of the smaller drop (Davies , 1988) . Thus, more violent the storm , greater is the shattering effect of rain drops . The kinetic energy is such that a rainfall of 50 mm an hour is sufficient force to lift 180 mm of top soil to a height of 910 mm 86 times during an hour's rain (Osborn , 1969) . Rain drop impact shatters clods and causes splash , and some of the droplets blown up carry fine soil granules and sand grains . A single rain drop may splash wet soil as much as 60 cm high and 150 cm away from the spot where it hits (Michael , 1981) . The force of falling rain drops may be 10000 times the energy of the surface run off in hard storms , even of steep slopes (Osborn , 1969) . As a result of splash , some of the finer particles , which contain much of the soil humus , disperse in water and run off the land leaving coarser sand particles behind . Thus , erosion due to splash and run off , tends to coarsen the texture of soil left behind . On level ground , where drops strike vertically , throwing up action by bombarding rain drops , and dispersal of soil charged water droplets tend to cancel one another , leaving the same amount of soil on the site at the end of rain . Experiments have shown that drops striking standard sand at different angles , indicated that the percentage of detached material moving down hill amounted to 50 percent plus the percentage of slope and on a 10 percent slope , movement down hill was three times higher than that uphill (Osborn , 1969) . Even on level ground , where the rain drops hitting vertically , they create extreme turbulence in the slowly moving thin film of muddy water. This enables it to carry far larger quantity of the splashed material than its carrying capacity would , otherwise , allow . The sealing of microscopic pores is yet another important effect of rain drops that needs elaboration.

The churning action of beating rain drops makes dispersed material into a pasty mass . In the violent shifting of particles on surface , finer ones are filled in between the coarser ones making an impervious seal which , coupled with levelling of soil surface due to break up of isolated clods and its compaction by the impact of rain drops , causes a resistant surface cap to be formed . Frequently this surface sealing is perfect enough to keep soil below a small distance quite dry even with continued rain , and after its drying and stiffening , strong enough not to let sprouting seeds (in loose soil beneath) to push through it (Bennett , 1955) . Besides

, this seal enhances run off dramatically . Detachability of soil particles is the parameter affecting the intensity of splash erosion.

There is a close relationship between soil detachment and splash erosion . Detachability is influenced by size and shape of particles . The most easily dislodged are fine sand , the coarser ones resisting the detachment because of their greater size and weight . Fine textures soils are less detachable because of aggregation of particles . The shape of particles affects detachability through differences in the degree of interlocking of particles . Other factors affecting detachability are structure , content of organic matter , moisture and tilth . Vegetation plays an important role in respect of splash erosion . The plant cover on the land offers natural resistance to the splash erosion process . By intercepting the shooting rain drops , vegetation dissipates their energy and reduces quantum of soil splashed . Essential criteria for adequate protection of soil against this menace is complete canopy over the land , either by litter on the ground or by standing vegetation provided , if it is tall enough to produce splash from drippings , under storey and ground cover , too , is present . In general , amount of vegetation is more important than its kind in its role of protection of soils against splash . Effective (95 percent) control of rain drop energy requires approximately 2000 kgs of sod grass , or 4000 kgs of ordinary crop , or 7000 kgs of tall grass per hectare and the vegetal cover after some rain is known to have interrupted .3 metric ton of splash soil per metric ton of oven dry weight of vegetation (Osborn , 1969) . This is only a small part of whole soil involved as beating rain drops continuously wash down intercepted splash material . In case of sandy areas subjected to aeolian erosion , soil conditioners , such as bitumen , polyacrylamide , and polyuria are known to reduce splash erosion by 88 , 90 and 91 percent , respectively , after one hour of rain fall of intensity of 40 mm per hour (De Kesel , 1990) .

Since the rain fall is quite stormy in the study area , any bare soil is subjected to serious dangers of splash erosion . This is specially so in cultivated areas with ploughed soils . Tea garden areas with poor density of tea bush canopy are also subjected to splash erosion as also the degraded forest areas. Splash erosion is seen in Ambootia tea garden where soils on slopes have been ploughed. The new plantation of tea takes five to ten years to cover the ground fully. This patch of Ambootia tea garden shall go on eroding for next many years. It should be thoroughly mulched during rains through straw to protect the soil. The patches having low canopy density of tea bushes in Single tea garden are also suffering from splash erosion. A younger tea plantation of Maharani tea garden is also seen affected by splash erosion. Some patches of Chhota Ringtong tea garden are also seen severely affected by splash erosion. A newly cut road in Chhota Ringtong is also showing large scale splash erosion. The Pumong Phatak-Dudhia road, which is newly cut, is also suffering from splash erosion. In hills, potato tuber is harvested during July by excavation of soil. The excavated soil is exposed to the full force of the monsoon showers. Large scale splash erosion is seen from the potato fields. The vegetables such as beans, cabbage etc. are planted after harvesting of potato. But they hardly provide any protection against lashing rain storms. In Dhobijhora and Mahaldram forest splash erosion is assisted by overgrazing. The soils loosened by hoofs of cattle are splashed around. So is also the case of the Senchal reserve forest area. In degraded forests of Senchal splash erosion is very surreptitious.

4.2 SHEET EROSION :

The run off takes the form of sheet flow and channelized flow ; former coupled with rain drop action produces sheet erosion . Its effects are gradual and often go unnoticed until most of the top soil is removed . It is the least conspicuous but the most extensive and insidious type of erosion (Bennett , 1955) . Areas where loose , shallow top soil overlies a tight sub soil are most susceptible to this form of erosion (Schawab , 1971) . Excess water collecting on the surface moves down hill and gains velocity in accordance with its depth and amount of vertical fall . The energy present is only that of translation , and is seldom of consequence in soil movement . As the depth of flow increases , turbulent patches form and travel down slope . The frequency of patches increases with increased depth and velocity until the entire flow is turbulent . Turbulence is accompanied by great increase in kinetic energy and erosivity

. The impacts of falling drops contribute greatly to erosion by such flows . Direct impact of splashes is reduced by as little as 2.5 mm depth of water but the energies of falling drops are transferred to the surface flow in form of turbulence . Strong vertical velocities in the water are directed downwards , to detach the soil , and upwards , to support the detached material . Under such conditions , sheet flow may carry large amount of soil , specially the finer fractions , and lighter organic and soluble materials , even without sufficiently erosive horizontal velocities . It is through the combined action of rain drop erosion and sheet flow that rain storms are able to remove fairly uniform layers of soils from large areas . This form of erosion involves selection and sorting of the erode material . Since selection process of erosion includes the washing out of valuable soluble substances from the soil , this process is one of great economic importance . The substances that may be washed out of soil in this way include those soluble in weak acid solutions , and humus substances of low molecular weight , both of which groups are very important for fertility of soil (Zachar , 1984) .

Frequently the removal of soil by sheet erosion is so slow and insidious that land appears absolutely protected but appears to be turning light coloured as the removal of dark hued top soil exposes relatively light coloured sub - surface material . Sheet washing is also indicated by change in texture towards coarseness and reduced plant growth . One may also recognize the extent of sheet washing by measuring the depth of A horizon in various parts of the field . As a rule

, depth of this horizon is fairly uniform unless erode . The departure of depth of A horizon from the normal is an accurate measure of the degree of sheet washing (Jacob , 1965) . Various factors affect the susceptibility of soils to sheet erosion .

The differences in susceptibility of various soils to sheet erosion depends , principally , on slope , climate , and the character of the soil . Steep and moderately steep lands and those subjected to heavy or intense rains are likely to be the most troublesome . Areas where loose shallow top soil overlies a tight dense clay sub-soil or other impervious sub-layers are most susceptible to sheet erosion (Schwab , 1971) . Fine grained soils (silt loam) , fragile sandy soils , and soils deficient in organic matter are also exceptionally vulnerable . Sheet erosion is quite intense in the study area.

In this region , from June to September 20 - 27 rainy days occur in each month with 5 - 20 days having rain fall more than 50 mm (Starkel , 1970) . Such a situation makes bare grounds , poor canopy density tea bush areas , deforested areas, over grazed areas and areas affected by forest fires quite prone to sheet washing . The extent of sheet erosion is easily seen in ploughed fields where small boulders , singles , or pebbles are seen lodged on small columns of soil after rain as the surrounding soil is washed away by sheet erosion . Often farmers put small boulders , singles on the bunds to protect it from sheet washing .

In the study area, sheet washing is seen in degraded forest areas of Mahaldram, Dhobijhora, Senchal and

Ghoom Simana. The reserve forest areas of Senchal and Rongbull are the worst affected. In Mahaldram forest, the degraded patch above Sepoydhura and Maharani tea gardens is very severely sheet washed. Overgrazing assists the process. In Ghoom-Simana reserve forest, a patch between Lepchajagat and Sukiapokhari also shows appreciable amount of sheet washing. The high rainfall in the area does not spare even lands covered with scrub vegetation. Such scrub lands, occurring in tea garden forest extensively, are also being sheet washed surreptitiously. Maling bamboo, which comes above 2000 mt altitude, gives fairly good cover but can not stop sheet washing of the soil. Patches of tea gardens in Springside, Ambootia, Singel, Maharani & Margarate´s Hope, having scanty tea bushes , are being sheet washed extensively. Younger tea plantations are very susceptible to sheet washing and need protection by mulching. Abandoned agricultural lands in and around Sonada, Sepoydhura, Dilaram, Tung, Chatakpur, Rongbul, and Sukiapokhari are also showing sheet washing.

Sheet erosion even though not quite visible at initiation , more often than not , soon degenerates into yet another advanced stage of soil erosion called rill erosion which is discussed next .

4.3 RILL EROSION :

Rill erosion is more apparent than ordinary sheet washing but is almost always neglected . Minute rilling takes place simultaneously with the first detachment and movement of soil particles . Constant meander and change of position of these microscopic rills under the impact of beating rain drops obscure their presence from normal observation . As the severity of sheet washing increases , micro-rills develop further producing more pronounced irregularities in the land surface which could not be obliterated by the action of beating rain drops . These tend to concentrate the flowing sheet water along certain lines and obstructions make the flow turbulent and more erosive . As the amount of water in the channel grows , velocity and turbulence increase . Minor rills coalesce down slope to form larger ones , and the run off is progressively concentrated in streams of greater violence . Thus larger and larger proportions of run off energy is directed against smaller and smaller portions of land surface . The scouring action of concentrated flow carves out rills a few centimetres wide and channelized flow removes soil by scouring along the lines of its travel , and , because of its great concentration of kinetic energy , carries away the detached soil fed into it by sheet flow and rain drop splashes .

Conventionally , rill erosion is said to occur when flow channels have become sufficiently large and stable to be readily seen . Rill erosion is considered as the advanced stage of sheet erosion and can be regarded as transition stage between sheet erosion and gullying . Thus , there is no sharp line of demarcation where sheet erosion ends and rill erosion begins , but rill erosion is more readily apparent than sheet erosion , the indentation in the ground being small enough to be obliterated by normal tillage operations . On soft freshly ploughed soils , especially those of high silt content and having slopes greater than 4 or 5 percent , rilling is probably the commonest form of soil erosion (Bennett , 1955) . This is more severe on fallow lands . Considerable rill erosion is caused by heavy rains on bare soils at a time when frost is coming out of ground . Exposed B horizons are vulnerable to rill erosion which situation is commonly encountered in zones of podzolisation and yellow soils .

Although rill erosion is often overlooked , it is this one which erodes the soils the most (Schwab, 1971) . In the study area rill erosion is seen in fallow lands and degraded forest areas. Rill erosion is seen in the overgrazed wooded lands of Nahar tea garden (Plate 3). Banks of Ghatta jhora show rill erosion of its upper reaches. Extensive rilling is seen on the steeper slopes of Pachim and Gorabari basty. Rilling has also been seen in Nahar, Oaks and Chhota Ringtong tea gardens. Invariably, rills are located on steeper slopes having very little vegetation. Rilling has also been seen in Avongrove tea garden and Nagari spur. Pubong and Tomsong tea gardens also show rilling in areas having low density of tea bushes. Govt. forests of Mahaldram and Senchal show rill erosion. Rills develop fast in overgrazed forests. Dhupi plantations contain very little ground flora. Rills develop faster in Dhupi plantations. In Senchal forests, the areas located above Rongbull and Sonada are the worst affected. Ghoom-Simana reserve forest also shows rill erosion in and around Lepchajagat and Sukiapokhari.

PLATE 3 : RILL EROSION IN OVERGRAZED TREELANDS (SINGLE T. G.)

Rills are also seen in forest around Debrepani FRH where some bathans are located. Area is heavily grazed. This promotes rilling. Abandoned agricultural fields
between Sonada and Rongbull show copious amount of rill erosion. Rilling is predominant in all tea gardens having poor canopy of tea bushes . The rill erosion , if unchecked , soon degenerates into still more damaging gully erosion.

4.4 GULLY EROSION :

In the study area, gully develops from rills and their development is influenced by several factors which , according to their intensity , affect , both , the extent and the development of gullying . The meteorological factors affecting gullying in the study area are rainfall intensity and its duration , temperature , and solar radiation . Geomorphological and pedological factors include slope , relief , soil structure , parent material , soil moisture holding capacity , degree of soil cover , aspect of the site and pattern of seasonal changes .

Recent and continuous orogenic uplift is chief cause of gully erosion in parts of the areas. Gullying is independent of other factors in such areas. Thermal changes in the lower parts of the crust or compression due to foreland / hinterland in orogenic belt may be reason of such uplift (Ahmad, 1973).

Man , too , affects it greatly . Gullies are most frequently found on convex slopes , appearing first on the steepest lower edges . On concave slopes they are less frequent , and where they do occur , tendency is to appear on the upper reaches of the slopes . On straight slopes , gullying begins roughly in the mid region and spreads down towards the foot. (Sakatula , 1984) . Loams and sandy soils are most susceptible to gullying while skeletal soils suffer the least . Cultivation techniques and agricultural practices have bearing on the susceptibility of any soil to gullying . Mechanism of erosion and transportation of soil particles by flowing water is of crucial significance to understand the gullying.

Run off energies of concentrated flows act parallel to the land surface and are most efficient in transporting detached material down slope . Besides this , such concentrated flows in gullies also brings about detachment of soil particles by rolling , lifting , and abrading . Kinetic energy off flow act horizontally on particles in the direction of flow . The forces may be enough to dislodge particles from the soil mass by rolling them out of position . A rough soil surface contains many small depressions between clods and crumbs where water has little or no horizontal movement while that just above may be flowing rapidly . The different velocities set up pressure differences which produce vertical current and eddies , and upward movement of water past soil particles lifts them off their anchorage and sets them in motion . Soil detachment by abrading occurs when moving particles strike over others in soil surface and set them in motion . Transportation of detached material takes place through surface creep , when particles roll or slide along the surface of stream bed , through saltation , when uneven forces of turbulence make them movealong by steps or jumps , and through suspension , when upward velocities of turbulence exceeds the settling velocity of the detached material . Size , density , and shape of particles , on the other hand , affect their settling velocities . Larger the surface area per unit mass of particles , larger the resistance offered and lower is the settling velocities . Higher the density of particles , higher is the settling velocity . The closest the particle shape to sphere , lower is the settling velocity and higher the transportability . All these factors of detachment and transportation of soil particles come in full play wherever concentrated run off from a slope is sufficient in volume and velocity to cut trenches and to keep continue cutting in the same groove long enough to form destructive soil incisions . Gullies often have their beginnings in slight depressions in field or below it . Ordinarily , they carry water only during or immediately after rains and cannot be obliterated by normal tillage . In woodlands , gully is usually defined as a newly erode channel deep enough to expose the main lateral roots of large trees . There are several distinctly identifiable stages in the development of gullies which are discussed next .

A gully passes through four distinct stages in its development (Datta , 1985) . The first is the formation stage which marks the initiation and is characterised by down ward scour of the top soil and this stage proceeds slowly where top soil is fairly resistant to erosion . The second is the development stage and is marked by upward movement of gully head accompanied with widening and deepening of the channel , development of water fall erosion at the gully head and exposure of `C' horizon . This phase involves the most rapid development of gully and some gullies are known to have extended upslope more than 30 mt during a single rain (Bennett , 1955) . The entrenching channel immediately develops three elements of landscape – the channel bottom , the valley slope , and the upland . The valley slope is most susceptible to erosion during the development stage of the gully (Smith , 1969) . The third is the healing stage when vegetation begins to grow . The fourth stage is the stage of stabilisation . During this stage vegetation cover spreads over the gully surface and gradient of the main channel and side slopes become more stable . During the last two stages the rate of run off into the gully head decreases due to reduction in drainage area as gully head moves progressively up . Remaining portions of run off enters the gully at different points along its length and stage is set for branching and rejuvenation of gully in the side branches . Shape of the gullies , too , are characteristic for each stage of development.

Gullies formed by channel erosion usually have sloping heads and sides and are often called ` V ´ gullies ( Tejwani et al, 1961 ). As the scouring continues , the gully becomes larger , deeper and wider . The lengthening of gully is usually much faster than it widening . The rate of deepening of gully in the steeper upper parts of the area is very rapid . ` U ´ - shaped gullies with straight , more or less vertical sides , and broad bottoms are generally less winding than the ` V ´ - shaped ones because of the soft material at the base of the sides tend to give way to the impact of current rather than to resist deflect the flow back and forth across the channel . Undercutting type , broad bottomed

` U ´ - shaped gullies are most difficult to control because of the instability of under strata as stated. In regions of high rain fall erosivity and high soil erodibility , the process of gullying , unless interrupted in its early stages , self propagates and may lead to wide spread removal of soil (Edward , 1990).

In the study area gullies in the traditional meaning of the term do not exist because of steep terrain , high permeability of soil mantle , and tendency of any water fall action , except when it occurs on rock outcrops , to degenerate soon into a land slide . Most of gullying action in the study area is restricted to the first and second stage of gully development . Unlike ravines , where gully head having a water fall travels up during the second stage of the formation of gully , what moves up in these parts is not a distinct gully head but a slump of bank from all three sides of flow and further the upslope movement of this slumps is preceded with cracks on the up slope side . The flow of water soon becomes sub- terrainean and takes the form of a debris flow , and unless checked right at the initial stage , deeper and deeper layers of soils gét lubricated pushing plane of failure progressively downwards . This leads to development of landslides where , unlike usual gullies , deep seated shear planes are the cause of the entire phenomena visible on surface . Cattle tracks often degenerate into gully (Plate 4).

4.5 STREAM BANK EROSION :

Besides gullying , another important soil degradation process is stream bank erosion. The stream bank erosion is yet another form of fluvial erosion . The scouring , gouging and under cutting of banks and mud flows are major processes of bank deterioration . The stream bank erosion differs from the gully erosion in that the former applies to the lower end tributaries and to the streams that have continuous flow and relatively flat gradient (Michael et al , 1981) . As the velocity and volume of discharge increases , flow of stream becomes turbulent and vertical eddies develop . These eddies scour deep holes in the river bed (Ray, 1954). The swirling water cuts on the outer side and deposits its sediment load on the inner side where velocity is lower . This generates a debris bar on the inner side of the bending stream which pushes the stream further outwards initiating fresh under cutting and tumbling down of vertical slices from the bank . The debris is quickly removed by the by the stream and the stage is further set for fresh under cutting (Plate 5). The process continues so long the velocity of the flowing water continues to be erosive . It often so happens that area lost on one bank is recovered on the other . The quality

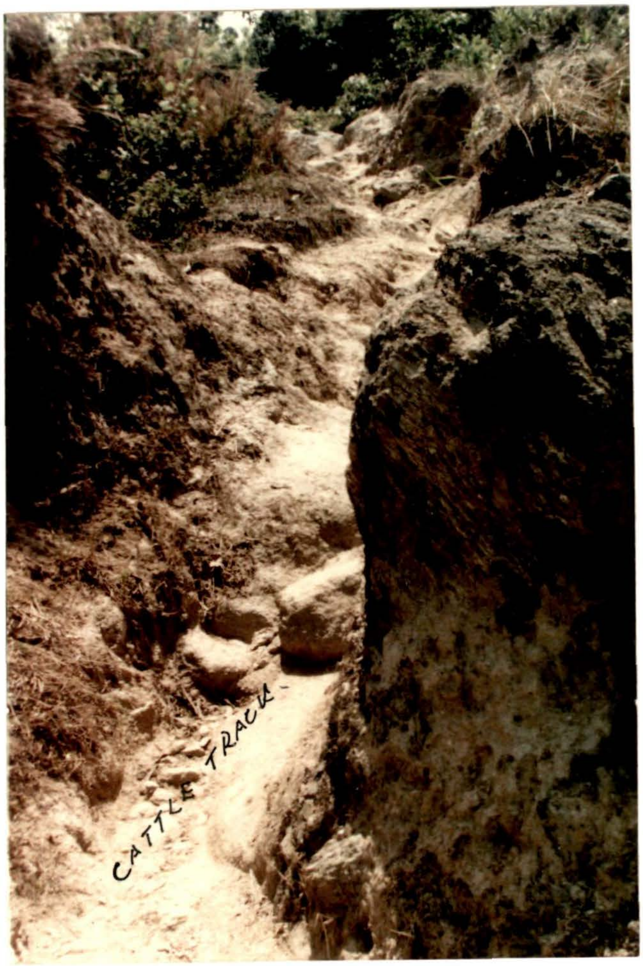


PLATE 4: CATTLE TRACK DEGENERATING INTO A GULLY (SEPOYDHURA)

PLATE 5: SEVERE STREAM BANK EROSION
(BALASON RIVER)

and the fertility of the recovered land is , however , often not of the same order as that of the lost soil . Stream bank erosion is affected by soil character , cover , size and character of floods , velocity of current , land use , stability of stream beds during floods and climatic conditions .

Stream bank erosion is very severe in higher order sections of river in the study area. Such erosions are seen opposite the confluence point of Rinchintong and Balson. Banks of Balason are severely eroded. Bank slumping is seen in the lower 200 mt reach of Rongmuk. Banks of Ghatta - Hussain khola near Single tea estate also show severe bank erosion.

4.6 POT HOLE AND TUNNEL EROSION :

Pot hole erosion occurs when an easily erodible part in stream bed is more eroded than its surroundings and , hence , pot holes develop . This is usually encountered in areas where gully passes through a stretch having great difference in levels (Datta , 1986) . Internal erosion and tunnel erosion are the two sub - surface forms of soil degradation . In the former , gravitational water washes away the finer particles and humus of the soil reducing the quality of the soil in the same way as surface erosion , although the consequences of internal erosion are usually worse . The former leaves a gravelly or stony surface which inhibits further erosion , the latter intensifies it as it progresses . The internal erosion is closely related with tunnel erosion. Genetically, tunnel erosion forms the same class as the internal erosion . In it a system of horizontal and vertical tunnels are created (Zachar , 1984) . These forms develop as a result of flow of ground water over impermeable strata . The size of tunnel may increase until its roof caves in , thus causing a sub - surface phenomena to appear as surface form . In other cases , washing out and corrosion of upper subsiding layer can lead to a land slide . Like other erosion forms , this , too , is affected by several factors .

The factors influencing pot hole and tunnel erosion include geomorphology , petrology , and pedology of the area as well as weather , vegetation and its type and predominant economic use of the area by man .

4.7 SLOUGHING EROSION :

Another form of important erosional process is sloughing erosion. In sloughing , a natural slope , a man made cut or embankment , under certain hydraulic conditions experiences a severe reduction of strength and the soil flows like a thick fluid . It is a retrogressive landslide , in which the failure surface develops through tension cracks and soil liquifies under undrained conditions (Figure 4.1 and 4.2) . Poorly graded fine sand or silt is the seat of such a failure and takes place on account of hydro-dynamic forces , erosive action of water , and non - homogeneity of deposits (Patel , 1980) . Soils in

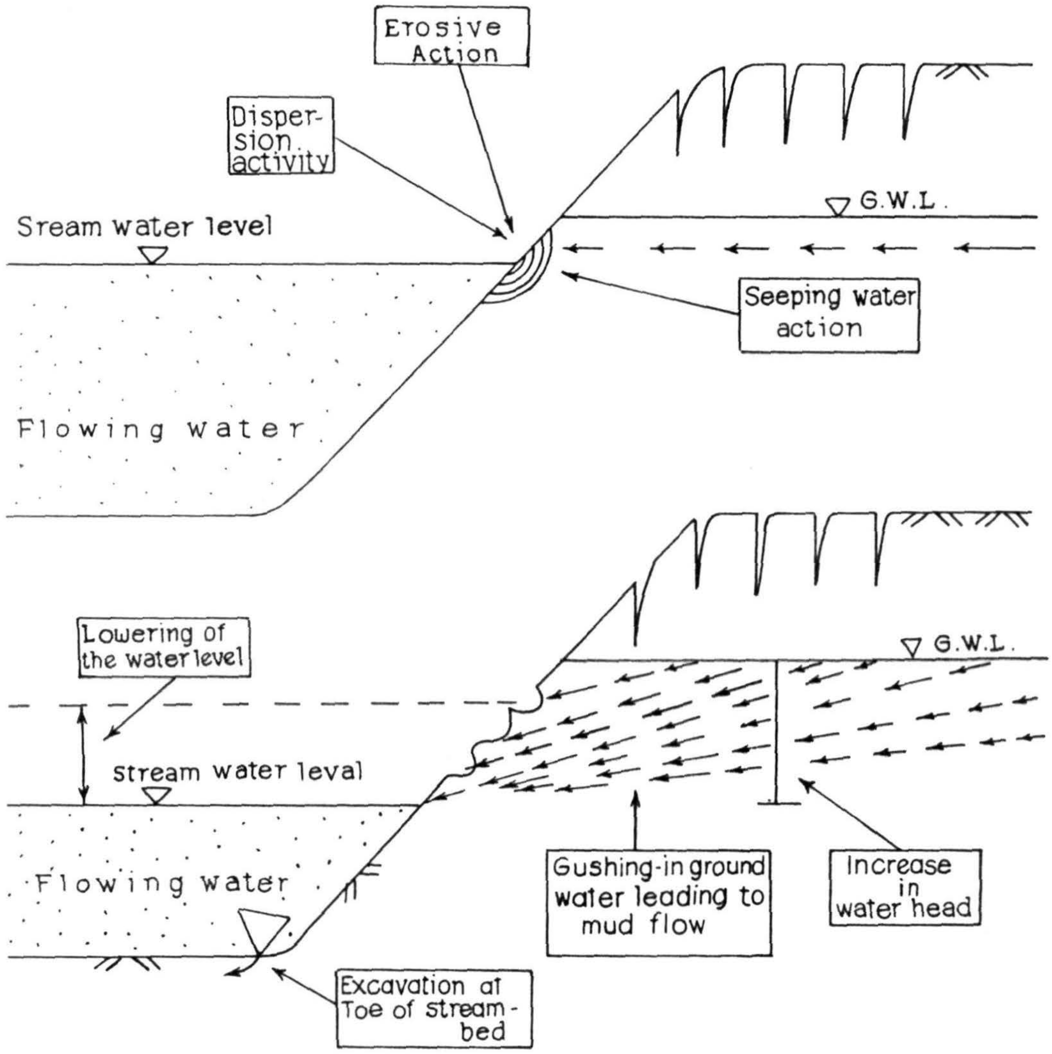


Fig. 4·1. Diagramme illustrating the mechanism of sloughing when groundwater level is higher than the streamwater level. Sudden creation of difference in water heads in channel and the banks led to gushing in of groundwater. Along with this flowing in groundwater non-cohesive fine grained soils started flowing leading to mudflow and large scale sloughing of the banks .

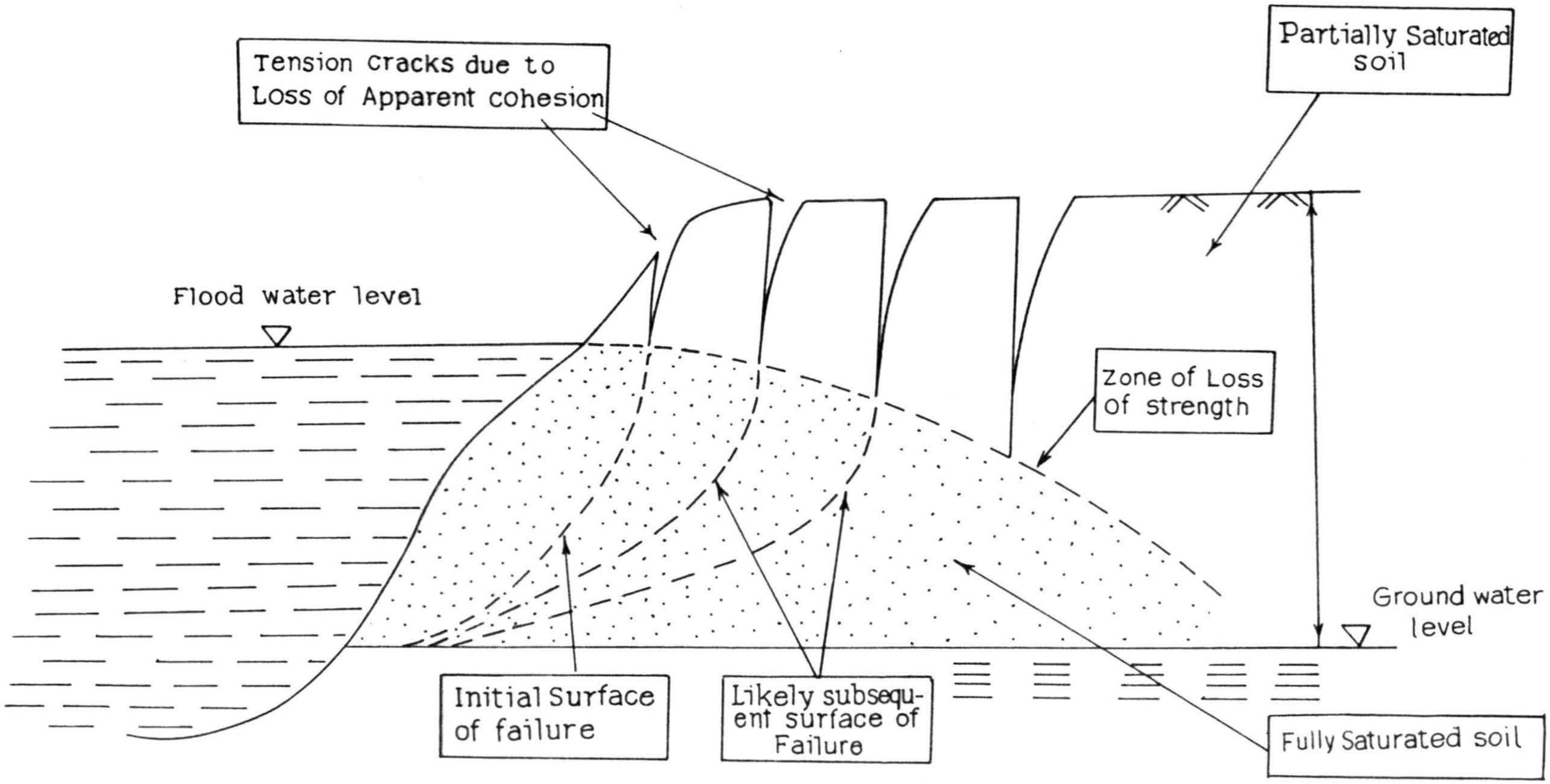


Fig. 4.2 Diagramme Illustrating Retrogressive Mature of Failure through Sloughing.

such location is also found to be non - cohesive and non - plastic with higher water permeability (Lakhanpal et al , 1980) . As is revealed from Figure 4.1 , both , water flowing in the channel as well as that seeping out of banks , create dents and notches . Excavation of beds or under cutting accentuates sloughing , too , in addition to stream bank erosion .

The contribution of apparent cohesion is of considerable significance in fine grained soils which have low angle of shearing resistance . Saturation of partially saturated embankment soil due to infiltration of water at higher flood levels destroys the apparent cohesion . This happens more severely whenever streams swell exceedingly during pre - monsoon and early monsoon showers following dry weather . When the seepage line from the embankments meets the slope face , soil in the region of emergence gets softened and local failure takes place . This leads to formation of steeper surface and instability in the higher levels causing successive slides of retrogressive nature (Figure 4.2) . The soils which show sloughing under the influence of seeping water are mainly of rounded grains , of fine variety , of poor gradation , non - cohesive in nature having poor compaction characteristics and high natural void ratio . Fine sands and coarse silts are chief among such soils and they liquify without any sudden or violent shock . Several past examples of sloughing in Darjeeling hills are available, one of which is that which took place in Tista bazzar .

During a very severe storm in 1968 mighty river Tista draining a large Himalayan tract was partly blocked near Tista bazzar where an arch bridge over Tista was clogged by uprooted trees flowing down stream . The river swelled enormously before the bridge gave way . Sloughing and serious subsidence set in resulting in abandonment of entire bazzar.

In the study area, many of the bank failures are a result of combined actions of stream bank erosion and sloughing . Such failures often take place during the first flooding of the season , especially if it is sever in nature.

4.8 LANDSLIDES :

A landslide is a natural geological process resulting from interacting topographical , hydrological , geological , seismological and biotic factors involving a displacement or settlement of a mass of rock or residual soil along a slope , the centre of gravity of the moving mass advancing in downward and upward direction . From an engineering point of view , a landslide is primarily the result of shear failure of a mass of soil or rock (Som , 1980) . Geotechnical , geomorphological , hydrological and seismological concepts explaining the behaviour of natural slopes are severely limited and it is seen that , in light of these concepts , slopes appearing only marginally stable do not fail even after a severe earthquake while those appearing more stable crumble down . Sites having shallow soils with pronounced sub-surface flow system are highly susceptible to landslides (Malkania, 1989). These concepts , however , provide an insight into the behaviour of landslides .

Weak geological formations constitute one of the biggest factors responsible for failure of slopes . In general , the clays , clay shales , over consolidated clays and phyllitic formations are invariably associated with most of the areas showing instability of slopes. Seismological factors , too , contribute by setting in long term instability in intensely uplifting young mountain ranges like Himalayas . The hydrological factors are , however , most important causative factors in Himalayas , especially in north eastern part of it . Excessive wetting of soil weakens them and brings about increased pore pressure leading to instability . Paddy cultivation by impounding water often leads to landslides (Plate 6). About 100 mm to 200 mm precipitation in 24 hours is usually sufficient to cause failure in Darjeeling Himalayas (Starkel , 1972). Accumulated amount of rainfall from 350 to 400 mm during a spell of rain brings about disasters (Haruyama, 1980). Higher the accumulated amount of preceding rainfall, lower is the required threshold intensity of rainfall for a given degree of sliding (Fukuoka, 1980). Closer the water table to the surface , higher are the chances of slope failure (Aoyama et al , 1980) . Excessive moisture increases unit weight and decreases shear strength of soils . For some soils water entering into the voids dissolved the binding material causing instability . In fine grained cohesionless soils saturation eliminates surface tension holding soil particles together and ,

PLATE 6 : PADDY CULTIVATION BY IMPOUNDING WATER LEADING TO LANDSLIDE

thus , brings about instability . Mudstone, shales and sandstones are most susceptible to sliding (Aoyama et al, 1980). Excessive moisture ruptures silica - cementing agent skeleton and slope fail (Natrajan et al, 1980). Besides this, indiscriminate use of explosives also brings about instability (Dogra, 1993). Incessant mud flows and rock falls are also triggered by earthquakes (Times of India, 1992).

Notorious Ambootia landslide lies at the southern tip of the study area. Towards the top and the middle of the landslide, an organic clay horizon in the sedimentary cover, is observed. It is located 8 to 10 mt below the valley floor. This impervious horizon of black clay is 20 cm thick. Water percolates down up to this layer at the top and the middle part of the slide area. At the lower level percolating water reaches major weak planes of weathered gneiss up to the level of 60 mt below the top of the scarp. Here water forms minor to fairly large drainage lines which later give rise to larger drainage system. The failure of slip surface seems to be as deep as the percolating water is reported to reach (Bandopadhyay, 1978).

CONCLUSION :

Thus it is seen that splash erosion is capable of causing large scale deterioration of soils in the study area on account of high rainfall and occurrence of storms of high intensity . Thin cover makes soils very much prone to this soil degradation process . Sheet erosion is also quite damaging in areas having poor structure , low organic carbon content and poor vegetal cover . Rill erosion is often seen in areas where proper protection against the splash and sheet erosion is not taken . These forms of erosions are also apparent in tea gardens wherever tea bush canopy does not provide optimum coverage . Gully erosion in traditional meaning of term is not seen in the study area . A gully invariably leads to slope failure on both of its sides and often degenerates into a landslide , if it is located well down the rim of the basin , or into a debris slide if located on the upper reaches . Stream bank erosion is seen along the rivers of higher orders and assumes serious dimensions when excessive flooding of river banks takes place immediately following summer season . Pot hole erosion is of lesser consequence as the steeper gradient of river beds soon degrades and the bed becomes bouldery . No pot hole can sustain itself on account of fragile coarse textured soils in the study area . Tunnel erosion is quite important and most of the active landslides , where water moves more underground than on the surface , are affected by this leading to subsidence of soil surface . Sloughing erosion becomes important whenever water impounding in river beds takes place on account of damming of channel by excessive bed load or on account of debris flow from landslides . Landslides are a major cause of concern , but they are one of the least understood soil degradational processes , specially huge ones having deep seated failure plains . Surficial landslides are simple slope failures not more than a few meters in thickness .

The discussion on soil erosion mechanisms and processes shows how various soil degradation processes work . There actual impact in the study area could be assessed by taking a look at problems related to soil erosion and their effects . These can be discussed in the next chapter .

CHAPTER V

PROBLEMS RELATED TO SOIL EROSION AND THEIR EFFECTS

INTRODUCTION :

This chapter deals with various land usages which are erosive in nature . They aid and abate the fundamental erosional mechanisms and processes bringing about the effect of overall deterioration of , both , the climate and the productivity of any area . The problematic practices discussed in details are , faulty cultivation practices , unauthorised quarrying , unscientific water disposal , construction of new roads , extension of existing roads , construction of dams bridges , etc . , over settlement , deforestation , overgrazing , and forest fires . The effects discussed in details are deterioration of climate , shortage of fuel and fodder , increase in flash floods , reduced water supply , damage to reservoir and irrigation channel , damage to communication routes . To get an insight into the effects of soil erosion the problems need be discussed first .

5.1 PROBLEMS :

Among the problems related with soil erosion , faulty cultivation and land management practices are of paramount importance .

5.1.1 FAULTY CULTIVATION PRACTICES :

Major land use in the study area is tea cultivation . There are some pockets of agriculture in sprawling tea gardens . Several faulty cultivation practices have been noticed in the study area .

The study area by virtue of having a very high rainfall , generates large amount of run off from the fields . Cultivation on contour terraces is absolutely necessary . The contour terraces act as a series of miniature reservoirs to hold excess run off and provide increased time opportunity to soil to absorb as much water as possible (Singh et al , 1991) .

It is seen that several tea gardens have raised tea crops without proper terracing of land. In other cases , even if terraces are made , they are very poorly maintained as in Singel tea garden (Plate 7) and do not provide any protection to soil against run off . Invariably in such tracts the tea bushes are extremely sickly and have very low yields . In some others (Ambootia tea garden) , it is seen that extensive soil working has been done to raise a new plantation without any terracing (Plate 8) . Though the slope is not steep and area is protected from

PLATE 7: POORLY MAINTAINED TERRACES IN TEA GARDEN
(SINGLE TEA ESTATE)

PLATE 8: SOIL WORKING ON SLOPING LAND IN TEA GARDENS
(AMBOOTIA TEA GARDEN)

straw mulch during rains , the soil and nutrient losses are formidable . In agriculture lands , terracing is quite common . But except a few patches on the stretch between Sonada and Ghoom - Jorbunglow , most of terraces are ill maintained and outwardly sloping ones . Since construction and maintenance of terraces is quite costly , it is only the wealthier farmers who are able to afford them . Outward sloping terraces have been seen in and around Gorabari , Dilaram , Tung , Sepoydhura , and Pachim . Among the tea gardens , Cedar , Mandakoti , and Talkat tea gardens are seen having outwardly sloping terraces . Large number of abandoned fields are seen around Gorabari and Pachim , probably , because of low fertility and exposure of rock outcrops due to excessive soil washing . Outward sloping terraces , especially in case of agriculture where intensive soil working is necessary , are instrumental in causing lots of damage by washing down top soil , soil nutrients and soil organic matter . Wherever impounding of water is done for cultivation as for paddy , land slides often result (Plate 6) . This is also seen that no proper arrangement are made for disposal of excess water from terraced fields . Terrace risers get broken here and there and once impounded water is let loose , it goes down breaking a series of them . This results in gullying . Soon landslides over take , devours part of field and renders rest the least fertile and most degraded . Such fields are abandoned as maintaining of terrace risers becomes uneconomical once the top soil is washed .

Among the agronomic practices , cultivation of potato and maize are quite extensive in the study area .Both of them need intensive soil working during rainy season . Cultivation of maize without any soil conservation measure causes heavy erosion on the sloping land (Khybri , 1991) . Both , maize and potato along with vegetables are considered as soil depleting crops as they leave little or no residue on or in the soil (Michael et al , 1981) . Besides , it has been seen that potato is planted along the slope (up down the slope) in the study area leading to enhanced erosion . No crop rotation is seen as most of agriculture is single cropped and rain fed . This leads to degradation of soil over a period of time . The fact that simply by adopting appropriate cultivation procedures , it is possible , without any great increase in cost to reduce soil erosion by up to 80 percent is realised little by cultivators (Zachar , 1984) .

5.1.2 UNAUTHORISED QUARRYING FOR BOULDERS :

Large size boulders are common on the jhora beds in humid regions . These boulders protect the soil underneath which would otherwise be washed down by the gushing torrential waters . Besides this , the boulders work as natural barriers , and reduce velocity of flow considerably . Roughness of beds , too , increases . On account of this , effective gradient of jhora and the height of water fall are reduced . Due to zig zag movement of flowing waters caused by presence of boulders in the jhora bed , the length of slope of running water is increased , thereby reducing the gradient of running water further . All these factors tend to reduce the energy gradient of running water as much as possible providing stability to jhora banks and beds .

Once the boulders are removed during dry season , the soil underneath gets exposed . The running waters rushing down the jhora during the following rainy season , carries the exposed soil along exposing still deeper layers . The process continues . The jhora goes on deepening and banks go on slumping till a fresh layers of boulders has lined the bed again either by exposer from deeper layers of soil or by deposition from the bed load carried from upstream side . During the next dry season these boulders , too , get removed by unauthorised quarrying . The process continues with consequence of widening and deepening of jhora ultimately leading to mass failure of the nature of land slide or debris flow .

The unauthorised quarrying was unknown a few years back . During political disturbances in Darjeeling hills between 1986 and 1988 slackened control resulted in ominous start of unauthorised quarrying . As per Forest (Conservation) Act , 1980 , boulders in hills are permitted to be brought only from a few river beds in plains , the collection by unauthorised quarrying of boulders increased by leaps and bounds . Being cheaper than that brought from plains , these boulders got ready market .

Tea gardens , too , are contributing to unauthorised quarrying . All the constructions in tea gardens , especially roads , culverts , bridges and buildings , use large quantities of boulders collected locally . Very little of boulders are imported by tea gardens from the stable river beds in plains . The boulders are usually dug out from the degraded areas within the tea garden leading to further degradation of site .

Specific localities where unauthorised quarrying is seen in the study area are large in number . The jhora near Phazi catchpit , meeting river Rinchintong on its left bank , (200 mt down stream from Dilaram factory) is subjected to quarrying .The stretch of Hill Cart road between Gorabari to Rinchintong has several sites of unauthorised quarrying . At the time of survey during November 1993 , about 200 cub. mt. of boulders were seen stacked along the Hill Cart road in this stretch . A site , 100 mt down the road from Dilaram bazzar , is subjected to intensive quarrying . A jhora crossing Hill Cart road , 200 mt north of Tung railway station , too , is subjected to intensive quarrying . So is the case of Chaitapani jhora draining the stretch between Goethal's memorial school and St. Mary's Hill (Plate 9) . On a site 100 mt down the Hill Cart road from Sonada bazzar , a precipitous uphill slope along the road is being quarried dangerously . The Sona Hollow Block Industry , located on the left bank of Rinchintong jhora on Hill Cart road has been quarrying sand over several decades without any apparent check adding enhanced sediment load in the stream . Near Cedar basti and Pachang bazzar , a few sites of unauthorised quarrying are seen . The list is the least exhaustive . Because of paucity of time and resources , detailed survey could not be undertaken . However , it is believed that unauthorised quarrying has taken very serious dimensions in the study area . There are innumerable spots where

PLATE 9 : UNAUTHORISED QUARRYING ALONG HILL CART ROAD

STACKS OF BOULDERS SEEN

men and women could be seen breaking boulders into chips and metals for selling . What is even more serious is that , after the loose boulders are exhausted , rock outcrops jutting either in the bed or in the bank are attacked with hammer and chisels . These rock outcrops are the anchors and help transfer the weight of the land mass lying upslope to the deeper strata of earth . When they give way , mass failures occur .

5.1.3 UNSCIENTIFIC WATER DISPOSAL :

The disposal of water in any tract should be done through natural drainage systems. Nature has designed each jhora , however small or large , to carry a certain quantity of water from its catchment . If this quantity is altered , the jhora redesigns itself . If flow is augmented , velocity of flowing water , hydraulic radius of flow , and gradient of surface of flow , increase . This shall be a high energy situation and hence unstable . The flowing water shall tend to attain a low energy situation by reducing the velocity . As per fundamental principles of flow of liquids in open channel (Manning's formula being one based on that) , the reduction in velocity can be brought about by reducing , either hydraulic radius or surface gradient or both , of the flow . The result is widening of flow channel or meandering of flow . The former reduces the hydraulic radius , and the latter , the surface gradient , of flow . In nature , usually , a combination of these two occur and a river , when it widens , invariably meanders , too . The results are disastrous from the point of view of soil conservation . Any considerable slumping of otherwise stable stream banks is sure indication that the flow in the channel might have been augmented.

The black top hill roads traversing across the slope and having elaborate drainage systems , are the biggest factors in changing fluvial pattern on hill slopes . The drains along the hills run for a considerable distance collecting flowing water from smaller jhora finally debauching the same in bigger ones where bed is considered " stable " . Little is realised that as per the fundamental principles of flow of liquids in open channels , slumping of banks shall take place . More often than not , such accumulated flows result either in landslide , or in subsidence . It is far better if each small drainage line is given its way ; its flow characteristics and natural catchment is altered as little as possible . It is not done , probably , on cost consideration as each jhora shall have to be provided with a safe passage across the road . The present practice may be economical for the time being , but the overall loss in long run is colossal.

The dirt road in the study area provide another instance of unscientific water disposal . These roads are often not provided with proper side drains . During a rain storm , it is a common sight that water is flowing on the surface of such dirt roads . Agricultural fields , even if terraced , do not have proper system of disposal of excess water by grassed water ways . In some instances , water from jhora is directed through irrigation channels for flood irrigation and excess water is not properly disposed off . This leads to soil degradation down slope .

Due to unscientific disposal of water several instances of soil erosion are seen in the study area . Dirt road in Maharani tea garden is damaged due to this about 2 km above Dilaram tea factory . In Margarate´s Hope tea garden , faulty water disposal along the roads has led to rill and gully erosion . In Chhota Ringtong and Bara Ringtong tea gardens , several dirt roads (some of them abandoned) , are seen without proper drainage . They are contributing a lot to the sediment load of Pachim river . Many foot tracks are degenerating into gullies . In Rongmuk , Oaks and Mandakoti tea gardens , too , roads are not provided with proper drains and water flows on the road surface causing severe soil erosion . In Talkat and Milling tea gardens few foot tracks are seen degenerating into gullies .

5.1.4 EXTENSION OF ROADS :

Extension and construction of roads is yet another activity causing lots of erosion . This involves cutting of earth for making road bench . In the steep hilly terrain , spoils are never transported from the site or are used otherwise . Invariably they get dumped on the down hill slope . With coming of rains, most of it gets washed down the slope . It buries productive fields rendering them waste . Progressively , it is washed down the stream making entire expenditure on soil conservation any where in the catchment infructuous . The process of washing down of spoils , continues over several years rendering the stream muddier that long .

In addition to soil erosion problems related with the dug up earth , the road bench cuts across many a streams changing hydrological characteristics of drainage lines . This often leads to flow of water on the surface of road dislodging freshly exposed soil particles . This adds to the spoils ready to be washed down the slope . Because of obstructing road bench , water starts flowing chaotically some times leading to failure of road bench and , if sufficient water flow is available , to mass movement of soil .

Study area has a well developed road network. Many are black topped with reasonably good side drains . On account of this , there is no great need for construction or extension of roads . Two specific instances that need be mentioned are the new road being constructed from Pubong Phatak (located near Lepchahagat) to Dudhia and an air strip under construction on a site about 2 km south west of Rongbul . The Pubong Phatak - Dudhia road is a very ambitious project taken up by Darjeeling Gorkha Hill Council . This has been only partly constructed and has brought about very severe soil erosion in Upper Balason Catchment . As the cutting of road bench proceeds further in future , it is likely to contribute increasingly higher amounts of sediment load to the rivers . The air strip is being constructed on top of a spur emanating from Rongbull . Here , too , flattening of ground involves huge amount of earth cutting . The dug up earth is getting washed down to , both , Upper Balason and Rongmuk rivers . Minor extension of some roads has been seen in Rongmuk tea garden . In Oaks tea garden , too , construction of one new dirt road is causing a lot of soil erosion . Similarly one dirt road , leading from Cedar tea garden to Rongmuk factory is also showing lots of soil erosion . One new foot track being constructed about 300 mt below Sonada bazzar is also showing erosion .

5.1.5 OVER SETTLEMENTS :

Over settlements , as such , do not affect very largely soil erosion status of any particular tract . The effect is more indirect than otherwise . Heavy concentration of population is often accompanied by increased concentration of cattle population , too . This necessitates increased supply of fodder and brings about increased pressure on pasture lands leading to their degradation . Grass becomes scarce during winter and summer when trees are badly lopped for fodder . This results in reduced canopy density causing greater splash and sheet washing during next rain. Heavy concentration of human population requires larger quantity of fuel wood . This tells very badly on the sustainable use of woody vegetation , especially forests . Heavy concentration of population is almost always associated with large destruction of forests . This leads to all possible forms of soil degradation including leaching down of soil nutrients and organic matter impoverishing the soil further .

In the study area , the highest population density is met in the Kurseong town , the density being 3566 persons per km² in 1981 (Appendix IX) . This value has gone up to 5430 in 1991 (Govt. of India, 1991). The lowest population density of 66 persons per km² is met in the Ghoom forest

. The Hill Cart road village and the ST. Mary's ` Khas mahal ' have high density of 2068 and 2039 persons per km² . Among the tea gardens , Maharani is the most and Ambootia the least , populous . Maharani tea garden is located very close to the Mahldram forest , causing spectacular degradation of forests around Sepoydhura , Tung and Dilaram (Plate 10) . It is seen that in 1981 the population density for the entire study area is 465 whereas the over all density for the Darjeeling district was 325 (over 143 percent above the average).

5.1.6 DEFORESTATION :

Another important factor leading to soil erosion is deforestation . To understand the menancing effects of deforestation , one has to consider , first of all , the influence of forests .

Deforestation , as is obvious , brings about a number of pedological , hydrological and environmental degradation . Removal or thinning out of canopy , exposes the soil beneath to the full erosivity of rain storms . This sets in various soil eroding processes and mechanisms active . So long top soil contains some organic matter , soil particles are not easily splashed by the impact of rain drops . The organic matter , however , does not last long . Organic molecules with low molecular weight are first to depart . Others follow soon . Soluble salts and soil nutrients are leached down far quickly than the organic matter . In situations of splash erosion , fine soil particles block the pore spaces making soil impervious . Even there

PLATE 10: EXTENSIVE DEFORESTATION ABOVE SEPOYDHURA

be elaborate root channels beneath , water is not allowed to percolate down . Thus , volume of run off is increased with consequent effect on soil erosion .

In various phases of forest´s progressive succession towards the climax , the corresponding plant associations modify the site and prepare the way for plant associations typical of following phases until the climax is reached . Wherever the progressive succession of forest vegetation is allowed to evolve without outside interference , above all by man , the forest supplies the most complete and most efficient defence of soils (Pavari , 1978) . There is a marked contrast between the influence of forests and influence of other plant covers , especially grass cover . Grass , when it is dense and unbroken , provides an effective defence against surface erosion ; but it affects soil porosity only along a comparatively thin layer , while the forests probe to a far greater depth . The grass cover (more so because it easily gets saturated) facilitates surface run off , while the forest , when there has been no interference , tends to encourage infiltration and absorption of water and to increase under ground supplies . In forest stand , water can move rapidly , both , parallel to the slope and downwards . Where underlying soil horizons are dense , root channels may be the principal path ways for water movement (Hoover , 1978) . More than 10,000 vertical channels per ha in a hard wood forests growing on silt loam soils has been reported (Gaiser , 1952) . These channels are formed by decay of roots . They may be nearly hollow or may be filled with soils resembling A1 or A2 horizon .

Many lateral channels radiate outwards from the central core and they also contain very permeable materials . In the course of one forest generation, several thousands of vertical channels are formed . The fact that the decayed root system are interlocking in a horizontal and vertical network , increases their efficiency in distributing water through the deeper soils . In addition to forming passage ways for rapid water movement , the large pore space provides an opportunity for temporary water storage . This water is only temporarily held , but this form of storage is exceedingly important because it prolongs the period during which water can percolate into underlying strata .This also provides emergency storage of water which is otherwise forced to move off over the soil surface . Forests use water in large quantities and a watershed bare of vegetation is capable of yielding a larger quantity of water than that when it is fully under the cover of forest . Denser and more luxuriant the forest vegetation , greater the loss of water to the watershed . Forest cover tends to equalise the run off over a longer period of time. It increases storage capacity of watershed (especially where soil are thin and heavy and impervious) and reduces soil erosion . In general, if primary object of land management is flood regulation and soil stabilisation , the aim should to maintain densest possible cover of vegetation . If , on the other hand , object is to obtain maximum water yield compatible with soil. stability and flood regulation , minimum of vegetation above the critical level of deterioration need be maintained (Hoover , 1978) .

As is seen from Appendix X , a total of 4777 ha of forest is there in the study area . Out of this , tea gardens have 845 ha and Govt. forests account for 3780 ha and the rest 152 ha are located in private ownership . The condition of privately owned forests , which are in small patches in homestead lands , is good . Tea garden forests are mostly degraded . So are those owned by the Government , especially on south - western aspect . The localities where extensive damage to forests have been done are Mahaldram and Senchal forests . These areas are flanked by heavy density of population and have degraded mostly on account of illicit collection of fuel wood .

5.1.7 OVERGRAZING :

Yet another practice leading to soil erosion , is overgrazing . This is a menance and generally does much more serious damage to vegetal cover than is usually believed . The entire country has the problem of overgrazing . In 52 percent of India's forests , there is no regeneration owing to the combined effect of biotic pressures , the chief among which is overgrazing . While the policies advocate a strict grazing practice , cattle entry into reserve forests continue to be free and unregulated (Sunder , 1992) . Constant grazing even in alpine pastures has caused the diminution of phosphoric acid in the soil (Chatterjee , 1980). Usually in alpine pastures , too , the numbers grazed is beyond the grazing capacity and , hence , impoverishment of pasture is the result . Sheep and goat are arch enemies of vegetation . Sheep graze on grass only whereas goat is a voracious browser which devours leaves , twigs , small branches , and leading shoots of the plants , either killing them or mauling them very badly . Overgrazed slopes show erosion and characteristic heavy trails of cattle cris crossing one another . Sheep and goat trails are spectacular and extend on even very steep slopes . Overgrazed grass lands degrade into bush land and dry thickets . The removal of protective vegetation combined with the trampling of the soil surface by animal hooves , leads to a rapid loss of soil , a lowering of infiltration rate and flash flooding (Edward et al , 1990) .In regions of high rainfall erosivity and high soil erodibility , this cycle is self propagating and may lead to the wide spread removal of soil by sheet and gully erosion . Moderate grazing produces only negligible soil erosion , whereas heavy grazing brings about great loss of soil . In forest ecosystem , under Deodar stands , overgrazed plots produce seven times more soil loss , several times more nutrient loss and less than one third litter fall in comparison to the control plot (Singh et al , 1995) . Though variable with species to species , in general , moderate grazing leaves approximately 10 cm of stubble height , whereas that height after a period of overgrazing is 5 cm or even less (Dunford et al 1969) .

Secondary succession on grazed timber lands can be encouraged by limiting animal use , which decreases damage by , both , grazing and trampling . Stepping on trees or grass and soil compaction can be even more damaging than grazing . Soil compaction is specially serious when the soil is too wet to bear an animal's weight without making deep foot prints (Harris et al , 1984) .

In Darjeeling Forest Division , which contributes north and north - western parts of the forests in the study area (Ghoom Simana forest) , open grazing was earlier allowed only in areas north of Little Rangit river . Elsewhere , it was restricted and allowed only on the strength of permits . The deleterious effect of overgrazing on soil and regeneration are noticeable in these parts of upper hill forests where undergrowth has been reduced to those species which are non - palatable to cattle . Natural regeneration of tree species have become practically non - existent as a result of continued browsing and trampling . There are a number of departmental bathans where cattle are stall fed . The owners are allowed to collect fodder from the adjoining forests and there are fenced areas around the stalls where cattle can exercise . This system was introduced to discourage open grazing which often degenerates into overgrazing . But in practice , bathan stall feeding has been found to be of limited utility due to indifferent attitude of cattle owners (Govt. of West Bengal , 1970) . Though Darjeeling Grazing Rules were made way back in 1895 , and were meant to regulate grazing in the reserve forests of Darjeeling Forest Division , they could not save the forests from being overgrazed . In case of Kurseong Forest Division , which contributes forests located on the eastern part of the study area all along , forests were always closed for grazing . Nevertheless unauthorised grazing took place along the boundaries . In younger plantations adjoining the localities , damage to seedlings is caused , particularly by goats (Govt. of West Bengal , 1959) . It is reported in subsequent Working Plan , too , that unauthorised grazing damages younger plantations near human habitations . Even forest villages , established with sole purpose of propagation of forests , have started contributing their share of cattle involved in such overgrazing (Govt. of West Bengal , 1976) .

5.1.8 FOREST FIRES :

Forest fires do a lot of damage from view point of soil conservation . They alter the physicochemical and biological property of soils by heating , altering and removing substances and exposing the surface . The nature and degree of alterations depend on soil properties , fire intensity , and duration , topography and climate . The processes involved are complex ; effects can not be predicted accurately and some times appear contradictory . During a forest fire heat moves into soil by conduction and within the soil by conduction , convection and diffusion (Barney et al , 1984). Quantity of availability to plants of N , P , K , Ca and Mg tend to increase temporarily in the upper mineral soil when overlying organic matter burns. Soil pH increases in direct proportion to the amount of material burnt. Virtually all species of mesofauna (mites , collembolids etc.) and macrofauna (large insects , spiders , earthworms , snails) experience an immediate , sharp population drop following a forest fire . Some require years to recover . Some are persistently kept at low levels by repeated burning . Earthworms tend to decline more than other species because of drier surface soils . Ants increase disproportionately because of more xeric habitat .

The effect of fire is so great on total runoff that control of fire is considered as one of the most effective tools of flood control (Heard et al , 1969). Potential harmful emissions from forest fires include carbon dioxide , carbon monoxide , hydrocarbons , nitrogen and sulphur oxides , and particulate tarry droplets , ash , shoot etc. The effects of burning are extremely detrimental when heavy rain follows immediately after (Dunford et al , 1969). Fire on grass land does much more damage than is generally recognised. The time one watershed needs for complete recovery from severe fire would be hard to determine . It may be measured in decades for grass lands and brushwood and in centuries for forests (Friedrich , 1969).

In Darjeeling district , fire is a great source of danger in upper hill forests . In these forests fire breaks out easily due to strong winds and presence of dense bamboo undergrowth. The study area , where upper hill forests are non - existent , does not suffer from any serious forest fire . Crown forest fire is unknown in the study area . In excessively dry weather , younger plantations do suffer from ground fires . Protection of younger plantations from grazing produce profuse regeneration of grasses . These dry during summer and present fuel for occasion fire , sweeping through plantations . Forest fires are completely unknown in the north - western parts of the study area which has easterly aspect . Another reason for absence of forest fires in the study area could be extensive monoculture by conifers which produce little leaf litter and do not encourage multi-tier forests .

5.2 EFFECTS OF SOIL EROSION :

Soil erosion has a multitude of effects on quality of life of any nation . One of the most important injurious effects of soil erosion is the deterioration of climate which is discussed next .

5.2.1 DETERIORATION OF CLIMATE :

Continued washing of soil progressively degrades the top soil and reduces the fertility leading to progressive deterioration and finally disappearance of vegetation . These leads to extremes of climatic conditions . In regard to temperature , maximum and minimum reach a new peak . Humidity is lowered because of absence of transpiring foliage . While the evaporation of moisture from the soil is increased , the incidence of convection rain are reduced because of disappearance of forest cover . Thus , erosion results in extremes of temperature , lower humidity , increased evaporation and decreased local precipitation .

In the study area , in general , soil erosion has brought about reduced density of forest vegetation . The effect is very pronounced if areas are grazed heavily . In tea gardens patches with sickly tea bushes are met in plenty . Though study area in too small to get any meaningful inference about impact of deterioration vegetal cover on various environmental parameters , it is a general experience that flood peaks , incidence of landslides and extremes of temperatures have increased .

5.2.2 DETERIORATION OF CULTIVATED FIELDS :

The surface soil lost with run off consists of rich productive soil and fresh or active organic matter . The eroded material which is ultimately carried into ocean , and thus lost , consists of colloidal matter , clay , silt , and finest grade of sand . Only a small fraction of the eroded material is generally deposited in river beds or plains when the velocity of water reduces with the reduction of slope of river bed . The soil deposited in a river bed or reservoir is not only unavailable for cultivation but is definitely harmful .

Shallow stony soils consequent to sheet erosion and badly cut up and gullied area consequent to gullying have never been liked by cultivators . Such area are often abandoned as agriculture there becomes uneconomical . Damage of cultivated fields also takes place due to deposition of erosion debris . Velocity of flow comes down appreciably as rivers enter the plains. Most of the debris are deposited in the bed forcing the streams either to change their course or overflow its banks . In former eventuality , rivers destroy large tracts of productive fields and in later deposit sand , gravel and boulders on the fertile fields turning them into barren waste . In dry and arid areas moving sand dune often cover the fertile fields rendering them a waste land .

In the study area , deterioration of cultivated fields is mainly on account of sheet washing , gullying and land slips . In the upper zones of almost all the five river basins large number of abandoned agricultural fields have been noticed . The soil depths are definitely shallower in the upper reaches and a slight negligence by the farmer erodes the shallow top soil beyond the stage of recovery . Such fields are soon abandoned . Many of such abandoned fields are also severely overgrazed , subsequently , causing reversal of natural restoration processes , if any . In tea gardens , too , wherever tea bushes do not provide complete cover to the soils , they have deteriorated resulting in rickety tea bushes struggling for survival . Most severe degradation is seen on the steeper slopes which are overgrazed , burnt and subjected to quarrying of boulders .

5.2.3 SHORTAGE OF FUEL AND FODDER :

As forest degrades , a very important source of fodder disappears . This affects badly the health of pasture lands as they as excessive burden of grazing is forced on them . The over all shortage of fodder affects the health of livestock in general . Consequently the cattle population slowly degenerates into scrub . Deteriorating forest do not produce optimum timber and fuelwood aggravating their scarcity further . In the study area , shortage of fodder is quite acute . It is a common sight to come across scrub cattle moving around inside reserve forests in huge numbers . Similarly , large number of illicit firewood collectors could be seen entering the forests and removing whatever wood they could lay their hands on .

5.2.4 INCREASE IN INCIDENCE OF FLOODS :

Because of complete absence or only a scanty presence of vegetation and greatly reduced infiltration capacity , the run off from river catchments is greatly increased . This results in more frequent floods than usual . Besides this persistent deposition of sediment load in flatter gradient of river beds , progressively reduces the capacity of river channel leading to more frequent floods even with smaller rate of discharge in the channel . In valleys , along the river banks , some paddy and maize fields are occasionally affected by floods for short duration of time .

5.2.5 REDUCED WATER SUPPLY :

Since eroding soils get their infiltration capacity greatly impeded , rain water flows down the slope quickly and is not able to replenish the underground reservoir which feeds the streams round the year . Consequently , streams become seasonal and are practically dry after rains . The dry season discharge of rivers , which is very crucial for supply of potable water and that for hydroelectric projects , comes down quite appreciably . Municipal catchments of Darjeeling and Kurseong towns fall in the study area . The forest cover in both of these catchments are very severely degraded . This , probably , is the reason of severe scarcity of water in these towns during dry season . In absence of monitoring of rivers during dry season over a longer period of time , it is not possible to draw any quantitative inference regarding the reduced supplies in the study area .

5.2.6 DAMAGE TO RESERVOIR , IRRIGATION CHANNEL , WATERWAYS AND HARBOURS :

Accumulating sediments silt up the reservoirs, clogg the irrigation channels, and fill up the navigational channels. Clogging of channels results in overflow and flooding of down stream areas which damages the crops and is disastrous to the man made structures . Some irrigation channels are seen to have been blocked because of deposition of silt .

5.2.7 DAMAGE TO COMMUNICATION ROUTES :

Damage to communication routes is probably the most visible effect of soil erosion . The instances of highway and railway embankments being washed away by cutting of uncontrolled water , land slips , landslides and debris avalanche during rains is a common feature . In dry and desert areas , they get buried under shifting sand dunes . It has been estimated that more than fifty percent of annual cost of maintenance of communication routes are due to erosion damages .

In the study area , disruption of communication routes is a major problem . This is mainly because of landslides . The landslides in Darjeeling district have been widely studied by several workers . The Hill Cart road which runs about 40 kms inside the study area , has been a subject of many a investigations . In 1950 , 1968 , 1980 , and 1984 , communication links were badly damaged in the study area (Chattopadhyay , 1987). In 1968 , Hill Cart road between Kurseong and Darjeeling was blocked at 18 different points (Gerrard , 1991) . In 1984 a 150 mt long stretch of the same road was washed out . During 1950 and 1980 , too , serious disruption of communication routes took place.

CONCLUSION :

Thus it is seen that various problems relating to soil erosion include faulty cultivation practices in agricultural lands and tea lands . Faulty agronomic practices , too , are a cause of concern . Unauthorised quarrying also adds to the sediment load and is instrumental in triggering slump of banks and even landslides . Unscientific water disposal along elaborate road networks also adds to soil degradation processes . Extension of roads and construction of new roads involving cutting of earth in highly fragile slopes also contributes to sediment loads of the streams of study area . Over settlements on account of presence of large number of tea gardens brings about consequences related to that . Heavy population density flanking the forest has taken a very heavy toll . Related with the high population density is the problem of deforestation due to illicit removal of firewood and excessive grazing in the forest . This has degraded soil greatly . Overgrazing is rampant in forest as well as on steep scrub lands attached with tea gardens . Connected with the cattle population is the heavy lopping of the trees of broad leaved species reducing crown cover and exposing soil underneath to eroding forces of rain drops . Forest fires are great menance in upper hill forests. A few occasional and and limited burning of younger plantations have taken place. Among the effects of soil erosion many of them , such as deterioration of climate , increased floods , reduced water supply and damage to reservoirs occur on a much larger tract and such effects are visible in the study area . Deterioration of cultivated fields , shortage of fuel and fodder is quite visible. What is most visible is the disruption of communication routes by landslides , landslips and debris avalanches .It is probably the severity of disruption of communication which has helped most in making people realise the importance of sound soil management practices .

For studying various soil characteristics , morphometric factors , soil eroding processes and other parameters relating to soil erosion , a number of methodologies have been utilised to analyze their effects on soil erosion . These methodologies have been discussed in subsequent chapter.

CHAPTER VI

METHODOLOGY

INTRODUCTION :

This chapter deals with the methodologies adopted for study of various parameters of soil and water conservation . Those discussed in details are analysis of various morphometric characters , measurement of flows and sediment load in rivers , measurement of various soil characteristics including infiltration capacity .

6.1 ANALYSIS OF MORPHOMETRIC CHARACTERISTICS :

Large number of parameters relating to drainage systems and slope patterns were analyzed . Among these drainage long profile , density , order , frequency , number , bifurcation ratio , stream length ratio and sinuosity have been discussed in detail. Those relating to slope are cross and composite profile , hypsometric curves , relative relief , ruggedness and distribution of slope .

6.1.1. DRAINAGE LONG PROFILE :

The drainage long profile of all the five streams in the study area are analyzed separately . Major contours at 100 mt interval are got and long profiles plotted . Percentage profiles , too , are calculated .

6.1.2 DRAINAGE DENSITY , RELATIVE RELIEF AND SLOPE :

These parameters are determined by laying square grid over the appropriate map of the area . Zones of river basins were classified on the basis of the weighted value of these parameters . It is necessary to study the permeability of the study area.

6.1.3 DRAINAGE ORDER :

The drainage lines were delineated from satellite imagery dated 26th January , 1996 . The ordering of streams was done as per Strahler's system . The drainages have been ordered seperately to know the lithology of the area. This also helps to study tectonic activity of the area.

6.1.4 DRAINAGE FREQUENCY AND OTHER PARAMETERS :

Each basin was taken as unit for evaluation of drainage frequency , total number of streams and their length . Data was analyzed from several view points and interpreted .

6.1.5. BIFURCATION RATIO :

Bifurcation ratio of streams of each order in each basin was calculated out by using the following formula .

$$Rb = N_u / N_{(u+1)}$$

where ,

Rb = Bifurcation ratio

N_u = Total number of streams of order u .

$N_{(u+1)}$ = Total number of streams of next higher order .

The overall bifurcation ratio for individual basins , too , has been calculated out graphically using standard techniques (Chorley , 1971) .

6.1.6 STREAM LENGTH RATIO :

The stream length ratio of each order of stream for each basin has been evaluated by using following formula .

$$Rl = L_u \backslash L_{(u-1)}$$

where ,

Rl = Stream length ratio

L_u = Total length of streams of order u .

$L_{(u-1)}$ = Total length of streams of next lower order .

Graphical depiction has also been done .

6.1.7 SINUOSITY :

Sinuosity of all the five rivers have been evaluated as per standard techniques (Dury , 1969) .

For a comparative study , Survey of India , toposheet , (1931) and recent satellite imagery has been used .

6.1.8 CROSS AND COMPOSITE PROFILE :

Two cross profiles of study area were calculated and plotted . Two transects running east-west and the north-south have been anlaysed. The lines obtained were smoothened and a vertical exaggeration of five times was provided. Composite profile , too , was drawn .

6.1.9 HYPSOMETRIC CURVE :

Hypsometric curve of the area was plotted using standard techniques . For assessment of percentage hypsometric curve , technique adopted by Chorley was used (Chorley) . Data was graphically plotted for ease of analysis . For studying comparative maturity of the river basins , they were compared with each other.

6.1.10 RUGGEDNESS :

Following formula has been used for calculation of ruggedness number .

$$R_n = D \times (H / 1000)$$

where ,

R_n = Ruggedness number
D = Drainage density in km per sq km .
H = Relative relief in mt per sq km .

Square grid was laid over the drainage map of the area and values evaluated . Weighted average values are used for classification of basin zones in different ruggedness classes .

6.2 MEASUREMENT OF RIVER FLOWS AND THEIR SEDIMENT LOAD :

Out of total five rivers in the Eastern Balason river basin , four were monitored for the river flows during July , August , September , October and November of 1991 and 1992 . The fifth river could not be monitored as no suitable bridge could be found across it . In all the four cases cross section area - velocity method was used . Each river was monitored at an interval of two hours from 0400 hrs to 22.00 hrs for flow level and for sediment . The Price current metre was used for evaluating velocity of flowing water . Readings were taken as per standard procedure (Wasi Ullah , 1972) . Rating charts , correlating depth of flow with rate discharge were prepared . They were used for assessment of total flow and total sediment load of the rivers . One litre water sample was collected every two hours , and quantity of sediment load evaluated .

6.3 MEASUREMENT OF VARIOUS SOIL CHARACTERISTICS :

Soil samples were collected from 15 different sites distributed all over the study area . Four predominant types of land use patterns , namely , forest (open and closed) , orchards , agriculture and tea gardens were represented in the samples . Soil samples were analyzed for assessment of fertility , pH , Cation Exchange capacity , organic matter , C / N ratio , specific gravity , pore space and water holding capacity . Four soil profiles were exposed and studied . Soils samples were collected from each horizon as thin vertical slices and analyzed . The colour was ascertained with the help of Munsell´s colour chart .

For assessment of earthworms , seven broad categories of land use pattern were selected . Cuboid of top soil were cut out and studied for the mesofauna . Soil infiltration capacity was determined in all the fifteen representative areas selected for collection of soil sample . The methodology used was to push down a 15 cm diametre and 45 cm long iron cylinder about 20 cm inside the ground and evaluating the rate of infiltration by filling the above ground part with water .

CONCLUSION :

Thus it is seen that drainage long profiles , drainage density , drainage frequency , bifurcation ratio , stream length ratio , sinuosity , cross and composite profiles , hypsometric curves , slope and ruggedness were evaluated by simple measurements on the toposheets . Recent satellite imagery was also used in some cases . Rivers of the study area were monitored for assessment of flow and sediment load

. Soil samples were collected from fifteen different sites and analyzed for assessment of physico-chemical properties . Four number of profiles were opened and studied in detail . Cubes of top soils were used for assessment for presence of earthworms and iron cylinder was used for evaluation of infiltration rate .

In light of discussions relating to soil characteristics , morphometric factors , processes and mechanisms of soil erosion and problems relating to the soil conservation , brings one to the point where one would like to have a look at the earlier strategies and measures in conservation of soil and water . This is discussed in the next chapter .

CHAPTER VII

EARLIER STRATEGIES OR MEASURES IN CONSERVATION OF SOIL AND WATER

INTRODUCTION :

The soil conservation is not entirely unknown in Darjeeling Himalayas including the study area . A large number of soil conservation strategies or measures are in vogue for quite some time . Some of these techniques , especially those used by farmers , are age old and based on common sense . Others have some scientific backgrounds though they do not always incorporate the latest developments in the fields of soil conservation . The earlier strategies discussed in detail relate to those adopted by different Government Departments , by individual farmers and by tea garden managements . Different schemes by Government aimed at conservation of soil and water , too , have been discussed in detail .

By and large , Government Departments are the most important agencies taking up works of soil and water conservation and the strategies adopted by them are discussed.

7.1 GOVERNMENT MEASURES FOR SOIL AND WATER CONSERVATION :

Two departments of State Government taking up soil and water conservation works in a big way are, the Departments of Agriculture and the Department of Forests . The former takes up such works in agricultural lands whereas the latter in the forests and , occasionally , in the fringes . Some soil conservation works , especially river bank protection works are also taken up by the Department of Irrigation .

7.1.1 JHORA TRAINING :

Among all the soil conservation measures taken up by the Government Departments , the jhora training is probably the most common. A large number of jhora and rivulets , looking completely dry during summer become torrential during rains in high rainfall humid tracts of eastern Himalayas . The volume of water flowing down the drainage lines as runoff is quite substantial . The intensity of the flow is further abated by the fact that rains are highly concentrated during 4 - 5 months when monsoon is active . For example , in the study area , during the period 1990 - 1995 , a little more than 92 percent of total rainfall (4122.70 mm out of 4459.3 mm) has occurred from May to

September . In terms of number of rainy days , more than 83 percent (109.5 days out of a total of 131.1) have occurred during the same period (Table 1.2) . This combined with high relief makes jhora and rivulets quite violent . Rock outcrops jutting out of beds , debris of huge boulders or interlocking miniature spurs , make the drainage lines pass through a tortuous course . Water flowing at a high velocity in steeply descending narrow channels sets up an appreciable tangential stress acting on the bed of the channel (Riedl , 1984) . This water flow sets in motion compacted detrius , boulders , gravels , pebbles and disintegrated products of weathered rocks . This causes lots of damage of banks by way of scouring and erosion of channel bed with bank failures or slumps . This is specially serious when jhoras pass through rock formations which are softer . The danger of such jhora shifting themselves always exists . This is precisely to take care of such shifting that jhora training is necessary .

The technique for training of jhoras in the study area is by making permeable gabion drop and guide structures . The guide walls are provided along the banks in descending steps . The slope in the bed of the jhora is broken by providing gabion drops across it . Care should be taken that top of the following drop is at the same level as the bottom of the preceding one . Several such drop and guide structures are seen as one passes through the Hill Cart road . Many of them have been constructed by the Public Works (Roads) Department , Govt. of West Bengal .

While there are a few such drop and guide structures which have failed on account of excessive flows spilling over the provided section , there are large many which are dry or have very meagre flow even during the strongest rain storm . It appears that proper hydraulic assessment has not been done while constructing resulting in wastage of resources . Absence or inappropriate hydraulic computation of possible peak flow in the jhora for a reasonable period of recurrence interval coupled with the apprehension that it might fail , usually results in the structure , more often than not , over - designed . Such jhora training has been done in Bangla khola, Rinchintong, and several others between Sonada and Rongbull. Khola just before Sepoydhura has also been treated with this measure.

The maintenance of the drop and guide structures is the most neglected aspect in jhora training works in the study area . Lack of maintenance often results in the entire thing getting washed down . Another menace for such structures is the theft of wire netting and stone boulders . The problem of theft has aggravated after the political turmoil in the hills in later half of 80s . Drop structures , over the years , accumulate fine sand and silt behind them where lots of weeds and bushes come up restricting the flow . The flow then spills the guide walls , scours the banks beyond them . Many a structures in the study area have failed this way .

7.1.2 CATCHWATER DRAINS :

The catchwater drains are constructed with the basic purpose of diversion of run-off from sites likely to get damaged comparatively more to ones where it shall be little or none . This is because of the fact that wherever the natural drainage are interfered with , they attempt to redesign themselves for adjusting to changed flow characteristics . This is also , however , true that some locations become so fragile on account of continuing defective land management or hydraulic practices that , unless the run-off is completely excluded from them , they may soon degenerate into mass movement . Comparatively speaking , diverted run-off shall do a lesser damage elsewhere .

One of the main areas where catchwater drains are used extensively is the treatment of landslides . The head of any landslide along with its banks on higher reaches is the most active . Surface run-off enters the head making it progress further uphill . As the debris material slides down slope , banks slump , widening the slide scar progressively . Besides overland flow , landslides , especially in wet eastern Himalayas get profuse sub-terranean flow of water . A high rate of 5 - 12 mt per hour of the sub-surface flow even during springs has been observed (Froehlich et al , 1991) . Water seeping down scores of meters uphill of the landslide , might be getting its way to the landslide . To eliminate such eventualities , the catchwater drains are utilised . Usually a series of catchwater drains are needed above the head of the landslide . All of them should run parallel to one another , should have non- erosive gradient , should preferably be lined with cement mortar and should be directed in any jhora having stable bed and bank . This helps remove surface flow quickly from the site upslope of slide head . This prevents rainwater from entering slide either as a surface flow through head or brims of slide or as a sub-surface flow down below .In highly permeable rock formations , higher concentration of catchwater drains are needed to cut seepage of water as much as possible .

Besides landslides , surface run-off is also needed to be kept away from sinking zones . Such zones are associated with highly fractured rock material characterised by high density parallel drainage lines . Here , too , a series of catchwater drains running parallel to one another are used for diversion of run-off and to cut out seepage of water .

In the study area, it is seen that proper hydraulic computation for the dimension of the catchwater drains is not done . The dimension of a catchwater drain is a function of its catchment area , the material which it is made of , gradient provided to it , and the rainfall intensity for the recurrence interval the structure is designed for . Improper designing makes some overflow with the mildest of storms and others underflow even with the severest ones . In both the cases resources are wasted ; in former by failure , and in latter by under-utilisation . Besides defective dimensions , gradients , too , are some times improper . Catchwater drains constructed with cement mortar are , some times , provided steeper than permissible gradients realising little that every construction material has an erodibility . This results into failures . Many an ill-designed catchwater drains , even with cement mortar , have ended up in deep eroding gullies .

7.1.3 RETAINING WALLS AND BREAST WALLS :

Retaining walls and breast walls have been the chief gravity structures being used quite extensively along the roads in the study area. A retaining wall is a wall built to resist the pressure of earth filling deposited behind it after it is built . A breast wall (or face wall) is a similar structure built to protect the freshly cut surface of a natural ground , whether with vertical or inclined face , to prevent it from fall due to the action of climatic factors . The stability of bank slopes depends on several factors . Safe slope of a bank with granular material does not decrease as the height increases because its shearing strength increases as the banks become higher (due to additional weight) . The safe slope of a clay bank becomes flatter as the height of the bank increases because its shearing strength does not increase to resist the corresponding increase in the height . The steepness of the safe slope of an embankment depends on the shearing strength of soil . The natural , the strongest and the ultimate form of the earth slope is a concave curve with the flattest portion at the bottom . In constructing slopes the reverse of this form is most often made , which invites landslips . Straight or convex slopes continue to slip until the natural form is attained (Khanna , 1982) . In cutting, concave slopes should be formed to avoid slips .

Large number of retaining and breast walls have been constructed for protection of road benches in the study area . Besides roads , protection to homestead lands , bridle paths , buildings and other structures , too , has been given by the protection walls . The terrain in the study area being quite steep and rugged coupled with high rainfall (in terms of quantity as well as intensity) , it is impossible to build any large structure without retaining or breast wall . In most cases, these gravity structures depend solely on their weights to resist the thrust of the back fill . This is because often bed rock is not economical to find to anchor the foundation of such structures . This makes them quite vulnerable to overturning and sliding (Plate 11).

It is seen that materials likely to slip are not removed and slopes not trimmed and flattened before constructing the retaining walls . In some instances , absence of inadequacy of weepholes is the cause of failure (Plate 12). The fact that under poor drainage conditions , the tendency of backfill to slip is very much increased when the material gets saturated with water is often ignored .

7.1.4 RIVER TRAINING :

The training of rivers involves construction of revetments , spurs and jetties (retards) to confine the flow and protect the bank from scouring . This may also include training walls , made of flexible semi-permanent materials used in double rows , parallel to banks , to facilitate settling

PLATE 11 : RETAINING WALL ABOUT TO SLIDE

(GOETHAL'S RESUME FOREST)

PLATE 12 : A MASSIVE RETAINING WALL WITH SCANTY WEEPHOLES (DILARAM)

down of silt and growth of vegetation . Temporary or permanent structures are needed to be constructed in steeper sections for facilitating siltation and for stabilisation of grades .

Erosive scouring of the banks at the outside of the bend tends to increase as the curvature and the length of arc increases , the greatest scouring occurring just behind the point where radius of curvature is the smallest , and continuing for a distance approximately twice the width of the channel at the water level (Riedl , 1984 A) .The smaller the radius , the deeper is the scouring . Both , the length and the radius of the rivers bend are very important in shaping of the channel .In natural water courses meanders are of common occurrence . These develop most rapidly during flash floods when erosion at bends is the greatest , the flow being strongly deflected from the outside bank of the curve back to the inside bank , thus bringing about a gradual change in , both , the length and the curvature of arc .

The study area being hilly and quite steep , most rivers , except in very little of their lower reaches , are torrential in nature . Some river training and stream bank protection works have been done in these parts by tea garden management as most of such stretches of rivers pass through one or the other tea garden . In the higher reaches , where forests are located , no such works are seen . It is seen that the designs of spurs or groynes is defective . The locations of groynes , too , has not been done as per standard principles of the hydraulics of torrential flow in channels . Often continuous bank protection is given even on the straight stretches . These structures are not protected by retards against scouring by the flow . This results in scouring of foundations of these gravity structures leading to their failure (Plate 13) . Sometimes rooting of groynes inside bank is not properly done resulting in dislodgement of the structure . If retards and groynes are not placed as per the hydraulic requirements of bank protection , streams scour banks behind their roots resulting in failure . At some places , retards have been made in such a way that they interfere with the channel itself . The fact that the retards must be erected as elements of an integral system providing a smooth line of flow along their heads , is often overlooked . It is not difficult to find existence of flow in between two retards . This is highly undesirable . This defeats the entire purpose and renders total expenditure wasteful . That the retards should usually slope downwards from their roots to head , is often neglected .

7.1.5 CHECKDAMS :

The most important device to control the torrents and gully erosion is the construction of checkdams by Govt. Departments. They are mostly used in series . The basic purpose of construction of checkdams is to raise bed level up to a height where safe support is provided to the slopes , to reduce the river gradient and to reduce the water depth (and hydraulic radius) by widening the river bed . The checkdams are mostly endangered by scouring . Foundation depth and the spill way size

PLATE 13 : SCOURING OF FOUNDATION AND FAILURE OF TRAINING WALL

have , therefore , to be selected taking scouring into consideration .

Because of highly fluctuating discharge in , and very steep gradients of , rivers checkdams are not very popular in the study area . Most of the rain fall in this region is concentrated between June and September with occasional very severe rain storms . A dry river during off monsoon period , turns turbulent and torrential in monsoon . In addition , steeper gradient and fragile embankments , too , discourage use of checkdams as a soil conservation tool in the study area . Heavy discharge makes wide spill way imperative to keep hydraulic radius of flow low to ward off scouring . The rivers flowing in narrow deep gorges often do not allow such opportunity . This might be another reason for non - utilisation of checkdam technology for soil conservation in the study area .

Yet another reason for non - application of checkdam technology is chronic failure of aprons in most hydraulic structures in these parts . Since the flows are quite turbulent , snaking their way through deep gorges containing huge pleistocene boulders in their beds , one menacing feature of flow in these parts is the rolling boulders . Any boulders which is loose and gets completely inundated in swiftly flowing water starts moving down stream . As soon as a checkdam is encountered , velocity of flow lessens and the bed load fills the back of such structures . The gradient of river reduces and , consequently , velocity lessens , depth of flow and its hydraulic radius increase . This inundates even larger boulders which start moving even with reduced velocities . As the average rock material has a specific gravity of about 2.65 , in the water it has considerable buoyancy , and a rock loses from half to third of its weight in air when entirely submerged (Raistrick , 1973) . This enables very large masses of rocks to be moved , which , even if moving with low velocity , acquire enormous kinetic energy and become powerful tools for breaking down other obstructions , including checkdams , and for grinding other rocks . In many cases , such rolling boulders fall on the apron of the checkdam and other hydraulic structures damaging them . Once the apron is gone , the rest of the struotures follows the same course soon .

Yet another reason for absence of checkdams could be the effect of swelling water behind the checkdams . Because of fragile rock formations , sloughing of banks is a strong possibility after the river bed is raised by checkdams.

Some stream sections in the study area have milder gradients and offer possibilities of construction of checkdams with wider spillways . In few of them, checkdams have , however , been constructed and are operating successfully . One such prominent checkdam is located about 100 mt downstream of Dilaram tea garden factory on Rinchintong river . This has a small spillway which alone conducts water during periods of lean flow . During storms , water spills over the entire checkdam . This structure is working effectively for quite some time . There are several such sites in the study area , especially in lower reaches of streams , where checkdams could be very effectively used to ease out river gradients and to reduce the velocity of flow .

Checkdams have been very effectively used in similar conditions world over and there is no reason for them for not being effective in these parts , given that adequate precautions are taken in accordance with local flow conditions .

Rubble checkdams with boulders , constructed in series , have , however , been extensively used in the study area for control of moving debris in smaller landslides . The surficial landslips have huge quantity of loose debris on their surface which move down slope , particularly during monsoon . Dry rubble checkdams of smaller dimensions are erected to control such movements . It is often seen that design and location of such dry rubble checkdams are defective . Proper batter is not given to the face of the structure and selection of size of boulders , too , is defective . This leads to their failures . The most serious flaw of this technology as practised in the study area by various Govt. Departments is highly inadequate maintenance of these structures . Since these are not anchored in the bed rock , they are pure gravity structures depending on their own weight for stability . Slight damage in one structure , if not mended quickly , leads to failure in a series of them down below .

The cheap and effective (on a short term basis) brush wood checkdam technology , too , has not been used in the study area . This can be used to a great advantage .

7.1.6 PALISADES AND WATTLING :

Palisades and wattlings are two important modes of soil conservation in controlling gullies , landslips and slides in the study area. The structure is erected mostly with locally available materials . Due to this , they are quite well suited for such soil degradations located in inaccessible areas . Both , palisades and wattles , are constructed along the contours on the sloping ground having loose debris susceptible to move down slope at the slightest disturbance.

Palisades , also called as balli (pole) terracing , are constructed on steeper slopes , the basic aim being to increase the debris holding capacity of the slip . Palisades are , by and large , mechanical in nature . The biological measures of stabilisation follow after the moving debris is established by covering the entire slip by palisades . Palisades are usually applied on slopes steeper than 30 degrees . Hard wood bullies 10 cm in diameter and 1.7 to 2.0 mt long are fixed vertically along contour , are spaced 50 cm apart and are fixed 80 to 110 cm below the ground 90 cm being above it (Govt. of West Bengal , 1995 A) . Usually seven such posts should be fixed making a 3 mt long palisade as a single unit . The above ground parts of posts are woven with brushwood material or with splitted bamboo .

Wattlings , on the other hand , are resorted to on milder slopes (less than 30 degrees) and are more biological than mechanical in nature . The posts in the palisades are replaced by 8 - 10 cm thick , 90 cm long cuttings of sproutable species and are fixed with 30 cm of it being above ground . To break the slope and for lowering down of the water table , 30 cm wide and 60 cm deep discontinuous staggered contour trenches are made . The sproutable cuttings are fixed on the down slope edge of the trenches and the upslope part of the trench is partly (about 40 cms) filled with brush wood bundles and rest with boulders . A brushwood net is woven around the above ground part of the sproutable posts . Wattles , too , are made in discontinuous lines to make any subsequent failure localised . Good soil binder species are planted in the inter - wattle area (Govt. of West Bengal , 1995 A) .

In respect of palisade and wattling it is seen that long line of them are made and failure at one point due to excessive debris disrupts the entire structure . Sometimes , in palisades , improper or inadequate embedding of posts results in overturning of structures. It is also seen that palisades are made on very mild slopes leading to wasteful expenditure of resources . Similarly wattling is made on steep slopes with actively moving loose debris . In no times wattles are overwhelmed by the moving debris and the sproutable species , before they could sprout and provide protective cover to soil , are buried under them . All the soil binder species planted in inter-wattle area, too, meet the same fate. For effectiveness , palisades should be made so that top of the lower tier is at the same level as the bottom of upper tier . This is often not true in field conditions , probably , for reasons of economy as , going by that rule , large many tiers , specially on steeper slopes , shall be needed . But it is never economical in long run .

The palisades and wattles are temporary cheap soil conservation structures meant to stabilise the soil with planting of some seedlings as an aid to the nature's attempt to reclaim the land . These temporary structures need be effective till nature has provided sufficient stability to the soil . More often than not , this is not so . Once constructed , these structures are forgotten , altogether . This is not difficult to locate these structures of previous years broken down here and there and having had lost their effectiveness to a very great extent . These structures , which should be maintained at least for five years , are not maintained at all. Theft of palisade material for firewood is another problem which plays havoc with these structures in localities closer to human habitations .

Since , both , palisades and wattlings aim at speedy establishment of vegetation , there is a need to look at the loose or partially stabilised debris as a medium of growth for plants . This is never done . It is usually taken for granted that once some seedlings are put in , and some sproutable cuttings planted , they will grow howsoever impoverished the growth medium is . This is probably the most serious flaw in this technology as applied in the study area . There is a need for getting soil samples of such sites tested , and in accordance with the result of that , soil amended . Since it is wished to establish the vegetation with most possible quickness , the growth medium should be the optimum . The soils in the study area being subjected to high degree of leaching , manure have to be organic .

The early or delayed planting of sproutable cuttings , too , sometimes cause failure . They either rot or dry out failing to sprout . There is a need to optimise the period cutting for each species for better results. The palisades and wattles , despite some defects in designs , have done commendable job in eastern Himalayas . But except a few Govt. Departments (Forest , Border Roads Organisation) , none have adopted these techniques . No private individual is seen practising this . There is a need to streamline the technique , remove the defects and disseminate this information to people at large .

7.2 SOIL CONSERVATION MEASURES BY INDIVIDUALS :

Progressive reduction of productivity of land exposed to eroding forces has put man on guard against soil erosion . A farmer knows the malady by his experience . The traditional corrective measures , too , are evolved that way only . Some common sense soil conservation measures have been adopted by individual farmers in the study area for ages . The chief among such soil conservation practices adopted by individual farmers is the terracing of land, protective vegetation belts, mulching, etc.

7.2.1 LAND TERRACING :

That , in hills , any land put to plough has to be essentially terraced for its sustained long term productivity , the farmer knows by his experience . There is no way out but to abandon an unterraced agricultural land after a few years as cultivation becomes highly uneconomical . Farmers terrace their fields in narrow strips , with risers made of dry rubble masonry . In due course of time , these risers get covered with thick mat of grass giving it perfect sealing from the effect of beating rains .

It is seen that terraces are maintained quite well wherever paddy cultivation is in vogue . This is because paddy cultivation in these parts is done through impounding of water for which level or inward sloping terraces with well maintained and well sodded risers are an essential requirement . This is not so where maize or other coarse grained crops or vegetables are raised . In such localities, the terraces almost always slope outwards instead of inwards as they ideally should do . Outwardly sloping terraces form a potential threat for enabling run - off to overtop risers . This results in gullying and degradation of a productive field .

Construction and maintenance of a good terraced field is quite expensive . It is not always affordable by small and marginal farmers . This is especially so on steeper slopes where terraced fields are much narrower , and number of risers per unit area much higher , than those on milder ones .

Besides , on steeper slopes , risers are much higher and cost of masonry works needed per unit area for their erection ,too , is much more . Steeper the slope , higher shall be the maintenance cost , too . Overall cost of production of agricultural products shall , obviously , be higher and returns lower on steeper slopes . The break even point for agricultural production on steeper slopes is likely to be so delicately balanced in favour of profit that any marginal decline in productivity makes cultivation of such lands commercially unviable . This is because of this that the agricultural lands on steeper slopes are the first to be abandoned . Conversely , the steepest slopes of farmer's field shall be the last to come under plough . In fact it is seen that lots of agricultural fields have been abandoned in the upper zones of almost all river basins in the study area .

As important as terracing itself , is the safe disposal of water from the terraces . It is seen that in many places , water is not given a safe passage down to jhora having stabler bed .

7.2.2 PROTECTIVE VEGETATION BELTS :

Traditionally , individual farmers have relied more on vegetation to provide protection to soil than on mechanical ones . In the study area , large number of farmers have raised private grove of trees on their homestead lands . The species planted are local with emphasis on fodder trees . Among the major tree species planted are Amla , Ambake , Arkaula , Arupate, Buk, Mithe Champ, Gamari, Jamun , Kapasi , Dalne Katus , Sungure

Katus , Chiple Kawla , Lapche Kawla and Utis. Among the fodder tree species Pipli , Nebharo and Gogun are the prominent ones . Besides this , farmers also plant good soil binding perennial grasses which yield fodder and other useful by products . Amlisho and Narkat are two such prominent species of grasses . While both yield fodder during fodder scarce winter months , former yields " Phul Jharu " from its spikes which sells at about Rs 10 to 15 a kg and the latter firewood from its stems . Amlisho is an excellent cash crop as well as a very good soil binder with highly fibrous root systems .

These protective vegetation belts are often planted on steeper terrain in small compact blocks . It is seen that terrace risers contain very few trees . This is probably because of fear that shade of such trees shall diminish productivity . That should not be so given right selection of species . It is also seen that trees are haphazardly planted , without proper mix of species . Often the crown cover is not optimum . The perennial grasses are planted in clumps instead of in protection belts along the contour which could be much more effective against sheet washing from the area .

7.2.3 MULCHING :

On account of high rainfall and intense rainstorms , splash erosion in worked soil is quite damaging . To minimise this loss mulching is very potent tool . Layers of dry or green straw is laid over the bare surface . The mulch intercepts the shooting rain drops and protects soil particles against it . Traditionally , while harvesting maize , paddy or other crops , a substantial part of straw is left in the field as stubble .This acts as a mulch to some extent . With passage of time , stubble decay from the collar region and tumble down on the surface , enhancing its mulch effect .

It is seen that wherever the stubble mulch , instead of being left standing upright , are cut and sprayed on the ground , their effectiveness as mulch increases . This is also seen that mulch is not used immediately after soil working . It is during this period that splashing is most violent and far more intense than during normal soil conditions . Mulches need be provided whenever soil is worked during monsoon .

7.2.4 MISCELLANEOUS :

Among other soil conservation measures adopted by individual farmers , boulder strewn waterways for safe disposal of water are important . These small jhoras dispose off excess water from the fields . The farmers have learnt by long experience not to remove boulders and pebbles from the beds of these channels flowing through their homestead lands . It is easy to find a number of such passages meant for safe disposal of excess water . Boulders , besides protecting the soil beneath and on sides , create natural obstructions in flow , reduce the velocity and the erosivity of flowing water .

Besides this, in some areas , it is seen that catchwater drains , too , have been made by farmers .

They are mostly lined by dry rubble masonry and are used to direct run-off away from unstable zones . They are often ill maintained , and in many cases , abandoned with deleterious effects. Dry rubble walls have been used by farmers in construction of dwelling houses as well as in erection of risers . They are often with improper batter and , usually , with excessively thick cross sections .

In addition to these soil conservation measures adopted by various Govt. Departments and by individual farmers , a number of schemes exclusively meant for soil and water conservation have been operative in the study area.

7.3 DIFFERENT SCHEMES OF SOIL AND WATER CONSERVATION :

With a view to checking soil erosion , soil and moisture conservation programmes were launched , both , under State as well as Central Sectors during the five year plans . Major soil and water conservation schemes executed in the study area are Operation Soil Watch (OSW), National Watershed Development Programme For Rainfed Agriculture (NWDPRA), and Integrated Afforestation and Eco-Development Project Scheme (IAEDPS).

In general , the main components of soil and water conservation schemes have been bunding , terracing , land sloping , levelling , contour cultivation and planting , water escapes and outlet for removal of excess water in agricultural lands , and closures , afforestation , raising of utility trees , plantations , grass land development , contour terracing and stone walls in non-agricultural lands . The components of engineering measures were water harvesting and silt detention structures , treating gullies , stream banks , landslides and slips , mine spoils in , both , agriculture and non-agriculture lands .

7.3.1 OPERATION SOIL WATCH (O S W) :

Operation Soil Watch started in the year 1980-81 was a scheme of soil , water and tree conservation in the Himalayas . The objectives of the scheme were to provide stability to the fragile and vulnerable Himalayan eco-system through engineering as well as vegetative methods of soil and water conservation . The scheme aimed at giving integrated production treatments to selected catchments mostly within the reserve and other forest lands . The programme was spread over in the entire Himalayan range covering parts of 14 states including West Bengal . The main components were afforestation , pasture development , stabilisation of slips , gullies , torrents and terracing of critically eroding agriculture lands .

In the study area , programme continued up to the year 1989-90 and an area of 475 ha was afforested under this scheme in Ghoom-Simana , Senchal , Mahldram and Dhobijhora forests (Govt. of West Bengal , 1995 B) . Large number of jhora training works with guide and drop structures were taken up on sides of Hill Cart road . Two landslides were treated with engineering structures in the Rongbong forests . A series of catchwater drains were constructed to divert water from the head of the slides . Catchwater drains were also constructed in and around Sukiapokhari . Few jhoras in the Upper Balason catchment below Sukiapokhari bazzar were treated with massive drop and guide structures .

7.3.2 NATIONAL WATERSHED DEVELOPMENT PROGRAMME FOR RAINFED AGRICULTURE (NWDPRA) :

The NWDPRA was started in 1986-87 with an objective to conserve and upgrade , both , croplands and cultivable waste lands on watershed basis ; to stabilise and increase crop yields from rainfed farming ; to augment the fruit , fodder and fuel resources through appropriate alternate land use systems ; to develop and disseminate technologies for proper soil and moisture conservation .

The scheme was restructured and expanded during 1990 to create models of scientific land use through development of integrated farming systems on the principles of watershed management in each development block where less than 30 percent arable area is under assured means of irrigation .

The objectives of the scheme , too , were made more broad based and were directed to achieve the twin goals of sustainable production of biomass and restoration of ecological balance in the vast tracts of rainfed areas in the country . The objectives would , specifically , focus on followings (Govt. of India , 1991) .

i. Conservation , upgradation , and utilisation of natural resources like land , water , plant , animal and human resources in a harmonious and integrated manner leading to perpetual availability of food , fodder , fuel , fibre , timber and biomass through diversified landuse .

ii. Generation of massive employment in the backward rainfed areas during and after the project period for under-privileged sections of rural population like small and marginal farmers , landless labourers , tribals etc.

iii. Improvement production environment through scientific management of land and rain water by introduction of in-situ moisture conservation , advanced production systems , ground water recharging devices and appropriate cash crops according to agro-climatic potentials .

iv. Reduction of inequality in productivity of irrigated and rainfed areas leading to the reduction in large scale migration from rural areas to cities .

v. To enhance cash flow to the rainfed farmers and landless agricultural labourers through increased casual employment , growing of cash crops etc. in suitable areas.

In the study area , the Department of Agriculture , Govt. of West Bengal , is taking up NWDPRA works and , in most cases , work is being done in agricultural lands . Since extent of agriculture land in the study area is quite meagre (substantial area being under tea cultivation) , the size of the project is quite small .

7.3.3 INTEGRATED AFFORESTATION AND ECO-DEVELOPMENT PROJECT SCHEME (IAEDPS) :

The scheme IAEDPS , started in 1989 , was earlier known as Integrated Wasteland Development Project Scheme (IWDPS) and was renamed so to reflect better its eco-development nature . IAEDPS was an important scheme of the National Wasteland Development Board (NWDB) which provides the necessary framework for attainment of the goals of restructured wastelands development programmes . The components of the scheme include checking land degradation , putting wastelands to sustainable use , increasing biomass availability , especially fuel wood and fodder , and restoring ecological balance (Kapoor , 1992) . The scheme envisages enlisting people's participation , harnessing science and technology inputs and ensuring inter-disciplinary co-ordination . Since its inception large number of projects have been taken up all over the country through the state forest departments and the District Rural Development Agencies (DRDA) in selected districts through approved microplans . Research institutes , universities and voluntary organisations , too , have been associated with the execution of the project .

In Darjeeling district in foothills , the scheme has been executed , inter alia , in some vast bouldery tracts devoid of all top soil due to long persisting land degradation specially deforestation. All that remained was bouldery river grit material with copious amount of sand. There was no organic matter in soil . Finer particles had either leached down or had been washed away with surface run-off . Since the top soil was completely lost , carried earth from outside the area was brought and utilised for filling up of the planting pits (Patel , 1992) . To augment the organic carbon in soil , cow dung manure was applied to the planting pits . The area , which was lying barren for decades , has been successfully regenerated through riverine species , namely , Sisu (Dalbergia sisoo) and Khair (Acacia catechue).

7.4 MISCELLANEOUS :

Besides the measures discussed earlier by Govt. and by individuals , tea gardens , mostly owned by corporations , companies or firms , have also practised some soil conservation measures in the study area .

Mulching has been practised by all the tea gardens in young tea plantations where canopy cover is less than optimum . Tea bushes are periodically pruned during winter months . The pruning material comes quite handy for the purpose of mulching of the exposed soil . Some gardens are seen to stone practise stone mulching , too , in younger tea plantations.

In some tea gardens , entire area is very well terraced . Dry rubble boulder masonry walls have been used to erect risers . The risers are kept well maintained . In steeply sloping parts of tea gardens, soil working is not very intense , especially during rains . Most tea gardens maintain a good protective belt of trees around the jhora banks . Trees of local species and large number of bamboo clumps are meticulously maintained in such protective belts . Catchwater drains , breast and retaining walls are also seen in the tea gardens .

The scrub lands , landslides , or seriously eroding stream banks , which make major soil erosion centres in many of the tea gardens , are , however , hardly paid any attention . Since tea gardens are commercial ventures operating on lands leased to them with provision for periodic renewal , they are averse to investing money unless it produces quick returns . Long term planning for soil and water conservation is often lacking . There is hardly any agency which monitors this aspect and erring tea gardens often go scot free . Severely sheet washed scrub lands are often seen around tea gardens , especially on steeper slopes on higher reaches of the study area . With scrubby vegetation , exposed rock outcrops and highly overgrazed condition , such tracts contribute a lot for soil degradation .

CONCLUSION :

Thus it is seen that , in previous years , a number of soil and water conservation measures are have been in vogue in the study area . Among the measures adopted by various Govt. agencies , jhora training is one of prime importance . It is seen that design is often defective – the structures being over-designed or under-designed causing wastage of resources in any case . The maintenance of structures is yet another severely neglected aspect . The next soil and water conservation measure of previous years has been construction of catchwater drains . Here , too , dimension as well as gradient are inappropriate leading to their failure . Construction of retaining walls and breast walls have been the next important soil conservation measures adopted by Govt. agencies , particularly along the roads . In construction of such walls, improper fashioning of slopes before construction and improper provision or complete absence of weepholes has been a major cause of failure of many such structures . Similarly , river training works have been done in lower reaches of streams . Placement of groynes , their design and inadequate rooting in the banks are found as the major defects in design of such structures . Lack of adequate protection on sites likely to develop potholes has often resulted in scouring of foundations leading to failure . Checkdams with dry rubble masonry has been extensively used by Govt. agencies for treatment of landslides . Improper face batter and lack of regular maintenance are major defects in design . Checkdams in river beds have not been very popular , though they could have been utilised very well in flatter sections of streams . Palisades and wattlings , too , have not been used in suitable slope conditions besides being very poorly maintained . Manuring of slopes aimed to be protected through quick establishment of vegetation has been completely neglected . Among soil conservation measures adopted by individual farmers , land terracing is of prime importance. Most of them slope outwards , do not have provision for safe disposal of excess water and are not maintained regularly . Protective vegetation belts raised on homestead lands are quite noteworthy , though most of the risers in the terraced fields do not have any tree . They could have been easily utilised for raising trees without hampering agricultural production . Mulching has been utilised in a very primitive way by leaving stubble of maize or paddy straw standing in the field . This could have been used more efficiently . Among various schemes of soil and water conservation , Operation Soil Watch (OSW) , National Watershed Development Project For Rainfed Agriculture (NWDPRA) and Integrated Afforestation and Eco-Development Project Scheme (IAEDPS) are the major ones with a number of soil and water conservation components including afforestation . Tea gardens have practised soil conservation through terracing , mulching , catchwater drains , jhora training etc. though they have often shirked away from long term capital intensive soil and water conservation measures .

Various soil and water conservation strategies adopted by Government and individual farmers in the past and inappropriateness in their approach brings failure. So appropriate suggenstions regarding different soil and water conservation measures are urgently necessary in the study area.

CHAPTER VIII

SUGGESTION REGARDING SOIL AND WATER CONSERVATION

INTRODUCTION :

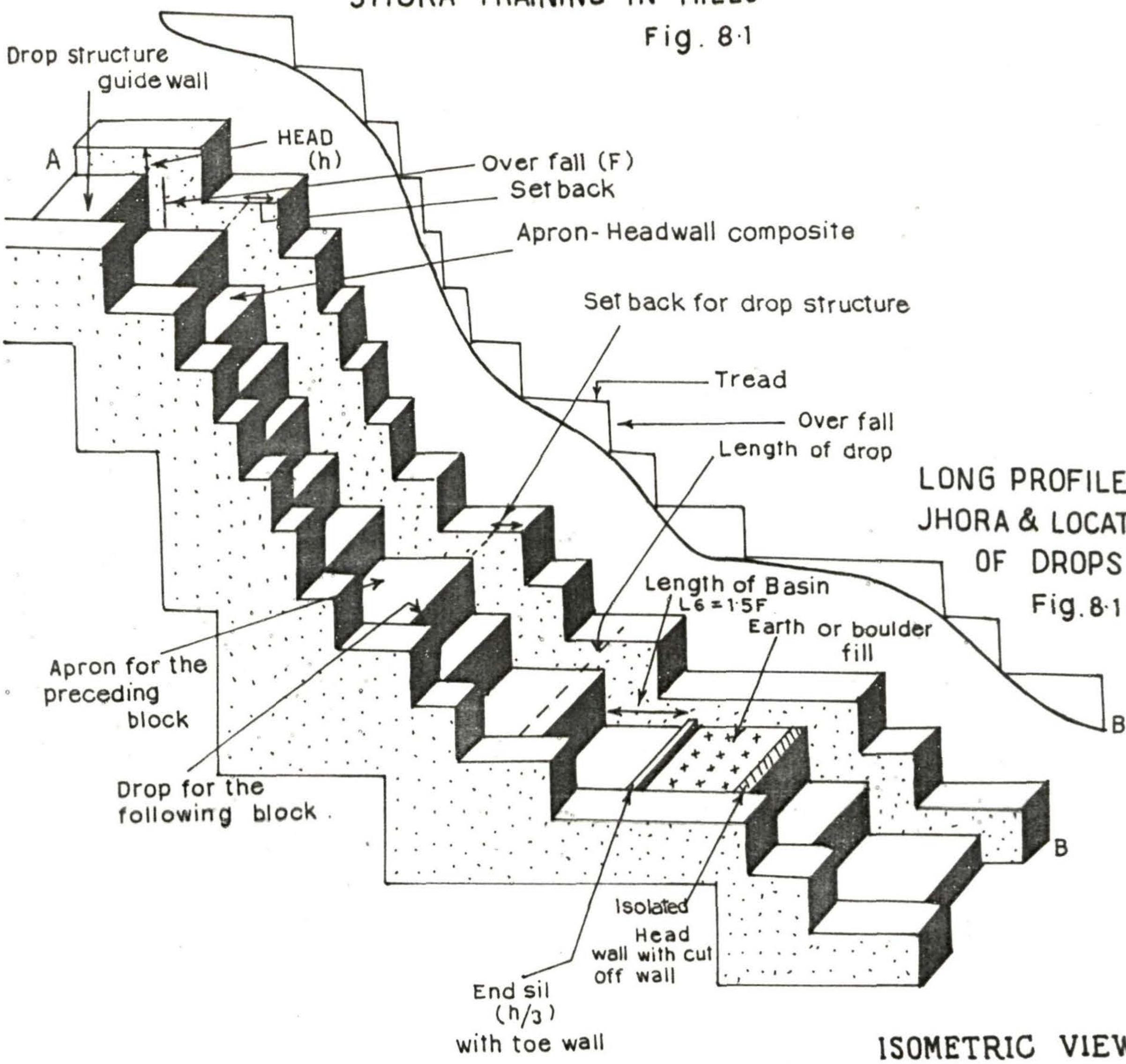
This chapter deals with suggestions regarding various soil and water conservation strategies suitable for the study area . Those discussed in detail relate to jhora and torrent training , catch water drains , retaining walls breast walls , river training , check dams , palisades and wattlings , slope protection , with live and dead material including geotextiles and hydroseeding . Some suggestions have also been given regarding measures to control landslides .

8.1 JHORA TRAINING :

For control of steep rivulets, Jhora training is very important. Drop and guide structures are provided for protection of banks of streams. Jhora training structures in the study area are often ill designed. Based on fundamental principles of flow of water in channels and pioneer works done by other workers (Ram Babu, et al, 1979 ; ICAR Bulletin No. T-13 / D-10, 1981) , following design is suggested. Peak discharge for a suitable recurrence interval should be evaluated. Dimensions of structures should be enough to carry through that discharge. The long profile of the jhora is evaluated and, keeping the overfall same , a schematic location of drops on it is prepared (Fig. 8.1 a, b, c) . Milder slopes shall have longer treads. The first tread in this staircase pattern shall be provided with a minimum head equal to half of the overfall . The tread block should be provided with a set back from its correlating guide wall block equal to head . Thereafter , both , twin guide blocks and apron - head wall composite , should be given drops equal to overfall , F , at intervals equal to length of each tread. The length of individual treads is assessed from the schematic location of drops on the long profile of jhora . Each apron - head wall composite less than 1.5 F in length shall consist of apron of requisite thickness integrated with head wall of the following drop . No cut off wall for head wall and no toe wall for apron need be provided in such cases (Fig. 8.1 d,e). End sills and head walls shall be provided with toe walls and cut off walls, respectively, whenever slopes are milder and tread in apron - head wall composite exceeds one and half times of the value of overfall. Most structures fail because of failure of apron. Apron thickness is, therefore, very important. It should never be less than 30 cm for masonry constructions. For higher overfall, it goes up to 45 cm. Thickness should be increased by one third for gabion

JHORA TRAINING IN HILLS

Fig. 8·1

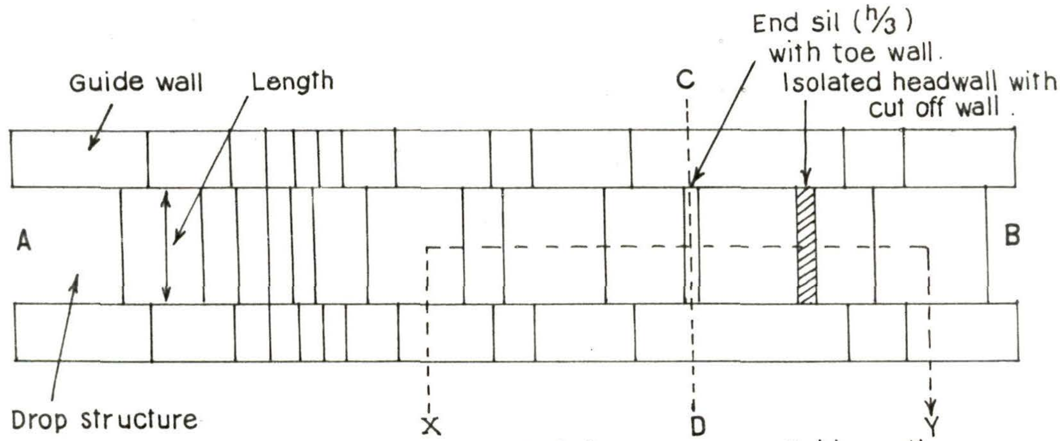


LONG PROFILE OF JHORA & LOCATION OF DROPS

Fig. 8·1 (a)

ISOMETRIC VIEW

Fig. 8·1 (b)



PLAN

Fig. 8.1(C)

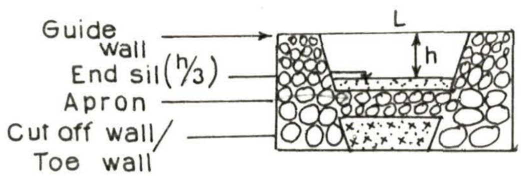
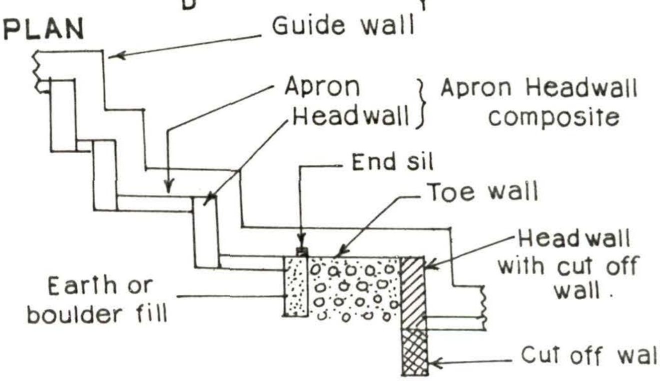


Fig. 8.1(d)
Ref. Para : 8.12

SECTION ON CD



SECTION AT X - Y

Fig. 8.1 (e)

constructions. It can be decreased by one third for construction in plain concrete. For guide walls and head walls, the minimum top width for stone or brick masonry constructions is 45 cm (Singh et al, 1991). In general, for gabion constructions, the top width should be increased and for plain concrete constructions it should be decreased, by one third.

8.2 CATCH WATER DRAINS :

Catch water drains should be provided to divert water away from locations where it is likely to damage soils more than otherwise . Landslips , landslides , severely gullied areas , sinking zones , etc. are such locations . Similarly, grassed water ways should be provided for safe disposal of excess run - off from agricultural, horticultural and grass lands etc. Grass lined waterways are a basic tool of soil conservation. These are best maintained in parabolic , triangular , or trapezoidal shapes . Grassed waterways are the most economical catchwater drainage systems. They are most suitable in locations where seepage of water does not lead to any serious problem. Grassed lined waterways are can be used as outlets for diversion of excess water from terraces. Terraced fields in the study area are not provided with proper catch water drains (sec 5.1.1). In such situations terrace risers break and gullying of land results. Catchwater drains of proper section should be provided to these fields. Peak discharge for a suitable recurrence interval should be calculated out for determining proper section of the drain. Grade of the drain is also very important. Hydraulic radius and the grade of the drain should be such that water in channel flows well below critical velocity. Grass lined water ways can serve the purpose well in the study area. There shall, however, be constant or prolonged flows in them. Special supplementary treatments by grade control structures, by stone centre or by sub-surface drainage system through pipes shall be required. Maintenance of protective vegetation cover is very important.

In i [illegible] Side drains of black top roads in the study area run a considerable distance and debauch large quantity of water in a single jhora. This should be changed. Side drains of all roads should be so made that each small drainage line is given its way down across the road bench. The natural catchment of each drainage line should be altered as little as possible.

For landslides and gullied areas where seepage of water need be cut, catchwater drains should be made with cement concrete or cement rubble masonry on sides with cement concrete bottom. This minimises the seepage. A series of parallel catchwater drains, running along contours, should be provided for protection of landslides and landslips. Most of the landslides in the study area are located in phyllitic formations. Soils are highly permeable in these. A network of parallel catchwater drains is very important for control entry of water into the head of the slide.

8.3 RETAINING WALLS AND BREAST WALLS :

The danger of sliding becomes imminent the moment the angle of slope exceeds angle of repose of the soil material. Retaining walls and breast walls are constructed for protection of slopes against such sliding actions. Retaining walls and breast walls are popular soil conservation measures in the study area. They have been constructed by Govt. Departments, as well as, by individual farmers, tea gardens, etc. Designs of these walls in study area are often defective (sec 7.1.3). Slopes are not trimmed and flattened before construction. More stable concave slopes are often not formed while cutting banks for constructions. The fact that backfill become more liable to slip when saturated with water, is often ignored in designing.

For cutting earthen embankments for construction of retaining walls and breast walls, following guidelines should be stuck to. In undisturbed earth and gravelly sand (up to 6 mt height), slope of cut should be 1:1. In well drained clays, slope of cut should never exceed 4:1. When a slope passes through two different soils, the top layer should be trimmed flatter. High cuts should be reduced by inserting one or more berm. A minimum factor of safety of two should be kept against sliding. Walls above 3 mt height should be checked for safety against sliding. If the resistance against sliding is too little, base width of the wall should be increased or the base should be sloped down towards the backfill. Walls should also be checked for safety against crushing. Thrust on the back of the wall should be calculated and dimensions of wall decided as per standard techniques. Depth of foundation of retaining walls should be at least one tenth of the height + 30 cm (Maslekar, 1981). Projection of any footing course should not exceed half the depth of the course. Maximum pressure on toe should not exceed seventy percent of the load bearing capacity of the ground. Minimum top width of the wall has to be 60 cm. Front face should be given a minimum batter of 1 in 24. The most common batter is 1 in 12. A batter economically adds to the stability of wall for any outward displacement. Back of wall should be left rough or built in steps to increase friction between wall and the backfill. Granular material should be used as backfill. It should be deposited in 10 to 15 cm layers with moderate compaction sloping downwards from the wall. Dimensions of the retaining walls constructed in the study area are often inappropriate. Soil conservation works usually do not require huge masonry constructions. Thumb rules are very handy for assessing dimensions of wall in such constructions. The thickness of retaining walls in bottom, middle, and top third sections should be, respectively, 1/3, 1/4, and 1/8 of the total height for retaining walls below 4 mt height. Height of the wall above ground added to the depth of foundation is total height. As pointed out earlier, the depth of foundation should be 1/10 of total height + 30 cm. For walls above 4 mt height, base width, top width and depth of foundation should be, respectively, 0.350, 0.175 and 0.520 of the total height for construction in cement mortar. For construction of dry retaining walls, top width is 0.60 mt, front face batter 1:4 to 1:3 (hor : Ver) and back as vertical. Long lengths of dry rubble retaining walls should be divided into panels separated from one another by short lengths of wall (1.5 mt to 2.0 mt) built in cement mortar. Such sections are required at an interval of 6 to 9 mt. These confine subsequent damage, if any, only to the panels affected.

Inadequate drainage of retaining walls is a major cause of their failure in the study area. Retaining walls in clean gravel sand and coarse sand should have a drain of loosely packed rubble running along the back footing. From this rubble, good size weepholes, 1.5 to 3.0 mt apart, should lead out through the base. A 25 to 30 cm wide drain should run nearly the whole way up the back of the wall in clayey soils. The size of weepholes should be 7.5 cm x 5.0 cm. The lowest weephole should be 30 cm above the ground level. They should be placed staggered. A fall of 1 in 8 should be given to them from the back of masonry to the face.

Combined action of stream bank erosion and sloughing cause bank failures in the study area (sec 4.7). It is suggested that gabion retaining walls be used in such locations. The width is reduced in steps to 1 mt at the top when there is no surcharge. A minimum of 2 mt of top width is, however, necessary when there is surcharge (Datta, 1986). Even for low walls, minimum bottom and top widths are kept 1 mt. Gabion retaining walls are permeable. They are most suited to support banks saturated with water.

Breast walls are not meant for retaining earth but to protect slope of cutting in bad soils. They may have vertical or inclined face. These are made soon after the cutting of the slope. They are usually built with similar front and back batter of 1 in 2 to 1 in 4 with top 60 cm wide.

Extension and construction of new roads are causing severe soil erosion in the study area (sec 5.1.4). Roads are basic needs of development and can not be banished altogether. Roads are extremely necessary in north-western part of the study area. The Dudhia-Pumongphatak road shall fulfil this vital need of the area. Similarly, air strip under construction near Rongbull, is also very essential. There is no question of abandoning of these development schemes. Suggestion is, however, made for in-situ stabilisation of spoils through construction of retaining walls. The gabion retaining walls shall be the most suitable. Down hill and up hill cuts of these constructions should also be protected through retaining walls. Road bench should be so cut that natural catchment of each jhora is altered the least. Side drain construction should be given the top most priority after the road bench is cut.

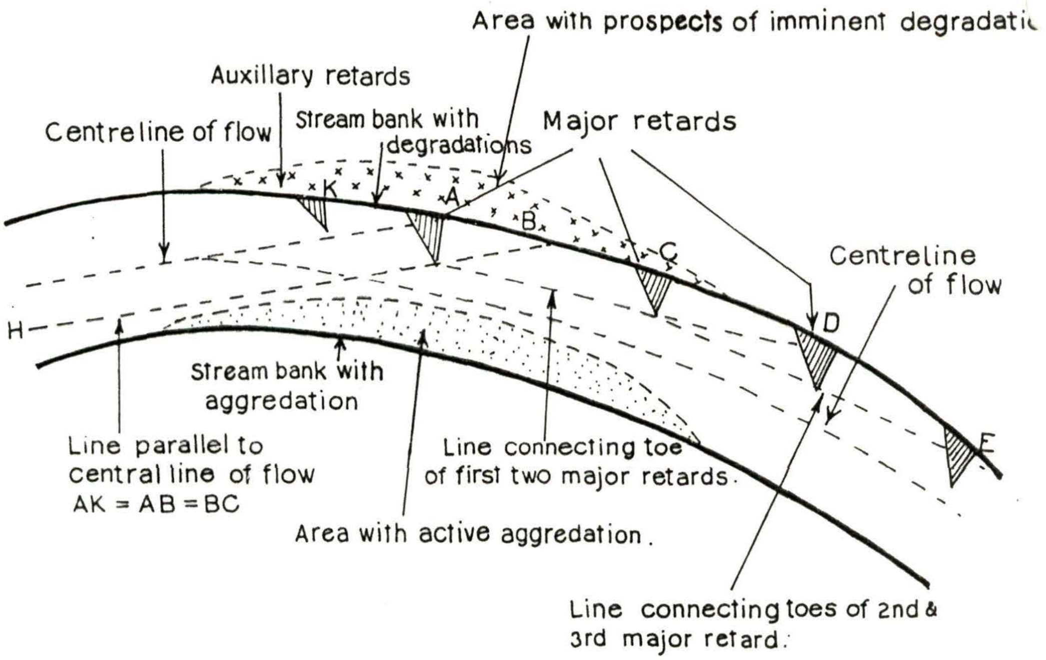
8.4 PROTECTION OF BANKS OF TORRENTS AND STREAMS :

Protection of banks of torrents and streams needs a two pronged strategy . One - through afforestation, grassland development, contour trenching , construction of drop structures and terracing of agricultural fields , the quantum of run off and accompanying sediment load should be reduced . Two - banks of torrents and streams should be protected by rip rap or loose retaining walls . Training walls , made of flexible semipermanent materials , can also be erected in double line. They should be constructed parallel to the banks , to facilitate settling down of silt and promotion of growth of vegetation (Ray, 1954). Besides this , construction of revetments , spurs , jetties , retards or groynes should be taken up to confine the flow of the stream .

Materials for construction of these retards are many and include wooden piles , trees , rocks , gabion walls and cement concrete . These retards , jetties , or groynes extend into the stream from its bank and serve to decrease the velocity of flowing water along the concave bank. They promote deposition of sediment and push the stream away from the concave bank . The proper location of these retards is of great importance. A traditional method of locating retards in a simple turn of stream is shown in Fig 8.2(a) . The method of location of retards gets a bit complicated where streams snake and areas of aggradation and degradation alternate from bank to bank . In such snaking streams , their flow pattern also alternates between clockwise to anticlockwise from one concavity to the other (Fig. 8.2) . In a stream , concave bank gives way and , thus , suffers from degradation whereas convex bank is subjected to aggradation and the gravel cone pushes more and more towards the centre of stream . The radius of curvature of concave bank tends to increase

STREAM BANK PROTECTION

Fig. 8·2 (a)

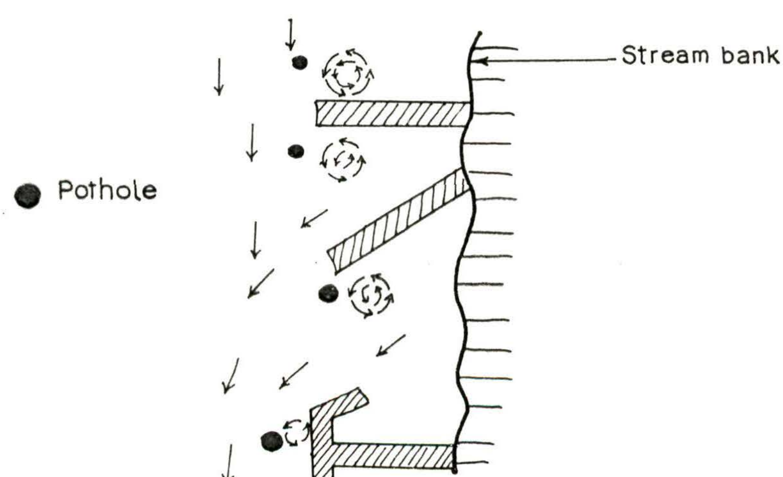


TRADITIONAL DESIGN AND LOCATION OF RETARDS

(*Ref. Para 8·4*)

(Source : Adopted by Author from ICAR Bull. No. T-13/D-10 (1981))

Fig. 8·2 (b)

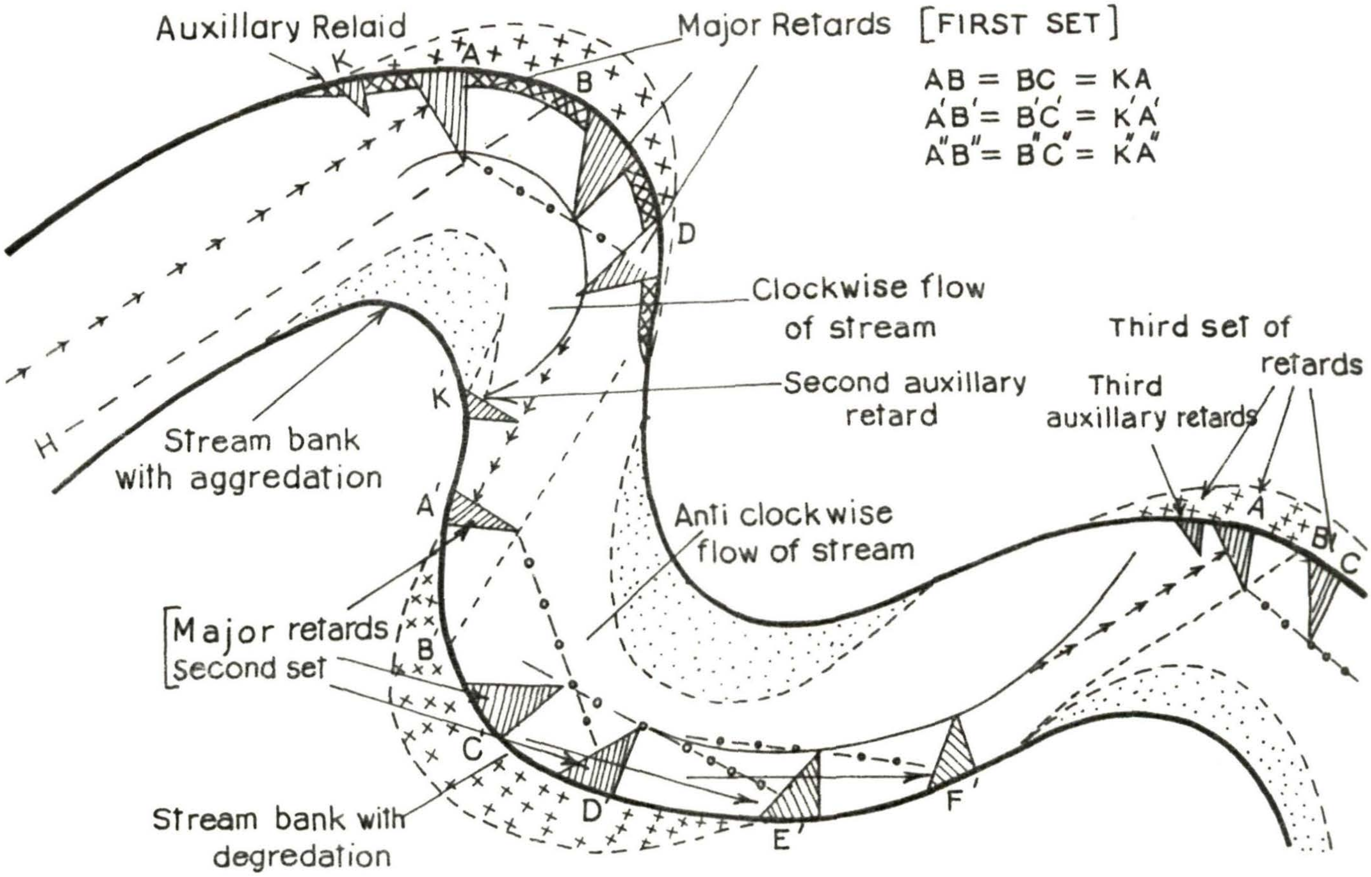


EFFECT OF OBSTRUCTIONS INFORMATION OF POTHOLES whereas that for convex bank decreases with passage of time (Fig 8.3) . The first major retard at A is located by the intersection of the projected centre line of flow with the concave bank . In locating the second major retard , C , a line HB is drawn parallel to the projected centre line and through the head of retard A . The intersection of this line with the concave bank locates point B . AC is , then , made equal to twice AB and second major retard is located at point C . Additional retards are located by the intersection of a line (connecting the head points of two previous retards) with concave bank . An auxiliary retard at K is located a distance AB upstream from A and is extended into the stream about one half the length of other retards . The retards should extend into the stream at an angle of 45 degrees (for most purposes) for a distance of about 30 percent of the channel width . On smaller streams , the spacing of retards may be made equal to the stream width , and the length , 0.25 times the spacing . On 30 degree or larger curves , continuous bank protection through revetments should be provided to ward off bank cutting . If the stream is needed to be driven away from the concave bank , retards need be provided in addition to bank protection .

A revetment is a protective cover to prevent scour by water . Gabion structures are popularly used for rivetting stream banks . Gabion being porous , allow subsurface flow to pass easily into the stream across it , thus avoiding any build up of pore water pressure . Revetment differs from the usual walls , its function being making available a blanket protection

RIVER TRAINING

Fig. 8·3



DESIGN AND LOCATION OF RETARDS

(Adopted by Author from SANSON et al , 1937)

(Ref. Para 8·4)

Area with Prospect of Imminent degradation

Area with active aggregation

Centreline of flow

Line parallel to centreline of flow

Extension of lips of successive retards

Arc of tip points of 3 retards

Preceding revesion of concave

Slope to convex slope

River bank

Retards

Continuous bank protection through relletments to the earth surface and not to withstand any thrust like retaining walls . The bank is graded to a slope of 1 : 1 and 0.50 mt thick gabion mattress is laid over it . The toe protection of revetment is ensured by placing one meter cube gabion boxes over it . Gabion mattress has a tendency to slip down and bundle up on slopes steeper than 1 : 1. Their use on such slopes should be avoided . When erection of revetments are unavoidable on such slopes , use of lateral ribs (running down the slope) , made of 1 mt x 1 mt boxes are required to reinforce the mattress . It is better to sink these ribs into the ground and the mattress is laid over them . The spacing of ribs will vary from 5 to 15 metres depending on the stability of the bank materials . The slopes steeper than 1 : 2 , and greater than 2 mt in height , may be better rivetted by forming steps with one metre x one metre boxes.

Methodology for location of retards in snaking streams , where retards need be provided on one bank first and thereafter on the other one alternatively , needs a bit more caution . All the major retards , including the auxiliary retard , on the first concavity of the stream shall be decided as per traditional method describe above . When the line connecting the head points of the last two major retards located on any concavity fails to intersect the same bank again , no further retards need be provided on that concavity. If this line does not intersect any of the two banks , no retards are needed on either bank as the stream is flowing straight . But if it intersects the opposite bank , a concavity has developed there , the flow pattern of the stream has reversed , and there is danger of degradation of this bank. Retards shall be needed to protect it .

For location of second set of retards on the opposite bank , the centreline of flow need be determined first . For this purpose the arch passing through the head points of last three major retards of first set is drawn . The down stream tip of the arch is extended smoothly (Fig 8.3) . This is the centreline of flow of the stream beyond the first concavity of the river . The point of intersection of this line with the opposite bank locates the first major retard , A´ , of the second set . Other major retards of this set , namely , C´ , D´ , E´ etc. and the auxiliary retard K´ , are located using the traditional methodology . Similarly for location of retards in third and subsequent sets , centreline of flow is determined and retards located thereafter following the same methodology .

The scheme for location of retards is based on the concept that retards should be built with an intervening distance which guarantees that the current even with a deflection of 15 degrees can not reach the bank (Tautscher , 1980) . In order to be effective , retards must be erected as elements of an integral system and distributed in such a way that a smooth line along the heads is obtained ; this means placement of retards should be such that no flow occurs between them (Riedl , 1984 A) . The spur foundation at the heads has to be much deeper (1.5 to 2.5 metre) than at the foot in the embankment since scouring is concentrated here . Submerged retards are normally built inclinant . Retards are sometimes made normal to banks where very serious deflection of river is needed . Both , submerged and high retards , are made with crown sloping from the banks . Where the retard bodies consist of unprotected dykes , the reinforced head has to reach the full height to prevent the cutting off of the head . In such cases on the upper side of dykes pitching has to be provided against cross current running along the retards to the centre of the river bed . For construction of submerged retards concrete , gabion , and big boulders should be used . It is also necessary that embankments consists of materials with equal resistance as that of the retard to prevent bypassing .

Since the retards create obstruction in flow , swirling action of water develops creating potholes which , in turn , endanger the foundation of structure . Such development of potholes is the most important cause of failure of retards . Potholes develop close to the head of the retards (Fig. 8.2 b) . The retards shield a body of water on their leeward side. This is formed into an eddy by main current brushing past one side of it . This swirling action scoops out a potholes . The down stream side of the retard is scoured more than the upstream one . For protection against pothole , chief aim is to locate the place where scouring is most likely to occur and to protect it . One such protection measure is to burry wire cages filled with boulders (gabion) near the head of retards . The foundation of such wire cages or blocks should extend to the maximum possible depth of scour while top of the block may be installed flush with the stream bed . If need be , gabion boxes of bigger size should be used . The second alternative for protection of head of retard will be a 50 cm thick flexible apron . For effectiveness , this should have a length 1.5 to 2 times the probable depth of scour . This flexible apron of gabion is constructed , not only at the head of the retard but also along the upstream face of it . Apron needs to be laid across the whole width of the retard rather than attaching it to side of them . In the study area, torrents carry large sized boulders and timber logs.The wire of gabion boxes gets damaged . Thicker wire should be used .

Besides protection through mechanical structures , vegetative control measures , too , need be used simultaneously . Live hedges of Vitex negundo , Arundodonax , Thysolaena maxima , mixed with Ipomea cornea should be planted along the bank . The steep and vertical banks should be sloped to a grade of 1.5 : 1 and planted with grasses like Aristida cyanthea , Arunodonax , bamboos etc. The freshly deposited silt near the spur and behind the live hedges should immediately be stabilised by planting cuttings suitable species . The cuttings should be planted in rows laid normal to the general direction of flow with rows spaced one to two metres apart . The sites having excessive proportion of shingles and boulders should preferably be planted with Aristida cyantha , Saccharum bengalensis and S. spontaneum . Area behind the banks , too , should be planted with suitable tree species .

The next important soil conservation tool is construction of checkdams which is discussed next .

8.5 CHECKDAMS :

Most discernible gullying in the study area is restricted to initiation stage (sec 4.4). Top soil gets eroded and bottom deepens. The next stage of development of gullying are indistinguishably mixed up. As gully head moves up and channel widens, banks slump causing landslips. In the study area the gully heads therefore, have to be controlled at the initial stage itself. Delay makes it incurable. It never stops until the whole soil mantle is wasted. Check dams are an invaluable tool for control of gullies. They are constructed in a series. They change longitudinal gradients into a series of steps. Checkdams could be temporary or permanent.

8.5.1 TEMPORARY CHECKDAMS :

Temporary check dams are very well suited for control of the gully in the study area. They are intended only to function until the vegetation becomes well established to provide necessary protection to the soil . They are to serve two main purposes - one , to collect sufficient soil behind them to enable vegetation to come up and , two , to check channel erosion until good vegetal cover is firmly established . These are excellent in controlling run off and soil erosion in small and medium sized gullies aimed at stabilising through vegetative means.

Temporary checkdams are usually made of brushwood , wooden poles or loose rocks , whichever material is available locally . The procedure for construction of some of these is described next .

8.5.1 a. Single Row Post Brushwood Dams : This method consists of erection of a single row of country wood stakes , to which are tied long branches of trees laid lengthwise of the gully with but ends facing upstream . The longest branches are laid first progressively those with shorter length at the top till the required height is obtained (Ayres, 1936). Such structures are useful for control of gullies 1 to 2 mt deep (Fig 8.4) .

Before the actual construction is begun , the sides of the gully at the dam site are sloped to 1 : 1 and the gully bottom for the whole length of the dam is lowered by about 15 cm . This 15 cm deep excavation is carried up into the bank as high as required to give necessary notch capacity for discharging the run off . The local wood stakes 7.5 cm in diameter are , then , driven 0.6 metres apart along the dam line . The stakes should go not less than 0.90 mt into the gully bed and their tops are kept at such height as to form a distinct depression in the middle , to form notch of the required specification to enable the peak discharge pass through without undermining the dams at the ends . First a layer of straw is placed at the bottom and over it longest branches , specially selected , are laid lengthwise of the gully and well pressed . Over this another layer of straw is spread and shorter branches laid . This process is repeated till a dam of required height at gully bed is obtained . The brushwood is anchored on to the stakes

SINGLE ROW POST BRUSHWOOD DAM

(Author's Design)
(Ref. page 8·5·1(a))

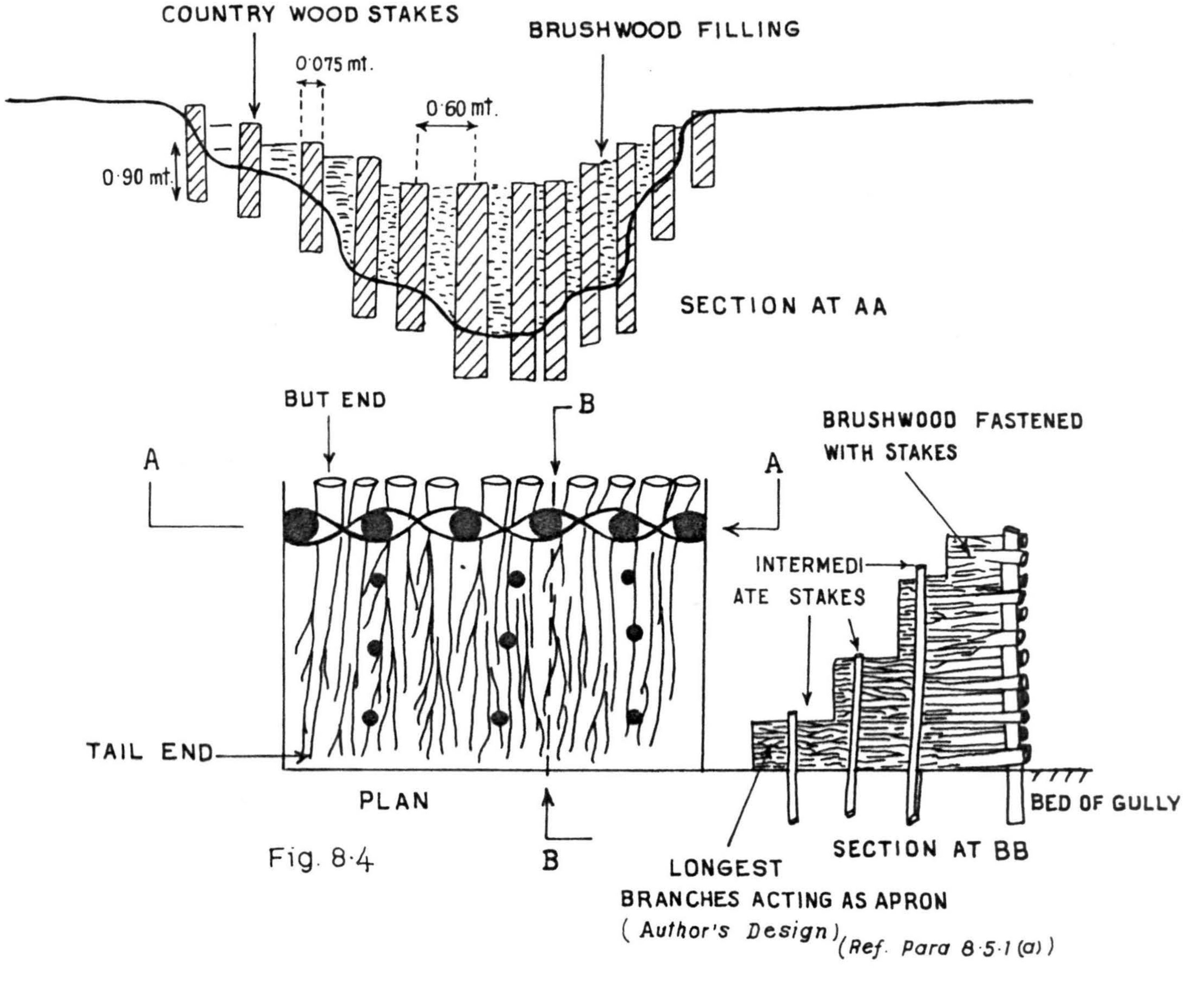
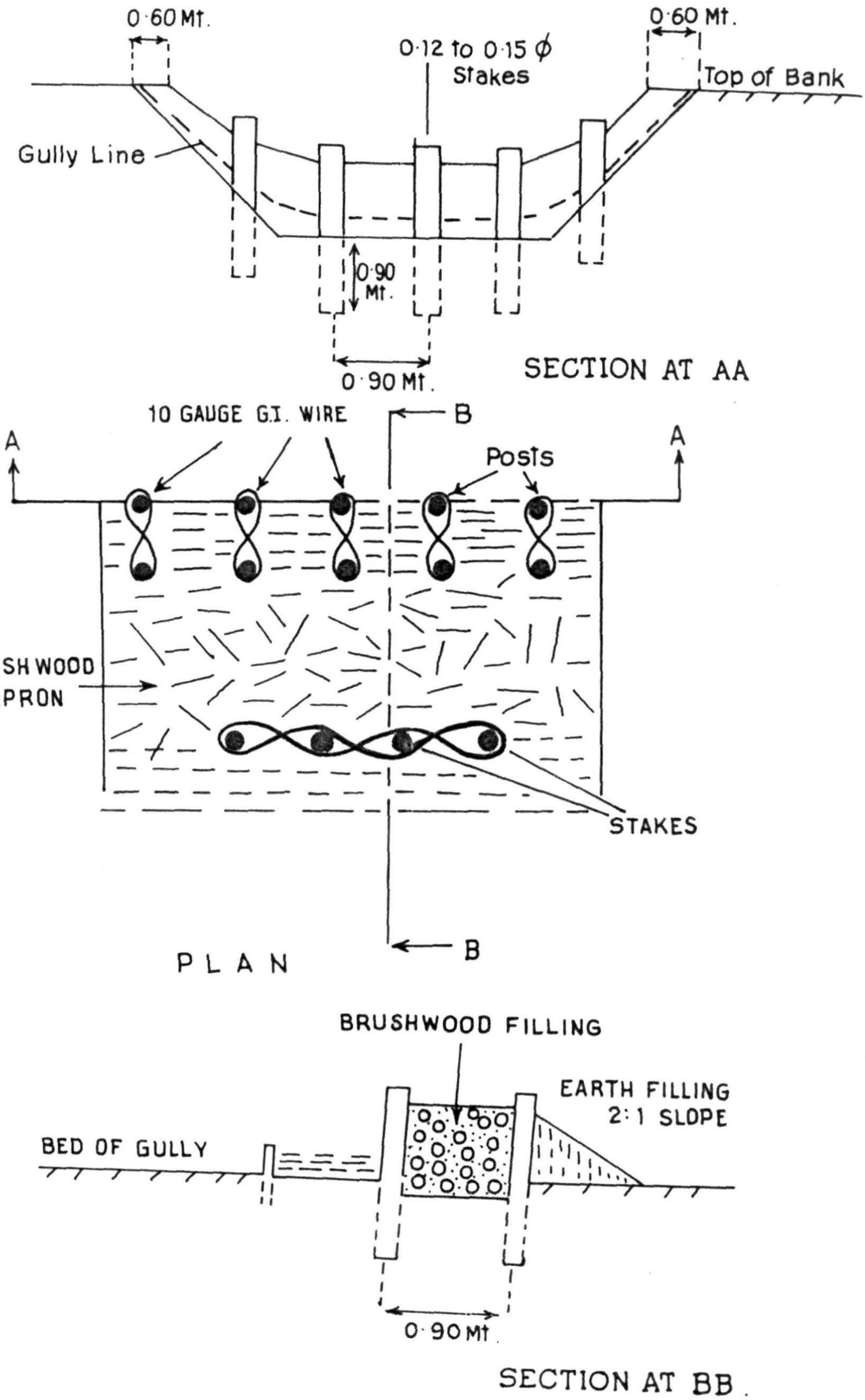


Fig. 8·4

by means of galvanized iron wire , so that it may not be washed away . Intermediate stakes of shorter lengths are driven and the brush is anchored on to them to prevent its being lifted from the bed by water . The longer branches sprawling on the gully bed act as apron for the dam and prevent overfall erosion by scour . As the green leave rot , branches loosen and the dam can not be kept rigid . This is overcome by the use of additional rows of stakes which can be driven down to take up the slack , wherever it is found necessary .

8.5.1 b. Double Row Post Brushwood Dams : This checkdam is used for control of medium deep gullies (2 to 3 mt deep and 10 mt wide) having a contributory watershed of around 100 ha . Though this construction requires more labour and material , they are definitely far more superior to single row post dams in respect of their strength and durability . The construction of dam is very much same as that of single row post brushwood dam excepting that in this case the straw and the brushwood is laid across the gully between two rows of wooden posts .

For the construction of this dam , 0.90 mt wide and 0.30 mt deep trench is dug across the channel . The sides here , too , are sloped to 1 : 1 . Post of local wood , about 15 cm in diameter , are driven (in two rows along the trench) 0.90 mt apart to go down at least 0.90 mt to 1.20 mt into the hard bed of the gully . Another line of stakes is driven about 1.50 mt to 2.00 mt lower down the gully (Fig. 8.5) . Two layers of brushwood , one after the other , is laid along the flow



A DOUBLE ROW-POST BRUSHWOOD CHECKDAM

Fig. 8·5

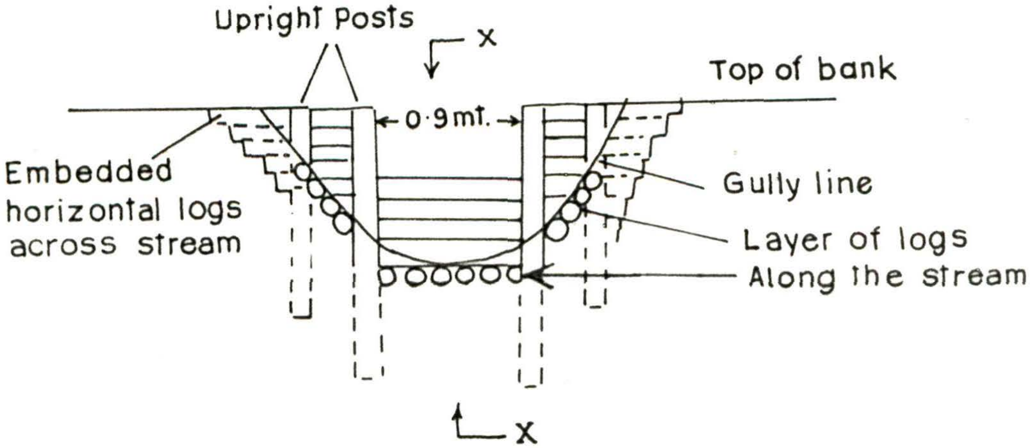
of water and tied to the post and the stakes lower down. Now the brushwood is laid across the nala in the tract in between the posts and thoroughly packed . The brushwood may be laid in individual pieces or in bundles tied with galvanized wire . On reaching the required height a notch of rectangular cross section is provided . When the required height is reached , the posts are tied with each other with galvanised wire .

8.5.1 c. Dry Stone Checkdams : Dry stone check dams constructed in the study area do not have proper batter. Their orientation, location, and dimensions are inappropriate. Following suggestions are made. They are usually made in form of an arch with the convex side facing the current . The curve to be given to the checkdam is assessed making a semicircle double the length of span of the checkdam . After deciding the arch , a foundation 0.45 mt deep and 1.20 mt wide is dug . Leaving the central half of the span ,foundation for the wing wall is also dug so that they would make an angle of 30 degrees with the bank . As the wing walls have to be taken into the sides , suitable digging is needed . Similarly foundation for apron , too , is dug out to about 15 cm depth . In foundation , stones are laid in layers , taking care to keep as big stones in the bottom layer as possible . The joints in the successive layers are broken according to the normal rules of wall construction . After filling foundation and laying stones in the first layer , a step of about 15 cm is usually left on the down stream side without deviating from the curve . Thus in successive layers , steps are left so that the top width is gradually reduced . After reaching a height of about 60 cm above bed level , a notch is left in middle . The length of notch is equal to the half the span and its depth is about 30 cm . Before starting construction above the notch , a big flat stone of the size of notch length should be placed over it so that there is little danger of its being washed down . The balance part is constructed giving to a height giving required notch depth . Wing walls are constructed thereafter . The apron should be built with stones on edges . At the back of the check dam , dug up earth , brushwood or stones are piles up to the notch level with a slope 1:1 towards upstream side . The stone filling should go up to 0.3 to 0.6 metres into the stable portion of gully side to prevent end cutting . Sufficient length and width of apron has to be provided to prevent scour . The thickness of apron packing should not be less than 0.45 mt and the gully sides above the apron have to be protected with stone pitching to a height of at least 0.30 mt above the anticipated maximum water level . Care should be taken to place bigger sized stones on top to prevent their being dislodged or carried away by the current . In some cases stone fills may be needed to be held down with woven wire netting. In the study area, maintenance of dry rubble checkdams is very poor. Proper maintenance is very important. It is suggested that dry rubble checkdams are inspected after each major storm and repaired, if necessary. Only then full benefits of structure can be obtained.

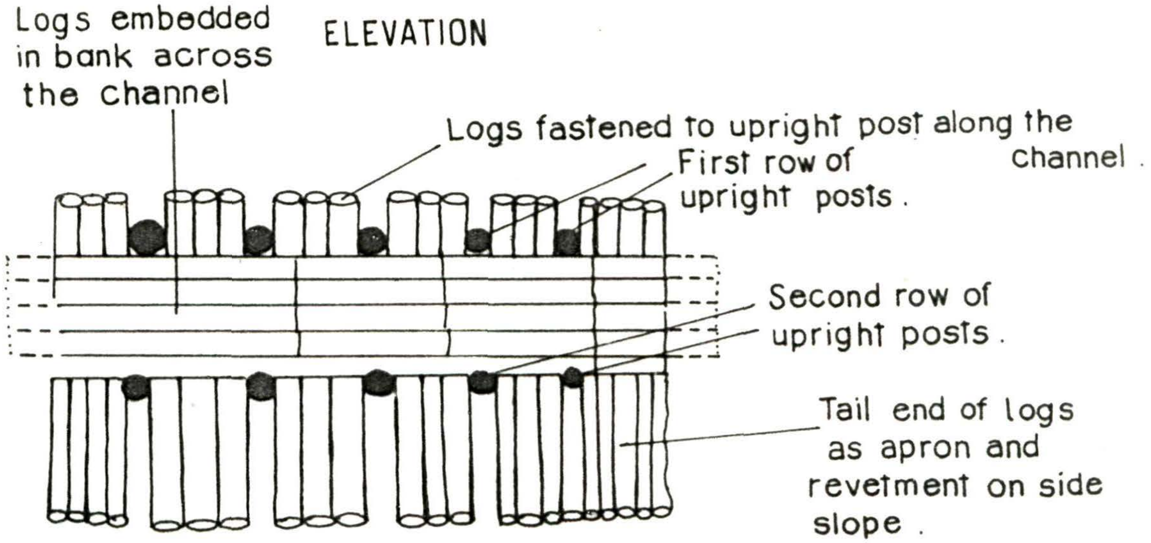
8.5.1 d. Log Checkdams : Log checkdams can also be very effectively used in the study area. They are especially useful in interior forest areas where timber is available in abundance. This is also very well suited at higher altitudes where rate of rotting of timber is low due to lower temperatures. Check dams are made of logs. For this, some logs shall have to be erected as uprights in two rows at spacing of about 0.45 of depth of gully or at 1.5 mt , whichever is lower . The central uprights are taken up to the notch level and others up to the height of the checkdam . Long logs are , then , laid along the flow of water in the bed of the stream as well as on the sides to an height of about 1.5 times the depth of notch to prevent scouring (Fig. 8.6) . Tail ends of these logs shall act as apron (in the bed) and as wingwall (on sides) of the checkdam . The subsequent layers of logs are put horizontally across the gully (between the two rows of uprights) in such a way so that they are embedded in the banks for at least 0.30 mt . These horizontal pieces are either tied with the uprights with galvanized wire or are nailed to them .

8.5.2 PERMANENT CHECKDAMS :

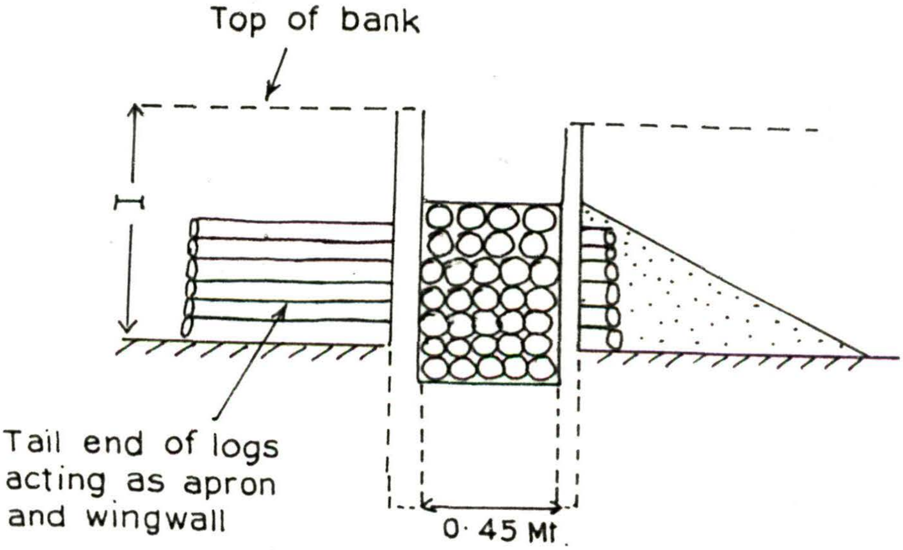
Permanent check dams can be used effectively in milder sections of rivers in the study area. Checkdams with drop spillways (Fig 8.7), with chute spillways (Fig.8.8 and 8.9) and drop inlet spillways (Fig. 8.10) can be used in such sections with advantage. Pondage should, however, be kept to bare minimum. It may lead to sloughing of river banks in the study area. Huge size boulders roll on the bed of the streams in the study area during heavy discharge (sec 7.1.5). They acquire enormous kinetic energy. Apron of hydraulic structures get



ELEVATION



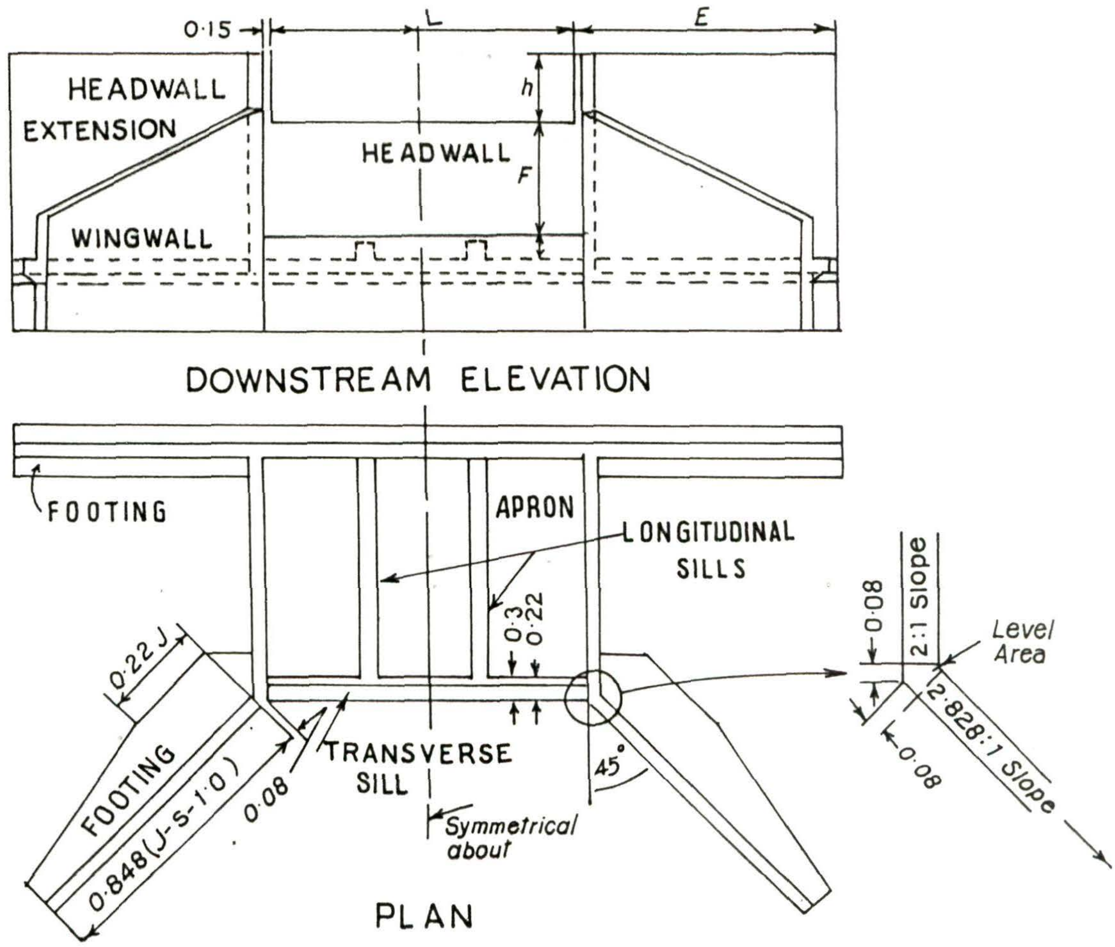
PLAN



SECTION AT X–X

A LOG WOOD CHECKDAM

Fig. 8·6.

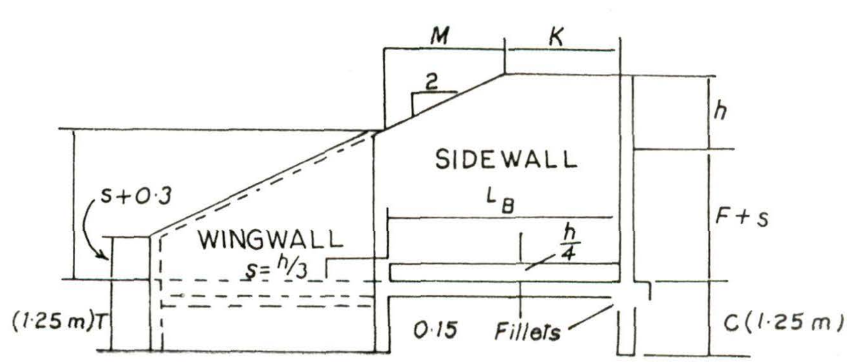


L = Length of wier.
h = Depth of wier.
F = Drop through spillway from crest of wier to top of transverse sill.
S = Height of transverse sill.
L_B = Length of apron.
T = Depth of Toe wall below top of apron.
C = Depth of cut off wall below top of apron.
E = Length of headwall extension.
J = Height of wingwall and sidewall at jungtion.

NOMENCLATURES AND SYMBOLS OF CHECKDAM WITH DROP SPILLWAY

Fig. 8·7

(*Ref. Para 8·5·2(b)(i)*)



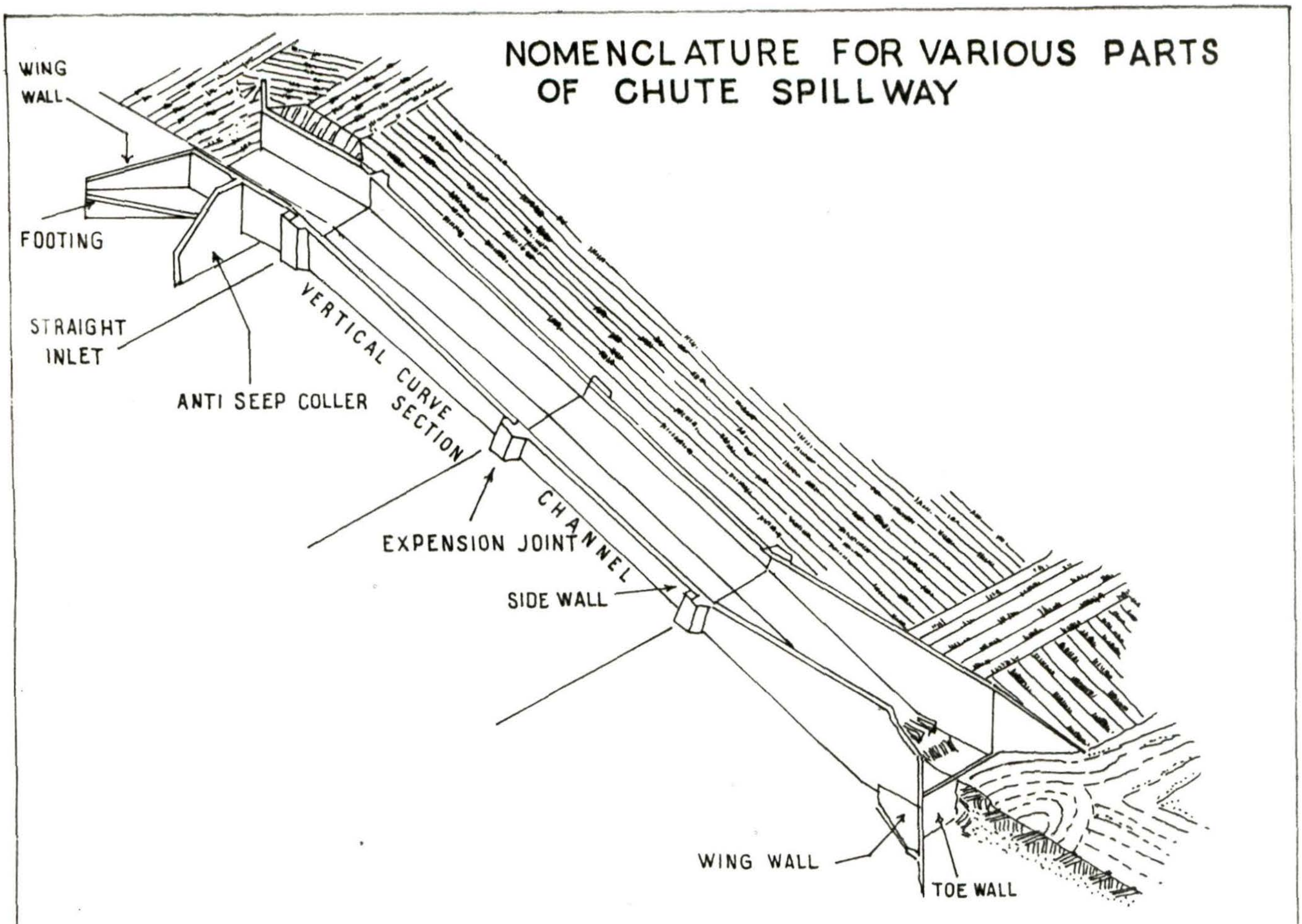
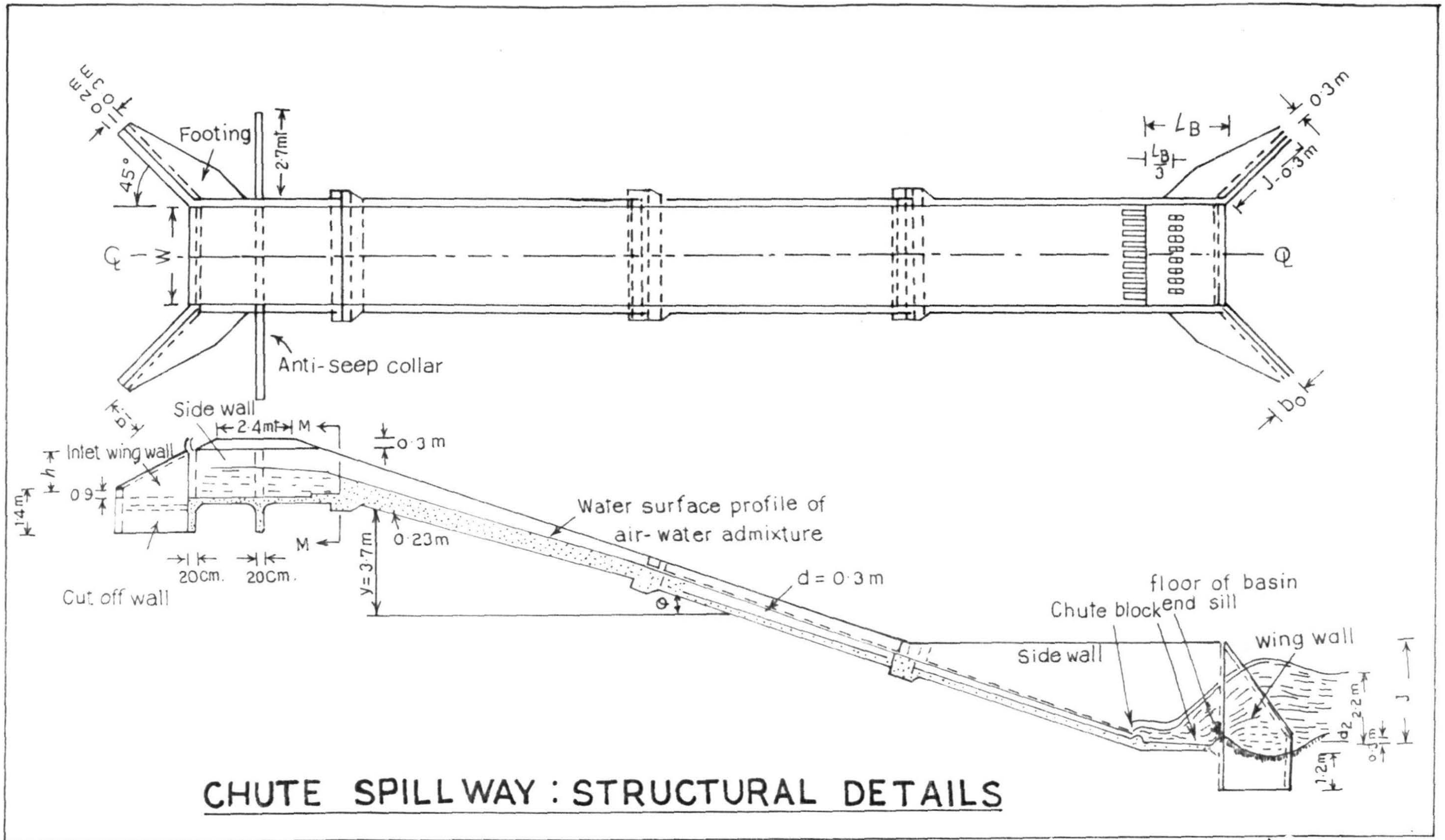
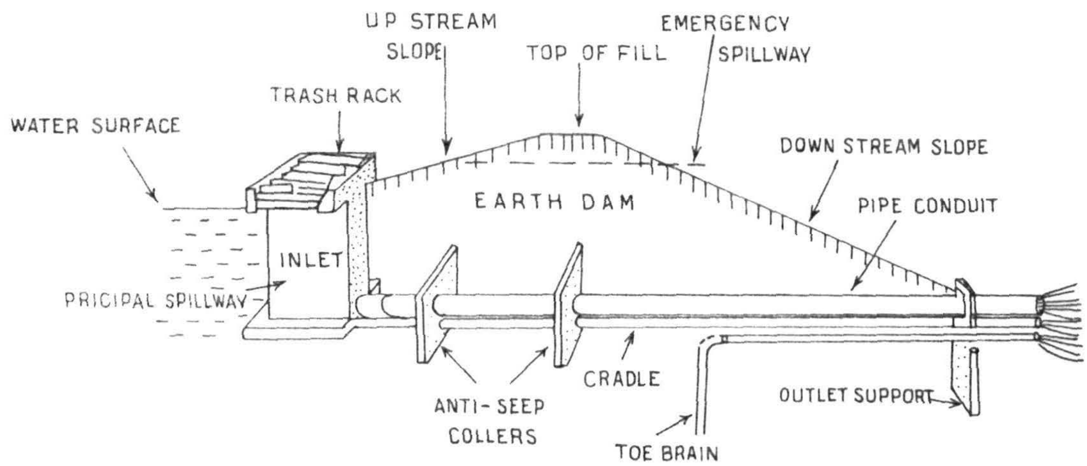

NOMENCLATURE FOR VARIOUS PARTS
OF CHUTE SPILLWAY
WING
WALL
FOOTING
STRAIGHT
INLET
ANTI SEEP COLLER
VERTICAL CURVE
SECTION
EXPENSION JOINT
CHANNEL
SIDE WALL
WING WALL
TOE WALL

Fig. 8·8



CHUTE SPILLWAY : STRUCTURAL DETAILS

Section at G-G (Source: Singh et all, 1990) Fig. 8.9 (Ref. Para 8.5.2)



Concrete pipe drop inlet spillway

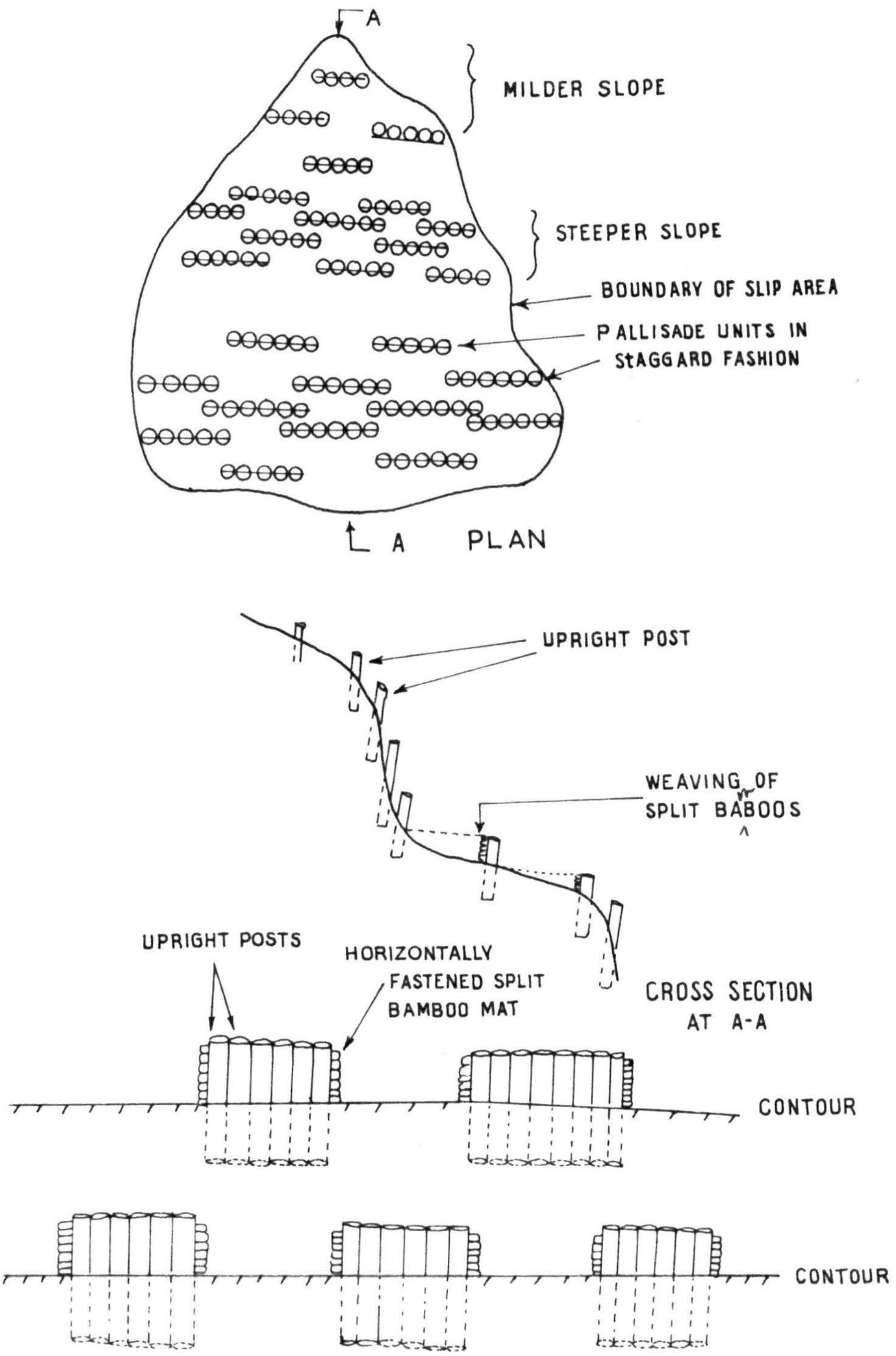
Fig. 8·10 (Ref. para 8·5·2).

Source: *ICAR Bulletin No. T-13/D-10 (1981)* damaged by their impact. This ultimately destroys structures. Due to this permanent checkdams are not popular in the study area in the higher reaches of streams.

8.6 PALISADES AND WATTLINGS :

Palisades and wattlings are two important modes of soil conservation in controlling gullies , landslips and slides . The structure is erected mostly with locally available materials . Palisades are usually applied on slopes steeper than 30 degrees . Hard wood bullies 10 cm in diameter and 1.7 to 2.0 mt long are fixed vertically along contour , are spaced 50 cm apart and are fixed 80 to 110 cm below the ground 90 cm being above it (Govt. of West Bengal , 1995 A). Posts should be fixed touching one another (Plate 14) on steeper slopes having moving debris (Fig. 8.11) . Usually seven such posts should be fixed making a 3 mt long palisade as a single unit . The above ground parts of posts are woven with brushwood material or with splitted bamboo .

Wattlings , on the other hand , are resorted to on milder slopes (less than 30 degrees) and are more biological than mechanical in nature . The posts in the palisades are replaced by 8 - 10 cm thick , 90 cm long cuttings of sproutable species and are fixed with 30 cm of it being above ground (Fig.8.12) . To break the slope and for lowering down of the water table , 30 cm wide and 60 cm deep discontinuous staggered contour



ELEVATION

PALLISADES IN SLOPE STABILISATION

Fig. 8.11.

CONTOUR WATTLING

with Brushwood mulch in inter wattle area.

Fig. 8·12

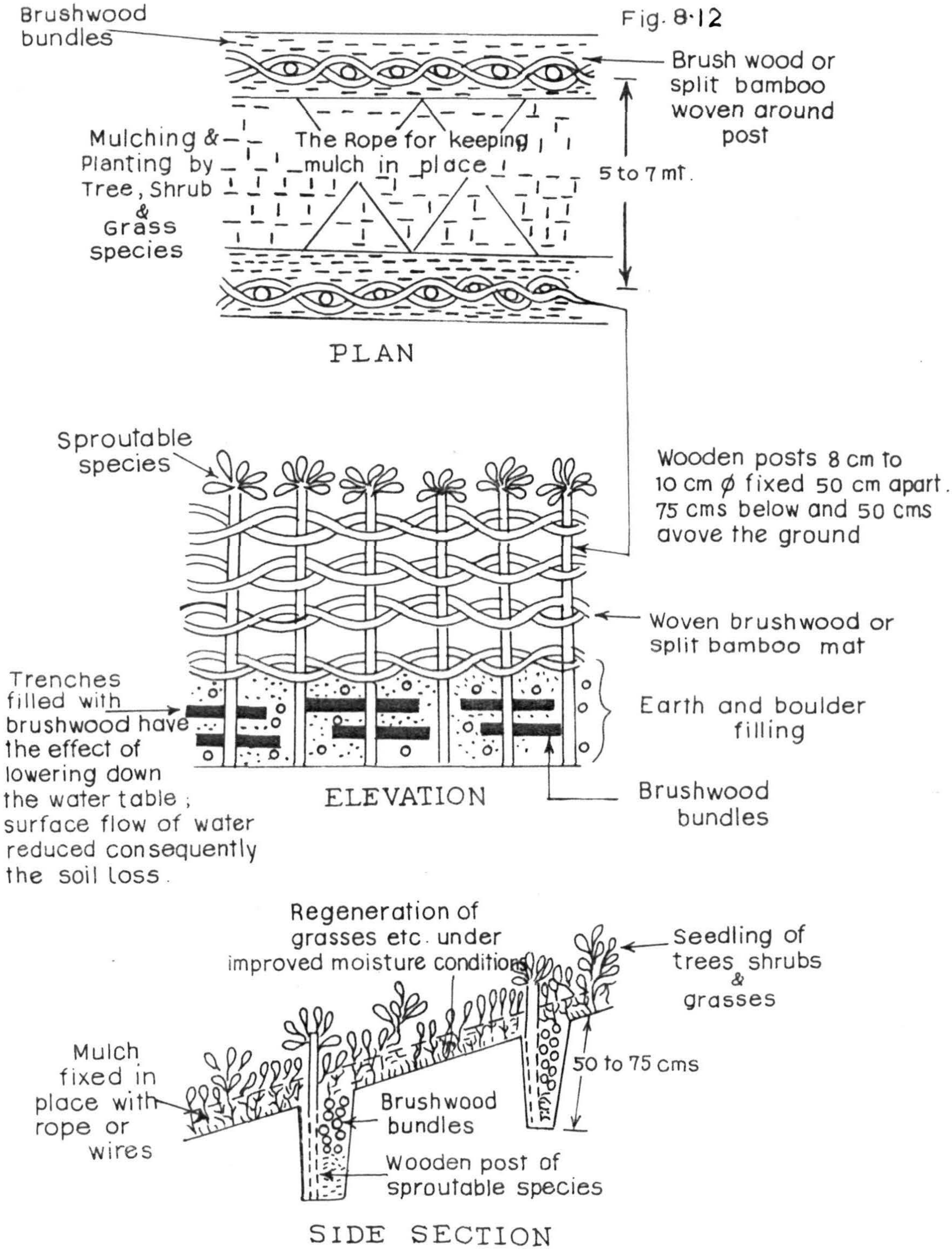
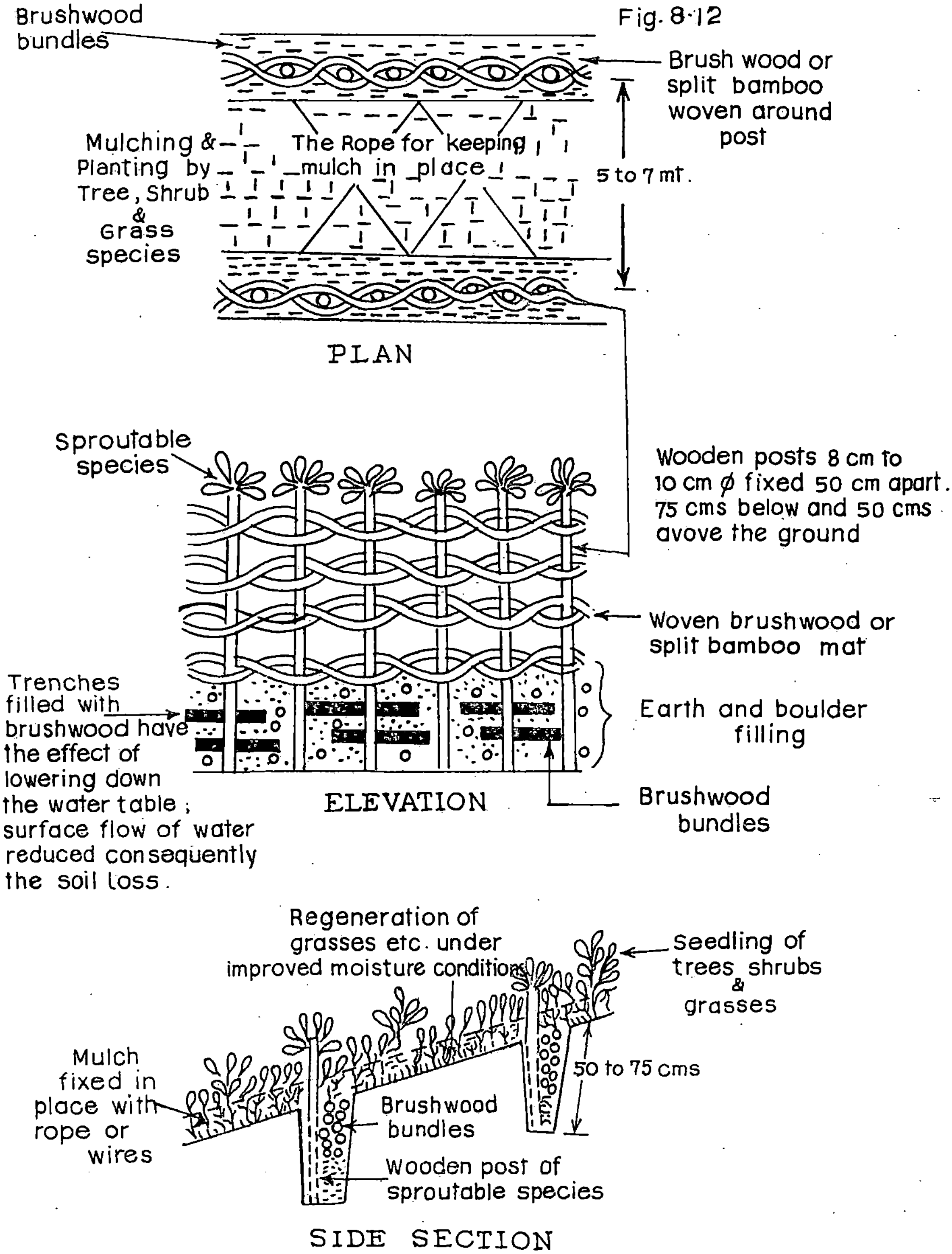


PLATE 14: PALLISADES ERECTED WITH LOCAL WOOD MATERIALS (SENCHAL R.F.)

CONTOUR WATTLING

with Brushwood mulch in inter wattle area.

Fig. 8·12



trenches are made . The sproutable cuttings are fixed on the down slope edge of the trenches and the upslope part of the trench is partly (about 40 cm) filled with brush wood bundles and rest with boulders . A brushwood net is woven around the above ground part of the sproutable posts . Wattles , too , are made in discontinuous lines to make any subsequent failure localised . Good soil binder species are planted in the inter - wattle area (Govt. of West Bengal , 1995 A) .

For effectiveness , palisades should be made so that top of the lower tier is at the same level as the bottom of upper tier . The palisades and wattles are temporary cheap soil conservation structures meant to stabilise the soil with planting of some seedlings as an aid to the nature's attempt to reclaim the land . These temporary structures need be effective till nature has provided sufficient stability to the soil . Since , both , palisades and wattlings aim at speedy establishment of vegetation , there is a need to look at the loose or partially stabilised debris as a medium of growth for plants . Since it is wished to establish the vegetation with most possible quickness , the growth medium should be the optimum . The soils in the study area being subjected to high degree of leaching , manure have to be organic . The early or delayed planting of sproutable cuttings sometimes cause failure . They either rot or dry out failing to sprout . There is a need to optimise the period of cutting for each species for better results .

The palisades and wattles , despite some defects in designs , have done commendable job in eastern Himalayas

. But except a few Govt. Departments (Forest , Border Roads Organisation) , none have adopted these techniques . No private individual is seen practising this . There is a need to streamline the technique , remove the defects and disseminate this information to people at large. The problem of sloughing in the study area (Sec 4.7) can be very effectively controlled by palisades and wattles. These can also be used for control of gullies at initial stages in replacement of checkdams. Gullies can also be controlled at the stage when they begin their march upslope through slumping of banks. Only surficial slips, however, can be reclaimed by this methodology. These are useless for slides with deep seated plane of failure.

Palisades and wattles are also excellent for in-situ stabilisation of spoils of Dudhia-Pumongphatak road and those from construction of air strip near Rongbul.

8.7 OTHER SLOPE STABILISATION TECHNIQUES WITH LIVE AND DEAD PLANT MATERIALS :

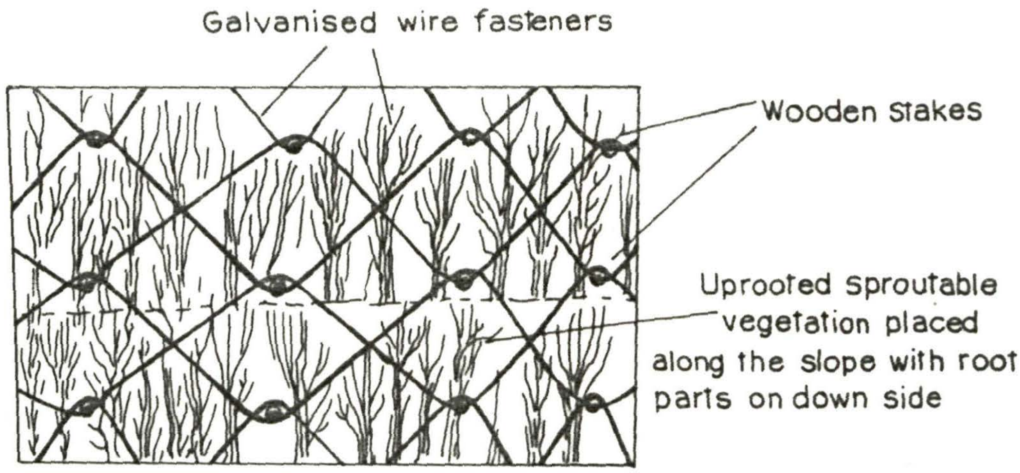
Several such techniques are in vogue and can be of great benefit in the study area.

8.7.1 SPREADING OF LIVE SPROUTABLE PLANT MATERIAL AND CONSTRUCTION OF BRUSHWOOD MATTRESSES :

Spreading of live sproutable herbs and shrubs during on eroded slopes during monsoon period is very effective . At first the vegetative layer acts as a mulch . The live vegetative material later develops roots and anchors itself in the soil . Prior fertilisation and soil racking is necessary.The vegetative material applied at the soil surface is usually uprooted and is placed along the slope with roots on downhill side so that the roots are in contact with soil . To avoid desiccation, overlapping of the layers is provided. For keeping the vegetation layer in place , woody stakes are driven and galvanised iron wire stretched through them in a cris cross fashion (Fig 8.13) . The operation should be done during the beginning of monsoon.

Brushwood mattresses can also be constructed with long (> 150 cm) , straight branches of sproutable species laid along the slope with at least 30 cm overlapping at but ends (FAO Construction Guide 13/1 , 1985) . They can similarly be fastened with pegs placed 50 to 80 cm apart and galvanised wire stretched among them . 20 to 50 branches shall be needed per running metre . 5 kgs of smooth or 5 - 10 kgs of bushy branches shall be required per sq mt.

It is suggested that localities in the study area affected with sheet erosion or rill erosion (Sec 4.1, 4.2 and 4.3) be treated with this method.



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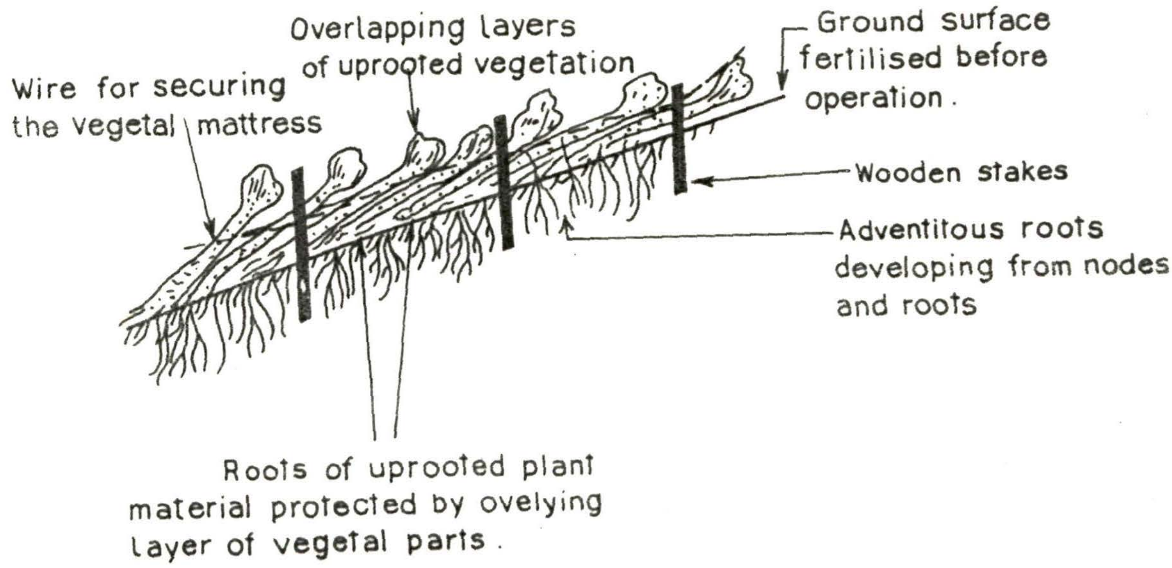


ELEVATION

PROTECTION OF SLOPE BY SPREADING LIVE SPROUTABLE PLANT MATERIAL

Fig. 8·13 (ref. para 8·7·1)

(Source : Author's own Design)

8.7.2 GRASS TURFING :

Turfing is planting of grasses as sod (with all the soil that clings to them) on side slope of embankments and on erodible soils . After the bank has been made to shape , the top earth is loosened to a depth of about 7.5 cm and if the soil is unsuitable for grass growth , a better soil about 5 cm deep is obtained from outside and worked into the existing one . The imported soil should , preferably be taken from the same locality , as the sod . The soil of degraded slope should be checked for adequacy of plant nutrient and , if need be , necessary amendment applied . Any raking of the soil for loosening should be done along contours . Sod should be lifted in a thickness of 6 cm and cut to 30 cm x 45 cm pieces . The strips should be placed on prepared bank slope along contour starting from bottom. Every fourth row should be fixed with wooden nails. Grazing should be prohibited. Turfing should be used to control splash erosion, sheet erosion and rill erosion in the study area.

8.7.3 HYDROSEEDING AND PLACING OF SEED MATS :

Hydroseeding is the seeding of barren degraded slopes , either manually or mechanically , with the help of a liquid mixture of seeds , organic matter , fertilizer and glue . Seeds are first mixed with water , fertilizer , materials which improve soil physically and chemically , and adhesive in a tank . With an attached pump , the emulsion is , then , sprayed on the area proposed to be revegetated (FAO, 1985). In the study area hydroseeding can be used for revegetating old landslides, degraded forest lands, and steep abandoned agriculture lands. Stabilised parts of Ambootia landslide can be vegetated by this method.

Seed mats can be placed directly on most of the well graded slopes . The mats must be pressed or beaten after application to ensure close contact with the soil . To avoid displacement of the mats , it is necessary to secure them with pegs and to burry the beginning and the end sections . Geotextiles can be very effectively used as seed mats Fig. 8.14 (a) . Geotextiles formed in special grids , meshes , nets , and webbing have been used to provide tractive resistance while retaining seeds and mulch to promote establishment of vegetative cover (US Department of Transportation , 1990) . Thick three dimensional geotextile mats (geogrids) help bind the particles of top soil together until the root mass takes over as the main anti-erosion protection after considerable growth . Geotextile mats are seeded after it has been laid and a mixture of top soil and seed are then brushed over the mat to completely fill it (Kumar , 1992) .

Geojute mat can also be used for seeding of the slopes . Geojute , woven from thick , widely spaced yarns are used for this purpose . It is typically made from thick open woven jute , is about 5 mm thick , has apertures about 15 mm x 15 mm size and weighs about 500 gms / sq. mt. Geojute can either be applied on the surface of slope or can be buried under 2 - 3 cm of soil (Plate 15).

PLATE 15 : APPLICATION OF GEOJUTE AS SEEDMAT

8.7.4 SLOPE STABILISATION THROUGH CONSTRUCTION OF CORDON , BRUSH WATTLE AND GROOVE :

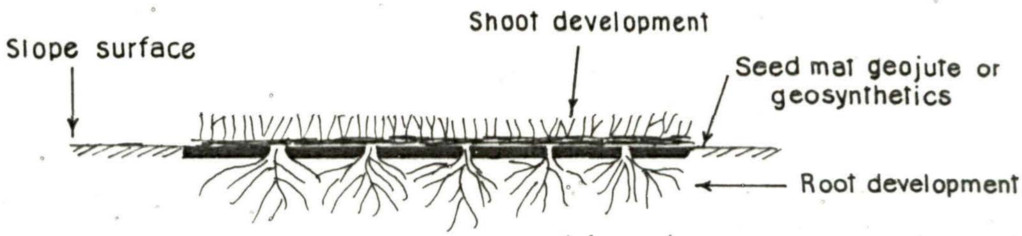
Construction of cordon , brush wattles and groove are soil stabilisation methods which should be used when dangerous , tensile , compressive mechanical forces threaten to develop in the ground . In such instances , deep reaching stabilisation of the soil is required . The methods under discussion accomplish this task.

For cordon construction, first a small horizontal terrace is prepared near the toe of the slope . The soil which was removed to build first terrace is dumped on to the toe of slope . If the bottom of the dug out terrace consists of very hard compact material that can not be penetrated by the roots , it must be loosened up . On this terrace two dead poles are placed horizontally (Fig 8.14 b) . A cross layer of coniferous branches are placed over it . Thereafter a soil layer approximately 10 cm thick is laid over it and compacted . Over this cuttings of sproutable species - Phalado , Dudhilo , Simul etc. are placed side by side , 2 - 3 cm apart from one another . Cuttings should be at least 10 cm longer than the width of the terraces . These cuttings are also covered with soil . 10 to 25 cuttings minimum length of 60 cm are required for each metre length of terrace assuming a minimum terrace width of about 50 cm . Cordon construction provides very good stabilisation of suitable slope section through the strong branch underlay . Good root penetration of ground depends on adequate soil loosening during construction. Landslips and the fill slopes in the study area can be very well stabilised by this method.

For construction of brush wattles, fascines of living woody plants are laid into ditches with a width and depth 30 to 50 cm . Each fascine should consist of at least five branches with a minimum diameter of one cm . Embedded branches take root easily provided they are well in contact with soil and are not placed too deep in it (Fig. 8.14 c). Immediately after placement of fascines, ditches are refilled with soil and well compacted. Manuring may be necessary. Landslips, fill slopes, excavated earth spoils can be very well stabilised by this method. Construction in the study area should be done during November to January.

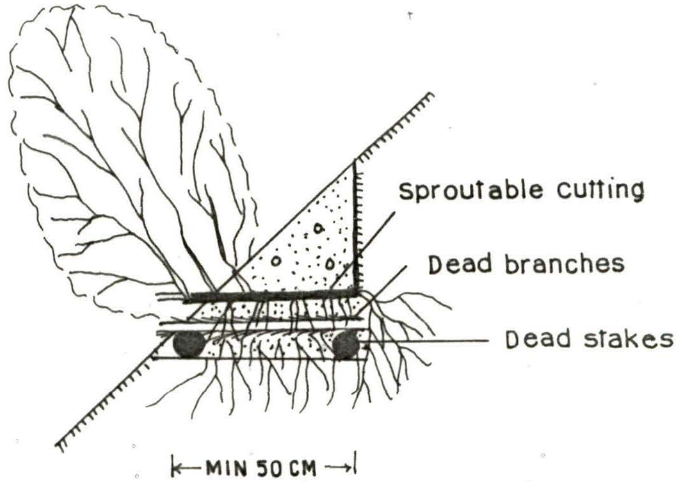
Grooves (ditches of 30 to 60 cm wide and 30 cm deep) are dug out along the slope . On their front side , thin fascines of living branches are placed and fastened with pegs as in other fascine constructions . The grooves are not filled with the soil that has been dug out but with top soil or compost or a combination of both . Seedlings are planted in the groove at the uphill side of the fascine placement (Fig. 8.15 a) . Because of the water impounding effect of the grooves and consequent danger of erosion in the study area, optimum placement of grooves is at an angle of 10° to the horizontal line. It is a good afforestation method for stable barren slopes in the study area. Living fascines composed of 3 to 10 live branches and one or two seedling per running meter of groove are needed .

Fig. 8·14.



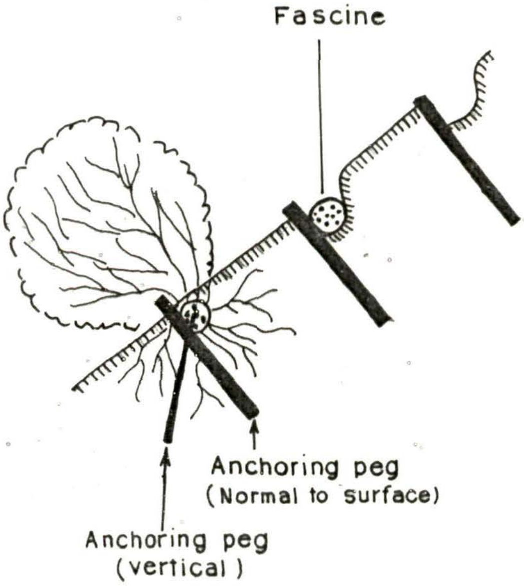
SEED MAT IN SLOPE PROTECTION

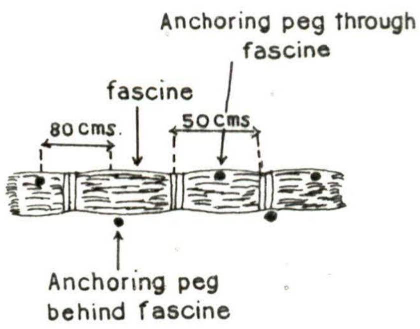
FIG. 8·14 (a)



CORDON CONSTRUCTION FOR SLOPE PROTECTION

FIG. 8·14(b)





BRUSH-WATTLE CONSTRUCTION

FIG. 8·14(c)

8.7.5 SLOPE STABILISATION THROUGH HEDGE LAYER , BRUSH LAYER AND HEDGE - BRUSH LAYER CONSTRUCTION :

These methods depend on the use of either seedlings or sproutable live branch cuttings and are quite suitable for stabilisation of slopes in the study area. These can be used for stabilisation of loose moving debris on slopes.

For hedge layer construction small terraces or berm are formed with depth of at least 50 to 70 cm . The terrace platform should have an angle of inclination (sloping up) of at least 10° to the outside (Fig. 8.15 b). Rooted plants are placed close together with their roots inside so that approximately one third of the entire plant length extends over the edge of the terrace (Plate 16). The terrace is then covered with soil that has been dug out from the terrace above . Manuring may be necessary. Rooted woody plants that are resistant to rockfall and coverage by bebris and which have ability to produce adventitious root system are required . Two to four year old transplants and very fast growing varieties of two year old seedlings should be used , if possible . The ratio of roots and shoots is very important . The stronger the root system , better is the plant development . Depending on species , approximately 5 to 20 plants are needed per running meter of hedge layer construction . These should be constructed during dormant season of plant growth . In the study are , however , dry season is quite limited and this system can be used through out the year with winters being the most effective .

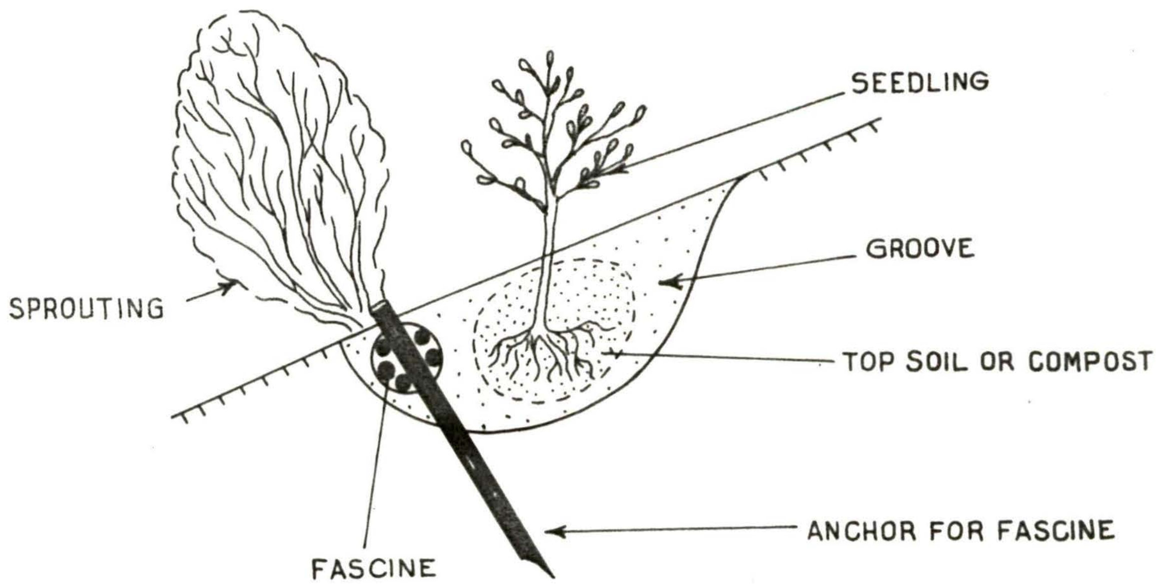
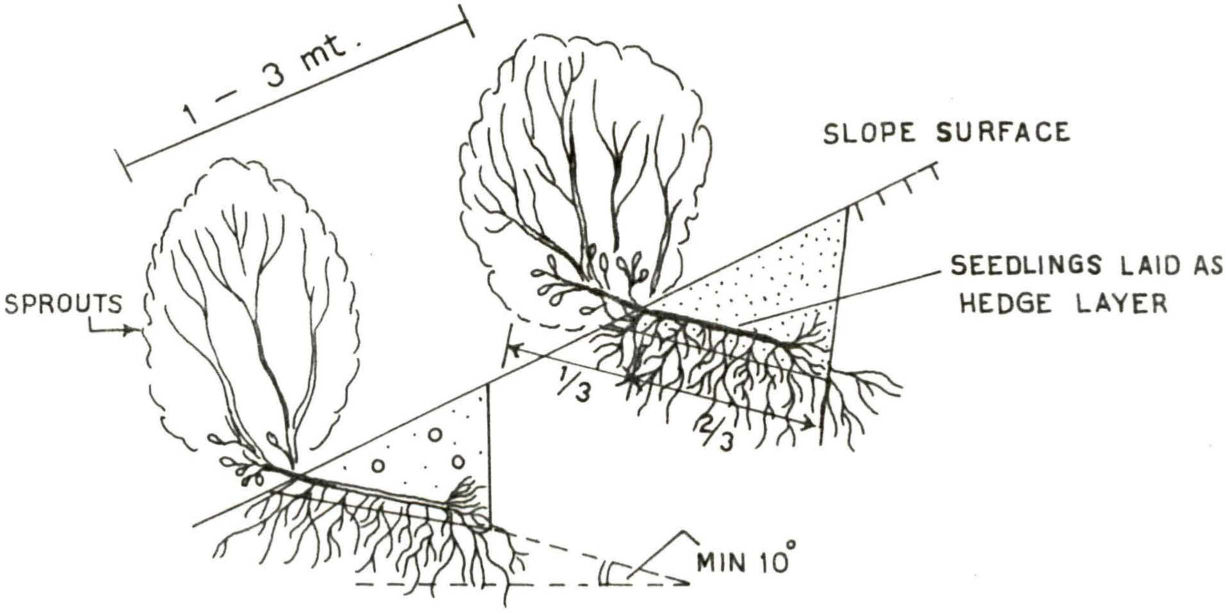


Fig. 8·15

GROOVE CONSTRUCTION

Fig. 8·15(a)



HEDGE LAYER CONSTRUCTION

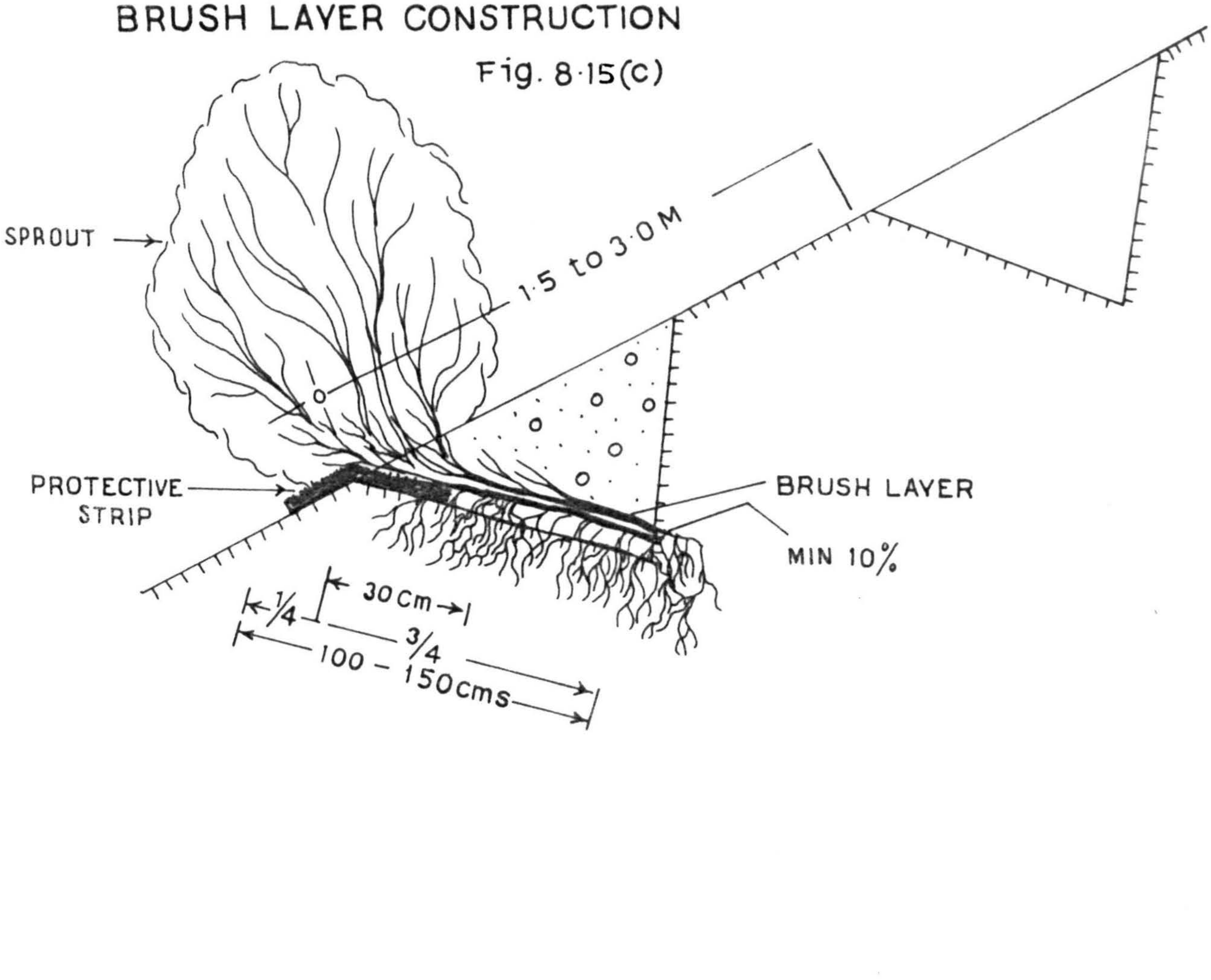
Fig. 8·15(b)

PLATE 16 : HEDGE LAYER CONSTRUCTION IN STUDY AREA (DARJEELING FOREST)

For brush layer construction, beginning at the toe of the slope , terraces 75 to 100 cm wide are dug out . The platform of terrace should have an inclination of at least 10 percent to the outside so that branches can root along their entire length (Fig. 8.15 c) . The branches should be at least one mt long and should not extend from the terrace edge more than one fifth or one fourth of their total length . The branches are placed cris cross and not parallel to one another so that pieces are covered with soil as much as possible . Placing the branches crosswise on to the terraces also permits the use of longer branches . It is important not only to mix the branches of different species but also to use branches of different age and diameter . This will allow roots to penetrate deeper into the soil and a better biodiversified surface growth shall develop . On slopes with cohesive soils , deeper and narrower ditches can be dug up without risk of failure . Whenever there is risk of slope failure , ditches should only be dug in short segment . This could be cheaper , too . Brush layer construction starts at the bottom and moves upward . The lower ditch is filled from the material dug up from the ditch above it . It is a good practice to press the soil material onto the brush to ensure that individual branches are in contact with soil as much as possible for better root formation . In order to prevent formation of rills on the fill slopes 10 to 30 cm wide synthetic fibre foil (geosynthetics) can be placed at the outer third of the terrace below the brush layer . Such longitudinal strips can also be used in hedge layer or hedge - brush layer constructions . Usually , branches of living

BRUSH LAYER CONSTRUCTION

Fig. 8·15(C)



woody plants , at least 20 pieces per running meter , including those with all side branches intact are used . Construction should be done during dormant season .

Hedge brush layer construction is identical to brush layer construction with the exception that rooted plants , too , are used along with live brushwood . In construction of hedge - brush layer , strong rooted plants are placed 50 to 100 cm apart among the layer of live brushwood . The rooted plants are covered with soil up to three quarter of their entire length in the berm (Fig. 8.16 a) .

8.7.6 MISCELLANEOUS MEASURES :

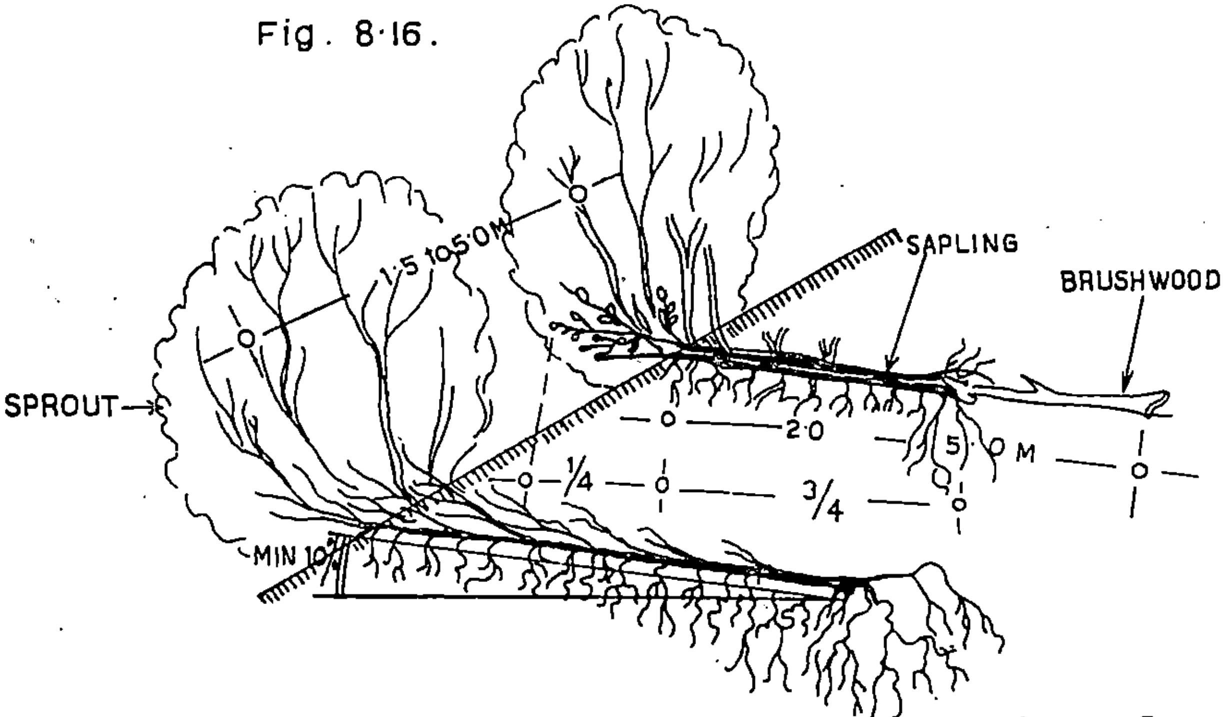
In the study area moving loose debris can also be stabilised through construction of wooden crib walls with brush wood layering, vegetated stone walls or vegetated gabion walls.

Wooden crib walls, single or double layered, should be built from round poles (10 to 25 cm in diameter) held together by nails or bolts. They should never be placed vertically but at an angle of 10:1 inclining towards the slope and should never be made higher than 4 mt (Fig. 8.16 b). Branches of easily sproutable plants having large number of side branches should be placed in open spaces between the timber in such a way that not more than one quarter of their length protrudes out. Approximately ten such branches per running mt are necessary. Construction is done during winters. In the study area this system can be used for stabilisation of slope, water channels, and toe of landslips. Over time, the crib timber will rot and be replaced by growing plants. The established plants drain the slope very effectively through transpiration. The addition of strong, rooted, pioneer woody plants is advantageous.

For construction of vegetated stone walls, living plant materials of sproutable species or seedlings are placed into the joints between the stones in such a way that they reach into the soil at the back of the wall (Fig. 8.17 a). Construction should be taken up during the dormant season.

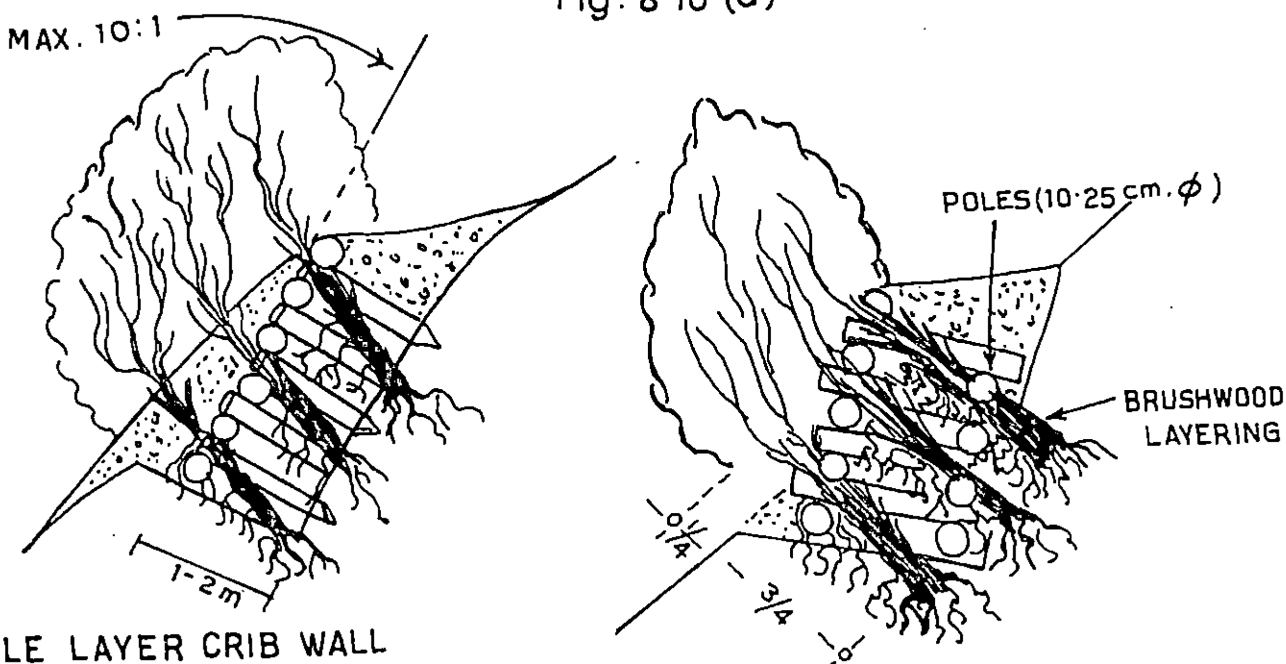
For construction of vegetated hard gabion, wire mesh is laid flat on the ground and is covered with coarse gravel, in stages, interspersed with live branches and rooted plants (Fig. 8.17 b). Live branches or rooted plants must lay across with their but ends or roots inside the soil beyond gabion. Vegetated soft gabion are constructed from non-rotting geotextiles with a mesh width less than 5 mm. Due to small mesh size, fine grained soil materials may be used for construction. Branches of live woody plants are embedded in the joints between the bags so that they reach the soil behind the gabion wall (Fig 8.17 c). Loose moving debris in inaccessible parts of the study area can be stabilised by vegetated soft gabion. Because of poor road net work cost of transportation of construction materials becomes prohibitive in the north-western part of the study area. This method is best suited here.

Fig. 8·16.



HEDGE BRUSH LAYER CONSTRUCTION ON FILL SLOPES

Fig. 8·16 (a)



SINGLE LAYER CRIB WALL WITH BRUSHWOOD LAYERING

DOUBLE LAYER CRIB WALL WITH BRUSHWOOD LAYERING.

Fig. 8·16 (b)

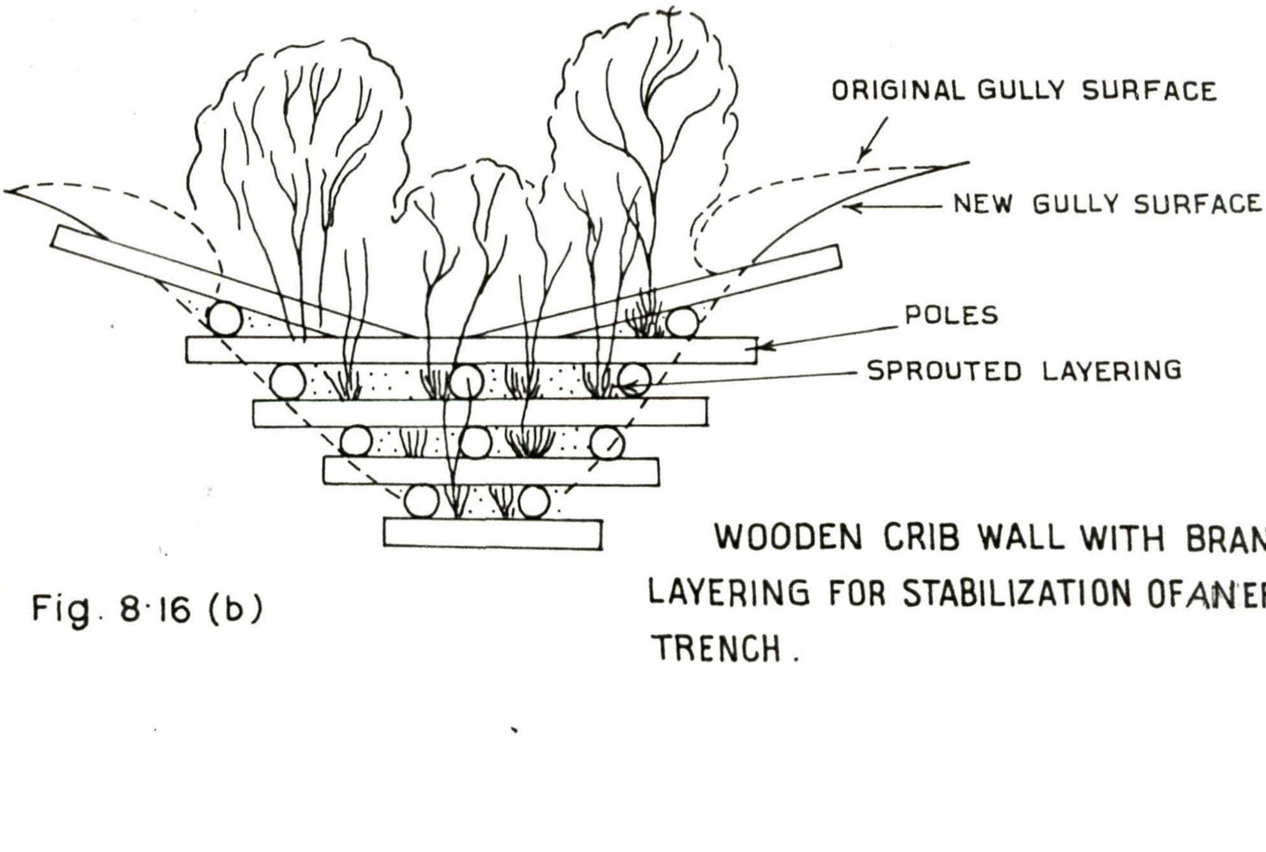
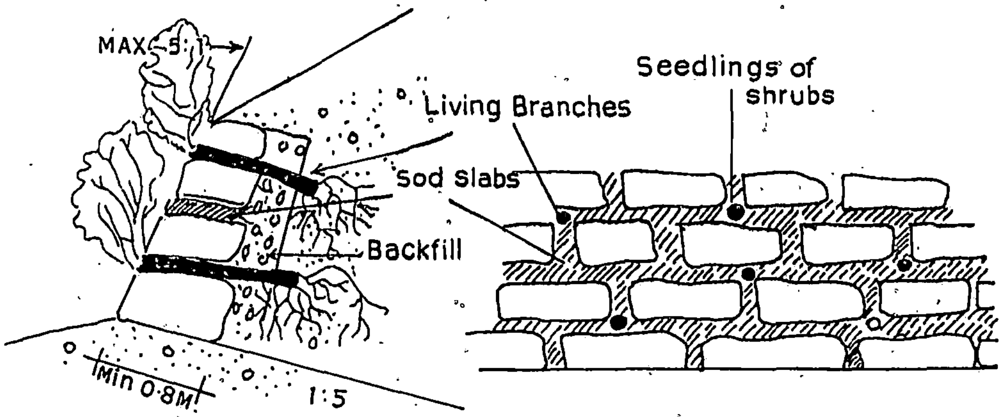


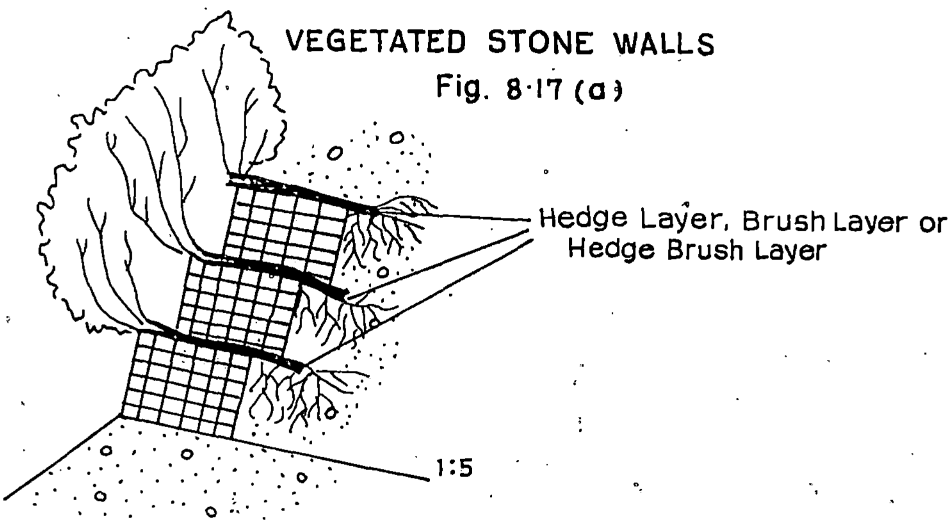
Fig. 8·16 (b)

WOODEN CRIB WALL WITH BRANCH LAYERING FOR STABILIZATION OF AN EROSION TRENCH.

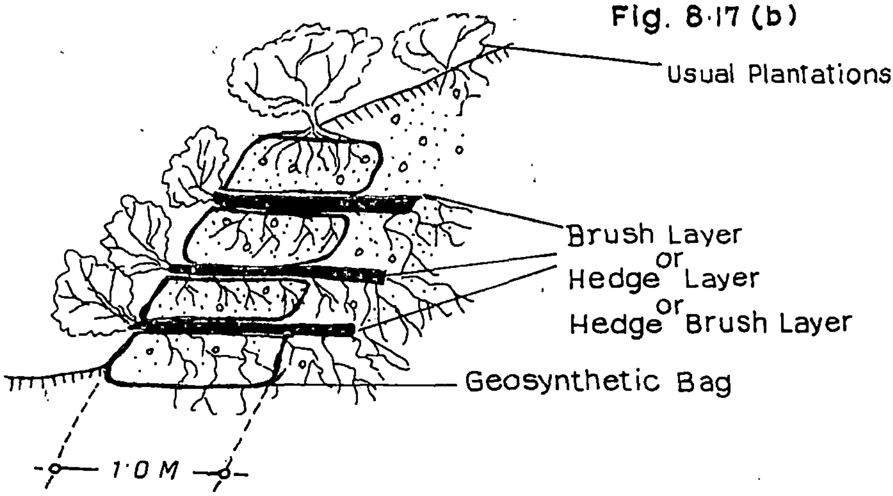
Fig. 8·17.



VEGETATED STONE WALLS
Fig. 8·17 (a)



VEGETATED HARD GABION
Fig. 8·17 (b)



Vegetated soft Gabion
used as Breast wall
Fig. 8·17 (c)

8.8 CONTROL MEASURES FOR LANDSLIDES :

Landslides are complex phenomenon the causative factors of which are yet not fully understood . For their control , the principle of synergism - the whole is bigger than the sum of its parts - is absolutely necessary . Several remedial measures acting in unison alone would ensure a certain degree of success (Natrajan et al , 1980 A) . In the study area, hydrological factors are the major cause of such landslides.

Therefore, sub-soil drainage is very crucial for treatment of landslides in the study area. Paved channels completely sealed against seepage by bentonite clay has been successfully used (Didwal, 1980). Such drains can be used in the study area. However, they rupture if there is movement of debris. Hence they are useless for large landslides. In such situations cheap bamboo drains are suggested.

For construction of bamboo drains , nodal septa of bamboos are broken. The wall of this pipe is perforated to permit sub-soil water to flow in . Perforations should be small. Denuded slope of landslide is cut into steps , the risers being given some mechanical support by loose boulder walls , or wooden palisades etc. Bamboo drains , thus prepared , are implanted in the sub-soil to the maximum possible length by help of wooden hammer . Insertion of about 3 mt should give good result.

Permanent gravel filled trapped drains can be used for stabilisation of large landslides. To construct permanent gravel filled trapped drains , a permeable gravel core , surrounded by a geosynthetic filter is provided in the sub-soil of the sliding area (Fig 8.18). The gravel size should be 16 / 32 mm to 35 / 70 mm to ensure a sufficiently high void ratio (Fritsch et al , 1980) . The geosynthetic filter should have optimum load strain behaviour , good permeability and filtration and resistance towards soil chemicals . Gravel filled trapped drains are suitable for all kinds of landslides caused due to pore water pressure and where sliding body is not thicker than 6.00 mt. The Lepchajagat landslide in the study area can be stabilised by this methodology.

Deep subsoil pipe drains are effective in slopes with granular materials and are most economical when placed in jointed rock aquifers in sub-soil (Forrester et al, 1980). Horizontal pipe drains radiating from one point , spreading out in a fan shaped manner are placed to reach water bearing strata in sub-soil by means of horizontal drilling .

The methodology , however , involves use of powerful and sophisticated machines. This is also very costly. In the study area, it can be used for stabilisation of Ambootia landslide.

Recent concept of reinforcement of earth is useful for control of landslides . The technique essentially consists of introduction of some reinforcing material inside the creeping debris for generating frictional forces. Railway embankments of Assam-Bengal Railways have been stabilised through this method (Palit, 1980). Such embankment piles are very

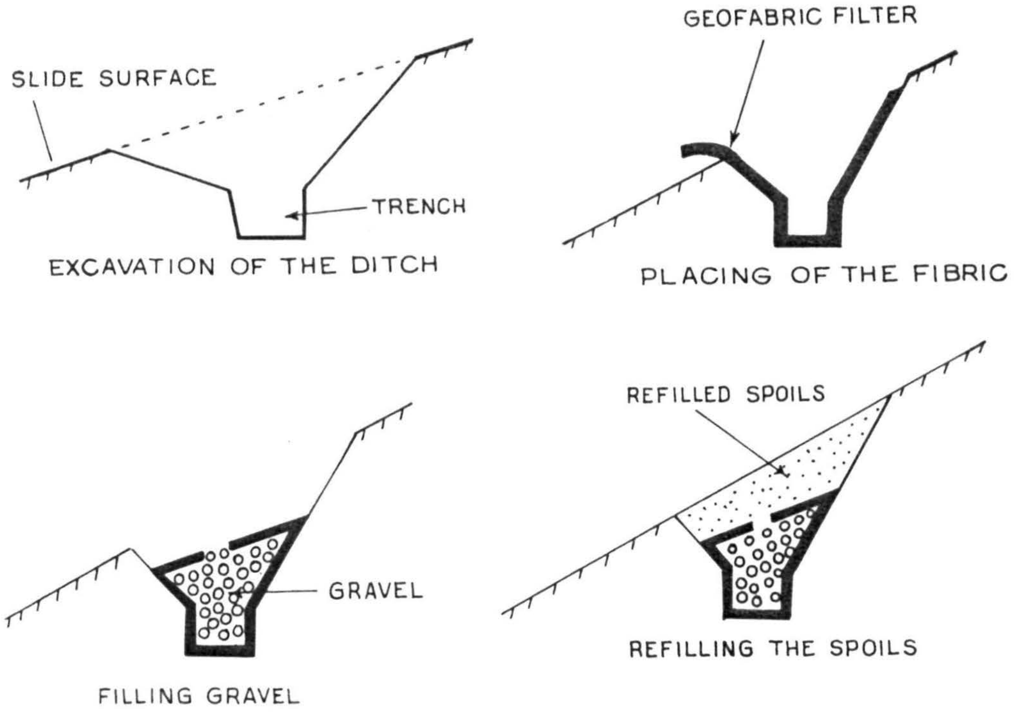


Fig. 8·18

CONSTRUCTION OF TRAPPED GRAVEL FILLED DRAINS effective in stopping the movement of the slope . They contribute to stability by transferring a part of the surcharged load to deeper soil layers well below the potential sliding surface(Fig. 8.19). The load transfer of the piles is ensured by the skin friction generated on the upper parts (Datye et al , 1980).It is important that piles are ductile.

8.9 CULTIVATION PRACTICES :

Several cultivation practices in the study area are faulty (Sec 5.1.1). There is a need to adopt sound cultivation practices. Following suggestions are made.

Terracing of cultivated lands are absolutely necessary. Greater the intensity of soil working greater is this need. Terraced fields should be provided with grassed water ways for disposal of excess water. Grade stabilisation structures or core reinforcement shall be necessary in such waterways due to prolonged flow. Outwardly sloping terraces should be cut back and levelled. Farmers should be persuaded to put their steep abandoned agriculture lands under fodder trees and grasses. Paddy cultivation by impounding water must be discouraged as it leads to landslides (Plate 6). Farmers should cultivate new high yielding varieties of paddy which does not need impounding of water. Farmers should be persuaded to opt for suitable crop rotation. Peas, mustard, kalai should be crop rotated with wheat, maize, potato, and vegetables. Mulching should be adopted where

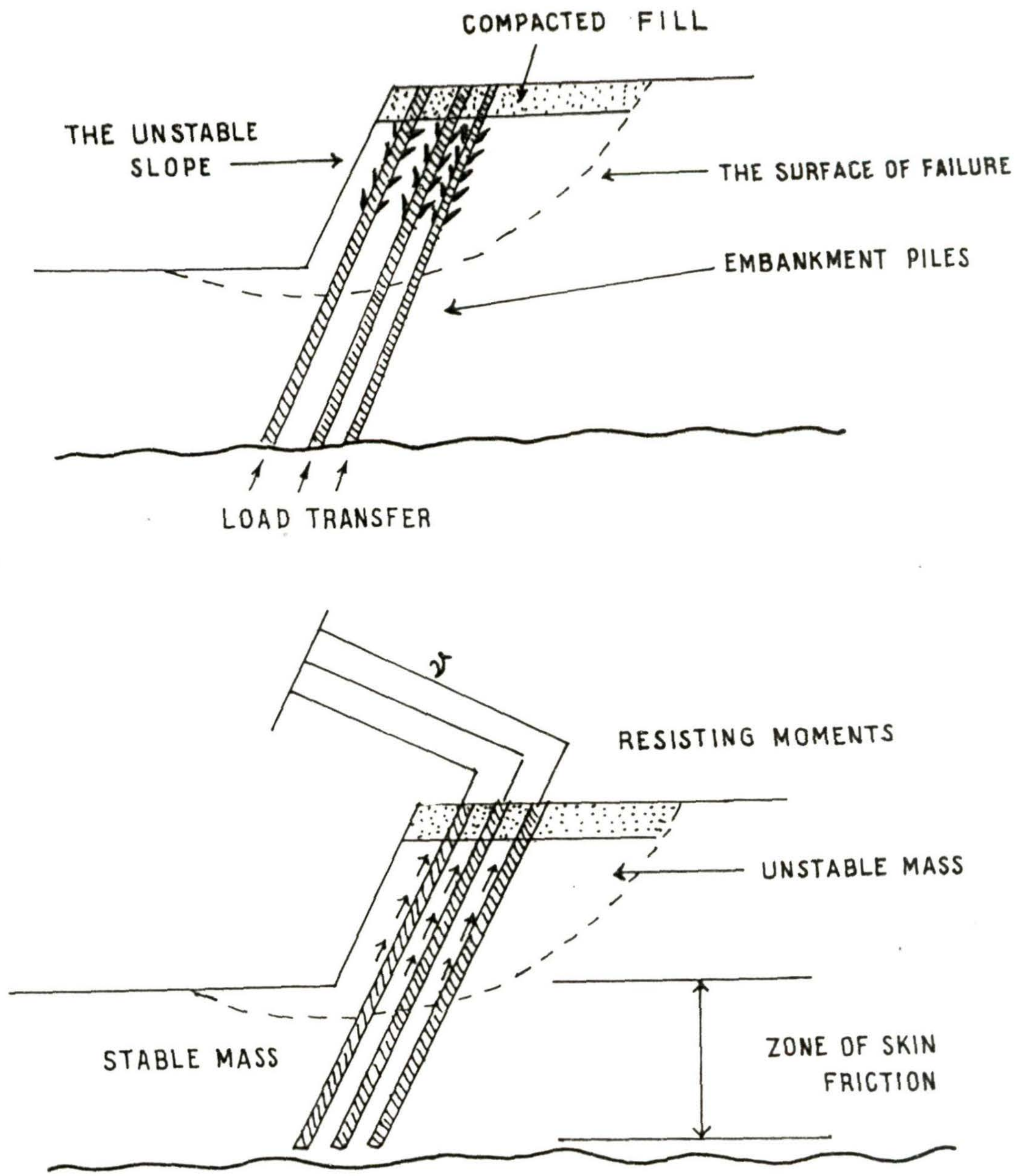


DIAGRAM ILLUSTRATING LOAD TRANSFER IN EMBANKMENT PILES. THE RESISTING MOMENT AS THE PRODUCT OF THE LOAD TRANSFERRED ALONG THE PILE AND THE DISTANCE OF THE PILES TO THE CENTRE OF THE SLIDING MASS IS SHOWN.

Fig. 8·19.

extensive soil working is necessary. During same growing season, strips of erosion permitting crops such as maize, and potato should alternate with erosion resisting crop such as pulses and mustard. Training and extension for farmers and labourers increases their efficiency considerably (Patel, 1987). Administrative measures should be taken in this direction. Tea gardens should terrace and plant tea bushes. Poorly maintained terraces seen in many tea gardens should be repaired adequately. Tea gardens should be persuaded by administration not to do soil working on rolling slopes.

8.10 AFFORESTATION :

Afforestation occupies a prime place for soil and water conservation in the study area. Forests are in a deplorable state. Percentage of forest lands allowed for retention by tea gardens is 10 % of its total area (Ghosh, 1987). Most of it is degraded. Both, Govt. and tea gardens forest lands should be afforested under a time bound plantation programme.

Choice of species is also very important. Bamboo grove in badly eroded areas are very helpful in arresting soil erosion (Kar, 1946). Utis (Alnus nepelensis), Saur (Betula alnoides) comes up very well naturally in freshly eroded areas. Oaks have very deep probing roots. They are excellent for recharging ground water. Weeping willow (Calix indica), locally called bayas, is very good for stabilisation of jhora beds and sides. Its branches are used for basket making and for manufacture of sports goods.

Though there is regular afforestation programme by the Forest Department, no tea garden has any such activity. It is suggested that the lease agreements of tea gardens are modified to provide for obligatory afforestation by tea gardens under overall supervision of administration. Major reason for deforestation is removal of timber and firewood by local people. In the study area, most of such collectors come from tea gardens. There is a need for energy audit of tea gardens to ensure that alternative fuel is made available to the tea garden labourers. Similarly, large number of houses are constructed in tea gardens each year. Timber used in these is often illecitely collected from Govt. forests. Some times, tea garden forest are hacked without proper authority from the administration. Verification of source of timber used in such construction is very crucial to control disappearance of forests. The forest of Senchal are being hacked for firewood by migratory population from Nepal. Some illicit distilleries located in Ghoom are the major buyers of such firewood. Proper administrative action is necessary. If forests in the study area are to be ameliorated, abundant supply of alternative fuel such as cooking gas, kerosine, hard coke and coal briquettes etc. is extremely necessary. Localities like Kurseong, Tung, Sepoydhura, Dilaram, Sonada, Rongbull, Ghoom, and Sukiapokhri should be liberally supplied with alternative fuels. Besides, there is great scope for harvesting of solar energy, and wind power in the study area. Large number of mini hydel projects can be established on Upper Balason, Rongmuk, Pachim and Ghatta rivers. Several problems of soil and water conservation are intricately connected with the health of forest in the study area. Healthy forest shall put a check on deteriorating climate, on incidence of flood in lower reaches and on blocking of irrigation channels in the study area. Wastelands having very little top soil can be afforested succesfully by using good soil imported from outside (Patel, 1996). Fertilisation of forest plantations are often done as if agricultural crop is grown. This is wrong. Since the tree seedlings are deep rooted, plants are raised in pits, and organic carbon is often in abundance, the requirement of fertilizer per pit should be calculated accordingly. Top flake of 30 cms soil should be considered for such computation (Sultan, 1995).

8.11 OVERGRAZING :

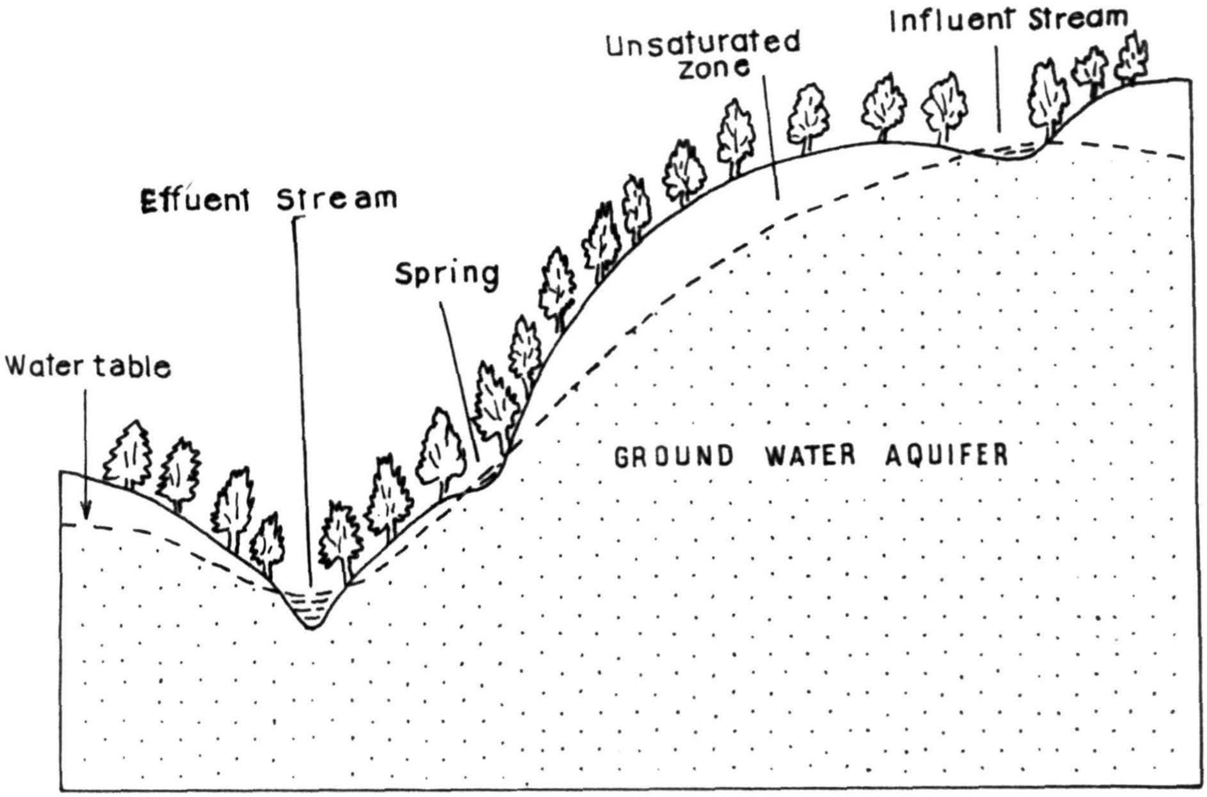
Overgrazing is doing great damage to the soils and to the young plantations (Sec 5.1.7). There being no pasture, cattle graze in forests. Help of non-governmental organisation should be taken for persuading people to go for stall feeding. If cattle have to graze at all, they should be allowed only in grown up forests and older plantations. Grazing is very severe in the forests of Senchal, Mahaldram and Dhobijhora. There are elaborate grazing rules for forest in the study area. They are, however, ineffective. They need reinforcement. In Darjeeling Forest Division, departmental ` bathans ´ are great source of rampant grazing. They should be discontinued or relocated. In past there was a system of issuing permits for grazing. It needs reintroduction so that number of cattle allowed to graze is kept within the carrying capacity of the forests. Weaning out of scrub cattle and introduction of improved cattle can reduce pressure of grazing on forests. Role of non-governmental organization could be very crucial in this regard. Shallow skeletal soils, abandoned agricultural lands and other marginal lands should be used for raising fodder trees and for pasture development. This will augment the fodder availability in the study area to a great extent. There is tremendous scope for utilising the terrace risers for raising of fodder and fuel wood trees. Some such fodder tree species are Gogun (Saurería nepelensis), Nebharo (Ficus hookeri), Dudhilo (Ficus nemoralis), Utis (Alnus nepelensis) and Pipli (Bucklandia populnea). Among fodder grasses Narkat (Orondo donax) and Amlisho (Thysanolena maxima) are the major ones.

The study area falls in the catchment of HIMUL. It is seen that collection of milk from collection centres is often not commensurate with the fodder resources of the area. Most of trees in Govt. and tea garden forests are lopped for fodder. It is suggested that HIMUL authorities should assess the availability of fodder resources of any particular area. They should discourage collection of milk in excess of what could be expected given the legitimate fodder resources of the area.

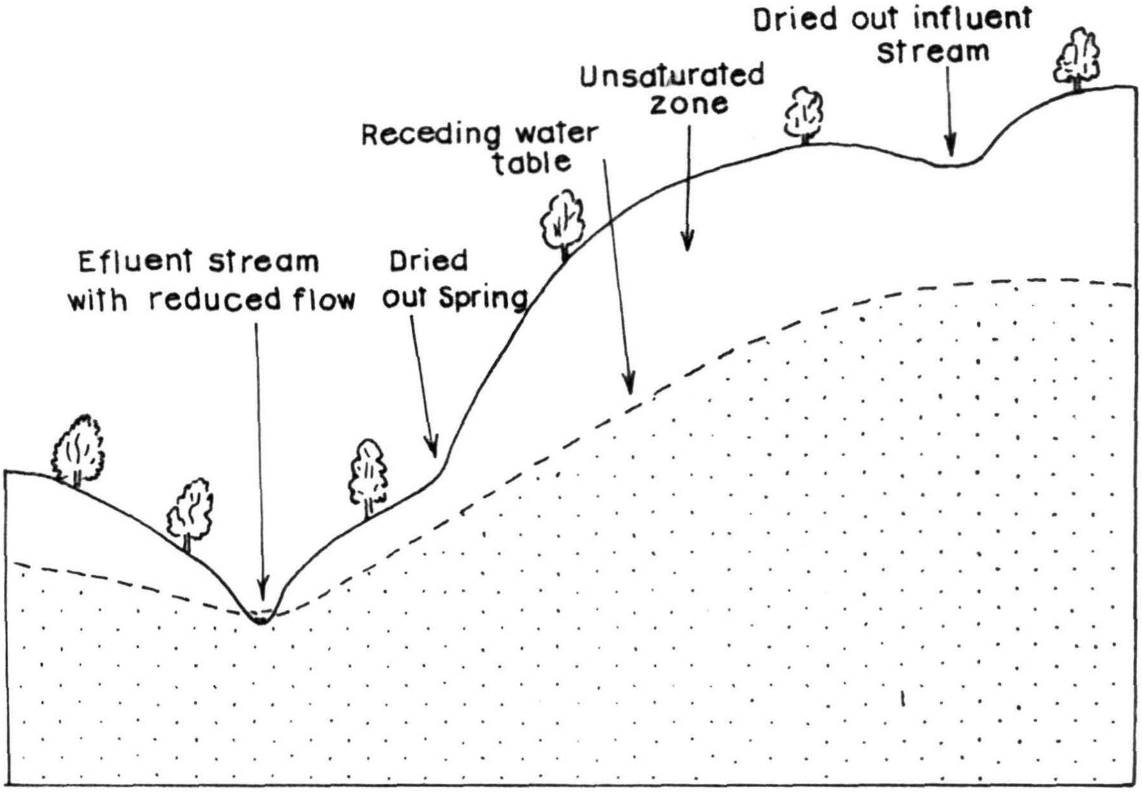
8.12 WATER SUPPLY :

Afforestation of municipal catchments of Darjeeling and Kurseong are the only solution to the scarcity of water supply during dry season (Sec. 5.2.5). They should be afforested with species naturally occurring in the area. Area should be fenced before afforestation work is taken up. Deforestation of these catchments has lowered the water table and many a streams have become dead. The result has been shown graphically (Fig.8.20). The concept of infiltration belts can be used for recharging of underground water (Fig. 8.21). The widths of infiltration belts should be calculated on the basis of slope, soil texture, intensity and duration of rainfall , and infiltration capacity of the soil under infiltration belt (Patel, 1992 A). In both the catchments, pilot projects should be launched to assess the same. Each individual stream should be delineated on large scale map and priorities decided. Afforestation should be taken priority wise and mini-catchment wise. If any mini catchment is denuded, it should be replanted. If it is having coniferous trees, it should be converted into broad leaved forests. Opening should be made into the canopy if the forest is excessively dense. These measures shall yield more water during non-monsoon months.

Involvement of local people is very crucial for success. The concept of joint forest management has been recently introduced by the forest department. A meticulous Govt. Order has been made to ensure genuine support of interested persons. It is, however, in no case, a total sell out to local



A WELL WOODED FOREST ECOSYSTEM

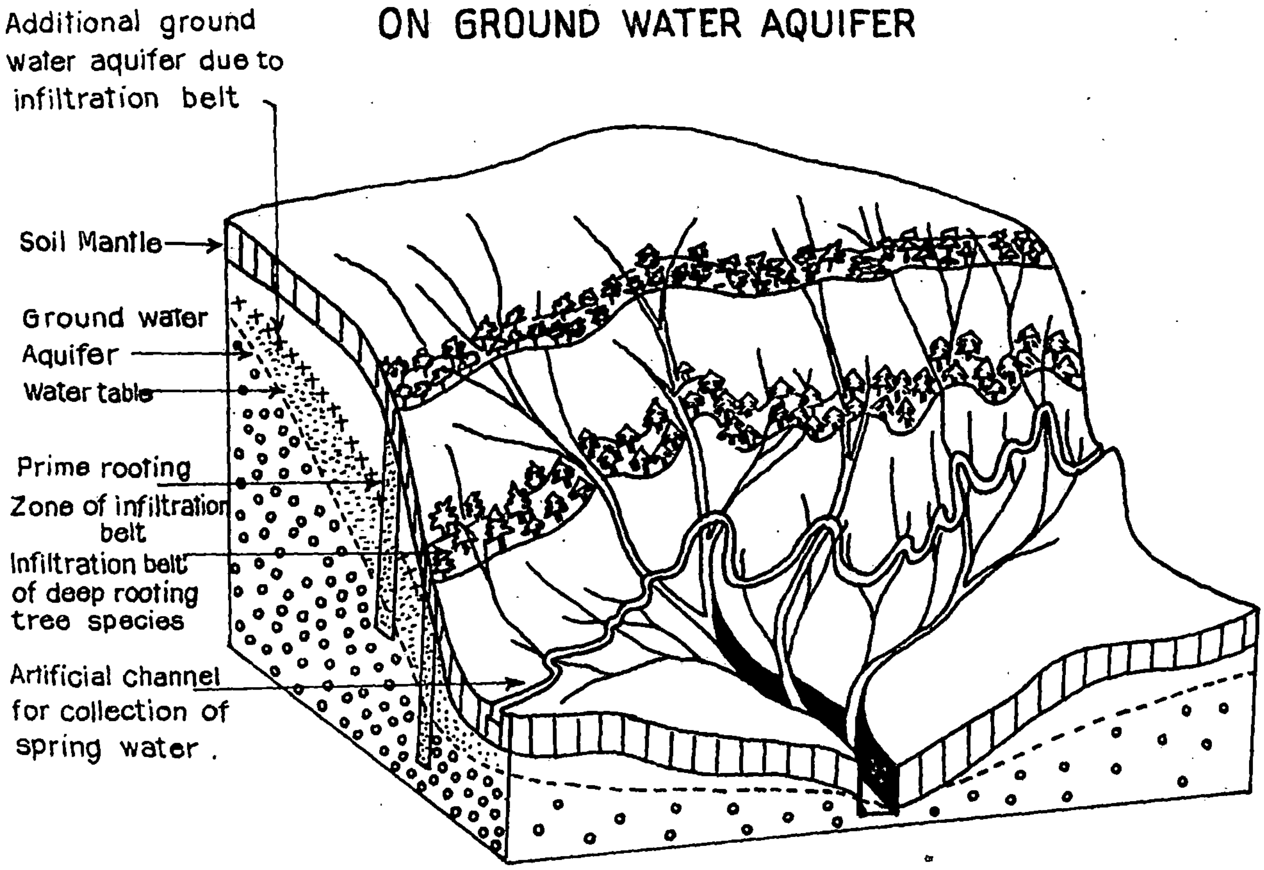


SAME FOREST ECOSYSTEM — SEVERELY DEFORESTED AND OVER GRAZED

RELATIONSHIP OF WATER TABLE, CONDITION OF FORESTS AND LIFE OF STREAMS.

Fig. 8·20.

EFFECT OF INFILTRATION BELTS ON GROUND WATER AQUIFER



BLOCK DIAGRAMME SHOWING EFFECTS OF INFILTRATION BELTS IN AUGMENTING GROUND WATER .

Fig. 8·21

population (Patel, 1995). The concept should be extended to cover the entire study area. Role of NGO (non governmental organisation) could be very crucial in this regard.

8.13 FOREST FIRES :

Forest fires damage younger plantations in the study area (Sec 7.1.8). Dry scrub forests found in lower reaches are burnt several times over during single dry season. It is suggested that younger plantations be fire traced for at least five years. Fire lines of fiver metre width should be made and collected slush is burnt under controlled conditions. In Govt. forests controlled burning is in vogue. In tea gardens waste lands need fire tracing. In lower reaches fire towers should be erected for quick location of fires.

8.14 OVERSETTLEMENTS :

Oversettlement generates increased pressure of fuel and fodder resources (Sec 5.1.5). This also creates excessive pressure of grazing in forests of, both, Govt. and tea gardens. The Hill Cart road passing through study area is drawing people from hinterlands because of better commercial opportunities along it. It is necessary that some administrative restrictions is placed on unbridled construction of houses in hills. Basic amenities are severely overstressed and corrective measures should be initiated fast. Supply of alternative sources of fuel, augmentation of fodder resources, awareness campaign through Govt organisation tea gardens and NGOs about the bad effects of oversettlements should be taken up.

8.15 UNAUTHORISED QUARRYING :

There are innumerable spots of unauthorised quarrying in the study area (Sec 5.1.2). Most of them are located on Hill Cart road. The stretch between Gorabari and Rinchintong is the worst affected. Administrative action is necessary to stop this menace. No quarry approved by Govt. is located in the hills. Many such quarries should be opened. Pending the opening of such quarries, Govt. agencies and tea gardens should be insisted not to use local stone materials for construction. Sona Hollow Block Industry located between Gorabari and Sonada on Hill Cart road is running on materials quarried locally for last two decades. It is setting a bad example . It is believed that its operation has emboldened others to go for unauthorised quarrying in a big way. It needs to be controlled. Its relocation is the best solution. Unauthorised quarrying has already done great damage. This is suggested that such sites be located and corrective measures for stabilisation of affected stream banks and beds should be taken on priority. This is necessary to avoid disaster in near future.

CONCLUSION :

Thus it is seen that a large number of soil and water conservation practices are desirable in the study area . Since it is flush with a large number of jhoras (streams) torrential in nature , some suggestions have been made in respect of jhora training works . Catchwater drains , though used extensively in the study area , are often ill designed . Suggestions have been made for their use in proper disposal of run off. Retaining walls and breast walls are also very popular soil conservation structures in the study area . In this regard , appropriate slope of bank cuttings , design of retaining walls , conditions of their stability , dimensions of various components have been suggested. Another important soil erosion problem in the study area is erosion of banks of torrents and streams . The protection of such spots has been discussed in detail. A new approach for location of retards has been suggested for snaking streams and jhoras . Scouring of the river bed immediately beyond the head of the retard is the most serious cause of failure of such structures . Measures have been suggested for protection of such sore spots . Checkdams , too , constitute an age old practice . They are , however , often ill-designed and are often made of costlier cement concrete masonry . Suggestions have been made for construction of single row post brushwood dam , double row post brushwood dam , dry stone checkdams and log checkdams all of which are capable of being erected by locally available materials . Permanent checkdams have been suggested for productive areas in milder sections of streams. Stabilisation of slopes by use of living and dead plant material , such as sproutable species of herbs and shrubs , turfing , brushwood mattresses , hydroseeding , placement of seed mats of geofabrics has also been discussed . Besides this, cordon constructions , brush wattle constructions and groove constructions have been suggested for stabilisation and revegetation of slopes . Where slope instability in more deep seated , suggestions have been made for constructions of hedge layer , brush layer and hedge-brush layer. Construction of vegetated wooden crib walls, stone walls, hard and soft gabion has also been suggested. Some measures have also been pointed out for control of landslides . Sub-soil drainage by bamboo drains , permanent gravel filled trapped drains , deep sub-soil pipe drains have been discussed. The concept of reinforcing of earth has also been discussed. The whole package of suggestions are directed to the specific requirement of the study area .

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APPENDIX I

FLOW AND SOIL LOSS IN GHATTA - HUSSAIN RIVER
AUGUST 1992

DATE	TIME	AV SEDIMENT gm\litre	AV "Q" CUMEC	TIME INTERVAL MINUTES	FLOW OF WATER HA.MT.	SOIL LOSS MT
02-Aug-92	2:00 PM	0.0029	0.7433			
	4:00 PM	0.0092	1.7380	120	1.2513	0.1151
03-Aug-92	10:00 AM	0.0160	1.7380	1080	11.2619	1.7963
	4:00 PM	0.0234	1.7380	360	3.7540	0.8784
04-Aug-92	2:00 PM	0.0203	1.7380	1320	13.7646	2.7942
05-Aug-92	8:00 AM	0.0130	2.3818	1080	15.4337	1.9987
06-Aug-92	8:00 AM	0.0165	3.2770	1440	28.3133	4.6575
07-Aug-92	10:00 AM	0.0145	2.3818	1560	22.2932	3.2214
	6:00 PM	0.0125	1.8888	480	5.4397	0.6772
08-Aug-92	6:00 AM	0.0147	2.7841	720	12.0271	1.7620
	8:00 AM	0.0150	3.2770	120	2.3594	0.3527
	12:00 PM	0.0129	3.2770	240	4.7189	0.6087
	2:00 PM	0.0047	2.3818	120	1.7149	0.0806
	6:00 PM	0.0053	1.8888	240	2.7199	0.1442
09-Aug-92	6:00 AM	0.0138	2.7841	720	12.0271	1.6537
	8:00 AM	0.0224	3.2770	120	2.3594	0.5273
	12:00 PM	0.0265	3.2770	240	4.7189	1.2505
	2:00 PM	0.0181	2.3818	120	1.7149	0.3095
	6:00 PM	0.0098	1.8888	240	2.7199	0.2665
10-Aug-92	8:00 AM	0.0243	2.3917	840	12.0542	2.9231
	12:00 PM	0.0293	2.4923	240	3.5889	1.0498
11-Aug-92	6:00 AM	0.0162	1.9894	1080	12.8913	2.0884
	8:00 AM	0.0168	1.4865	120	1.0703	0.1798
	12:00 PM	0.0193	1.4865	240	2.1406	0.4121
	4:00 PM	0.0149	1.4865	240	2.1406	0.3179
	6:00 PM	0.0120	1.4865	120	1.0703	0.1279
12-Aug-92	6:00 AM	0.0090	1.7380	720	7.5079	0.6757
	10:00 AM	0.0076	1.9894	240	2.8647	0.2163
	12:00 PM	0.0263	1.7380	120	1.2513	0.3285
	4:00 PM	0.0441	1.4865	240	2.1406	0.9440
	6:00 PM	0.0886	1.5871	120	1.1427	1.0119
13-Aug-92	6:00 AM	0.0711	1.5871	720	6.8563	4.8714
	2:00 PM	0.0136	1.7380	480	5.0053	0.6807
14-Aug-92	8:00 AM	0.0107	2.1403	1080	13.8688	1.4840
	4:00 PM	0.0034	2.5879	480	7.4532	0.2534
	6:00 PM	0.0086	2.8847	120	2.0770	0.1786
15-Aug-92	8:00 AM	0.0098	4.2895	840	21.6191	2.1187
	12:00 PM	0.0034	4.2895	240	6.1769	0.2100
	4:00 PM	0.0071	3.0809	240	4.4364	0.3150
	6:00 PM	0.1435	3.2770	120	2.3594	3.3858
16-Aug-92	6:00 AM	0.1453	2.8847	720	12.4617	18.1006
	10:00 AM	0.0398	2.4923	240	3.5889	1.4266
	2:00 PM	0.0395	2.8847	240	4.1539	1.6408

DATE	TIME	AV SEDIMENT gm\litre	AV "Q" CUMEC	TIME INTERVAL MINUTES	FLOW OF WATER HA.MT.	SOIL LOSS MT
	6:00 PM	0.0191	3.2770	240	4.7189	0.9013
17-Aug-92	10:00 AM	0.0692	2.7338	960	15.7467	10.8888
	2:00 PM	0.0649	2.5377	240	3.6542	2.3716
	6:00 PM	0.0265	3.0809	240	4.4364	1.1757
18-Aug-92	6:00 AM	0.0293	2.6332	720	11.3754	3.3330
	6:00 PM	0.0153	5.4169	720	23.4008	3.5686
			GHATTA - HUSSAIN			
19-Aug-92	8:00 AM	0.0124	5.1654	840	26.0336	3.2282
	4:00 PM	0.0096	2.9861	480	8.6000	0.8213
20-Aug-92	12:00 PM	0.0063	2.9861	1200	21.4999	1.3437
	4:00 PM	0.0085	2.3818	240	3.4297	0.2898
21-Aug-92	12:00 PM	0.0059	2.6332	1200	18.9590	1.1186
	6:00 PM	0.0092	2.2409	360	4.8402	0.4453
22-Aug-92	8:00 AM	0.1187	4.0933	840	20.6302	24.4881
	12:00 PM	0.1416	4.4857	240	6.4593	9.1464
	6:00 PM	0.1342	2.6332	360	5.6877	7.6329
23-Aug-92	6:00 AM	0.1160	3.8419	720	16.5968	19.2523
	12:00 PM	0.0339	5.0900	360	10.9944	3.7271
	4:00 PM	0.0408	3.2376	240	4.6621	1.9021
24-Aug-92	6:00 AM	0.0239	3.2376	840	16.3173	3.8917
	6:00 PM	0.0159	6.6650	720	28.7928	4.5637
25-Aug-92	6:00 AM	0.0183	6.0607	720	26.1820	4.7913
	10:00 AM	0.0180	3.0809	240	4.4364	0.7963
	4:00 PM	0.0207	3.0809	360	6.6546	1.3742
26-Aug-92	6:00 AM	0.0157	10.4655	840	52.7461	8.2811
	8:00 AM	0.0646	15.2646	120	10.9905	7.0944
	12:00 PM	0.1573	10.8597	240	15.6380	24.5985
	4:00 PM	0.1533	5.6683	240	8.1624	12.5088
27-Aug-92	12:00 PM	0.0676	4.0933	1200	29.4718	19.9082
	6:00 PM	0.0513	4.0933	360	8.8415	4.5357
28-Aug-92	8:00 AM	0.0587	3.4890	840	17.5846	10.3221
	12:00 PM	0.0319	4.4857	240	6.4594	2.0573
	4:00 PM	0.0323	3.4890	240	5.0242	1.6203
	6:00 PM	0.0463	2.3917	120	1.7220	0.7964
29-Aug-92	6:00 AM	0.0362	2.5879	720	11.1797	4.0415
	4:00 PM	0.0238	2.5879	600	9.3164	2.2127
30-Aug-92	6:00 AM	0.0693	2.3917	840	12.0542	8.3535
	6:00 PM	0.0691	2.4923	720	10.7667	7.4398
31-Aug-92	10:00 AM	0.0217	2.4923	960	14.3556	3.1152
	6:00 PM	0.0163	2.2409	480	6.4536	1.0487
				TOTAL	803.3875	297.0217

DATE	TIME	AV SEDIMENT gm\litre	AV "Q" CUMEC	TIME INTERVAL MINUTES	FLOW OF WATER HA.MT.	SOIL LOSS MT
SEPTEMBER 1992						
01-Sep-92	10:00 AM	0.0042	0.2490			
	6:00 PM	0.0174	0.4980	480	1.4342	0.2488
04-Sep-92	10:00 AM	0.0177	0.5823	4320	15.0919	2.6713
05-Sep-92	12:00 AM	0.0194	0.5823	4680	16.3496	3.1718
09-Sep-92	12:00 PM	0.0288	0.6665	7320	29.2727	8.4159
	4:00 PM	0.8151	2.4898	240	3.5852	29.2233
	6:00 PM	1.0465	3.3738	120	2.4291	25.4205
11-Sep-92	12:00 PM	0.8211	2.5740	2640	40.7722	334.7802
12-Sep-92	8:00 AM	0.2993	3.3738	3720	75.3021	225.3792
	12:00 PM	0.0728	3.1100	240	4.4784	3.2603
13-Sep-92	6:00 AM	0.0698	3.1100	1320	24.6312	17.1803
	4:00 PM	0.0203	1.4368	600	5.1723	1.0474
14-Sep-92	10:00 AM	0.0255	1.5025	1680	15.1452	3.8620
	12:00 PM	0.0145	1.0980	120	0.7906	0.1146
15-Sep-92	12:00 PM	0.0156	1.0323	1560	9.6619	1.5024
	4:00 PM	0.0151	0.9008	240	1.2971	0.1952
GHATTA - HUSSAIN						
16-Sep-92	2:00 PM	0.0138	0.8165	1560	7.6424	1.0547
	4:00 PM	0.0117	0.6665	120	0.4799	0.0559
17-Sep-92	10:00 AM	0.0162	0.7508	1200	5.4054	0.8757
	6:00 PM	0.0126	0.6665	480	1.9195	0.2409
18-Sep-92	10:00 AM	0.0169	0.6665	1440	5.7586	0.9732
	4:00 PM	0.0102	0.5823	360	1.2577	0.1283
	6:00 PM	0.0071	0.6665	120	0.4799	0.0338
19-Sep-92	10:00 AM	0.0080	0.6665	1080	4.3189	0.3455
	6:00 PM	0.0105	0.6665	480	1.9195	0.2015
20-Sep-92	10:00 AM	0.0084	0.6665	1440	5.7586	0.4837
21-Sep-92	10:00 AM	0.0184	0.6665	2400	9.5976	1.7660
	4:00 PM	0.0171	0.5823	360	1.2577	0.2151
22-Sep-92	8:00 AM	0.0165	0.5823	1320	4.6114	0.7586
	12:00 PM	0.0095	0.4980	240	0.7171	0.0678
	6:00 PM	0.0122	0.4980	360	1.0757	0.1307
23-Sep-92	6:00 AM	0.0116	0.4980	720	2.1514	0.2496
	12:00 PM	0.0099	0.4980	1080	3.2270	0.3179
	6:00 PM	0.0091	0.4980	360	1.0757	0.0973
24-Sep-92	10:00 AM	0.0047	0.4980	1320	3.9442	0.1854
	4:00 PM	0.0066	0.4468	360	0.9650	0.0637
25-Sep-92	10:00 AM	0.0038	0.4980	1440	4.3027	0.1614
	4:00 PM	0.0060	0.4980	360	1.0757	0.0645
26-Sep-92	6:00 AM	0.0440	0.4980	840	2.5099	1.1031
	12:00 PM	0.0649	0.4468	360	0.9650	0.6263
	2:00 PM	0.2857	1.1513	120	0.8289	2.3678
	6:00 PM	0.1988	0.6810	360	1.4710	2.9243
27-Sep-92	12:00 PM	0.2660	1.2868	1320	10.1911	27.1082
	4:00 PM	0.0117	0.6665	240	0.9598	0.1118

DATE	TIME	AV SEDIMENT gm\litre	AV "Q" CUMEC	TIME INTERVAL MINUTES	FLOW OF WATER HA.MT.	SOIL LOSS MT
	6:00 PM	0.0181	0.6665	120	0.4799	0.0866
28-Sep-92	10:00 AM	0.0160	0.6665	1080	4.3189	0.6910
29-Sep-92	12:00 PM	0.0150	0.6665	2520	10.0775	1.5066
	6:00 PM	0.0101	0.5823	360	1.2577	0.1270
				TOTAL	347.4146	701.5970

OCTOBER 1992

DATE	TIME	AV SEDIMENT gm\litre	AV "Q" CUMEC	TIME INTERVAL MINUTES	FLOW OF WATER HA.MT.	SOIL LOSS MT
01-Oct-92	4:00 PM		0.0035	0.3333		
	6:00 PM	120	0.0082	0.6665	0.4799	0.0391
02-Oct-92	12:00 PM	1080	0.0094	0.5823	3.7730	0.3547
04-Oct-92	10:00 AM	3840	0.0099	0.5823	13.4150	1.3281
05-Oct-92	6:00 PM	4680	0.0111	0.5823	16.3496	1.8148
09-Oct-92	12:00 PM	7320	0.0079	0.4468	19.6213	1.5501
	4:00 PM	5640	0.0105	0.5310	17.9690	1.8778
10-Oct-92	12:00 PM	1440	0.0043	0.3955	3.4171	0.1452
	6:00 PM	1560	0.0106	0.3955	3.7019	0.3924
11-Oct-92	8:00 AM	1200	0.0054	0.3955	2.8476	0.1523
	4:00 PM	480	0.0076	0.3955	1.1390	0.0860
12-Oct-92	10:00 AM	1560	0.0095	0.4468	4.1816	0.3952
	6:00 PM	1560	0.0103	0.4468	4.1816	0.4307
13-Oct-92	4:00 PM	1800	0.0116	0.4980	5.3784	0.6212
	6:00 PM	120	0.0128	0.4980	0.3586	0.0459
14-Oct-92	10:00 AM	960	0.0115	0.4980	2.8685	0.3284
	6:00 PM	480	0.0085	0.4980	1.4342	0.1219

GHATTA - HUSSAIN

DATE	TIME	AV SEDIMENT gm\litre	AV "Q" CUMEC	TIME INTERVAL MINUTES	FLOW OF WATER HA.MT.	SOIL LOSS MT
15-Oct-92	8:00 AM	1320	0.0079	0.4980	3.9442	0.3116
	10:00 AM	120	0.0074	0.4980	0.3586	0.0265
	4:00 PM	360	0.0070	0.4980	1.0757	0.0748
	6:00 PM	120	0.0064	0.4980	0.3586	0.0229
				TOTAL	106.8532	10.1196

NOVEMBER 1992

DATE	TIME	AV SEDIMENT gm\litre	AV "Q" CUMEC	TIME INTERVAL MINUTES	FLOW OF WATER HA.MT.	SOIL LOSS MT
01-Nov-92	4:00 PM	0.0028	0.1465			
	6:00 PM	0.0026	0.1465	120	0.1055	0.0027
02-Nov-92	4:00 PM	0.0040	0.2930	1320	2.3206	0.0928
	6:00 PM	0.0045	0.2930	120	0.2110	0.0095
03-Nov-92	4:00 PM	0.0042	0.2930	1320	2.3206	0.0963
	6:00 PM	0.0040	0.2930	120	0.2110	0.0084
04-Nov-92	4:00 PM	0.0054	0.2930	1320	2.3206	0.1241
	6:00 PM	0.0057	0.2930	120	0.2110	0.0119

DATE	TIME	AV SEDIMENT gm\litre	AV "Q" CUMEC	TIME INTERVAL MINUTES	FLOW OF WATER HA.MT.	SOIL LOSS MT
05-Nov-92	2:00 PM	0.0048	0.2930	1200	2.1096	0.1002
	6:00 PM	0.0060	0.2930	240	0.4219	0.0251
06-Nov-92	12:00 PM	0.0068	0.2930	1080	1.8986	0.1291
	6:00 PM	0.0065	0.2930	360	0.6329	0.0411
07-Nov-92	12:00 PM	0.0080	0.2930	1080	1.8986	0.1519
	6:00 PM	0.0076	0.2930	360	0.6329	0.0481
08-Nov-92	4:00 PM	0.0075	0.2930	1320	2.3206	0.1729
	6:00 PM	0.0065	0.2930	120	0.2110	0.0136
09-Nov-92	4:00 PM	0.0071	0.2930	1320	2.3206	0.1636
	6:00 PM	0.0052	0.2930	120	0.2110	0.0109
10-Nov-92	12:00 PM	0.0081	0.2480	1080	1.6070	0.1302
	6:00 PM	0.0065	0.2930	360	0.6329	0.0411
11-Nov-92	8:00 AM	0.0081	0.2030	840	1.0231	0.0829
	4:00 PM	0.0068	0.2930	480	0.8438	0.0574
	6:00 PM	0.0067	0.2480	120	0.1786	0.0120
12-Nov-92	4:00 PM	0.0045	0.2930	1320	2.3206	0.1033
	6:00 PM	0.0060	0.2930	120	0.2110	0.0127
13-Nov-92	12:00 PM	0.0044	0.2480	1080	1.6070	0.0699
	6:00 PM	0.0071	0.2930	360	0.6329	0.0446
14-Nov-92	12:00 PM	0.0059	0.2030	1080	1.3154	0.0776
	6:00 PM	0.0064	0.2930	360	0.6329	0.0405
16-Nov-92	6:00 AM	0.0051	0.2030	2160	2.6309	0.1342
	4:00 PM	0.0054	0.2930	600	1.0548	0.0570
	6:00 PM	0.0059	0.2480	120	0.1786	0.0105
17-Nov-92	10:00 AM	0.0069	0.2480	960	1.4285	0.0986
	4:00 PM	0.0081	0.2930	360	0.6329	0.0509
	6:00 PM	0.0066	0.2480	120	0.1786	0.0118
18-Nov-92	12:00 PM	0.0071	0.2480	1080	1.6070	0.1133
	4:00 PM	0.0089	0.2930	240	0.4219	0.0376
	6:00 PM	0.0064	0.2480	120	0.1786	0.0113
19-Nov-92	8:00 AM	0.0109	0.1815	840	0.9148	0.0993
	4:00 PM	0.0079	0.1815	480	0.5227	0.0410
	6:00 PM	0.0101	0.0700	120	0.0504	0.0051
20-Nov-92	8:00 AM	0.0084	0.1365	840	0.6880	0.0578
	4:00 PM	0.0059	0.1365	480	0.3931	0.0232
	6:00 PM	0.0082	0.2030	120	0.1462	0.0119

GHATT - HUSSAIN

21-Nov-92	8:00 AM	0.0047	0.2030	840	1.0231	0.0481
	4:00 PM	0.0079	0.2030	480	0.5846	0.0462
	6:00 PM	0.0071	0.2030	120	0.1462	0.0105
22-Nov-92	10:00 AM	0.0065	0.2030	960	1.1693	0.0754
	12:00 PM	0.0067	0.2030	120	0.1462	0.0098
	4:00 PM	0.0058	0.2030	240	0.2923	0.0170
	6:00 PM	0.0051	0.2030	120	0.1462	0.0075
23-Nov-92	10:00 AM	0.0057	0.1365	960	0.7862	0.0444
	12:00 PM	0.0533	0.1365	120	0.0983	0.0524
	6:00 PM	0.0081	0.0700	360	0.1512	0.0122

DATE	TIME	AV SEDIMENT gm\litre	AV "Q" CUMEC	TIME INTERVAL MINUTES	FLOW OF WATER HA.MT.	SOIL LOSS MT
24-Nov-92	10:00 AM	0.0542	0.0700	960	0.4032	0.2187
	4:00 PM	0.0100	0.0700	360	0.1512	0.0151
	6:00 PM	0.0036	0.0700	120	0.0504	0.0018
25-Nov-92	4:00 PM	0.0065	0.0700	1320	0.5544	0.0360
	6:00 PM	0.0047	0.0700	120	0.0504	0.0023
26-Nov-92	8:00 AM	0.0044	0.0700	840	0.3528	0.0153
	4:00 PM	0.0061	0.0700	480	0.2016	0.0123
	6:00 PM	0.0069	0.0700	120	0.0504	0.0035
27-Nov-92	8:00 AM	0.0039	0.0700	840	0.3528	0.0138
	12:00 PM	0.0048	0.0700	240	0.1008	0.0048
	6:00 PM	0.0042	0.0700	360	0.1512	0.0064
28-Nov-92	8:00 AM	0.0029	0.0700	840	0.3528	0.0102
	4:00 PM	0.0041	0.0700	480	0.2016	0.0083
	6:00 PM	0.0041	0.0700	120	0.0504	0.0021
29-Nov-92	12:00 PM	0.0036	0.0700	1080	0.4536	0.0163
	4:00 PM	0.0035	0.0700	240	0.1008	0.0035
	6:00 PM	0.0043	0.0700	120	0.0504	0.0022
30-Nov-92	8:00 AM	0.0028	0.0700	840	0.3528	0.0097
	12:00 PM	0.0066	0.0700	240	0.1008	0.0066
	6:00 PM	0.0027	0.0700	360	0.1512	0.0041
				TOTAL	51.1668	3.3542

APPENDIX II

FLOW AND SOIL LOSS IN RINCHINTONG JHORA

JULY 1992

DATE	TIME	AV SEDIMENT GM\LITTER	AV "Q" CUMEC	TIME INTERVAL MINUTES	FLOW OF WATER HA.MT.	SOIL LOSS MT
19-Jul-92	6:00 PM	0.0029	3.6784			
20-Jul-92	10:00 AM	0.0165	6.5855	960	37.9325	6.2589
21-Jul-92	8:00 AM	0.0184	6.5855	1320	52.1572	9.5708
	12:00 PM	0.0088	7.3567	240	10.5936	0.9269
	4:00 PM	0.0098	7.3567	240	10.5936	1.0329
22-Jul-92	10:00 AM	0.0092	7.4403	1080	48.2131	4.4115
	4:00 PM	0.0084	7.0547	360	15.2381	1.2800
	6:00 PM	0.0113	6.9711	120	5.0192	0.5672
23-Jul-92	6:00 AM	0.0109	6.5855	720	28.4494	3.0868
	6:00 PM	0.0090	5.8143	720	25.1178	2.2606
24-Jul-92	6:00 AM	0.0295	7.8710	720	34.0028	10.0308
	4:00 PM	0.0281	7.8710	600	28.3357	7.9623
	6:00 PM	0.0073	5.8143	120	4.1863	0.3035
25-Jul-92	2:00 PM	0.0073	4.4869	1200	32.3053	2.3583
	6:00 PM	0.0054	4.1013	240	5.9058	0.3189
26-Jul-92	6:00 AM	0.1583	6.1999	720	26.7836	42.4118
	6:00 PM	0.1612	5.2581	720	22.7148	36.6162
27-Jul-92	6:00 AM	0.0118	3.7157	720	16.0516	1.8941
	6:00 PM	0.0152	5.4287	720	23.4520	3.5530
28-Jul-92	6:00 AM	0.0137	6.5855	720	28.4494	3.8976
	6:00 PM	0.0099	5.5829	720	24.1183	2.3877
29-Jul-92	6:00 AM	0.0066	4.4261	720	19.1209	1.2620
	6:00 PM	0.0060	3.8825	720	16.7725	1.0064
30-Jul-92	6:00 AM	0.0072	4.0368	720	17.4388	1.2469
	6:00 PM	0.0077	4.4261	720	19.1209	1.4628
31-Jul-92	6:00 AM	0.0085	4.6575	720	20.1204	1.7102
	6:00 PM	0.0066	4.8117	720	20.7867	1.3719
			TOTAL		592.9803	149.1899

AUGUST 1992

DATE	TIME	AV SEDIMENT GM\LITTER	AV "Q" CUMEC	TIME INTERVAL MINUTES	FLOW OF WATER HA.MT.	SOIL LOSS MT
01-Aug-92	6:00 AM	0.0061	2.5216			
	6:00 PM	0.0094	4.4906	720	19.3995	1.8139
02-Aug-92	6:00 AM	0.0067	4.4135	720	19.0663	1.2679
03-Aug-92	6:00 AM	0.0071	4.0241	1440	34.7685	2.4512
	6:00 PM	0.0072	3.7157	720	16.0516	1.1477
04-Aug-92	6:00 AM	0.0070	4.1607	720	17.9740	1.2492
	6:00 PM	0.0069	4.1607	720	17.9740	1.2402
05-Aug-92	6:00 AM	0.0070	4.2719	720	18.4546	1.2826

DATE	TIME	AV SEDIMENT GM\LITTER	AV "Q" CUMEC	TIME INTERVAL MINUTES	FLOW OF WATER HA.MT.	SOIL LOSS MT
06-Aug-92	6:00 AM	0.0125	4.4261	1440	38.2418	4.7611
	6:00 PM	0.0147	4.4261	720	19.1209	2.8012
08-Aug-92	6:00 AM	0.0113	4.3490	2160	56.3633	6.3691
	6:00 PM	0.0090	3.7928	720	16.3848	1.4664

RINICHINTONG

DATE	TIME	AV SEDIMENT GM\LITTER	AV "Q" CUMEC	TIME INTERVAL MINUTES	FLOW OF WATER HA.MT.	SOIL LOSS MT
09-Aug-92	6:00 AM	0.0082	3.7157	720	16.0516	1.3082
	12:00 PM	0.0178	4.8117	360	10.3934	1.8500
	6:00 PM	0.0195	4.7005	360	10.1531	1.9798
10-Aug-92	6:00 AM	0.0117	4.1607	720	17.9740	2.1030
	6:00 PM	0.0089	4.1050	720	17.7337	1.5783
11-Aug-92	10:00 AM	0.0090	3.8269	960	22.0429	1.9728
	6:00 PM	0.0093	3.2743	480	9.4301	0.8770
12-Aug-92	6:00 AM	0.0222	3.1075	720	13.4242	2.9802
	2:00 PM	0.0895	3.8269	480	11.0215	9.8587
	6:00 PM	0.0970	3.8825	240	5.5908	5.4203
13-Aug-92	6:00 AM	0.0310	3.9596	720	17.1057	5.3028
	6:00 PM	0.0095	3.8484	720	16.6251	1.5794
14-Aug-92	6:00 AM	0.0087	3.2150	720	13.8889	1.2014
	4:00 PM	0.0120	3.1594	600	11.3738	1.3592
15-Aug-92	6:00 AM	0.3930	10.0317	840	50.5598	198.6746
16-Aug-92	6:00 AM	0.4045	10.9736	1440	94.8115	383.5124
	6:00 PM	0.0267	4.3794	720	18.9189	5.0419
17-Aug-92	6:00 AM	0.0125	4.3794	720	18.9189	2.3649
	4:00 PM	0.0101	5.6601	600	20.3762	2.0478
18-Aug-92	6:00 AM	0.0130	5.3516	840	26.9720	3.4929
	6:00 PM	0.0124	4.0153	720	17.3460	2.1422
19-Aug-92	6:00 AM	0.0071	3.3275	720	14.3748	1.0206
	12:00 PM	0.0078	3.6056	360	7.7882	0.6075
20-Aug-92	6:00 AM	0.0088	3.6600	1080	23.7170	2.0752
	12:00 PM	0.0128	3.6044	360	7.7855	0.9927
21-Aug-92	6:00 AM	0.0127	3.7157	1080	24.0774	3.0578
	12:00 PM	0.0154	4.2125	360	9.0990	1.3967
22-Aug-92	8:00 AM	0.0337	13.6158	1200	98.0334	32.9882
	6:00 PM	0.0315	15.7883	600	56.8379	17.8755
23-Aug-92	6:00 AM	0.0197	8.2182	720	35.5027	6.9763
	6:00 PM	0.0170	6.4313	720	27.7830	4.7092
24-Aug-92	6:00 AM	0.0117	5.8143	720	25.1178	2.9388
	6:00 PM	0.0091	5.4287	720	23.4520	2.1341
25-Aug-92	6:00 AM	0.0367	5.4287	720	23.4520	8.5952
	6:00 PM	0.0382	5.1202	720	22.1194	8.4385
26-Aug-92	6:00 AM	0.0161	7.1769	720	31.0044	4.9917
	6:00 PM	0.0187	7.7168	720	33.3365	6.2339
27-Aug-92	6:00 AM	0.0155	5.6601	720	24.4515	3.7778
	4:00 PM	0.0120	4.9319	600	17.7547	2.1306
28-Aug-92	6:00 AM	0.0068	3.8825	840	19.5679	1.3208
	2:00 PM	0.0080	5.5362	480	15.9442	1.2755

DATE	TIME	AV SEDIMENT GM\LITTER	AV "Q" CUMEC	TIME INTERVAL MINUTES	FLOW OF WATER HA.MT.	SOIL LOSS MT
29-Aug-92	6:00 AM	0.0127	6.5855	960	37.9325	4.8174
	6:00 PM	0.0116	4.7650	720	20.5847	2.3775
30-Aug-92	6:00 AM	0.0099	4.3794	720	18.9189	1.8635
	6:00 PM	0.0077	4.6019	720	19.8801	1.5308
31-Aug-92	6:00 AM	0.0070	4.6019	720	19.8801	1.3817
	6:00 PM	0.0067	3.9925	720	17.2474	1.1556
			TOTAL		1390.154	789.1613

RINICHINTONG

SEPTEMBER 1992

01-Sep-92	6:00 AM	0.0032				
	6:00 PM	0.0052	4.5981	720	19.8638	1.0329
02-Sep-92	6:00 AM	0.0667	4.0583	720	17.5317	11.6936
	6:00 PM	0.0695	4.0026	720	17.2914	12.0175
03-Sep-92	6:00 AM	0.0066	3.3263	720	14.3695	0.9484
	6:00 PM	0.0034	3.2707	720	14.1292	0.4733
04-Sep-92	6:00 AM	0.0111	3.4375	720	14.8501	1.6409
	6:00 PM	0.0101	3.4932	720	15.0904	1.5166
05-Sep-92	6:00 AM	0.0763	3.3263	720	14.3695	10.9639
	12:00 PM	0.0927	3.1619	360	6.8296	6.3276
	6:00 PM	0.0188	2.6698	360	5.7668	1.0813
06-Sep-92	6:00 AM	0.0045	3.3349	720	14.4066	0.6483
07-Sep-92	6:00 AM	0.0037	3.7157	1440	32.1032	1.1878
	12:00 PM	0.0033	2.8874	360	6.2368	0.2058
	6:00 PM	0.0045	2.4522	360	5.2968	0.2384
10-Sep-92	6:00 AM	0.0073	3.0023	3600	64.8502	4.7341
	6:00 PM	0.0085	3.1655	720	13.6751	1.1624
11-Sep-92	6:00 AM	0.0060	2.6154	720	11.2985	0.6723
	6:00 PM	0.0055	2.7242	720	11.7685	0.6473
12-Sep-92	6:00 AM	0.0370	6.8300	720	29.5056	10.9171
	6:00 PM	0.0355	9.3426	720	40.3601	14.3278
13-Sep-92	6:00 AM	0.0080	8.0254	720	34.6698	2.7563
	6:00 PM	0.0106	7.3119	720	31.5875	3.3483
14-Sep-92	6:00 AM	0.0583	6.1228	720	26.4504	15.4074
	12:00 PM	0.0581	5.7372	360	12.3923	7.1999
	6:00 PM	0.0064	5.5058	360	11.8926	0.7552
15-Sep-92	6:00 AM	0.0109	5.4287	720	23.4520	2.5563
	6:00 PM	0.0085	4.7776	720	20.6393	1.7543
16-Sep-92	6:00 AM	0.0446	4.1607	720	17.9740	8.0074
	6:00 PM	0.0562	4.0494	720	17.4934	9.8313
17-Sep-92	6:00 AM	0.0374	4.4350	720	19.1592	7.1655
	6:00 PM	0.0258	4.1013	720	17.7174	4.5622

X

DATE	TIME	AV SEDIMENT GM\LITTER	AV "Q" CUMEC	TIME INTERVAL MINUTES	FLOW OF WATER HA.MT.	SOIL LOSS MT
18-Sep-92	6:00 AM	0.0029	3.7157	720	16.0516	0.4655
	6:00 PM	0.0029	3.6069	720	15.5816	0.4519
19-Sep-92	6:00 AM	0.0058	3.4400	720	14.8607	0.8619
20-Sep-92	6:00 AM	0.0123	4.0494	1440	34.9868	4.3034
	6:00 PM	0.0112	3.3880	720	14.6363	1.6393
21-Sep-92	6:00 AM	0.0106	3.1655	720	13.6751	1.4427
	6:00 PM	0.0071	3.0567	720	13.2051	0.9310
22-Sep-92	6:00 AM	0.0089	3.2236	720	13.9260	1.2394
	12:00 PM	0.0097	3.6044	360	7.7855	0.7552
	6:00 PM	0.0081	2.9962	360	6.4718	0.5210
23-Sep-92	6:00 AM	0.0118	3.2187	720	13.9048	1.6408
24-Sep-92	6:00 AM	0.0078	3.5488	1440	30.6614	2.3763
	6:00 PM	0.0070	2.9999	720	12.9595	0.9007
25-Sep-92	6:00 AM	0.0087	2.5610	720	11.0635	0.9570
	6:00 PM	0.0037	2.3434	720	10.1235	0.3746
26-Sep-92	6:00 AM	0.0221	3.1717	720	13.7015	3.0280
	6:00 PM	0.0342	3.2261	720	13.9365	4.7663
27-Sep-92	12:00 PM	0.0231	2.9479	1080	19.1026	4.4127
	6:00 PM	0.0176	3.3831	360	7.3076	1.2825
		RINICHINTONG				
28-Sep-92	6:00 AM	0.0100	3.0506	720	13.1786	1.3113
	2:00 PM	0.0177	2.8330	480	8.1590	1.4442
30-Sep-92	6:00 AM	0.0165	2.5066	2400	36.0950	5.9376
			TOTAL		944.3951	186.8244

OCTOBER 1992

01-Oct-92	6:00 AM	0.0000	1.7466			
	6:00 PM	0.0048	2.8911	720	12.4894	0.5995
02-Oct-92	6:00 AM	0.0095	2.7242	720	11.7685	1.1180
	6:00 PM	0.0068	2.6698	720	11.5335	0.7785
03-Oct-92	6:00 AM	0.0080	2.6154	720	11.2985	0.8982
	6:00 PM	0.0059	2.6698	720	11.5335	0.6805
04-Oct-92	6:00 AM	0.0013	2.8911	720	12.4894	0.1686
	6:00 PM	0.0060	2.9999	720	12.9595	0.7776
05-Oct-92	6:00 AM	0.0346	2.8886	720	12.4789	4.3114
	6:00 PM	0.0318	2.7798	720	12.0088	3.8128
08-Oct-92	6:00 AM	0.0023	2.6698	3600	57.6677	1.2975
	6:00 PM	0.0031	2.5610	720	11.0635	0.3430
11-Oct-92	6:00 AM	0.0063	1.8909	3600	40.8434	2.5527
	6:00 PM	0.0078	1.4848	720	6.4142	0.5003
12-Oct-92	6:00 AM	0.0053	1.9373	720	8.3690	0.4394
	6:00 PM	0.0043	2.3434	720	10.1235	0.4353
13-Oct-92	10:00 AM	0.0102	2.3978	960	13.8113	1.4018
	6:00 PM	0.0087	2.7242	480	7.8457	0.6787

DATE	TIME	AV. SEDIMENT GM\LITTER	AV "Q" CUMEC	TIME INTERVAL MINUTES	FLOW OF WATER HA.MT.	SOIL LOSS MT
14-Oct-92	6:00 PM	0.0026	2.2624	1440	19.5474	0.5082
15-Oct-92	6:00 AM	0.0054	1.9904	720	8.5986	0.4600
	6:00 PM	0.0068	1.9002	720	8.2088	0.5541
16-Oct-92	6:00 AM	0.0022	2.0090	720	8.6788	0.1909
	6:00 PM	0.0019	2.1444	720	9.2636	0.1760
17-Oct-92	6:00 PM	0.0094	1.8458	1440	15.9475	1.4991
18-Oct-92	6:00 AM	0.0091	1.9360	720	8.3636	0.7569
	6:00 PM	0.0035	1.8909	720	8.1687	0.2859
19-Oct-92	6:00 PM	0.0020	1.7104	1440	14.7779	0.2882
20-Oct-92	6:00 AM	0.0723	2.3261	720	10.0488	7.2602
	2:00 PM	0.0747	2.5066	480	7.2190	5.3926
	6:00 PM	0.0069	1.8458	240	2.6579	0.1834
21-Oct-92	6:00 AM	0.0059	2.1722	720	9.3838	0.5536
	6:00 PM	0.0071	1.6653	720	7.1940	0.5108
22-Oct-92	6:00 PM	0.0052	1.5750	1440	13.6082	0.7076
23-Oct-92	6:00 PM	0.0085	1.4397	1440	12.4386	1.0511
24-Oct-92	6:00 AM	0.0096	1.4848	720	6.4142	0.6126
	6:00 PM	0.0064	1.3494	720	5.8294	0.3702
25-Oct-92	6:00 AM	0.0027	1.3945	720	6.0243	0.1627
	6:00 PM	0.0034	1.3945	720	6.0243	0.2048
26-Oct-92	6:00 PM	0.0064	1.1689	1440	10.0993	0.6464
28-Oct-92	6:00 PM	0.0030	1.1377	2880	19.6595	0.5898
29-Oct-92	6:00 AM	0.0000	1.3633	720	5.8896	0.0000
	6:00 PM	0.0041	1.4397	720	6.2193	0.2519
30-Oct-92	6:00 PM	0.0069	1.1828	1440	10.2197	0.7000
			TOTAL		505.1833	44.7108

NOVEMBER 1992

01-Nov-92	6:00 AM	0.0007	0.5533			
	6:00 PM	0.0007	0.9193	720	3.9715	0.0278
02-Nov-92	6:00 AM	0.0000	1.0408	720	4.4962	0.0000
	6:00 PM	0.0085	1.2592	720	5.4395	0.4624
03-Nov-92	6:00 AM	0.0453	1.3043	720	5.6345	2.5496
	6:00 PM	0.0368	1.1171	720	4.8259	1.7735
04-Nov-92	6:00 AM	0.0028	1.0720	720	4.6310	0.1274
	6:00 PM	0.0060	0.9784	720	4.2267	0.2515
05-Nov-92	6:00 AM	0.0080	0.8881	720	3.8368	0.3069
	6:00 PM	0.0048	0.8881	720	3.8368	0.1842
07-Nov-92	6:00 PM	0.0020	0.7322	2880	12.6519	0.2530
08-Nov-92	6:00 AM	0.0083	0.9505	720	4.1063	0.3388
	6:00 PM	0.0075	0.7946	720	3.4325	0.2557
09-Nov-92	6:00 PM	0.0012	0.6074	1440	5.2478	0.0630
10-Nov-92	6:00 AM	0.0021	0.8881	720	3.8368	0.0787
	6:00 PM	0.0021	0.9193	720	3.9715	0.0814
11-Nov-92	6:00 PM	0.0000	0.8258	1440	7.1345	0.0000

DATE	TIME	AV SEDIMENT GM\LITTER	AV "Q" CUMEC	TIME INTERVAL MINUTES	FLOW OF WATER HA.MT.	SOIL LOSS MT
12-Nov-92	6:00 AM	0.0059	1.0892	720	4.7055	0.2753
	6:00 PM	0.0091	1.0581	720	4.5708	0.4159
15-Nov-92	6:00 PM	0.0033	0.9505	4320	24.6379	0.8007
16-Nov-92	6:00 AM	0.0028	1.0129	720	4.3758	0.1225
	6:00 PM	0.0028	0.7634	720	3.2977	0.0923
17-Nov-92	6:00 AM	0.0005	0.7634	720	3.2977	0.0148
	6:00 PM	0.0007	0.8258	720	3.5673	0.0232
18-Nov-92	6:00 PM	0.0017	0.6698	1440	5.7869	0.0984
19-Nov-92	6:00 PM	0.0015	0.7010	1440	6.0564	0.0908
20-Nov-92	6:00 AM	0.0000	0.8570	720	3.7020	0.0000
	6:00 PM	0.0000	0.8570	720	3.7020	0.0000
21-Nov-92	6:00 PM	0.0000	0.7322	1440	6.3259	0.0000
22-Nov-92	6:00 PM	0.0000	0.7322	1440	6.3259	0.0000
23-Nov-92	6:00 AM	0.0022	0.8258	720	3.5673	0.0785
	6:00 PM	0.0022	0.8570	720	3.7020	0.0814
24-Nov-92	6:00 PM	0.0505	0.7946	1440	6.8650	3.4668
26-Nov-92	6:00 PM	0.0505	0.7634	2880	13.1909	6.6614
27-Nov-92	6:00 AM	0.0000	0.7946	720	3.4325	0.0000
	6:00 PM	0.0149	0.7946	720	3.4325	0.5114
28-Nov-92	6:00 AM	0.0167	0.8570	720	3.7020	0.6164
	6:00 PM	0.0018	0.8881	720	3.8368	0.0671
29-Nov-92	6:00 AM	0.0000	0.8570	720	3.7020	0.0000
	6:00 PM	0.0000	0.8258	720	3.5673	0.0000
30-Nov-92	6:00 PM	0.0000	0.7634	1440	6.5955	0.0000
			TOTAL		217.2261	20.171

APPENDIX III

FLOW AND SOIL LOSS IN PACHIM RIVER
JULY 1992

DATE	TIME	AV SEDIMENT gm\litre	AV "Q" CUMEC	TIME INTERVAL MINUTES	WATER FLOW HA.MT.	SOIL LOSS MT
20-Jul-92	12:00 PM	0.0085	0.8518			
	4:00 PM	0.0661	1.7036	240	2.4532	1.6203
	6:00 PM	0.0638	1.7036	120	1.2266	0.7820
21-Jul-92	8:00 AM	0.0157	1.7036	840	8.5861	1.3480
	12:00 PM	0.0156	1.7036	240	2.4532	0.3815
	6:00 PM	0.0303	1.7036	360	3.6798	1.1150
22-Jul-92	6:00 AM	0.0243	1.7036	720	7.3596	1.7847
	8:00 AM	0.0077	1.7036	120	1.2266	0.0938
	10:00 AM	0.0077	1.7036	120	1.2266	0.0938
	12:00 PM	0.0122	1.7036	120	1.2266	0.1490
	4:00 PM	0.0231	1.7036	240	2.4532	0.5655
	6:00 PM	0.0186	1.7036	120	1.2266	0.2281
23-Jul-92	8:00 AM	0.0264	1.7036	840	8.5861	2.2667
	12:00 PM	0.0245	1.7036	240	2.4532	0.6010
	4:00 PM	0.0124	1.7036	240	2.4532	0.3042
	6:00 PM	0.0144	1.7036	120	1.2266	0.1766
24-Jul-92	8:00 AM	0.0166	1.7036	840	8.5861	1.4253
	10:00 AM	0.0140	1.7036	120	1.2266	0.1717
	6:00 PM	0.0262	1.7036	480	4.9064	1.2830
25-Jul-92	8:00 AM	0.0257	1.7036	840	8.5861	2.2023
	10:00 AM	0.0096	1.7036	120	1.2266	0.1171
	12:00 PM	0.0100	1.7036	120	1.2266	0.1220
	4:00 PM	0.0121	1.7036	240	2.4532	0.2956
	6:00 PM	0.0119	1.7036	120	1.2266	0.1460
26-Jul-92	8:00 AM	0.0128	1.7036	840	8.5861	1.0990
	10:00 AM	0.0144	2.3016	120	1.6572	0.2386
	12:00 PM	0.0333	2.7554	120	1.9839	0.6596
	4:00 PM	0.0370	2.1574	240	3.1066	1.1479
	6:00 PM	0.0267	1.7036	120	1.2266	0.3269
	8:00 PM	0.0198	1.7036	120	1.2266	0.2429
27-Jul-92	8:00 AM	0.0235	2.0131	720	8.6966	2.0437
	10:00 AM	0.1187	2.6111	120	1.8800	2.2316
	12:00 PM	0.3680	4.4436	120	3.1994	11.7722
	4:00 PM	0.3531	4.1551	240	5.9833	21.1272
	6:00 PM	0.1350	2.3226	120	1.6723	2.2567
28-Jul-92	8:00 AM	0.0712	2.3226	840	11.7059	8.3346
	10:00 AM	0.0271	2.3226	120	1.6723	0.4532
	12:00 PM	0.0209	2.3226	120	1.6723	0.3495
	4:00 PM	0.0250	2.3226	240	3.3445	0.8361
	6:00 PM	0.0539	2.3226	120	1.6723	0.9005

DATE	TIME	AV SEDIMENT gm\litre	AV "Q" CUMEC	TIME INTERVAL MINUTES	WATER FLOW HA.MT.	SOIL LOSS MT
29-Jul-92	8:00 AM	0.0510	2.0131	840	10.1460	5.1745
	10:00 AM	0.0174	1.7036	120	1.2266	0.2128
	12:00 PM	0.0164	1.7036	120	1.2266	0.2012
	4:00 PM	0.0205	1.7036	240	2.4532	0.5017
	6:00 PM	0.0267	1.7036	120	1.2266	0.3275
			PACHIM			
30-Jul-92	6:00 AM	0.0247	1.7036	720	7.3596	1.8141
	8:00 AM	0.0245	1.7036	120	1.2266	0.2999
	10:00 AM	0.0226	1.7036	120	1.2266	0.2772
	12:00 PM	0.0185	1.7036	120	1.2266	0.2269
	4:00 PM	0.0197	1.7036	240	2.4532	0.4821
31-Jul-92	8:00 AM	0.0304	2.0131	960	11.5955	3.5250
	10:00 AM	0.0358	2.3226	120	1.6723	0.5987
	12:00 PM	0.0266	2.3226	120	1.6723	0.4440
	4:00 PM	0.0236	2.0131	240	2.8989	0.6827
	6:00 PM	0.0942	1.7036	120	1.2266	1.1548
			TOTAL		185.398	87.21672

AUGUST 1992

DATE	TIME	AV SEDIMENT gm\litre	AV "Q" CUMEC	TIME INTERVAL MINUTES	WATER FLOW HA.MT.	SOIL LOSS MT
01-Aug-92	6:00 AM	0.0051	0.8518			
	8:00 AM	0.1157	1.7036	120	1.2266	1.4192
	10:00 AM	0.1241	1.7036	120	1.2266	1.5216
	12:00 PM	0.0212	1.7036	120	1.2266	0.2594
	2:00 PM	0.0162	1.7036	120	1.2266	0.1981
	4:00 PM	0.0224	1.7036	120	1.2266	0.2741
	6:00 PM	0.0979	1.7036	120	1.2266	1.2008
02-Aug-92	6:00 AM	0.0884	1.7036	720	7.3596	6.5022
	8:00 AM	0.0134	1.7036	120	1.2266	0.1644
	10:00 AM	0.0186	1.7036	120	1.2266	0.2275
	12:00 PM	0.0193	1.7036	120	1.2266	0.2367
	2:00 PM	0.0244	1.7036	120	1.2266	0.2987
	6:00 PM	0.0197	1.7036	240	2.4532	0.4833
03-Aug-92	6:00 AM	0.0114	1.7036	720	7.3596	0.8353
	8:00 AM	0.0109	1.7036	120	1.2266	0.1331
	10:00 AM	0.0087	1.7036	120	1.2266	0.1067
	12:00 PM	0.0085	1.7036	120	1.2266	0.1043
	2:00 PM	0.0093	1.7036	120	1.2266	0.1135
	4:00 PM	0.0118	1.7036	120	1.2266	0.1447
	6:00 PM	0.0125	1.7036	120	1.2266	0.1533
04-Aug-92	8:00 AM	0.0120	1.7036	840	8.5861	1.0346
	6:00 PM	0.0113	1.7036	600	6.1330	0.6900
05-Aug-92	6:00 PM	0.0142	2.1574	1440	18.6395	2.6375
06-Aug-92	8:00 AM	0.0178	2.3121	840	11.6530	2.0742
	6:00 PM	0.0128	2.1679	600	7.8043	0.9989

DATE	TIME	AV SEDIMENT gm\litre	AV "Q" CUMEC	TIME INTERVAL MINUTES	WATER FLOW HA.MT.	SOIL LOSS MT
07-Aug-92	8:00 AM	0.0134	1.8764	840	9.4568	1.2672
08-Aug-92	6:00 AM	0.0129	1.4301	1320	11.3264	1.4554
	8:00 AM	0.0078	1.4301	120	1.0297	0.0798
	4:00 PM	0.0076	1.4301	480	4.1187	0.3110
	6:00 PM	0.0113	1.4301	120	1.0297	0.1158
09-Aug-92	6:00 AM	0.1151	1.8764	720	8.1058	9.3298
	2:00 PM	0.1163	2.1679	480	6.2434	7.2611
	6:00 PM	0.0203	2.0131	240	2.8989	0.5870
10-Aug-92	8:00 AM	0.0227	1.7216	840	8.6769	1.9653
	12:00 PM	0.0170	1.5122	240	2.1775	0.3691
	4:00 PM	0.0379	1.5122	240	2.1775	0.8253
	6:00 PM	0.0656	1.4301	120	1.0297	0.6749
			PACHIM			
11-Aug-92	6:00 AM	0.0373	1.2934	720	5.5873	2.0841
	8:00 AM	0.0112	1.1566	120	0.8328	0.0933
	6:00 PM	0.0301	1.1566	600	4.1638	1.2512
12-Aug-92	6:00 AM	0.0254	1.1566	720	4.9965	1.2666
	2:00 PM	1.0018	1.5849	480	4.5644	45.7258
	4:00 PM	1.1160	2.0131	120	1.4494	16.1757
	6:00 PM	0.1445	1.8584	120	1.3380	1.9328
13-Aug-92	8:00 AM	0.0312	1.4301	840	7.2077	2.2488
	12:00 PM	0.0107	1.1566	240	1.6655	0.1782
14-Aug-92	6:00 AM	0.0091	1.2387	1080	8.0265	0.7264
	12:00 PM	0.0048	1.3207	360	2.8527	0.1369
	2:00 PM	0.2127	1.8217	120	1.3116	2.7891
	6:00 PM	0.3078	2.3226	240	3.3445	10.2945
15-Aug-92	6:00 AM	1.1694	5.1096	720	22.0735	258.1272
	8:00 AM	2.0872	8.2370	120	5.9306	123.7836
	10:00 AM	1.1172	5.5942	120	4.0278	44.9988
	12:00 PM	0.1368	2.3740	120	1.7093	2.3383
	4:00 PM	0.0492	1.9822	240	2.8543	1.4029
	6:00 PM	0.0409	2.0131	120	1.4494	0.5928
16-Aug-92	12:00 PM	0.0305	1.8692	1080	12.1121	3.6942
	6:00 PM	0.0104	1.4848	360	3.2072	0.3319
17-Aug-92	6:00 AM	0.0126	1.4301	720	6.1780	0.7753
	6:00 PM	0.0055	1.8764	720	8.1058	0.4458
18-Aug-92	12:00 PM	0.0048	1.8217	1080	11.8043	0.5607
19-Aug-92	12:00 PM	0.0113	1.2660	1440	10.9382	1.2306
21-Aug-92	6:00 PM	0.0438	1.3207	3240	25.6744	11.2454
22-Aug-92	12:00 PM	0.1511	2.6206	1080	16.9815	25.6505
25-Aug-92	2:00 PM	0.1213	2.7883	4440	74.2803	90.0649
	6:00 PM	0.0155	1.8893	240	2.7206	0.4217
26-Aug-92	12:00 PM	0.0194	2.3121	1080	14.9824	2.9066
27-Aug-92	2:00 PM	0.1017	2.3121	1560	21.6413	22.0092
	6:00 PM	0.1154	2.0131	240	2.8989	3.3453

DATE	TIME	AV SEDIMENT gm\litre	AV "Q" CUMEC	TIME INTERVAL MINUTES	WATER FLOW HA.MT.	SOIL LOSS MT
28-Aug-92	10:00 AM	0.0796	2.3121	960	13.3177	10.6009
	2:00 PM	0.0649	2.4669	240	3.5523	2.3036
29-Aug-92	6:00 AM	0.0172	2.2298	960	12.8434	2.2091
	8:00 AM	0.0145	1.9203	120	1.3826	0.1998
	6:00 PM	0.0153	1.8584	600	6.6901	1.0202
30-Aug-92	6:00 AM	0.0191	1.8584	720	8.0281	1.5334
	8:00 AM	0.0186	1.7036	120	1.2266	0.2281
	6:00 PM	0.0157	1.7036	600	6.1330	0.9598
31-Aug-92	12:00 PM	0.0200	1.6216	1080	10.5076	2.0963
	6:00 PM	0.0206	1.5669	360	3.3844	0.6972
			TOTAL		511.8606	746.7313

SEPTEMBER 1992

DATE	TIME	AV SEDIMENT gm\litre	AV "Q" CUMEC	TIME INTERVAL MINUTES	WATER FLOW HA.MT.	SOIL LOSS MT
09-Sep-92	8:00 AM	0.1141	0.7151			
10-Sep-92	6:00 AM	0.1199	1.2934	1320	10.2433	12.2818
	6:00 PM	0.0112	1.2387	720	5.3510	0.5993
11-Sep-92	6:00 PM	0.0105	1.5122	1440	13.0650	1.3718
13-Sep-92	6:00 PM	0.0093	1.8584	2880	32.1123	2.9704
14-Sep-92	6:00 PM	0.0237	1.8584	1440	16.0561	3.8053
15-Sep-92	12:00 PM	0.0319	1.6763	1080	10.8621	3.4650
			PACHIM			
16-Sep-92	6:00 PM	0.0198	1.5669	1800	16.9220	3.3421
17-Sep-92	12:00 PM	0.0136	1.4028	1080	9.0898	1.2362
	6:00 PM	0.0174	1.3207	360	2.8527	0.4949
18-Sep-92	6:00 AM	0.0202	1.2387	720	5.3510	1.0809
	6:00 PM	0.0170	1.1566	720	4.9965	0.8469
19-Sep-92	6:00 PM	0.0125	1.1566	1440	9.9930	1.2441
20-Sep-92	6:00 PM	0.0210	1.1566	1440	9.9930	2.0985
21-Sep-92	6:00 AM	0.0265	1.1566	720	4.9965	1.3241
	6:00 PM	0.0131	1.1566	720	4.9965	0.6545
22-Sep-92	8:00 AM	0.1450	1.1107	840	5.5979	8.1142
23-Sep-92	12:00 PM	0.1577	0.9960	1680	10.0392	15.8318
	4:00 PM	0.0355	0.9271	240	1.3350	0.4739
	6:00 PM	0.0287	0.9271	120	0.6675	0.1916
25-Sep-92	6:00 PM	0.0147	0.9271	2880	16.0203	2.3470
26-Sep-92	6:00 PM	0.0198	0.9271	1440	8.0101	1.5860
27-Sep-92	12:00 PM	0.0219	1.6249	1080	10.5290	2.3059
28-Sep-92	12:00 PM	0.1356	1.6249	1440	14.0387	19.0295
29-Sep-92	6:00 PM	0.1365	0.9271	1800	10.0127	13.6623
30-Sep-92	12:00 AM	0.0268	0.9271	360	2.0025	0.5367
	6:00 PM	0.0247	0.9271	1080	6.0076	1.4839
			TOTAL		241.1415	102.3786

DATE	TIME	AV SEDIMENT gm\litre	AV "Q" CUMEC	TIME INTERVAL MINUTES	WATER FLOW HA.MT.	SOIL LOSS MT
		OCOBER 1992				
07-Oct-92	6:00 PM	0.0037	0.3143			
08-Oct-92	10:00 AM	0.0096	0.6286	960	3.6207	0.3494
09-Oct-92	6:00 PM	0.0161	0.6286	1920	7.2415	1.1623
10-Oct-92	6:00 PM	0.0203	0.6286	1440	5.4311	1.1025
12-Oct-92	12:00 PM	0.0306	0.7320	2520	11.0671	3.3865
13-Oct-92	6:00 PM	0.0457	0.7665	1800	8.2777	3.7829
14-Oct-92	12:00 PM	0.0311	0.6976	1080	4.5204	1.4036
	6:00 PM	0.0092	0.6976	360	1.5068	0.1386
16-Oct-92	12:00 PM	0.0078	0.6976	2520	10.5477	0.8227
17-Oct-92	6:00 PM	0.0237	0.6976	1800	7.5341	1.7893
18-Oct-92	6:00 AM	0.0308	0.6976	720	3.0136	0.9297
	12:00 PM	0.0148	0.6976	360	1.5068	0.2223
	6:00 PM	0.0070	0.6976	360	1.5068	0.1055
19-Oct-92	12:00 PM	0.0154	0.6976	1080	4.5204	0.6939
	6:00 PM	0.0159	0.6976	360	1.5068	0.2396
20-Oct-92	6:00 AM	0.0326	0.6976	720	3.0136	0.9840
	6:00 PM	0.0328	0.6976	720	3.0136	0.9900
21-Oct-92	12:00 PM	0.0117	0.6976	1080	4.5204	0.5289
22-Oct-92	6:00 AM	0.0301	0.6804	1080	4.4087	1.3292
	12:00 PM	0.0270	0.6631	360	1.4323	0.3874
	6:00 PM	0.0170	0.6631	360	1.4323	0.2442
23-Oct-92	6:00 PM	0.0153	0.6459	1440	5.5801	0.8538
24-Oct-92	12:00 PM	0.0079	0.6114	1080	3.9615	0.3130
	6:00 PM	0.0096	0.5941	360	1.2833	0.1226
25-Oct-92	6:00 AM	0.0080	0.5941	720	2.5665	0.2040
	12:00 PM	0.0821	0.5941	360	1.2833	1.0529
	6:00 PM	0.1046	0.5941	360	1.2833	1.3423
26-Oct-92	6:00 AM	0.0345	0.5941	720	2.5665	0.8867
	6:00 PM	0.0728	0.5941	720	2.5665	1.8684
			PACHIM			
27-Oct-92	6:00 PM	0.0728	0.5941	1440	5.1330	3.7368
28-Oct-92	6:00 AM	0.0106	0.5941	720	2.5665	0.2721
	12:00 PM	0.0129	0.5941	360	1.2833	0.1649
	6:00 PM	0.0103	0.5941	360	1.2833	0.1322
29-Oct-92	6:00 PM	0.0000	0.5941	1440	5.1330	0.0000
30-Oct-92	6:00 PM	0.0000	0.5941	1440	5.1330	0.0000
			TOTAL		131.2457	31.5421

APNDX4

APPENDIX IV

FLOW AND SOIL LOSS IN RONGMUK RIVER
JULY 1992

DATE	TIME	AV SEDIMENT gm\litre	AV "Q" CUMEC	TIME INTERVAL MINUTES	WATER FLOW HA.MT.	SOIL LOSS MT
20-Jul-92	8:00 AM	0.0211				
	4:00 PM	0.0387	15.9530	480	45.9446	17.7576
	6:00 PM	0.0424	15.9530	120	11.4862	4.8701
21-Jul-92	6:00 AM	0.0425	14.7958	720	63.9179	27.1651
	8:00 AM	0.0390	13.6386	120	9.8198	3.8297
	10:00 AM	0.0550	13.6386	120	9.8198	5.3960
	12:00 PM	0.0662	14.7958	120	10.6530	7.0469
	4:00 PM	0.0475	15.9530	240	22.9723	10.9004
	10:00 PM	0.0662	13.6386	360	29.4594	19.5021
22-Jul-92	6:00 AM	0.0682	12.4814	480	35.9464	24.4975
	8:00 AM	0.0389	13.6386	120	9.8198	3.8150
	10:00 AM	0.0320	14.7958	120	10.6530	3.4090
	12:00 PM	0.0274	15.9530	120	11.4862	3.1472
	2:00 PM	0.0510	15.9530	120	11.4862	5.8579
	4:00 PM	0.0865	15.9530	120	11.4862	9.9298
	6:00 PM	0.0849	15.9530	120	11.4862	9.7460
23-Jul-92	4:00 AM	0.0514	15.9530	600	57.4308	29.5194
	6:00 AM	0.0556	15.9530	120	11.4862	6.3806
	8:00 AM	0.0662	15.9530	120	11.4862	7.5981
	10:00 AM	0.0977	14.7958	120	10.6530	10.4080
	12:00 PM	0.1750	13.6386	120	9.8198	17.1797
	2:00 PM	0.1447	13.6386	120	9.8198	14.2043
	4:00 PM	0.0725	13.6386	120	9.8198	7.1144
	6:00 PM	0.0855	12.4814	120	8.9866	7.6835
	8:00 PM	0.1171	11.3242	120	8.1534	9.5436
24-Jul-92	6:00 PM	0.0801	13.6386	1320	108.0177	86.5222
28-Jul-92	4:00 PM	0.0436	14.7958	5640	500.6899	218.0504
	6:00 PM	0.0611	13.6386	120	9.8198	5.9999
29-Jul-92	6:00 AM	0.0543	12.4814	720	53.9196	29.2514
	12:00 PM	0.0394	11.3242	360	24.4603	9.6251
	6:00 PM	0.0243	11.3242	360	24.4603	5.9438
30-Jul-92	6:00 AM	0.0388	11.3242	720	48.9205	18.956711
	6:00 PM	0.1124	12.4814	720	53.9196	60.605684
31-Jul-92	6:00 AM	0.1159	13.6386	720	58.9188	68.2868
	2:00 PM	0.0473	12.4814	480	35.9464	16.9847
	6:00 PM	0.0502	11.3242	240	16.3068	8.1860
			TOTAL		1379.4720	794.9148

DATE	TIME	AV SEDIMENT gm\litre	AV "Q" CUMEC	TIME INTERVAL MINUTES	WATER FLOW HA.MT.	SOIL LOSS MT
			AUGUST 1992			
01-Aug-92	6:00 AM	0.0185	5.6621			
	6:00 PM	0.0318	11.3242	720	48.9205	15.5323
03-Aug-92	6:00 PM	0.1278	11.3242	2880	195.6822	250.0818
04-Aug-92	6:00 AM	0.1790	11.3242	720	48.9205	87.5433
05-Aug-92	6:00 AM	0.1323	11.3242	1440	97.8411	129.4438
	6:00 PM	0.5991	12.4814	720	53.9196	323.0057
06-Aug-92	6:00 AM	0.5595	12.4814	720	53.9196	301.6535
	6:00 PM	0.0416	10.1670	720	43.9212	18.2712
			RONGMUK			
07-Aug-92	6:00 AM	0.0225	7.8525	720	33.9228	7.6157
08-Aug-92	6:00 AM	0.0209	6.6953	1440	57.8474	12.0612
09-Aug-92	6:00 AM	0.0175	7.8525	1440	67.8456	11.8391
11-Aug-92	6:00 PM	0.0162	7.8525	3600	169.6140	27.4775
12-Aug-92	6:00 AM	0.0338	6.6953	720	28.9237	9.7762
	6:00 PM	0.0301	6.6953	720	28.9237	8.6916
13-Aug-92	6:00 PM	0.0157	6.0804	1440	52.5342	8.2216
14-Aug-92	6:00 AM	0.0143	5.4654	720	23.6105	3.3645
	2:00 PM	0.1116	9.5520	480	27.5098	30.6871
15-Aug-92	4:00 AM	0.6294	29.7876	840	150.1295	944.8400
17-Aug-92	6:00 AM	0.5367	28.6304	3000	515.3472	2765.6107
	6:00 PM	0.1430	11.3242	720	48.9205	69.9564
18-Aug-92	6:00 PM	0.1377	9.0098	1440	77.8442	107.1915
	6:00 AM	0.0239	6.6953	720	28.9237	6.9128
	12:00 PM	0.0398	6.6953	360	14.4618	5.7558
	6:00 PM	0.0327	6.6953	360	14.4618	4.7218
20-Aug-92	6:00 AM	0.0190	6.6953	720	28.9237	5.4810
	6:00 PM	0.0381	6.0804	720	26.2671	9.9946
21-Aug-92	6:00 AM	0.0369	5.4654	720	23.6105	8.7005
	12:00 PM	0.0311	6.0804	360	13.1336	4.0780
	6:00 PM	0.2163	6.6953	360	14.4618	31.2810
22-Aug-92	6:00 AM	0.4370	9.0098	720	38.9221	170.0897
	6:00 PM	0.3295	10.1670	720	43.9212	144.6985
24-Aug-92	6:00 AM	0.1943	11.3242	2160	146.7610	285.0832
	6:00 PM	0.2075	11.3242	720	48.9203	101.5097
25-Aug-92	6:00 AM	0.1207	7.8525	720	33.9228	40.9279
	6:00 PM	0.3367	7.8525	720	33.9228	114.2181
26-Aug-92	6:00 PM	0.4788	7.8525	1440	67.8456	324.8108
27-Aug-92	6:00 AM	0.1817	6.6953	720	28.9237	52.5544
			TOTAL		2433.4817	6443.6822

DATE	TIME	AV SEDIMENT gm\litre	AV "Q" CUMEC	TIME INTERVAL MINUTES	WATER FLOW HA.MT.	SOIL LOSS MT
			SEPTEMBER 1992			
11-Sep-92	6:00 AM		0.0486	7.9765		
	12:00 PM	360	0.1689	17.4608	37.7154	63.7013
	6:00 PM	360	0.1941	17.4608	37.7154	73.2056
12-Sep-92	6:00 AM	720	0.3015	20.4765	88.4587	266.7029
	6:00 PM	720	0.3037	28.7481	124.1916	377.1079
13-Sep-92	6:00 AM	720	0.1485	34.7361	150.0601	222.8392
	6:00 PM	720	0.1228	26.4646	114.3271	140.3365
14-Sep-92	6:00 AM	720	0.0824	20.4765	88.4587	72.8900
	6:00 PM	720	0.1679	18.1621	78.4604	131.6958
15-Sep-92	6:00 AM	720	0.2053	10.1670	43.9212	90.1703
	2:00 PM	480	0.1385	10.1670	29.2808	40.5539
	6:00 PM	240	0.1691	11.3242	16.3068	27.5666
16-Sep-92	6:00 AM	720	0.1002	11.3242	48.9204	49.0182
20-Sep-92	6:00 AM	5760	0.0500	9.0097	311.3763	155.5324
	6:00 PM	720	0.0813	3.3477	14.4618	11.7503
21-Sep-92	6:00 AM	720	0.0371	6.6953	28.9237	10.7162
	6:00 PM	720	0.0134	6.6953	28.9237	3.8758
22-Sep-92	6:00 AM	720	0.0191	6.6953	28.9237	5.5100
	6:00 PM	720	0.0176	6.6953	28.9237	5.0906
			RONGMUK			
23-Sep-92	6:00 AM	720	0.0113	6.6953	28.9237	3.2539
	6:00 PM	720	0.0051	6.6953	28.9237	1.4606
24-Sep-92	6:00 AM	720	0.0106	6.6953	28.9237	3.0514
	6:00 PM	720	0.0443	6.6953	28.9237	12.7987
25-Sep-92	6:00 AM	720	0.0398	6.6953	28.9237	11.4972
26-Sep-92	6:00 AM	1440	0.0146	9.0097	77.8441	11.3263
	6:00 PM	720	0.0162	13.6386	58.9187	9.5448
27-Sep-92	6:00 AM	720	0.0842	17.4608	75.4308	63.5128
	6:00 PM	720	0.2490	18.9687	81.9447	204.0014
28-Sep-92	6:00 AM	720	0.2029	17.4608	75.4308	153.0115
	6:00 PM	720	0.0519	15.9530	68.9170	35.7679
30-Sep-92	6:00 AM	2160	0.0363	13.6386	176.7560	64.0740
	6:00 PM	720	0.0265	9.0097	38.9220	10.2949
			TOTAL		2098.1321	2331.8590
			OCTOBER 1992			
01-Oct-92	6:00 AM	0.0032	3.3477			
01-Oct-92	6:00 PM	0.0055	6.6953	720	28.9237	1.5763
02-Oct-92	6:00 AM	0.0070	6.6953	720	28.9237	2.0102
02-Oct-92	6:00 PM	0.0062	6.6953	720	28.9237	1.7933
03-Oct-92	6:00 AM	0.0046	6.6953	720	28.9237	1.3160
11-Oct-92	6:00 AM	0.0045	6.6953	11520	462.7791	20.5937

DATE	TIME	AV SEDIMENT gm\litre	AV "Q" CUMEC	TIME INTERVAL MINUTES	WATER FLOW HA.MT.	SOIL LOSS MT
11-Oct-92	6:00 PM	0.0178	9.0097	720	38.9220	6.9087
12-Oct-92	6:00 AM	0.0578	13.6386	720	58.9187	34.0550
12-Oct-92	6:00 PM	0.0583	13.6386	720	58.9187	34.3496
13-Oct-92	6:00 AM	0.0197	9.0097	720	38.9220	7.6676
13-Oct-92	6:00 PM	0.0047	6.6953	720	28.9237	1.3450
14-Oct-92	6:00 AM	0.0048	6.6953	720	28.9237	1.3739
14-Oct-92	6:00 PM	0.0128	4.5049	720	19.4610	2.4910
15-Oct-92	6:00 AM	0.0139	9.0097	720	38.9221	5.3907
15-Oct-92	6:00 PM	0.0544	7.8525	720	33.9229	18.4371
16-Oct-92	6:00 AM	0.0614	6.6953	720	28.9237	17.7591
16-Oct-92	6:00 PM	0.0195	7.8525	720	33.9229	6.6150
17-Oct-92	6:00 AM	0.0126	9.0097	720	38.9221	4.8847
			TOTAL		1026.0774	168.5668

APPENDIX V

FLOW AND SOIL LOSS IN GHATTA - HUSSAIN RIVER
JULY 1993

DATE	TIME	AV SEDIMENT gms	AV "Q" CUMEC	TIME INTERVAL MINUTES	WATER FLOW HA.MT.	SOIL LOSS MT
01-Jul-93	6:00 AM	0.2275				
	8:00 AM	0.3614	7.6700	120	5.5224	19.9552
	10:00 AM	0.1934	7.6700	120	5.5224	10.6803
	12:00 PM	0.0989	6.3915	120	4.6019	4.5490
02-Jul-93	6:00 AM	0.0501	3.7738	1080	24.4539	12.2514
	4:00 PM	0.0315	2.6983	600	9.7137	3.0550
05-Jul-93	6:00 AM	0.0254	2.0300	3720	45.3096	11.4860
	4:00 PM	0.0156	1.0980	600	3.9528	0.6166
06-Jul-93	6:00 AM	0.0233	1.0980	840	5.5339	1.2894
	4:00 PM	0.0201	1.0980	600	3.9528	0.7925
08-Jul-93	6:00 AM	0.0175	0.9665	2280	13.2217	2.3138
09-Jul-93	10:00 AM	0.1849	0.8350	1680	8.4168	15.5627
	12:00 PM	0.1956	0.9008	120	0.6485	1.2682
	4:00 PM	0.0343	0.9665	240	1.3918	0.4767
10-Jul-93	8:00 AM	0.0180	0.9665	960	5.5670	0.9993
	4:00 PM	0.0085	0.9665	480	2.7835	0.2366
11-Jul-93	10:00 AM	0.0112	0.9008	1080	5.8369	0.6508
	6:00 PM	0.0128	0.9008	480	2.5942	0.3321
12-Jul-93	10:00 AM	0.0175	0.9008	960	5.1883	0.9054
	4:00 PM	0.0393	0.9008	360	1.9456	0.7646
13-Jul-93	10:00 AM	0.0315	0.9008	1080	5.8369	1.8386
	4:00 PM	0.0253	0.9008	360	1.9456	0.4913
	6:00 PM	0.7099	2.3020	120	1.6574	11.7662
14-Jul-93	10:00 AM	0.7014	2.2363	960	12.8808	90.3395
	6:00 PM	0.0229	0.8350	480	2.4048	0.5495
15-Jul-93	6:00 AM	0.0511	1.1688	720	5.0490	2.5800
	8:00 AM	0.0561	1.5025	120	1.0818	0.6069
	10:00 AM	0.0320	1.5025	120	1.0818	0.3456
	4:00 PM	0.0955	1.7048	360	3.6823	3.5147
16-Jul-93	8:00 AM	0.0828	1.9070	960	10.9843	9.0895
	2:00 PM	0.0161	1.7048	360	3.6823	0.5928
	6:00 PM	0.0193	1.5025	240	2.1636	0.4176
17-Jul-93	10:00 AM	0.0274	1.5025	960	8.6544	2.3713
	12:00 PM	0.0381	1.5025	120	1.0818	0.4122
	4:00 PM	0.0329	1.3003	240	1.8724	0.6151
18-Jul-93	6:00 AM	0.0179	1.0323	840	5.2025	0.9287
	8:00 AM	0.0198	1.0323	120	0.7432	0.1472
19-Jul-93	8:00 AM	0.0314	1.5025	1440	12.9816	4.0762
	10:00 AM	0.0385	1.9070	120	1.3730	0.5286
	4:00 PM	0.0499	2.0125	360	4.3470	2.1670
	6:00 PM	0.0632	2.1180	120	1.5250	0.9638
20-Jul-93	6:00 AM	0.0412	1.8103	720	7.8203	3.2180

DATE	TIME	AV SEDIMENT gms	AV "Q" CUMEC	TIME INTERVAL MINUTES	WATER FLOW HA.MT.	SOIL LOSS MT
21-Jul-93	12:00 PM	0.0227	1.3003	1800	14.0427	3.1807
	2:00 PM	0.1824	2.7055	120	1.9480	3.5531
	4:00 PM	0.3822	4.7130	120	3.3934	12.9677
	6:00 PM	0.2471	3.5100	120	2.5272	6.2447
22-Jul-93	6:00 AM	0.0722	1.9070	720	8.2382	5.9439
	8:00 AM	0.0496	1.9070	120	1.3730	0.6803
	6:00 PM	0.0205	1.5025	600	5.4090	1.1088

GHATTA - HUSSAIN

DATE	TIME	AV SEDIMENT gms	AV "Q" CUMEC	TIME INTERVAL MINUTES	WATER FLOW HA.MT.	SOIL LOSS MT
23-Jul-93	8:00 AM	0.0268	1.0980	840	5.5339	1.4803
	4:00 PM	0.0275	1.0980	480	3.1622	0.8680
24-Jul-93	8:00 AM	0.0302	1.4216	960	8.1884	2.4688
	12:00 PM	0.0301	1.6239	240	2.3383	0.7038
	4:00 PM	0.0294	1.3003	240	1.8724	0.5505
25-Jul-93	6:00 PM	0.0367	1.3003	1560	12.1703	4.4665
26-Jul-93	12:00 AM	0.0278	1.3003	360	2.8085	0.7794
	6:00 PM	0.0223	1.0980	1080	7.1150	1.5867
28-Jul-93	10:00 AM	0.0133	1.0980	2400	15.8112	2.0950
	4:00 PM	0.0199	1.0980	360	2.3717	0.4708
29-Jul-93	10:00 AM	0.0203	1.0980	1080	7.1150	1.4408
	4:00 PM	0.0165	1.2194	360	2.6338	0.4346
30-Jul-93	12:00 AM	0.4520	3.2269	480	9.2933	42.0012
	6:00 AM	0.0160	3.0661	360	6.6227	1.0596
	4:00 PM	0.4580	1.2608	600	4.5389	20.7858
31-Jul-93	12:00 AM	0.0350	1.7048	480	4.9097	1.7184
	6:00 AM	0.0279	1.7857	360	3.8570	1.0761
	8:00 AM	0.5018	3.3887	120	2.4398	12.2431
	2:00 PM	0.0768	3.5100	360	7.5816	5.8227
	4:00 PM	0.5084	1.9070	120	1.3730	6.9798
			TOTAL		402.8779	368.4569

AUGUST 1993

DATE	TIME	AV SEDIMENT gms	AV "Q" CUMEC	TIME INTERVAL MINUTES	WATER FLOW HA.MT.	SOIL LOSS MT
01-Aug-93	6:00 PM	0.0174				
02-Aug-93	6:00 AM	0.0258	1.0980	720	4.7434	1.2214
	8:00 AM	0.0233	1.0980	120	0.7906	0.1842
	12:00 PM	0.0329	1.0980	240	1.5811	0.5202
03-Aug-93	12:00 PM	0.0380	1.0980	1440	9.4867	3.6002
	4:00 PM	0.0322	1.0980	240	1.5811	0.5091
	6:00 PM	0.0206	1.5025	120	1.0818	0.2229
04-Aug-93	4:00 PM	0.0148	1.5025	1320	11.8998	1.7612
	6:00 PM	0.0179	1.0980	120	0.7906	0.1411

DATE	TIME	AV SEDIMENT gms	AV "Q" CUMEC	TIME INTERVAL MINUTES	WATER FLOW HA.MT.	SOIL LOSS MT
05-Aug-93	6:00 AM	0.0207	1.5025	720	6.4908	1.3436
	8:00 AM	0.0213	1.9070	120	1.3730	0.2918
	12:00 PM	0.0397	1.7048	240	2.4548	0.9733
	4:00 PM	0.0390	1.7048	240	2.4548	0.9562
	6:00 PM	0.0327	2.1180	120	1.5250	0.4979
06-Aug-93	6:00 AM	0.0381	2.6455	720	11.4286	4.3486
	12:00 PM	0.0273	2.5928	360	5.6003	1.5261
	4:00 PM	0.1080	2.9305	240	4.2199	4.5575
	6:00 PM	0.1501	3.6375	120	2.6190	3.9298
07-Aug-93	6:00 AM	0.0765	2.7723	720	11.9761	9.1557
	8:00 AM	0.0345	1.9070	120	1.3730	0.4730
	10:00 AM	0.0268	1.9070	120	1.3730	0.3680
	4:00 PM	0.0188	1.8261	360	3.9444	0.7415
08-Aug-93	6:00 AM	0.0192	1.8261	840	9.2035	1.7625
	8:00 AM	0.0271	1.9070	120	1.3730	0.3721
	6:00 PM	0.0197	1.8261	600	6.5740	1.2951
09-Aug-93	6:00 AM	0.0185	1.8261	720	7.8888	1.4555
	8:00 AM	0.0216	1.9070	120	1.3730	0.2959
	2:00 PM	0.0316	2.0653	360	4.4609	1.4097
	4:00 PM	0.0298	2.0653	120	1.4870	0.4424

GHATTA - HUSSAIN

DATE	TIME	AV SEDIMENT gms	AV "Q" CUMEC	TIME INTERVAL MINUTES	WATER FLOW HA.MT.	SOIL LOSS MT
10-Aug-93	8:00 AM	0.0139	1.7857	960	10.2853	1.4297
	10:00 AM	0.0099	1.6643	120	1.1983	0.1180
	4:00 PM	0.0108	1.6239	360	3.5075	0.3771
	6:00 PM	0.0119	1.5834	120	1.1400	0.1357
11-Aug-93	6:00 AM	0.0249	1.8507	720	7.9950	1.9908
	8:00 AM	0.0342	2.0125	120	1.4490	0.4948
	2:00 PM	0.0207	1.8261	360	3.9444	0.8165
	4:00 PM	0.0105	1.7452	120	1.2565	0.1313
12-Aug-93	6:00 AM	0.0139	1.6239	840	8.1842	1.1335
	4:00 PM	0.0154	1.5025	600	5.4090	0.8330
13-Aug-93	6:00 AM	0.0227	1.3003	840	6.5533	1.4876
	4:00 PM	0.0221	1.0980	600	3.9528	0.8716
14-Aug-93	6:00 AM	0.0194	1.2194	840	6.1455	1.1922
	8:00 AM	0.0248	1.3407	120	0.9653	0.2389
	4:00 PM	0.1147	1.7821	480	5.1324	5.8844
	6:00 PM	0.1960	2.1708	120	1.5629	3.0634
15-Aug-93	10:00 AM	0.1069	1.6080	960	9.2621	9.8965
	6:00 PM	0.0202	1.0323	480	2.9729	0.5990
16-Aug-93	6:00 AM	0.0284	0.9665	720	4.1753	1.1837
	4:00 PM	0.0339	0.9928	600	3.5741	1.2098
17-Aug-93	6:00 AM	0.0175	0.9928	840	5.0037	0.8731
	8:00 AM	0.0143	0.9665	120	0.6959	0.0995
	4:00 PM	0.0128	0.9665	480	2.7835	0.3549
	6:00 PM	0.0152	0.9665	120	0.6959	0.1054

DATE	TIME	AV SEDIMENT gms	AV "Q" CUMEC	TIME INTERVAL MINUTES	WATER FLOW HA.MT.	SOIL LOSS MT
18-Aug-93	6:00 AM	0.0163	0.9271	720	4.0049	0.6528
	6:00 PM	0.0216	0.8876	720	3.8344	0.8282
19-Aug-93	6:00 AM	0.0218	0.8876	720	3.8344	0.8340
	8:00 AM	0.0183	0.8876	120	0.6391	0.1170
	4:00 PM	0.0948	0.9928	480	2.8593	2.7106
	6:00 PM	0.1243	1.0980	120	0.7906	0.9827
20-Aug-93	8:00 AM	0.0502	1.0323	840	5.2025	2.6117
	6:00 PM	0.0176	0.9402	600	3.3847	0.5940
21-Aug-93	8:00 AM	0.0158	0.9139	840	4.6061	0.7278
22-Aug-93	6:00 AM	0.1186	2.6135	1320	20.6985	24.5484
	8:00 AM	0.2336	4.3130	120	3.1054	7.2541
	4:00 PM	0.1687	3.3738	480	9.7164	16.3916
	6:00 PM	0.0935	2.4345	120	1.7528	1.6389
23-Aug-93	8:00 AM	0.0615	2.1708	840	10.9406	6.7230
	10:00 AM	0.0392	1.9070	120	1.3730	0.5382
	4:00 PM	0.0300	1.7048	360	3.6823	1.1047
	6:00 PM	0.0338	1.5025	120	1.0818	0.3651
24-Aug-93	6:00 AM	0.4209	4.5863	720	19.8126	83.3813
	8:00 AM	0.5551	6.7915	120	4.8899	27.1437
	4:00 PM	0.1979	3.9100	480	11.2608	22.2851
	6:00 PM	0.0657	1.9070	120	1.3730	0.9014
25-Aug-93	6:00 AM	0.0663	2.4345	720	10.5170	6.9675
	6:00 PM	0.0689	2.4345	720	10.5170	7.2462
26-Aug-93	8:00 AM	0.0459	2.1708	840	10.9406	5.0217
	12:00 PM	0.0208	2.4345	240	3.5057	0.7274
	6:00 PM	0.0140	2.2763	360	4.9167	0.6883

GHATTA – HUSSAIN

DATE	TIME	AV SEDIMENT gms	AV "Q" CUMEC	TIME INTERVAL MINUTES	WATER FLOW HA.MT.	SOIL LOSS MT
27-Aug-93	6:00 AM	0.0108	2.0125	720	8.6940	0.9346
	10:00 AM	0.0158	1.9070	240	2.7461	0.4325
	6:00 PM	0.0218	1.7857	480	5.1427	1.1211
28-Aug-93	6:00 AM	0.0146	1.6643	720	7.1898	1.0461
	6:00 PM	0.0113	1.6643	720	7.1898	0.8088
30-Aug-93	6:00 AM	0.0198	1.7857	2160	23.1420	4.5705
	6:00 PM	0.0223	1.9070	720	8.2382	1.8371
			TOTAL		440.5758	312.6132

DATE	TIME	AV SEDIMENT gms	AV "Q" CUMEC	TIME INTERVAL MINUTES	WATER FLOW HA.MT.	SOIL LOSS MT
			SEPTEMBER 1993			
01-Sep-93	6:00 AM					
	6:00 PM	0.0110	1.5025	720	6.4908	0.7140
03-Sep-93	8:00 AM	0.0091	1.3003	2280	17.7874	1.6098
	10:00 AM	0.0088	1.0980	120	0.7906	0.0692
	6:00 PM	0.5466	3.5055	480	10.0958	55.1839
04-Sep-93	6:00 AM	0.5481	3.6269	720	15.6680	85.8684
	6:00 PM	0.0216	1.2194	720	5.2676	1.1352
05-Sep-93	6:00 AM	0.0223	1.0980	720	4.7434	1.0578
	6:00 PM	0.0119	1.2194	720	5.2676	0.6242
06-Sep-93	6:00 AM	0.0122	1.3407	720	5.7918	0.7037
	6:00 PM	0.0126	1.2194	720	5.2676	0.6611
07-Sep-93	8:00 AM	0.0875	2.4353	840	12.2739	10.7397
	10:00 AM	0.2858	5.7213	120	4.1193	11.7731
	12:00 PM	0.0422	5.5862	120	4.0221	1.6973
	4:00 PM	0.0745	2.7047	240	3.8948	2.9016
08-Sep-93	6:00 AM	0.0468	1.9070	840	9.6113	4.4933
	8:00 AM	0.0294	1.9070	120	1.3730	0.4030
	12:00 PM	0.0390	1.7857	240	2.5713	1.0028
	6:00 PM	0.0513	2.2077	360	4.7685	2.4439
10-Sep-93	6:00 AM	0.0406	2.0459	2160	26.5142	10.7648
	6:00 PM	0.0248	1.3407	720	5.7918	1.4364
11-Sep-93	6:00 AM	0.0211	1.2194	720	5.2676	1.1088
	6:00 PM	0.0094	1.0980	720	4.7434	0.4435
12-Sep-93	6:00 AM	0.0121	1.0323	720	4.4593	0.5373
	6:00 PM	0.0121	0.9665	720	4.1753	0.5031
13-Sep-93	6:00 AM	0.0142	0.9271	720	4.0049	0.5687
	12:00 PM	0.0094	0.8876	360	1.9172	0.1802
	4:00 PM	0.0090	0.8876	240	1.2781	0.1144
14-Sep-93	6:00 AM	0.0151	1.1951	840	6.0231	0.9095
	6:00 PM	0.0267	1.2608	720	5.4467	1.4543
15-Sep-93	6:00 AM	0.0436	1.3417	720	5.7961	2.5242
	6:00 PM	0.0416	1.5834	720	6.8403	2.8421
16-Sep-93	6:00 AM	0.0393	1.5025	720	6.4908	2.5509
	6:00 PM	0.0476	1.3003	720	5.6171	2.6709
17-Sep-93	6:00 AM	0.0351	1.0980	720	4.7434	1.6649
	12:00 PM	0.0177	1.0717	360	2.3149	0.4097
	6:00 PM	0.0134	1.0323	360	2.2297	0.2988
18-Sep-93	6:00 AM	0.0080	1.0191	720	4.4025	0.3500
	6:00 PM	0.0033	1.0191	720	4.4025	0.1453
20-Sep-93	8:00 AM	0.0047	0.9928	2280	13.5815	0.6315
	12:00 PM	0.0065	0.9665	240	1.3918	0.0905
	6:00 PM	0.0136	0.9665	360	2.0876	0.2829

DATE	TIME	AV SEDIMENT gms	AV "Q" CUMEC	TIME INTERVAL MINUTES	WATER FLOW HA.MT.	SOIL LOSS MT
			GHATTA - HUSSAIN			
21-Sep-93	6:00 AM	0.0178	1.1536	720	4.9836	0.8871
	6:00 PM	0.0204	1.1536	720	4.9836	1.0142
23-Sep-93	8:00 AM	0.0224	0.9402	2280	12.8619	2.8746
	10:00 AM	0.2775	4.2920	120	3.0902	8.5753
	6:00 PM	0.3232	4.7885	480	13.7909	44.5721
24-Sep-93	6:00 AM	0.1492	1.9070	720	8.2382	12.2873
	12:00 PM	0.1249	1.8261	360	3.9444	4.9265
	4:00 PM	0.0434	1.7048	240	2.4548	1.0642
25-Sep-93	6:00 AM	0.0235	1.6643	840	8.3881	1.9670
	10:00 AM	0.0202	1.6643	240	2.3966	0.4829
	4:00 PM	0.0188	1.6643	360	3.5949	0.6758
	6:00 PM	0.0264	1.6643	120	1.1983	0.3158
27-Sep-93	6:00 AM	0.0551	2.1549	2160	27.9275	15.3881
	8:00 AM	0.0513	2.5400	120	1.8288	0.9373
	10:00 AM	0.0318	2.1708	120	1.5629	0.4970
	4:00 PM	0.0345	1.9070	360	4.1191	1.4190
	6:00 PM	0.0817	2.1708	120	1.5629	1.2769
28-Sep-93	6:00 AM	0.0932	2.0090	720	8.6787	8.0842
	10:00 AM	0.0558	1.5834	240	2.2801	1.2712
	6:00 PM	0.0428	1.4621	480	4.2107	1.8022
29-Sep-93	6:00 AM	0.0223	1.2194	720	5.2676	1.1747
	10:00 AM	0.0147	1.0980	240	1.5811	0.2316
	6:00 PM	0.0115	1.0980	480	3.1622	0.3621
30-Sep-93	6:00 AM	0.0140	1.0980	720	4.7434	0.6641
	2:00 PM	0.0144	1.0980	480	3.1622	0.4538
	6:00 PM	0.0116	1.0980	240	1.5811	0.1826
			TOTAL		390.9183	328.952

OCTOBER 1993

01-Oct-93	6:00 AM	0.0303	0.5490			
	12:00 PM	0.0362	1.0980	360	2.3717	0.8574
02-Oct-93	6:00 AM	0.0264	2.0300	1080	13.1544	3.4662
	6:00 PM	0.0357	2.4345	720	10.5170	3.7493
03-Oct-93	6:00 AM	0.0354	1.9070	720	8.2382	2.9122
	6:00 PM	0.0324	1.9070	720	8.2382	2.6692
04-Oct-93	6:00 AM	0.0190	1.9070	720	8.2382	1.5611
	12:00 PM	0.0112	2.0125	360	4.3470	0.4869
05-Oct-93	6:00 AM	0.0169	1.6889	1080	10.9441	1.8495
	4:00 PM	0.0154	1.1789	600	4.2440	0.6536
	6:00 PM	0.0140	1.0980	120	0.7906	0.1103
06-Oct-93	6:00 AM	0.0187	1.0586	720	4.5729	0.8529
	10:00 AM	0.0257	1.0191	240	1.4675	0.3771

DATE	TIME	AV SEDIMENT gms	AV "Q" CUMEC	TIME INTERVAL MINUTES	WATER FLOW HA.MT.	SOIL LOSS MT
07-Oct-93	6:00 AM	0.0218	1.0060	1200	7.2428	1.5753
	4:00 PM	0.0158	0.9928	600	3.5741	0.5629
08-Oct-93	6:00 AM	0.0213	0.9797	840	4.9374	1.0492
	6:00 PM	0.0131	0.9665	720	4.1753	0.5449
09-Oct-93	6:00 AM	0.0103	0.9008	720	3.8912	0.4008
	6:00 PM	0.0130	0.8350	720	3.6072	0.4689
10-Oct-93	6:00 AM	0.0107	0.8350	720	3.6072	0.3842
	6:00 PM	0.0139	0.8350	720	3.6072	0.4996
11-Oct-93	6:00 AM	0.0162	0.8350	720	3.6072	0.5844
	6:00 PM	0.0250	0.8350	720	3.6072	0.9018
			GHATTA - HUSSAIN			
12-Oct-93	6:00 AM	0.0222	0.8350	720	3.6072	0.8008
	6:00 PM	0.0102	0.8350	720	3.6072	0.3679
13-Oct-93	6:00 AM	0.0137	0.7508	720	3.2432	0.4443
	6:00 PM	0.0217	0.6665	720	2.8793	0.6248
14-Oct-93	6:00 AM	0.0168	0.6665	720	2.8793	0.4823
	6:00 PM	0.0068	0.6665	720	2.8793	0.1944
15-Oct-93	6:00 AM	0.0109	0.6665	720	2.8793	0.3124
	6:00 PM	0.0089	0.6665	720	2.8793	0.2548
16-Oct-93	6:00 AM	0.0040	0.6665	720	2.8793	0.1152
	6:00 PM	0.0040	0.6665	720	2.8793	0.1152
17-Oct-93	6:00 AM	0.0125	0.6665	720	2.8793	0.3585
	6:00 PM	0.0119	0.6665	720	2.8793	0.3426
18-Oct-93	6:00 AM	0.0044	0.6665	720	2.8793	0.1252
	6:00 PM	0.0024	0.6665	720	2.8793	0.0691
19-Oct-93	6:00 AM	0.0000	0.5823	720	2.5153	0.0000
	6:00 PM	0.0035	0.4980	720	2.1514	0.0753
20-Oct-93	6:00 AM	0.0035	0.4980	720	2.1514	0.0753
	6:00 PM	0.0015	0.4980	720	2.1514	0.0323
21-Oct-93	6:00 AM	0.0033	0.4980	720	2.1514	0.0699
	6:00 PM	0.0037	0.4980	720	2.1514	0.0796
22-Oct-93	6:00 AM	0.0029	0.4980	720	2.1514	0.0613
	6:00 PM	0.0009	0.4980	720	2.1514	0.0194
23-Oct-93	6:00 AM	0.0021	0.4980	720	2.1514	0.0452
	6:00 PM	0.0041	0.4980	720	2.1514	0.0882
24-Oct-93	6:00 AM	0.0022	0.4980	720	2.1514	0.0463
	6:00 PM	0.0019	0.4980	720	2.1514	0.0409
25-Oct-93	6:00 AM	0.0054	0.4980	720	2.1514	0.1162
	6:00 PM	0.0041	0.4980	720	2.1514	0.0871
26-Oct-93	6:00 AM	0.0004	0.4980	720	2.1514	0.0086
	6:00 PM	0.0010	0.4980	720	2.1514	0.0215
27-Oct-93	6:00 AM	0.0010	0.4980	720	2.1514	0.0215
	6:00 PM	0.0013	0.4980	720	2.1514	0.0269

DATE	TIME	AV SEDIMENT gms	AV "Q" CUMEC	TIME INTERVAL MINUTES	WATER FLOW HA.MT.	SOIL LOSS MT
28-Oct-93	6:00 AM	0.0043	0.4980	720	2.1514	0.0925
	6:00 PM	0.0055	0.4980	720	2.1514	0.1183
29-Oct-93	6:00 AM	0.0031	0.4980	720	2.1514	0.0656
	6:00 PM	0.0021	0.4980	720	2.1514	0.0441
30-Oct-93	6:00 AM	0.0047	0.4980	720	2.1514	0.1011
	6:00 PM	0.0063	0.4980	720	2.1514	0.1355
			TOTAL		213.1071	32.5978

NOVEMBER 1993

DATE	TIME	AV SEDIMENT gms	AV "Q" CUMEC	TIME INTERVAL MINUTES	WATER FLOW HA.MT.	SOIL LOSS MT
01-Nov-93	6:00 AM	0.0015	0.2285			
	6:00 PM	0.0043	0.4570	720	1.97424	0.0839
02-Nov-93	6:00 AM	0.0085	0.4570	720	1.97424	0.1668
	6:00 PM	0.0108	0.4570	720	1.97424	0.2122
03-Nov-93	6:00 AM	0.0070	0.4570	720	1.97424	0.1372
	6:00 PM	0.0034	0.4570	720	1.97424	0.0671
04-Nov-93	6:00 AM	0.0042	0.4570	720	1.97424	0.0829
	10:00 PM	0.0043	0.4570	960	2.63232	0.1132
05-Nov-93	2:00 PM	0.0043	0.4570	960	2.63232	0.1132
	6:00 PM	0.0042	0.4570	240	0.65808	0.0276

GHATTA - HUSSAIN

DATE	TIME	AV SEDIMENT gms	AV "Q" CUMEC	TIME INTERVAL MINUTES	WATER FLOW HA.MT.	SOIL LOSS MT
06-Nov-93	6:00 AM	0.0015	0.4570	720	1.97424	0.0296
	6:00 PM	0.0000	0.4570	720	1.97424	0.0000
07-Nov-93	6:00 AM	0.0066	0.4570	720	1.97424	0.1293
	6:00 PM	0.0070	0.4570	720	1.97424	0.1372
08-Nov-93	6:00 AM	0.0010	0.4570	720	1.97424	0.0197
	6:00 PM	0.0006	0.4570	720	1.97424	0.0118
			TOTAL		29.6136	1.3320

APPENDIX VI

FLOW AND SOIL LOSS IN RINCHINTONG RIVER
JULY 1993

DATE	TIME	AV SEDIMENT gm\litre	AV "Q" CUMEC	TIME INTERVAL MINUTES	WATER FLOW HA.MT.	SOIL LOSS MT
01-Jul-93	6:00 AM	0.1511	9.0098			
	10:00 AM	0.4339	14.8755	240	21.4207	92.9336
	12:00 PM	0.4060	11.7313	120	8.4465	34.2929
02-Jul-93	6:00 AM	0.1366	9.9620	1080	64.5534	88.1800
04-Jul-93	6:00 AM	0.0187	6.7721	2880	117.0217	21.8245
05-Jul-93	6:00 AM	0.0112	5.5829	1440	48.2366	5.4025
06-Jul-93	6:00 AM	0.0206	5.6601	1440	48.9029	10.0495
	6:00 PM	0.0147	5.6601	720	24.4515	3.5821
07-Jul-93	6:00 AM	0.0035	5.8143	720	25.1178	0.8791
	6:00 PM	0.0064	5.6601	720	24.4515	1.5649
08-Jul-93	6:00 AM	0.0115	5.6601	720	24.4515	2.7997
	12:00 PM	0.0136	5.9685	360	12.8920	1.7533
09-Jul-93	6:00 AM	0.0090	5.9685	1080	38.6761	3.4615
	12:00 PM	0.0098	4.7650	360	10.2923	1.0035
12-Jul-93	8:00 AM	0.0094	4.5336	4080	110.9829	10.4324
	4:00 PM	0.0060	5.1202	480	14.7462	0.8848
13-Jul-93	6:00 AM	0.0119	5.0431	840	25.4172	3.0119
	6:00 PM	0.0171	4.9660	720	21.4530	3.6685
14-Jul-93	6:00 AM	0.0131	5.1202	720	22.1194	2.8976
15-Jul-93	6:00 AM	0.0402	8.1664	1440	70.5578	28.3289
	12:00 PM	0.0906	10.3774	360	22.4151	20.2969
	2:00 PM	0.0941	9.6580	120	6.9537	6.5435
16-Jul-93	6:00 AM	0.0959	8.3725	960	48.2253	46.2240
17-Jul-93	6:00 AM	0.0776	7.2796	1440	62.8956	48.7755
	10:00 AM	0.0536	6.6626	240	9.5942	5.1377
19-Jul-93	8:00 AM	0.0758	9.3792	2760	155.3194	117.7321
	10:00 AM	0.0985	12.5452	120	9.0325	8.8970
	6:00 PM	0.1052	12.3643	480	35.6092	37.4431
20-Jul-93	6:00 AM	0.0644	10.9210	720	47.1786	30.3830
	6:00 PM	0.0291	9.1311	720	39.4463	11.4789
21-Jul-93	6:00 AM	0.0198	7.6398	720	33.0040	6.5348
	12:00 PM	0.0116	6.7397	360	14.5578	1.6814
	4:00 PM	1.3299	15.3860	240	22.1559	294.6402
22-Jul-93	6:00 AM	1.3715	16.2861	840	82.0820	1125.7552
	4:00 PM	0.5521	8.4434	600	30.3961	167.8170
23-Jul-93	6:00 AM	0.5051	7.8582	840	39.6055	200.0475
	6:00 PM	0.0193	8.1926	720	35.3920	6.8307
24-Jul-93	6:00 AM	0.0245	7.9548	720	34.3646	8.4193
	12:00 PM	0.0124	6.8940	360	14.8910	1.8390
	6:00 PM	0.0172	7.1318	360	15.4047	2.6419

DATE	TIME	AV SEDIMENT gm\litre	AV "Q" CUMEC	TIME INTERVAL MINUTES	WATER FLOW HA.MT.	SOIL LOSS MT
25-Jul-93	4:00 PM	0.0172	7.5239	1320	59.5891	10.2493
26-Jul-93	6:00 AM	0.0098	6.6691	840	33.6122	3.2772
	2:00 PM	0.2435	6.7527	480	19.4477	47.3552
	6:00 PM	0.2456	6.7527	240	9.7239	23.8818
27-Jul-93	6:00 AM	0.0189	5.9685	720	25.7841	4.8603
	4:00 PM	0.0218	5.8143	600	20.9315	4.5526
			RINCHINTONG			
28-Jul-93	8:00 AM	0.0087	5.5058	960	31.7135	2.7591
29-Jul-93	8:00 AM	0.0080	5.6601	1440	48.9029	3.8878
31-Jul-93	8:00 AM	0.0309	5.9685	2880	103.1364	31.8176
	12:00 PM	0.0333	6.5855	240	9.4831	3.1531
			TOTAL		1855.0393	2601.8643

AUGUST 1993

DATE	TIME	AV SEDIMENT gm\litre	AV "Q" CUMEC	TIME INTERVAL MINUTES	WATER FLOW HA.MT.	SOIL LOSS MT
01-Aug-93	8:00 AM	0.0303	2.9072			
	4:00 PM	0.0597	5.5829	480	16.0789	9.5991
03-Aug-93	8:00 AM	0.0335	5.5829	2400	80.3943	26.8919
	4:00 PM	0.0130	5.5829	480	16.0789	2.0903
04-Aug-93	6:00 AM	0.0115	5.4287	840	27.3606	3.1465
	4:00 PM	0.0653	5.2745	600	18.9881	12.3897
05-Aug-93	6:00 AM	0.2528	5.8143	840	29.3041	74.0807
	10:00 AM	0.3004	6.4313	240	9.2610	27.8201
	2:00 PM	0.1952	6.3541	240	9.1500	17.8607
06-Aug-93	6:00 AM	0.1845	6.4313	960	37.0441	68.3278
	8:00 AM	0.1269	6.4313	120	4.6305	5.8761
	10:00 AM	0.0445	6.3541	120	4.5750	2.0336
	12:00 PM	0.0362	6.2770	120	4.5195	1.6338
	4:00 PM	0.0240	6.1999	240	8.9279	2.1427
08-Aug-93	8:00 AM	0.0283	6.2770	2400	90.3891	25.5801
	10:00 AM	0.0553	6.5084	120	4.6860	2.5914
	2:00 PM	0.0453	6.5084	240	9.3721	4.2409
	4:00 PM	0.0478	6.4313	120	4.6305	2.2111
09-Aug-93	8:00 AM	0.0582	6.5084	960	37.4883	21.7994
	10:00 AM	0.0347	6.5855	120	4.7416	1.6453
	12:00 PM	0.0517	6.5084	120	4.6860	2.4203
10-Aug-93	10:00 AM	0.0971	6.5084	1320	51.5464	50.0515
	12:00 PM	0.0625	6.1999	120	4.4639	2.7877
	4:00 PM	0.0525	5.8143	240	8.3726	4.3914
11-Aug-93	6:00 AM	0.0562	6.0457	840	30.4701	17.1090
	4:00 PM	0.0628	6.0457	600	21.7644	13.6571

DATE	TIME	AV SEDIMENT gm\litre	AV "Q" CUMEC	TIME INTERVAL MINUTES	WATER FLOW HA.MT.	SOIL LOSS MT
12-Aug-93	6:00 AM	0.0792	5.9685	840	30.0814	23.8095
	8:00 AM	0.0396	6.1228	120	4.4084	1.7435
	12:00 PM	0.0173	6.1999	240	8.9279	1.5401
	4:00 PM	0.0325	6.0457	240	8.7058	2.8294
13-Aug-93	8:00 AM	0.0318	5.6601	960	32.6019	10.3511
	4:00 PM	0.0096	5.3516	480	15.4126	1.4796
14-Aug-93	6:00 AM	0.0571	5.2745	840	26.5833	15.1791
	2:00 PM	0.1005	6.0457	480	17.4115	17.4986
	4:00 PM	0.0566	6.3541	120	4.5750	2.5872
15-Aug-93	6:00 AM	0.0114	5.8914	840	29.6928	3.3850
	4:00 PM	0.0072	5.8143	600	20.9315	1.5071
16-Aug-93	8:00 AM	0.0035	5.8143	960	33.4904	1.1722
	4:00 PM	0.0030	5.4287	480	15.6347	0.4690
17-Aug-93	6:00 AM	0.0034	5.0431	840	25.4172	0.8515
	4:00 PM	0.0070	4.7346	600	17.0446	1.1931
18-Aug-93	6:00 AM	0.0060	4.5804	840	23.0851	1.3851
	6:00 PM	0.0005	4.3920	720	18.9735	0.0949
19-Aug-93	6:00 AM	0.0017	4.1607	720	17.9740	0.3056
	6:00 PM	0.0040	4.3490	720	18.7878	0.7421

RINCHINTONG

DATE	TIME	AV SEDIMENT gm\litre	AV "Q" CUMEC	TIME INTERVAL MINUTES	WATER FLOW HA.MT.	SOIL LOSS MT
20-Aug-93	6:00 AM	0.0058	4.5033	720	19.4541	1.1186
	6:00 PM	0.0041	4.3149	720	18.6403	0.7549
21-Aug-93	6:00 AM	0.0049	4.0494	720	17.4934	0.8484
	4:00 PM	0.0083	3.9382	600	14.1773	1.1767
22-Aug-93	8:00 AM	0.0248	4.5892	960	26.4340	6.5556
	2:00 PM	0.0716	5.5829	360	12.0592	8.6283
	4:00 PM	0.6865	13.0570	120	9.4010	64.5334
	6:00 PM	1.2349	20.6491	120	14.8673	183.5891
	8:00 PM	1.1069	20.7655	120	14.9512	165.4944
23-Aug-93	6:00 AM	0.5488	14.3626	600	51.7054	283.7332
24-Aug-93	6:00 AM	0.1417	13.1061	1440	113.2369	160.4567
	8:00 AM	0.1482	18.0197	120	12.9741	19.2277
	10:00 AM	0.1978	18.0197	120	12.9741	25.6564
	2:00 PM	0.3091	17.9081	240	25.7876	79.6967
	4:00 PM	0.3823	17.9081	120	12.8938	49.2931
25-Aug-93	8:00 AM	0.2885	14.4233	960	83.0784	239.6395
	4:00 PM	0.1025	9.7606	480	28.1104	28.8132
26-Aug-93	6:00 AM	0.0501	7.6398	840	38.5047	19.2716
	4:00 PM	0.1207	6.5084	600	23.4302	28.2802
27-Aug-93	6:00 AM	0.1311	6.1228	840	30.8588	40.4405
	6:00 PM	0.0747	5.6601	720	24.4515	18.2652

DATE	TIME	AV SEDIMENT gm\litre	AV "Q" CUMEC	TIME INTERVAL MINUTES	WATER FLOW HA.MT.	SOIL LOSS MT
28-Aug-93	8:00 AM	0.1175	5.5058	840	27.7493	32.6055
	6:00 PM	0.1369	5.4287	600	19.5433	26.7548
30-Aug-93	6:00 AM	0.0880	5.5058	2160	71.3554	62.7571
	6:00 PM	0.0563	5.5058	720	23.7851	13.3791
31-Aug-93	6:00 AM	0.0565	5.5829	720	24.1183	13.6268
	6:00 PM	0.0318	5.8143	720	25.1178	7.9875
			TOTAL		1705.8159	2073.0858

SEPTEMBER 1993

DATE	TIME	AV SEDIMENT gm\litre	AV "Q" CUMEC	TIME INTERVAL MINUTES	WATER FLOW HA.MT.	SOIL LOSS MT
01-Sep-93	6:00 AM	0.0149	2.9072			
	6:00 PM	0.0384	5.6601	720	24.4515	9.3771
02-Sep-93	6:00 AM	0.0428	5.6601	720	24.4515	10.4530
	6:00 PM	0.0437	5.8143	720	25.1178	10.9639
03-Sep-93	6:00 AM	0.0270	5.6601	720	24.4515	6.6019
	6:00 PM	0.0293	5.2745	720	22.7857	6.6648
04-Sep-93	6:00 AM	0.0518	4.8117	720	20.7867	10.7675
	10:00 AM	0.0506	4.5033	240	6.4847	3.2780
	4:00 PM	0.0634	4.5033	360	9.7270	6.1669
05-Sep-93	6:00 AM	0.0670	4.9660	840	25.0285	16.7566
	6:00 PM	0.0538	5.1202	720	22.1194	11.9002
06-Sep-93	2:00 PM	0.0722	5.2745	1200	37.9761	27.4188
	6:00 PM	0.0531	5.5829	240	8.0394	4.2689
07-Sep-93	10:00 AM	0.1165	8.6186	960	49.6429	57.8340
	12:00 PM	0.4263	11.7313	120	8.4465	36.0076
	4:00 PM	0.3721	11.1892	240	16.1125	59.9546
08-Sep-93	6:00 AM	0.0929	8.2307	840	41.4829	38.5168
	6:00 PM	0.1079	5.8914	720	25.4509	27.4488
09-Sep-93	6:00 AM	0.1037	5.5058	720	23.7851	24.6652
	6:00 PM	0.0872	4.8117	720	20.7867	18.1156
10-Sep-93	6:00 AM	0.1126	4.8117	720	20.7867	23.3954

RINCHINTONG

DATE	TIME	AV SEDIMENT gm\litre	AV "Q" CUMEC	TIME INTERVAL MINUTES	WATER FLOW HA.MT.	SOIL LOSS MT
11-Sep-93	6:00 AM	0.0711	4.8117	1440	41.5734	29.5587
	6:00 PM	0.0287	4.3705	720	18.8806	5.4093
12-Sep-93	2:00 PM	0.0344	4.1050	1200	29.5562	10.1525
13-Sep-93	6:00 AM	0.0247	4.1050	960	23.6449	5.8403
	4:00 PM	0.0115	4.2163	600	15.1786	1.7455
14-Sep-93	6:00 AM	0.0156	5.5829	840	28.1380	4.3895
	12:00 PM	0.0441	6.5855	360	14.2247	6.2660
15-Sep-93	8:00 AM	0.1133	6.8169	1200	49.0814	55.5847
	12:00 PM	0.1261	7.1253	240	10.2605	12.9333
	6:00 PM	0.0914	6.3541	360	13.7249	12.5446

DATE	TIME	AV SEDIMENT gm\litre	AV "Q" CUMEC	TIME INTERVAL MINUTES	WATER FLOW HA.MT.	SOIL LOSS MT
16-Sep-93	6:00 AM	0.0680	5.8143	720	25.1178	17.0675
	4:00 PM	0.0421	5.5058	600	19.8210	8.3446
17-Sep-93	6:00 AM	0.0213	4.6790	840	23.5821	5.0112
	6:00 PM	0.0197	3.9382	720	17.0128	3.3515
18-Sep-93	6:00 AM	0.0224	3.8269	720	16.5322	3.6949
	6:00 PM	0.0129	3.7713	720	16.2919	2.1017
19-Sep-93	6:00 AM	0.0198	3.9382	720	17.0128	3.3600
	6:00 PM	0.0460	4.2163	720	18.2143	8.3786
20-Sep-93	6:00 AM	0.0434	4.1607	720	17.9740	7.8007
	6:00 PM	0.0161	3.9938	720	17.2531	2.7778
21-Sep-93	6:00 AM	0.0230	3.9382	720	17.0128	3.9044
	2:00 PM	0.0344	3.9382	480	11.3419	3.8959
	6:00 PM	0.0639	3.7713	240	5.4306	3.4675
22-Sep-93	6:00 AM	0.0609	3.9382	720	17.0128	10.3608
	8:00 PM	0.0362	4.3705	840	22.0274	7.9629
23-Sep-93	6:00 AM	0.0578	5.0431	600	18.1552	10.4846
	8:00 AM	0.0405	5.5058	120	3.9642	1.6055
	12:00 PM	0.0424	6.4313	240	9.2610	3.9267
	6:00 PM	0.0439	6.5855	360	14.2247	6.2446
24-Sep-93	6:00 AM	0.0396	5.8143	720	25.1178	9.9341
	6:00 PM	0.0779	5.5829	720	24.1183	18.7761
25-Sep-93	6:00 AM	0.0571	5.2745	720	22.7857	12.9992
	12:00 PM	0.0185	4.9660	360	10.7265	1.9790
	6:00 PM	0.0130	4.7346	360	10.2268	1.3295
26-Sep-93	6:00 AM	0.0101	5.1202	720	22.1194	2.2341
	6:00 PM	0.0099	5.2745	720	22.7857	2.2558
27-Sep-93	8:00 AM	0.0237	5.5829	840	28.1380	6.6546
	6:00 PM	0.0408	5.8143	600	20.9315	8.5400
28-Sep-93	6:00 AM	0.0295	5.3516	720	23.1188	6.8085
30-Sep-93	6:00 AM	0.0070	4.8117	2880	83.1469	5.7787
			TOTAL		1302.6351	746.0115

OCTOBER 1993

03-Oct-93	6:00 AM	0.0010	2.2902			
04-Oct-93	6:00 AM	0.0054	4.5033	1440	38.9082	2.1010
05-Oct-93	6:00 AM	0.0102	4.2378	1440	36.6143	3.7347
06-Oct-93	6:00 AM	0.0123	3.9382	1440	34.0256	4.1681
07-Oct-93	6:00 AM	0.0165	3.6600	1440	31.6226	5.2019
08-Oct-93	6:00 AM	0.0198	3.4932	1440	30.1808	5.9607
09-Oct-93	6:00 AM	0.0113	3.4375	1440	29.7002	3.3413
10-Oct-93	6:00 AM	0.0022	3.2163	1440	27.7884	0.6113
11-Oct-93	6:00 AM	0.0011	3.0506	1440	26.3572	0.2899

DATE	TIME	AV SEDIMENT gm\litre	AV "Q" CUMEC	TIME INTERVAL MINUTES	WATER FLOW HA.MT.	SOIL LOSS MT
			RINCHINTONG			
12-Oct-93	6:00 AM	0.0014	3.1050	1440	26.8272	0.3756
13-Oct-93	6:00 AM	0.0021	3.1594	1440	27.2972	0.5596
14-Oct-93	6:00 AM	0.0028	3.0506	1440	26.3572	0.7248
	10:00 AM	0.0111	2.9418	240	4.2362	0.4681
15-Oct-93	6:00 AM	0.0173	2.9418	1440	25.4172	4.3845
16-Oct-93	6:00 AM	0.0222	2.7786	1440	24.0071	5.3176
17-Oct-93	6:00 AM	0.0106	2.5066	1440	21.6570	2.2956
18-Oct-93	6:00 AM	0.0079	2.3978	1440	20.7170	1.6366
19-Oct-93	6:00 AM	0.0045	2.2890	1440	19.7770	0.8900
20-Oct-93	6:00 AM	0.0016	2.1802	1440	18.8369	0.2920
21-Oct-93	6:00 AM	0.0027	2.1802	1440	18.8369	0.4992
27-Oct-93	6:00 AM	0.0025	1.9904	8640	103.1836	2.5280
28-Oct-93	6:00 AM	0.0058	1.7555	1440	15.1677	0.8797
29-Oct-93	6:00 AM	0.0055	1.7104	1440	14.7779	0.8128
30-Oct-93	6:00 AM	0.0026	1.7104	1440	14.7779	0.3768
			TOTAL		637.0713	47.4499

NOVEMBER 1993

03-Nov-93	6:00 AM	0.0188	0.7650			
04-Nov-93	6:00 AM	0.0233	1.4848	1440	12.8285	2.9890
05-Nov-93	6:00 AM	0.0100	1.4397	1440	12.4386	1.2376
06-Nov-93	6:00 AM	0.0065	1.3945	1440	12.0487	0.7832
			TOTAL		37.3157	5.0098

APPENDIX VII

FLOW AND SOIL LOSS IN PACHIM RIVER
JULY 1993

DATE	TIME	AV SEDIMENT gm\litre	AV "Q" CUMEC	TIME INTERVAL SECONDS	WATER FLOW HA.MT.	SOIL LOSS MT
10-Jul-93	6:00 AM	0.0157	0.4636			
	6:00 PM	0.0981	0.9271	720	4.0051	3.9290
11-Jul-93	6:00 AM	0.0956	0.9271	720	4.0051	3.8268
	12:00 PM	0.0427	0.9271	360	2.0025	0.8541
	6:00 PM	0.0365	0.9271	360	2.0025	0.7309
12-Jul-93	6:00 AM	0.1016	0.9271	720	4.0051	4.0692
	10:00 AM	0.6825	0.9271	240	1.3350	9.1109
	12:00 PM	0.6276	0.9271	120	0.6675	4.1893
	2:00 PM	0.9949	0.9271	120	0.6675	6.6411
	6:00 PM	0.9679	0.9271	240	1.3350	12.9217
13-Jul-93	6:00 AM	0.0194	0.9271	720	4.0051	0.7750
	12:00 PM	0.0140	0.8124	360	1.7547	0.2457
	2:00 PM	0.2942	1.0639	120	0.7660	2.2535
	4:00 PM	0.4546	1.4301	120	1.0297	4.6804
	6:00 PM	0.5635	1.4301	120	1.0297	5.8022
14-Jul-93	6:00 AM	0.4091	1.2934	720	5.5873	22.8547
	12:00 PM	0.0247	1.0419	360	2.2504	0.5558
	6:00 PM	0.0189	0.9271	360	2.0025	0.3775
15-Jul-93	6:00 AM	0.5617	6.2422	720	26.9663	151.4697
	8:00 AM	1.4769	6.9400	120	4.9968	73.7972
	10:00 AM	1.0096	2.4669	120	1.7761	17.9318
	12:00 PM	0.1209	2.6111	120	1.8800	2.2720
	6:00 PM	0.1086	2.3121	360	4.9941	5.4211
16-Jul-93	6:00 AM	0.2000	1.8584	720	8.0281	16.0521
	12:00 PM	0.1898	1.8584	360	4.0140	7.6166
	6:00 PM	0.1984	2.0131	360	4.3483	8.6248
17-Jul-93	6:00 AM	0.1627	1.7216	720	7.4373	12.0968
	12:00 PM	0.0547	1.7216	360	3.7187	2.0341
	6:00 PM	0.0675	2.0131	360	4.3483	2.9351
18-Jul-93	6:00 AM	0.0851	1.8584	720	8.0281	6.8319
	12:00 PM	0.1258	1.7036	360	3.6798	4.6292
	6:00 PM	0.1392	1.7036	360	3.6798	5.1222
19-Jul-93	6:00 AM	1.8449	17.5962	720	76.0156	1402.3735
	8:00 AM	2.9861	21.2600	120	15.3072	457.0796
	2:00 PM	1.2817	6.1504	360	13.2848	170.2707
	4:00 PM	0.1378	3.2696	120	2.3541	3.2428
	6:00 PM	0.0939	3.1771	120	2.2875	2.1468
20-Jul-93	6:00 AM	0.0556	2.8479	720	12.3027	6.8342
	12:00 PM	0.0325	2.4669	360	5.3284	1.7317
	6:00 PM	0.0444	2.3226	360	5.0168	2.2250

DATE	TIME	AV SEDIMENT gm\litre	AV "Q" CUMEC	TIME INTERVAL SECONDS	WATER FLOW HA.MT.	SOIL LOSS MT
21-Jul-93	6:00 AM	0.0483	2.1679	720	9.3651	4.5233
	10:00 AM	0.0219	2.0131	240	2.8989	0.6349
	12:00 PM	0.0223	2.1679	120	1.5609	0.3473
	4:00 PM	1.1249	17.9057	240	25.7842	290.0337
	6:00 PM	2.1685	19.3295	120	13.9172	301.7946
22-Jul-93	6:00 AM	1.0910	3.8906	720	16.8074	183.3602
	12:00 PM	0.0390	2.3121	360	4.9941	1.9452
	6:00 PM	0.0185	2.1679	360	4.6826	0.8639

PACHIM

DATE	TIME	AV SEDIMENT gm\litre	AV "Q" CUMEC	TIME INTERVAL SECONDS	WATER FLOW HA.MT.	SOIL LOSS MT
23-Jul-93	6:00 AM	0.0089	2.1679	720	9.3651	0.8335
	8:00 AM	0.0046	2.0131	120	1.4494	0.0659
	12:00 PM	0.0056	2.0131	240	2.8989	0.1609
	2:00 PM	0.0572	2.0131	120	1.4494	0.8284
	4:00 PM	0.0996	2.0131	120	1.4494	1.4429
	6:00 PM	0.0655	2.0131	120	1.4494	0.9494
24-Jul-93	6:00 AM	0.0295	1.8584	720	8.0281	2.3643
	8:00 AM	0.0573	1.7036	120	1.2266	0.7022
	10:00 AM	0.0752	2.1574	120	1.5533	1.1681
	4:00 PM	0.0515	2.3121	360	4.9941	2.5720
	6:00 PM	0.0250	2.3121	120	1.6647	0.4162
25-Jul-93	6:00 AM	0.0085	2.1574	720	9.3198	0.7922
	10:00 AM	0.0168	1.7036	240	2.4532	0.4109
	12:00 PM	0.0175	1.7036	120	1.2266	0.2147
	4:00 PM	0.0155	1.7036	240	2.4532	0.3802
	6:00 PM	0.0150	1.8584	120	1.3380	0.2000
26-Jul-93	6:00 AM	0.0139	1.5849	720	6.8466	0.9517
	10:00 AM	0.0170	1.1566	240	1.6655	0.2823
	12:00 PM	0.0162	1.2934	120	0.9312	0.1504
	4:00 PM	0.0179	1.7216	240	2.4791	0.4438
	6:00 PM	0.0133	2.0131	120	1.4494	0.1920
27-Jul-93	6:00 AM	0.0057	1.8584	720	8.0281	0.4536
	10:00 AM	0.0104	1.7036	240	2.4532	0.2539
	12:00 PM	0.0144	1.7036	120	1.2266	0.1760
	4:00 PM	0.0166	1.7036	240	2.4532	0.4060
	6:00 PM	0.0152	1.5669	120	1.1281	0.1715
28-Jul-93	6:00 AM	0.0120	1.4301	720	6.1780	0.7414
	10:00 AM	0.0126	1.4301	240	2.0593	0.2584
	12:00 PM	0.0155	1.4301	120	1.0297	0.1591
	4:00 PM	0.0151	1.4301	240	2.0593	0.3099
	6:00 PM	0.0124	1.4301	120	1.0297	0.1272

DATE	TIME	AV SEDIMENT gm\litre	AV "Q" CUMEC	TIME INTERVAL MINUTES	WATER FLOW HA.MT.	SOIL LOSS MT
29-Jul-93	6:00 AM	0.0084	1.4301	720	6.1780	0.5190
	10:00 AM	0.0059	1.4301	240	2.0593	0.1205
	12:00 PM	0.0058	1.4301	120	1.0297	0.0597
	4:00 PM	0.0065	1.2934	240	1.8624	0.1201
	6:00 PM	0.0064	1.1566	120	0.8328	0.0533
30-Jul-93	6:00 AM	0.0095	1.2934	720	5.5873	0.5280
	10:00 AM	0.0136	1.4301	240	2.0593	0.2790
	12:00 PM	0.0135	1.4301	120	1.0297	0.1390
	4:00 PM	0.0118	1.7216	240	2.4791	0.2913
	6:00 PM	0.0180	2.0131	120	1.4494	0.2609
31-Jul-93	6:00 AM	0.0173	1.7216	720	7.4373	1.2867
	10:00 AM	0.0102	1.4301	240	2.0593	0.2101
	12:00 PM	0.5634	1.8764	120	1.3510	7.6114
	4:00 PM	0.6307	2.4669	240	3.5523	22.4024
	6:00 PM	0.1735	2.4669	120	1.7761	3.0816
			TOTAL		472.3330	3285.6015

PACHIM

OCTOBER 1993

DATE	TIME	AV SEDIMENT gm\litre	AV "Q" CUMEC	TIME INTERVAL MINUTES	WATER FLOW HA.MT.	SOIL LOSS MT
02-Oct-93	6:00 AM					
	12:00 PM	0.0091	2.0206	360	4.3645	0.3950
	6:00 PM	0.0067	1.4301	360	3.0890	0.2054
04-Oct-93	6:00 AM	0.0047	1.2934	2160	16.7618	0.7794
	12:00 PM	0.0034	1.1566	360	2.4983	0.0849
	6:00 PM	0.0034	1.1566	360	2.4983	0.0849
05-Oct-93	6:00 AM	0.0019	1.1566	720	4.9965	0.0924
	12:00 PM	0.0033	1.1566	360	2.4983	0.0824
	6:00 PM	0.0027	1.1566	360	2.4983	0.0675
06-Oct-93	6:00 AM	0.0025	1.0419	720	4.5008	0.1103
	12:00 PM	0.0028	0.9271	360	2.0025	0.0561
	6:00 PM	0.0031	0.9271	360	2.0025	0.0621
07-Oct-93	6:00 AM	0.0029	0.9271	720	4.0051	0.1161
	12:00 PM	0.0019	0.9271	360	2.0025	0.0380
	6:00 PM	0.0034	0.9271	360	2.0025	0.0681
08-Oct-93	6:00 AM	0.0032	0.9271	720	4.0051	0.1282
	12:00 PM	0.0024	0.9271	360	2.0025	0.0481
	6:00 PM	0.0026	0.9271	360	2.0025	0.0521
09-Oct-93	6:00 AM	0.0017	0.9271	720	4.0051	0.0661
	12:00 PM	0.0019	0.9271	360	2.0025	0.0370
	6:00 PM	0.0182	0.9271	360	2.0025	0.3635
11-Oct-93	6:00 AM	0.0192	0.9271	2160	12.0152	2.3069
	12:00 PM	0.0029	0.9271	360	2.0025	0.0581
	6:00 PM	0.0052	0.9271	360	2.0025	0.1041

DATE	TIME	AV SEDIMENT gm\litre	AV "Q" CUMEC	TIME INTERVAL MINUTES	WATER FLOW HA.MT.	SOIL LOSS MT
12-Oct-93	6:00 AM	0.0055	0.9271	720	4.0051	0.2203
	12:00 PM	0.0017	0.9271	360	2.0025	0.0340
	6:00 PM	0.0019	0.9271	360	2.0025	0.0380
13-Oct-93	6:00 AM	0.0027	0.9271	720	4.0051	0.1061
	12:00 PM	0.0024	0.9271	360	2.0025	0.0481
	6:00 PM	0.0015	0.9271	360	2.0025	0.0290
14-Oct-93	6:00 PM	0.0091	0.9271	1440	8.0101	0.7289
15-Oct-93	6:00 AM	0.0095	0.9271	720	4.0051	0.3785
	12:00 PM	0.0014	0.9271	360	2.0025	0.0280
	6:00 PM	0.0011	0.9271	360	2.0025	0.0210
16-Oct-93	6:00 AM	0.0020	0.9271	720	4.0051	0.0801
	12:00 PM	0.0018	0.9271	360	2.0025	0.0360
	6:00 PM	0.0021	0.9271	360	2.0025	0.0421
18-Oct-93	6:00 AM	0.0010	0.9271	2520	14.0178	0.1402
	12:00 PM	0.0021	0.9271	360	2.0025	0.0411
	6:00 PM	0.0021	0.9271	360	2.0025	0.0411
19-Oct-93	6:00 AM	0.0015	0.9271	720	4.0051	0.0581
	12:00 PM	0.0015	0.9271	360	2.0025	0.0300
	6:00 PM	0.0019	0.9271	360	2.0025	0.0370
20-Oct-93	6:00 AM	0.0029	0.9271	1080	6.0076	0.1712
	12:00 PM	0.0030	0.9271	360	2.0025	0.0601
	6:00 PM	0.0015	0.9271	360	2.0025	0.0290
			TOTAL		163.8578	7.8048

APPENDIX VIII

FLOW AND SOIL LOSS IN RONGMUK RIVER
JULY 1993

DATE	TIME	AV SEDIMENT	AV "Q"	TIME INTERVAL MINUTES	WATER FLOW HA.MT.	SOIL LOSS MT
09-Jul-93	6:00 AM	0.0012	6.8193			
10-Jul-93	6:00 AM	0.0046	14.7958	1440	127.8356	5.8165
11-Jul-93	6:00 AM	0.0084	15.9530	1440	137.8339	11.5091
15-Jul-93	4:00 PM	0.0877	18.9687	6360	723.8454	634.4505
16-Jul-93	6:00 AM	0.1080	21.9844	840	110.8013	119.6654
17-Jul-93	6:00 AM	0.0443	25.0001	1440	216.0008	95.5804
18-Jul-93	6:00 AM	0.0882	32.4960	1440	280.7655	247.6352
19-Jul-93	8:00 AM	0.1989	41.4564	1560	388.0320	771.7956
20-Jul-93	8:00 AM	0.3457	36.9762	1440	319.4744	1104.2632
21-Jul-93	8:00 AM	0.2640	20.8272	1440	179.9469	475.0599
24-Jul-93	8:00 AM	0.0736	14.7958	4320	383.5069	282.0693
26-Jul-93	8:00 AM	0.0628	14.7958	2880	255.6713	160.4337
27-Jul-93	8:00 AM	0.0449	13.6386	1440	117.8373	52.9090
28-Jul-93	8:00 AM	0.0155	12.4814	1440	107.8390	16.7151
29-Jul-93	8:00 AM	0.0146	11.3242	1440	97.8407	14.2847
			TOTAL		3447.2311	3992.1876

AUGUST 1993

DATE	TIME	AV SEDIMENT	AV "Q"	TIME INTERVAL MINUTES	WATER FLOW HA.MT.	SOIL LOSS MT
06-Aug-93	4:00 PM	0.0085	7.9765			
08-Aug-93	8:00 AM	0.0447	15.9530	2400	229.7232	102.5714
09-Aug-93	8:00 AM	0.0597	15.9530	1440	137.8339	82.2869
10-Aug-93	8:00 AM	0.0261	15.9530	1440	137.8339	35.9057
11-Aug-93	8:00 AM	0.0087	18.9687	1440	163.8895	14.1764
	4:00 PM	0.0084	18.9687	480	54.6298	4.5616
12-Aug-93	8:00 AM	0.0052	15.9530	960	91.8892	4.7323
13-Aug-93	8:00 AM	0.0051	14.7958	1440	127.8356	6.4557
	4:00 PM	0.0221	13.6386	480	39.2791	8.6807
16-Aug-93	8:00 AM	0.0271	13.6386	3840	314.2328	85.0000
17-Aug-93	8:00 AM	0.0151	13.6386	1440	117.8373	17.7934
18-Aug-93	8:00 AM	0.0174	14.7958	1440	127.8356	22.2434
19-Aug-93	8:00 AM	0.0157	13.6386	1440	117.8373	18.4415
	4:00 PM	0.2707	16.6543	480	47.9643	129.8394
20-Aug-93	8:00 AM	0.2716	17.8115	960	102.5941	278.5944
	4:00 PM	0.0142	12.4814	480	35.9463	5.1044
22-Aug-93	8:00 AM	0.1120	28.6304	2400	412.2774	461.5446
23-Aug-93	8:00 AM	0.0335	9.4843	1440	81.9447	27.4515
24-Aug-93	8:00 AM	0.0925	21.9844	1440	189.9451	175.6043
25-Aug-93	4:00 PM	0.0719	21.9844	1920	253.2601	182.0941

DATE	TIME	AV SEDIMENT	AV "Q"	TIME INTERVAL MINUTES	WATER FLOW HA.MT.	SOIL LOSS MT
26-Aug-93	4:00 PM	0.0184	18.9687	1440	163.8894	30.0737
27-Aug-93	8:00 AM	0.0106	18.9687	960	109.2596	11.5815
28-Aug-93	8:00 AM	0.0114	17.4608	1440	150.8616	17.1982
29-Aug-93	8:00 AM	0.0146	15.9530	1440	137.8339	20.1238
30-Aug-93	8:00 AM	0.0148	15.9530	1440	137.8339	20.3305
31-Aug-93	8:00 AM	0.0107	13.6386	1440	117.8373	12.5497
			TOTAL		3602.1058	1774.9391

RONGMUK

SEPTEMBER 1993

01-Sep-93	8:00 AM	0.0020	5.6621			
02-Sep-93	8:00 AM	0.0053	12.4814	1440	107.8393	5.6616
03-Sep-93	8:00 AM	0.0053	13.6386	1440	117.8375	6.2454
04-Sep-93	8:00 AM	0.0044	13.6386	1440	117.8375	5.1259
	2:00 PM	0.0207	13.6386	360	29.4594	6.0834
05-Sep-93	8:00 AM	0.0391	13.6386	1080	88.3781	34.5558
06-Sep-93	8:00 AM	0.0520	13.6386	1440	117.8375	61.2755
07-Sep-93	4:00 PM	0.0494	13.6386	1920	157.1167	77.5371
09-Sep-93	4:00 PM	0.0203	13.6386	2880	235.6750	47.8420
10-Sep-93	2:00 PM	0.0045	13.6386	1320	108.0177	4.8068
11-Sep-93	8:00 AM	0.0052	13.6386	1080	88.3781	4.5957
12-Sep-93	4:00 PM	0.0130	13.6386	1920	157.1167	20.3466
13-Sep-93	10:00 AM	0.0154	13.6386	1080	88.3781	13.5660
15-Sep-93	4:00 PM	0.0167	14.7958	3240	287.6304	48.0343
16-Sep-93	4:00 PM	0.0150	13.6386	1440	117.8375	17.6167
17-Sep-93	2:00 PM	0.0079	10.1670	1320	80.5224	6.3210
21-Sep-93	8:00 AM	0.0074	9.0097	5400	291.9156	21.4558
22-Sep-93	10:00 AM	0.0157	4.5049	1560	42.1656	6.6200
23-Sep-93	2:00 PM	0.0227	11.3242	1680	114.1475	25.9115
24-Sep-93	10:00 AM	0.0477	14.7958	1200	106.5297	50.7614
25-Sep-93	8:00 AM	0.2455	12.4814	1320	98.8525	242.6828
26-Sep-93	2:00 PM	0.2151	10.1670	1800	109.8031	236.1864
27-Sep-93	2:00 PM	0.0110	13.6386	1440	117.8373	12.9032
28-Sep-93	8:00 AM	0.0090	12.4814	1080	80.8793	7.2387
			TOTAL		2861.9924	963.3735

DATE	TIME	AV SEDIMENT	AV "Q"	TIME INTERVAL MINUTES	WATER FLOW HA.MT.	SOIL LOSS MT
			OCTOBER 1993			
04-Oct-93	4:00 PM	0.0025	4.5049			
05-Oct-93	4:00 PM	0.0074	9.0097	1440	77.8442	5.7605
06-Oct-93	8:00 AM	0.0086	9.0097	960	51.8961	4.4631
07-Oct-93	8:00 AM	0.0082	9.0097	1440	77.8442	6.3832
09-Oct-93	8:00 AM	0.0070	9.0097	2880	155.6883	10.8982
11-Oct-93	8:00 AM	0.0057	9.0097	2880	155.6883	8.7964
12-Oct-93	8:00 AM	0.0054	10.1670	1440	87.8424	4.7435
13-Oct-93	8:00 AM	0.0045	10.1670	1440	87.8424	3.9090
14-Oct-93	8:00 AM	0.0062	9.0097	1440	77.8442	4.8263
15-Oct-93	8:00 AM	0.0065	9.0097	1440	77.8442	5.0599
			TOTAL		850.3342	54.8400
			NOVEMBER 1993			
04-Nov-93	8:00 AM	0.0013	3.3477			
05-Nov-93	8:00 AM	0.0020	6.6953	1440	57.8474	1.1569
06-Nov-93	4:00 PM	0.0050	6.0803	1920	70.0454	3.4672
08-Nov-93	4:00 PM	0.0073	5.4654	2880	94.4414	6.8470
09-Nov-93	4:00 PM	0.0039	5.4654	1440	47.2207	1.8180
10-Nov-93	4:00 PM	0.0018	5.4654	1440	47.2207	0.8264
18-Nov-93	4:00 PM	0.0050	5.4654	11520	377.7657	18.8883
			RONGMUK			
19-Nov-93	4:00 PM	0.0052	5.4654	1440	47.2207	2.4555
20-Nov-93	4:00 PM	0.0024	5.4654	1440	47.2207	1.1333
22-Nov-93	8:00 AM	0.0055	5.4654	2400	78.7012	4.3286
23-Nov-93	8:00 AM	0.0044	5.4654	1440	47.2207	2.0777
24-Nov-93	8:00 AM	0.0028	5.4654	1440	47.2207	1.3222
25-Nov-93	8:00 AM	0.0036	5.2194	1440	45.0954	1.6234
26-Nov-93	8:00 AM	0.0029	4.9734	1440	42.9700	1.2461
27-Nov-93	8:00 AM	0.0023	4.9734	1440	42.9700	0.9883
29-Nov-93	8:00 AM	0.0020	4.9734	2880	85.9401	1.6758
			TOTAL		1179.1009	49.8548

APPENDIX IX

DEMOGRAPHIC DATA OF STUDY AREA

Village	AREA(HA)	TOTPOP	DENSTY no/sqkm
PUGRIAPONG KM	270	2101	778
SIMRIK TG (P)	45	106	233
AVONGROVE TG (P)	25	194	776
GHUM FOREST	878	577	66
PULUNGDONG KM (P)	50	143	286
PULUNGDONG TG	106	522	490
PUBONG TG	411	789	192
PUSSIMBING TG	560	2086	373
JORBUNGLOW	306	564	184
SENCHAL FOREST	2902	3308	114
RONGBUL	435	2246	516
HILL CART ROAD KM	72	1481	2068
SONADA KM	581	4555	784
KOLLEGEVALLEY TG	638	2351	369
DOOTERIA TG	1183	3857	326
RONGMUK CEDAR TG	714	4217	590
OAKS TG	221	1085	490
MANDAKOTI TG	585	1896	324
RONGTONG TG	768	2603	339
NAHAR TG (P)	398	1710	430
MARGERATE´S HOPE TG	693	3455	498
DILARAM TG	283	1548	546
MAHARANI TG	139	1612	1161
EDENVALLEY TG	37	139	373
SEPORDHURA TG	165	516	313
SINGLE TG	454	2458	541
MONTVIET TG	79	520	662
SPRINGSIDE TG	221	456	206
AMBOOTIA TG	1021	1505	147
ST. MARY KM	67	1370	2039
GOETHALS KM	62	448	719
CART ROAD KM (P)	450	2760	613
KURSEONG	505	18008	3566
TOTAL	15325	71186	465

TOTPOP = Total population
DNSTY = Population density in nos \ sq km

(Source : Govt. of India, 1981)

APPENDIX X

LAND USE PATTERN IN STUDY AREA

Village	AREA(HA)	LAND USE PATTERN FST	IRG	NIRG	CW	NCW
PUGRIAPONG KM	270	40	121	40	40	27
SIMRIK TG (P)	45	–	–	45	–	–
AVONGROVE TG (P)	25	–	–	25	–	–
GHUM FOREST	878	878	–	–	–	–
PULUNGDONG KM (P)	50	40	10	–	–	–
PULUNGDONG TG	106	–	–	89	–	17
PUBONG TG	411	20	–	235	81	75
PUSSIMBING TG	560	36	–	450	40	32
JORBUNGLOW	306	30	28	53	174	20
SENCHAL FOREST	2902	2902	–	–	–	–
RONGBUL	435	40	32	89	233	40
HILL CART ROAD KM	72	–	–	30	10	31
SONADA KM	581	–	202	318	–	61
KOLLEGEVALLEY TG	638	81	87	365	42	64
DOOTERIA TG	1183	202	91	520	237	134
RONGMUK CEDAR TG	714	–	–	532	101	81
OAKS TG	221	14	46	121	–	40
MANDAKOTI TG	585	–	122	283	81	99
RONGTONG TG	768	53	–	397	216	102
NAHAR TG (P)	398	102	40	147	59	49
MARGERATE HOPE TG	693	–	–	403	250	40
DILARAM TG	283	–	–	231	12	40
MAHARANI TG	139	–	–	88	23	28
EDENVALLEY TG	37	–	–	24	–	13
SEPORDHURA TG	165	14	–	82	21	49
SINGLE TG	454	81	–	304	–	70
MONTVIET TG	79	–	–	57	2	20
SPRINGSIDE TG	221	–	–	148	6	68
AMBOOTIA TG	1021	241	231	365	110	74
ST. MARY KM	67	–	12	20	6	28
GOETHALS KM	62	–	10	40	–	12
CART ROAD KM (P	450	–	–	–	–	450
KURSEONG	505	–	–	–	–	505
TOTAL	15325	4777	1032	5499	1746	2270

FST = Forest
IRG = Irrigated
NIRG = Non - irrigated
CW = Culturable waste
NCW = Non- culturable waste (not available for cultivation)

(Source : Govt. of India, 1981)