Sediment transport in the Burhi Dihing River, India

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ABSTRACT The Burhi Dihing is a tributary of the Brahmaputra River in north-east India. The basin covers an area of 6000 km^2 and receives about 300 cm average annual rainfall. Data on suspended sediment of the river span the period from 1972 to 1982. Higher concentration of sediment occurs from April to October. The highest concentration that has been measured so far is 1.19 gm l^{-1}. The suspended sediment load is generally higher in the rising limb of the flood hydrograph as compared to the recession limb. The sediment-rating curve shows a highly positive correlation between the sediment load and the water discharge. The heaviest loads of sediment are related to sudden flash floods. The mean annual sediment load is 3 620 000 tons; 33 percent of the annual total is transported in the month of July. Duration-curve analysis shows that in some years it took only 25 days to transport 50 percent of the total annual sediment load. The present rate of average sediment load represents an overall soil denudation rate of 0.39 mm per year.

INTRODUCTION

The River Burhi Dihing is one of the important south-bank tributaries of the Brahmaputra. It flows through the major coal belt and some oil fields of north-east India and its drainage basin lies in the states of Assam and Arunachal Pradesh (Fig. 1). This paper is an integral part of the drainage basin study of the Burhi Dihing. The study presents a short analysis of the available data on hydrology and suspended sediment load. The main purpose of the investigation is to study the suspended sediment discharge characteristics of the river. The meteorological, hydrological and suspended sediment transport data used in this paper have been recorded by the government and some government recognized private authorities. The topographic maps of 1:50 000 scale and published geological maps provided good basic information.

THE BURHI DIHING BASIN

The Burhi Dihing drains a basin of 6000 km^2. Within this area there are wide contrasts of relief, slope, lithology, vegetation and land use. The basin has a maximum latitudinal extent of about 195 km around 27° 20'N and meridional extent of 75 km around 95° 30'E. The hypsographic analysis has been made from area-altitude data from the topographic maps. The solid line in Figure 2 represents the normal hypsographic curve for the whole basin indicating 60 percent of the area of the basin above 150 m a.m.s.l. From a hydrological viewpoint, the dashed line showing the relation between area increase and river elevation along the main thalweg is more significant. The debouching point of the river is at 97 m a.m.s.l. whereas the main thalweg of the river reaches a level of 150 m within a basin area of only 1600 km^2. This imparts a serious

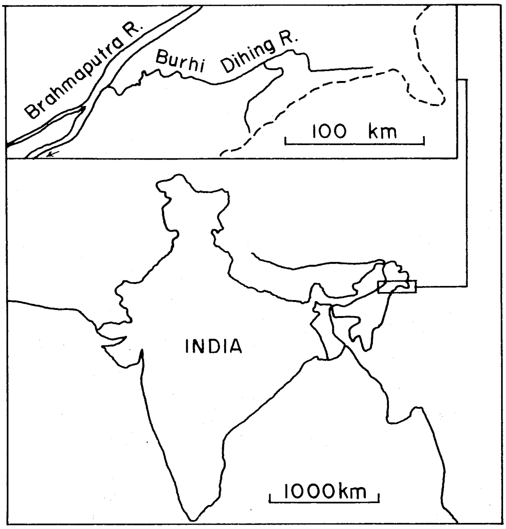


Figure 1 Location map.

damping effect on the river thalweg causing lowering of energy towards downstream. So, the upper section of the curve representing the hilly area is concave upward and the lower section is significantly flat.

Most of the hilly part of the basin is underlained by sedimentary rocks of Tertiary age along with some older metamorphics. The extensive plain region below 150 m a.m.s.l. is covered by recent alluvium.

HYDROMETEOROLOGY, VEGETATION AND LAND USE

The Burhi Dihing drainage basin is situated in the temperate zone. Within the plain region the mean monthly temperature does not exceed 32° C and the mean minimum for January is close to 10°C. The average monthly rainfall for 16 selected rainfall stations within and closely peripheral to the basin and the mean annual rainfall map of the basin are shown in Figure 3 and Figure 4 respectively. The mean annual rainfall varies from 210 cm to 388 cm.

The dry season (monthly precipitation less than 50 mm) is short - from November to January. Rain with thundershowers start intermittently from March to May. Monsoon with heavy rain starts from June and lasts generally up to September, sometimes stretching up to October. The distribution of the mean monthly rainfall shows that the rainfall is the lowest in December, which is always less than one percent of the annual total and increases up to two percent in January, four percent in February, six percent in March and 10 to 13 percent in April. More than 60 percent of the annual rainfall occur from May to August, thereafter rainfall declines gradually - not exceeding 10 percent of the annual total in September, five percent in October and two percent in November.

The month of July has maximum number of rainy days (a day with at least 0.25 mm rainfall, Jackson, 1972) and December has the minimum. In general from November to February the intensity of daily rainfall is low, not exceeding 40 mm. The first spell of rain with high intensity occurs generally in the month of April, sometimes rarely in late March or early May. This is closely related to the occurrence of the first flash flood in otherwise smooth hydrograph of the river. The mean daily

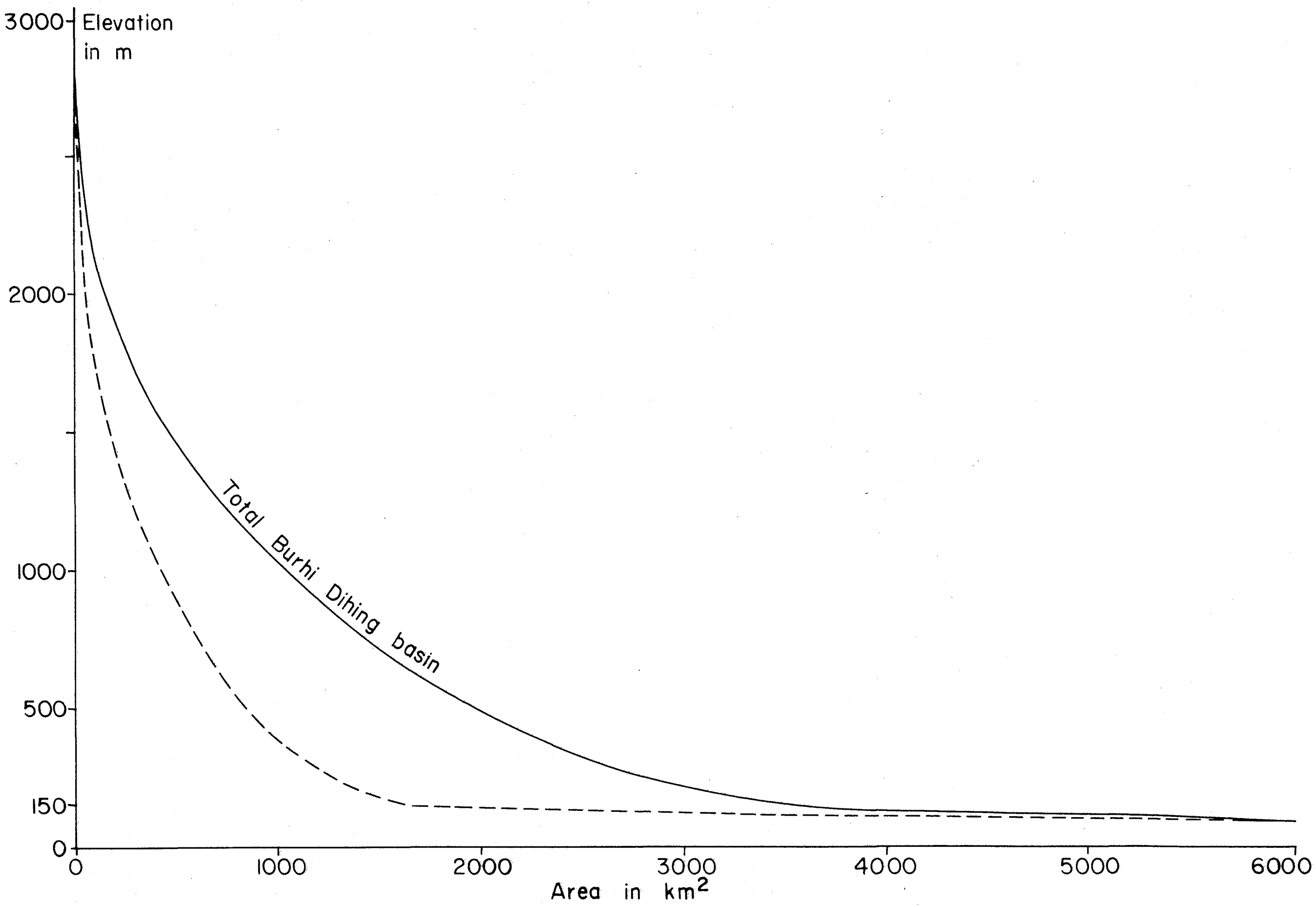


Figure 2 Hysographic analysis of the Burhi Dihing basin showing the hysographic curve (solid) of the total basin area and a curve (dashed) showing area-elevation relationships along the main thalweg.

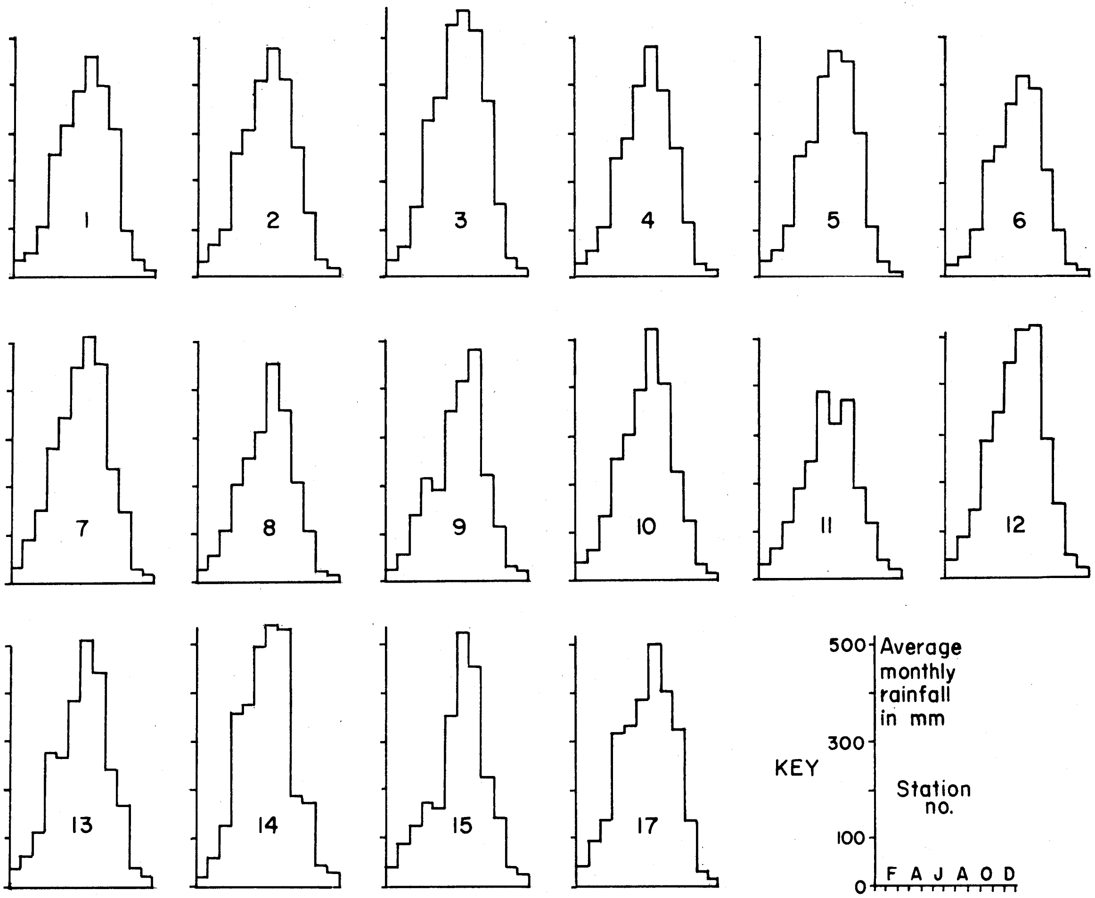


Figure 3 Bar graphs show average monthly rainfall at different stations of the basin.

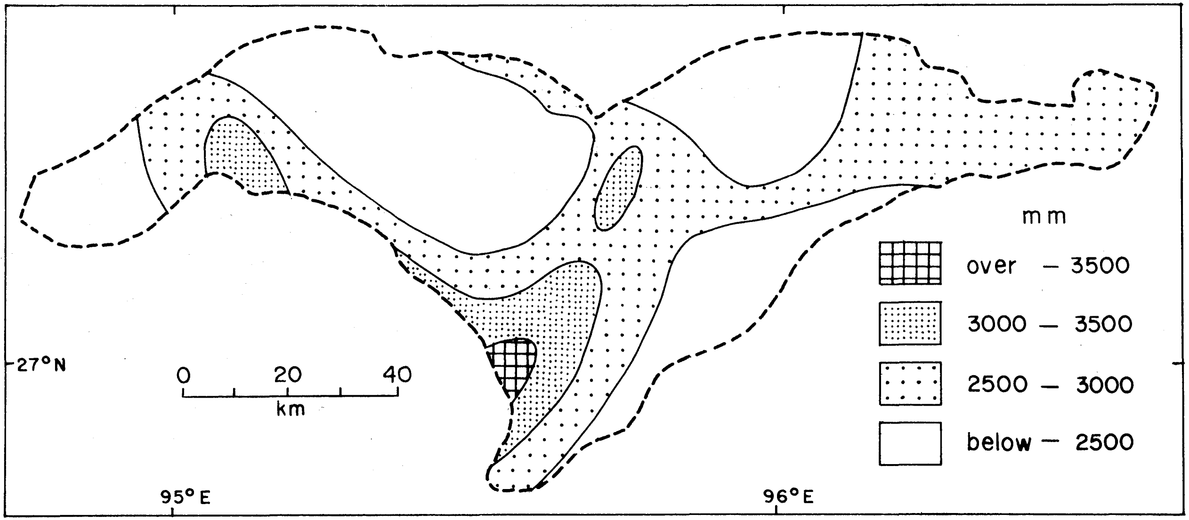


Figure 4 Average annual rainfall map over the Burhi Dihing basin.

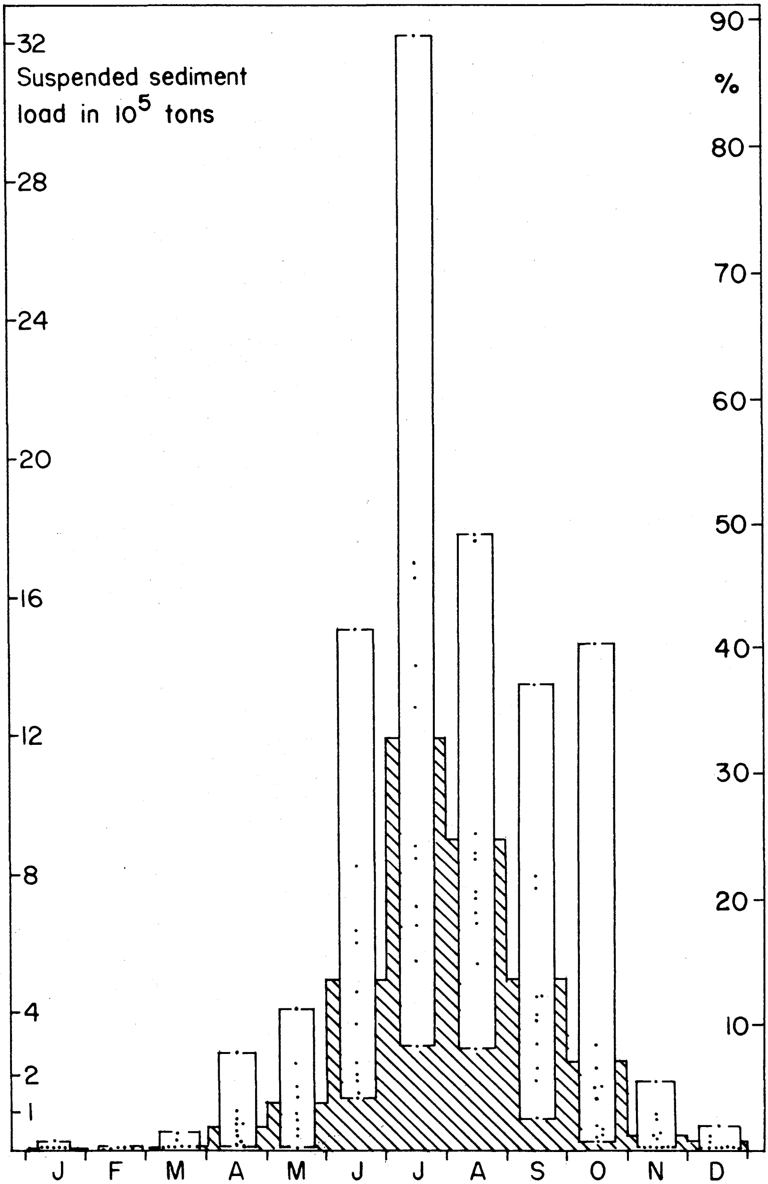


Figure 5 Dispersion value of suspended sediment load by month (tons) for the Burhi Dihing River at Khowang for the period 1972-1982. Mean monthly sediment load shaded with percentage scale to the right.

intensity for different months as given by the ratio of total monthly rainfall to the total number of rainy days is highest in August and lowest in January.

About 50 percent of the hill area and 15 percent of the plains are covered by reserve forests. The hill people practice shifting cultivation. The high level and low lying areas of the plains are exclusively under cultivation of tea and paddy respectively.

HYDROLOGICAL STATIONS AND AVAILABLE DATA

Among the different hydrological stations of the Burhi Dihing the measurement of suspended sediment has been made only at Khowang. Upstream of the station at Khowang the river has an area of 5180 km . The sampling of the suspended sediment has been carried out regularly by the Investigation Division, Brahmaputra Board (eastwhile Brahmaputra Flood Control Commission). The samples are collected in sediment sampling bottles from a standard depth - 0.6 d from the surface, where d is the depth of the river. The size analysis is done by sieving and analytical gravimetric method.

Unfortunately the detail data on the suspended sediment of the river are normally not available in published form. The data used in this paper are collected from some development plans of the Department of Irrigation, Government of Assam and span the period from 1972 to 1982. Suspended sediment data on daily basis are available for 1972-1974, 1979 and 1982. For the other years these are available in 10 days total basis. The data on daily basis are taken into consideration for detail analysis.

MAIN CHARACTERISTICS OF SUSPENDED SEDIMENT TRANSPORT

The dispersion graph of month-wise suspended sediment load for the Burhi Dihing River at Khowang is shown in Figure 5. The shaded columns behind the dispersion graphs show the mean monthly sediment load with percentage scale to the right.

The average monthly discharge is the highest in July and the lowest in February. On an average, the sediment load of July accounts for about 33.11 percent of the annual total compared to 0.14 percent in February.

The maximum value of monthly sediment load has been recorded in July, 1976 (3 217 300 tons), and minimum in February, 1975 (570 tons). The dispersion graph indicates that over the recorded period the month of July subjects to by far the greatest fluctuations of mean sediment discharge and the month of February the least.

It is apparent from the Figure 5 that the load of suspended sediment during the period from January to March is almost negligible. The period from June to September has experienced high average sediment load; except an unusual heavy flood in October 1979, accompanied by a higher sediment discharge of 1 464 700 tons, the monthly sediment load in October in other years is also low.

WATER DISCHARGE AND SEDIMENT LOAD ANALYSIS

It is understood that the concentration of suspended sediment is related to water discharge, an increasing discharge being accompanied by an increase in sediment concentration. The data for the years 1974, 1979 and 1982 have been plotted as examples to illustrate their relationship in these years with early flash flood, late flash flood and minimum fluctuation of discharge in the flood period respectively (Fig. 6).

The suspended sediment discharge is high in the months from April to October, as evident from Figure 6. The highest sediment discharge recorded so far is 2415 kg s^{-1} on June 18, 1973 with accompanying water discharge of 2024 $m^3 s^{-1}$. The sediment discharge mentioned above corresponds to sediment concentration of about 1.19 gm l^{-1}. From

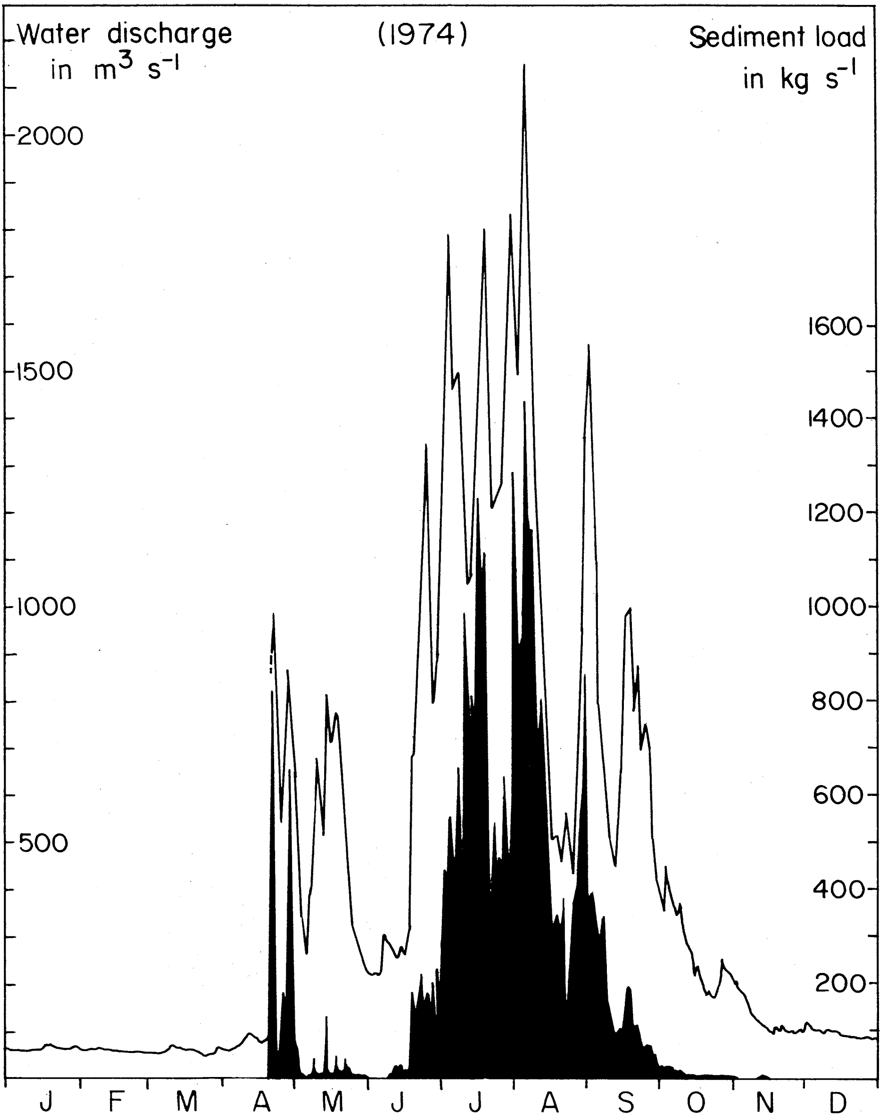


Figure 6 Water discharge and sediment load for the Burhi Dihing River at Khowang; solid line - water discharge and shaded curve - sediment load.

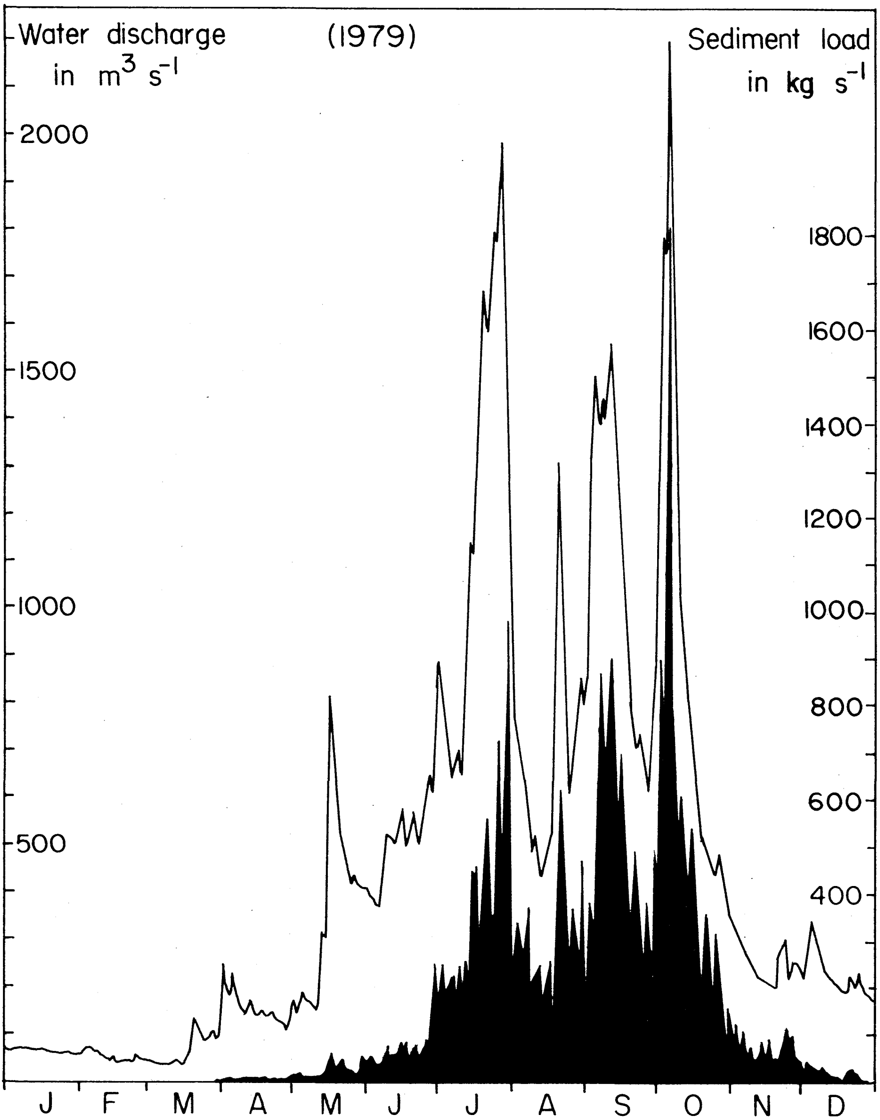
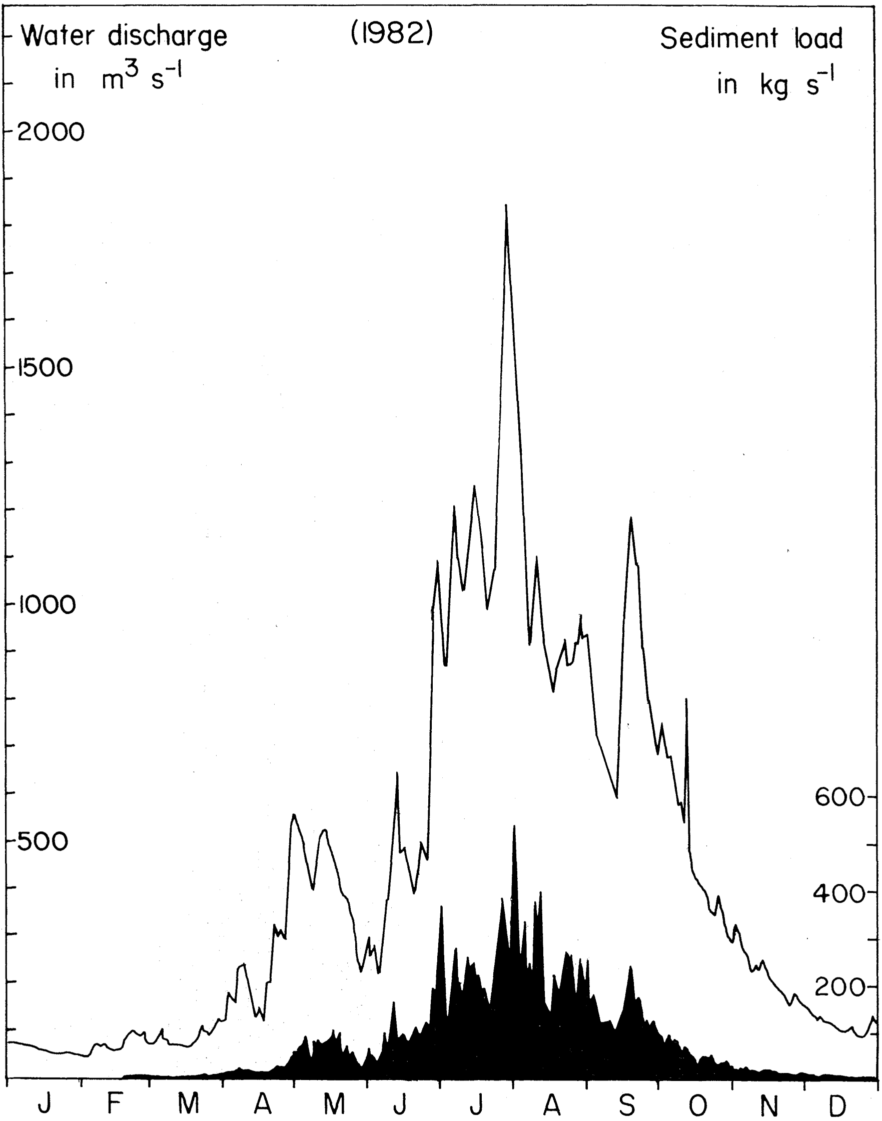


Figure 6 (Continued)



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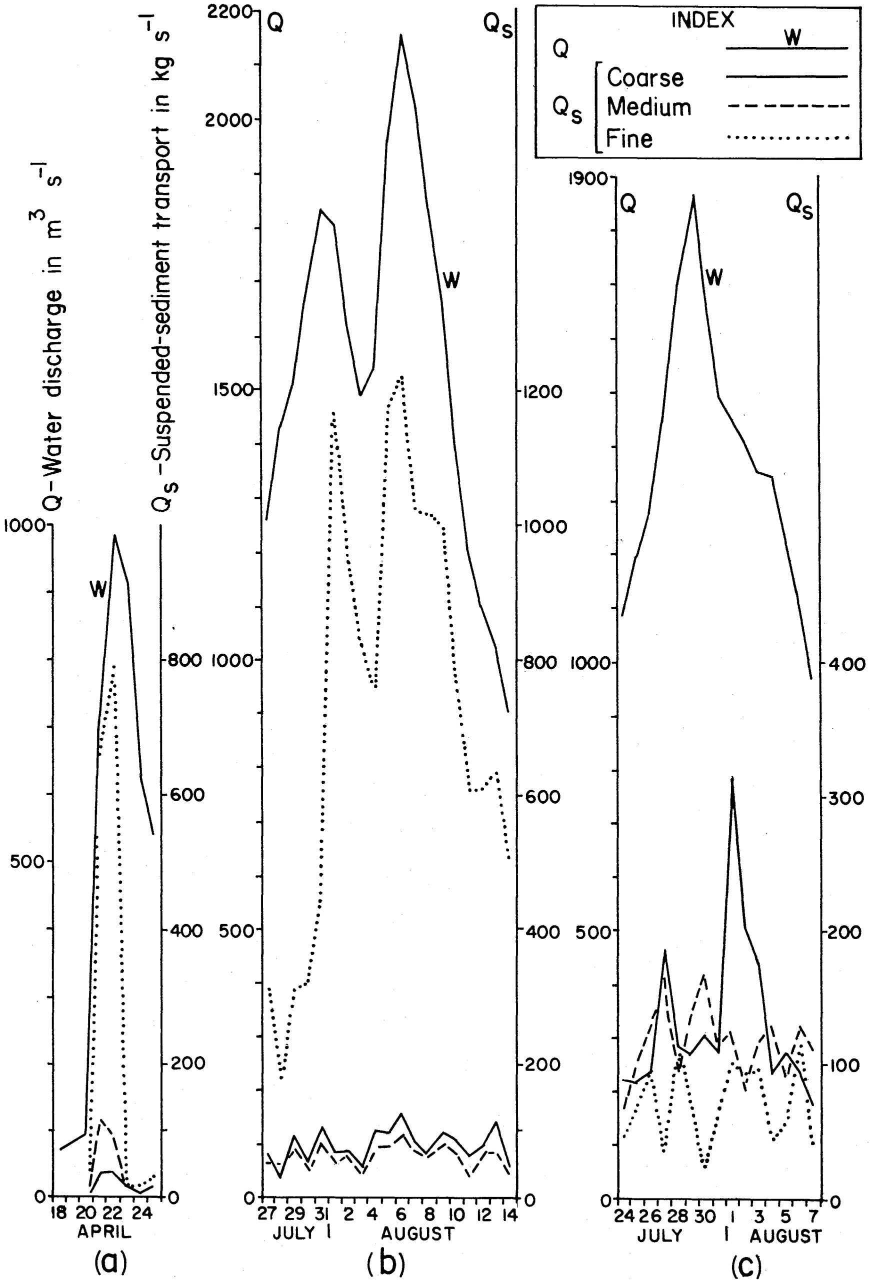

Figure 7 Relation of coarse, medium and fine suspended sediments with water discharge during passage of (a) flash flood, (b) high flood and (c) flood normal magnitude.

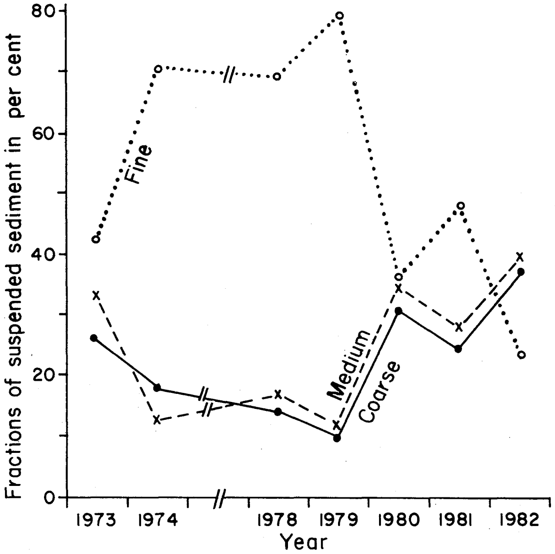

Figure 8 Fractions of coarse, medium and fine suspended sediments in different years where data available.

December to March the sediment discharge is rather negligible. The sediment discharge is comparatively high in the rising limb of the hydrograph especially when it is associated with early flash floods e.g. April, 1974.

In normal cases the discharge of sediment fall more significantly in the recession limb of the hydrograph e.g. 1974 and 1982, while the water discharge, though continuing to fall is still relatively high. But when there is a late flood e.g. 1979, the sediment discharge remains relatively higher in the recession limb also.

The sediment discharge peaks are generally associated with the peaks of water discharge especially in the rising limb of the hydrograph. In a majority of the cases, the day with highest sediment discharge of the year occur simultaneously along with the highest water discharge. In certain other years it lagged by one, two or three days behind the day with the highest water discharge of the corresponding year.

Simultaneous occurrence of the maximum sediment discharge and water discharge in some years signify a stabilized sediment influx vis-a-vis water discharge. On the contrary lagging of the sediment discharge peak behind the water discharge by one to three days indicate comparatively slower movement of the sediment concentration peak. The high rate of collapse of soft alluvial banks just after the flood peak may be another cause of high sediment concentration after the flood with maximum discharge.

From the relation between sediment load and water discharge a year can be divided into two periods viz. the flood period and the recession period. The beginning of a flood period is marked by the occcurrence of flash floods on the slowly rising base flow.

Fractions of suspended sediment

The suspended sediments are found to be divided into three groups on the basis of grain size viz. coarse sediment (above 0.20 mm), medium

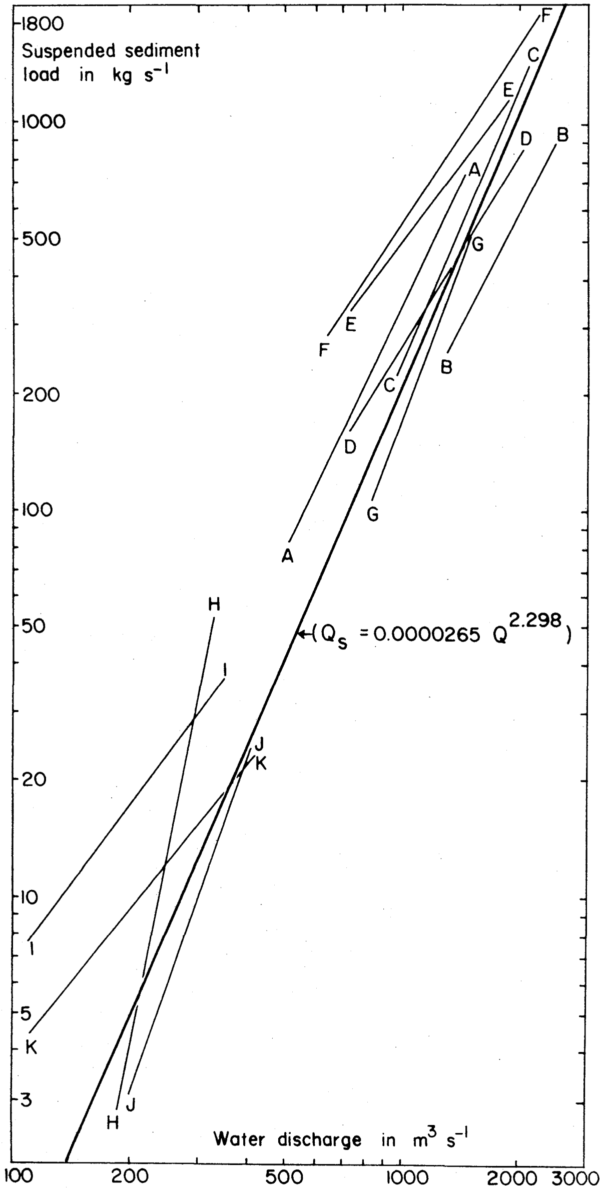

Figure 9 Sediment-rating curves for different flood and recession periods at Khowang. Coarse line indicates sediment rating curve computed from all available data.

sediment (0.20-0.075 mm) and fine sediment (below 0.075 mm). The amount of sediment load comprising these three size fractions during the passage of flash flood, high flood and flood of normal sediment load consists mainly of fine fraction in the former two cases whereas coarse and medium fractions are dominant in the latest case. The fractions of coarse, medium and fine sediments transported in different years, where data available, are shown in Figure 8. It is apparent that the fraction of fine sediments plays a dominant role in many years. But the same may be also a subordinate component in some years e.g. 1982.

SEDIMENT-RATING CURVE

The relationship of daily suspended sediment discharge to water discharge has been calculated by the method of least squares. The graph of suspended sediment discharge versus water discharge usually plots on a straight line on logarithmic coordinates (Fig. 9) and therefore conforms to the equation ($Q_s = a\ Q^b$). The following relation was obtained from the graph.

$$Q_s = 0.000\ 0265\ Q^{2.298}$$

Where Q_s is the suspended sediment discharge in kg s^{-1} and Q is the water discharge in $m^3\ s^{-1}$. The value of the exponent in the present case is 2.298. Tha value of this exponent found by other workers at other places of the world are as follows:

Gregory & Walling	(1973)	On streams of East Devon	b = 2.0 approx.
Rapp et al.	(1972)	On Morogoro River, Tanzania	b = 2.9
Leopold & Maddock	(1953)	On rivers of West USA	b = 2.0-3.0
Campbell & Bauder	(1940)	On rivers of West USA	b = 2.0-3.0

Hence the value of the exponent of the Burhi Dihing River conforms well to the values calculated on other rivers.

The correlation coefficient in the present case is 0.83 taking into account of all available data, which signifies the existance of a good relation between sediment discharge and water discharge. It may be therefore considered justifiable to use the rating curve, as defined by the above equation, for calculation of probable discharge of suspended sediment corresponding to a particular value of water discharge.

It is also important to note that each group of data on sediment and water discharge for different flood and recession periods defines a

Table 1 Correlation coefficients for the regression lines

Period	Type	Correlation Coefficient
AA	Flood	0.78
BB	Flood	0.52
CC	Flood	0.77
DD	Flood	0.60
EE	Flood	0.81
FF	Flood	0.80
GG	Flood	0.66
HH	Recession	0.80
II	Recession	0.86
JJ	Recession	0.81
KK	Recession	0.89

separate rating curve. These rating curves can be distinguished from one another as it is evident from Figure 9. The correlation coefficient for the regression lines for the flood period is found to vary widely (0.52-0.81) whereas it is more regular (0.80-0.89) in the recession period as given in Table 1. It indicates a higher degree of internal dispersion of sediment discharge during the flood period and a comparatively uniform sediment influx during the recession period.

SEDIMENT TRANSPORT OVER DIFFERENT INTERVALS OF TIME

The probable amount of suspended sediments at different years can be calculated from the rating curve and the flow duration curve. In order to give an idea about the duration of transport of sediment and water in a year the analysis of the data of the year 1974 are shown here as an example. The cumulative percentages of suspended sediment discharge and water discharge of the year 1974 are plotted against cumulative percentage of time (Fig. 10). It is evident from the graphs that 50 percent of the total annual suspended sediment discharge and water discharge took place during a total time period of about 25 days (seven percent of the time of the year) and 56 days (15 percent of the time of the year) respectively. It clearly indicates that a high rate of daily sediment discharge occurs only for a small fraction of time of the year.

SOIL EROSION IN THE BASIN AND SOURCES OF SEDIMENTS

Data on total suspended sediment load of the Burhi Dihing at Khowang reveal that mean annual sediment load during the period 1972-1982 is 3 620 000 tons. The basin of the river contributing discharge up to Khowang has an area of 5180 km^2. The rate of sediment load and basin are mentioned above correspond to about 698.83 tons of annual suspended sediment yield per km^2 of drainage area. It should be remembered that the value of sediment load discussed above does not include materials carried as bed load or in solution. No data on measurement of bed load transport or solute exist and no calculation with conventional bed load estimation has been applied so far. The above value of average annual sediment yield from the Burhi Dihing River basin represents an overall soil denudation rate of the order of 0.39 mm per year.

The important sites of soil erosion in the basin and the sources of sediment of the river may be as follows:

(a) The inhabitants of the hilly area use to clear and burn annually a vast region of the forest in the hill for shifting (Jhum) cultivation exposing the bare soil in the hillslope for atmospheric action. Thus a considerable amount of erosion of hillslope occur in this process.

The tea gardens of this region are situation on high level plains with a sloping surface. The garden soil is tilled in the dry season and the tea twigs are pruned. The high intensity rain in the summer falls directly on the soil and wash away some amount of the latter from the extensive tea garden belt within the river basin.

(b) Intensive open-cast coal mining activities of this region produce huge amount of loose debris. The Burhi Dihing flows very close to these areas and derives sediments from the debris through several small streams.

(c) The average rate of bank erosion of the river within the plains is about 4.42 km^2 per year (Sarma & Basumallick,

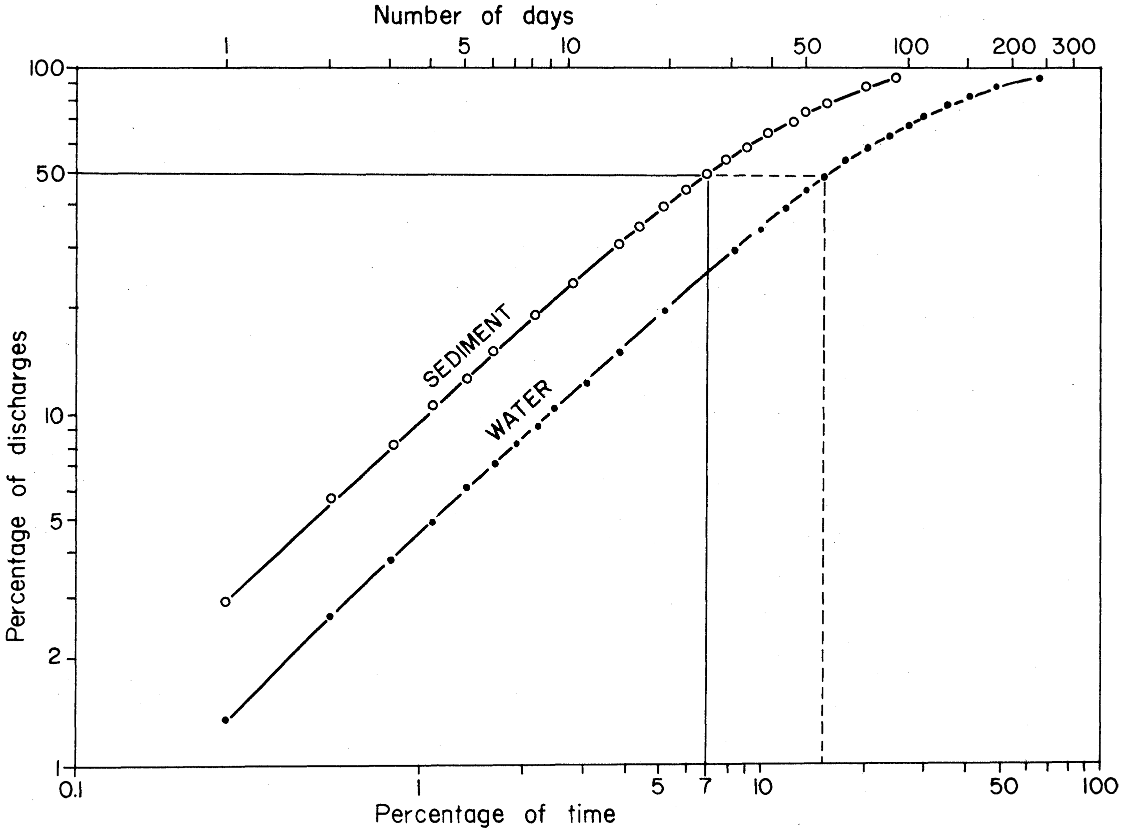

Figure 10 Cumulative percentage of suspended sediment discharge and water discharge in the Burhi Dihing River plotted against cumulative percentage of time for the year 1974.

1982). A good amount of fine sediment is derived from the eroded areas and collapsed alluvial banks consisting chiefly of clays, silts and sandy silts.

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